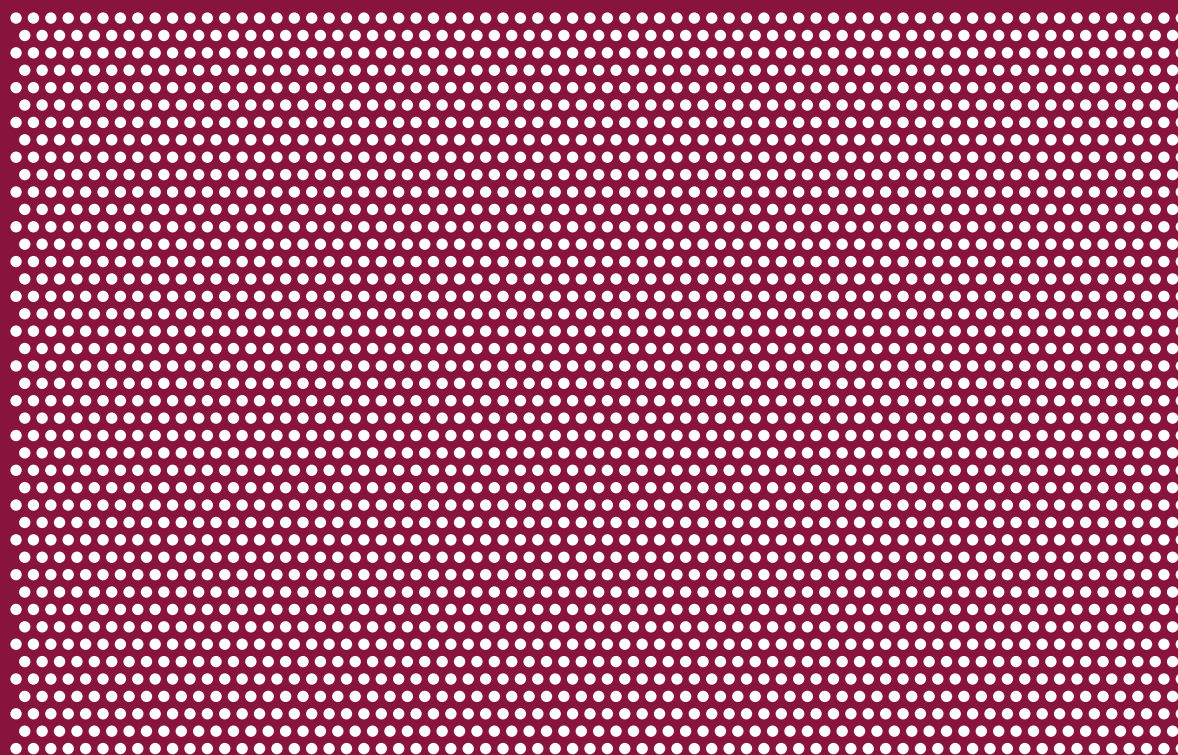# ANNUAL REPORT No. 41

Research Institute for Science and Technology

April, 2023 – March, 2024

TOKYO UNIVERSITY OF SCIENCE

Introduction

This annual report is the activity records of Research Institute for Science and Technology, Organization for Research Advancement, Tokyo University of Science (TUS-RIST) in FY2023 (from April 2023 to March 2024).

Research Institute for Science and Technology has innovated and strengthened its research system in Tokyo University of Science with the aim of opening up new research areas and developing research activities based on an organic collaboration system in line with the new era. In FY2023, Research Center for Drug Discovery and Applied Sciences and Research Center for Multi-hazard Urban Disaster Prevention, Division of Implementation of Sustainable Technology in Society were newly installed.

As a result, Research Institute for Science and Technology consisted of four Research Centers, two Research Hubs, nineteen Research Divisions, one Joint Usage / Research Center, and two Open Innovation Projects at the end of FY2023.

Purposes of establishment of this research institute are as follows.
– Promotion of substantial collaborative research
– Development of cross-sectional research
– To open up new fields from a comprehensive perspective on basic and applied research
– Promotion of collaborative research that removes both domestic and international barriers within and outside academia
– Strengthening cooperation with society
– Nurturing highly creative and diverse human resources that are responsible for the next generation of society

In order to actively promote collaborative research to achieve these goals, we introduced a domain system in FY2010. At present, the system consists of five domains: "Bio and Pharmacy", "Fundamentals", "Functional Materials", "Information and Societal", and "Structural Materials". In addition, since FY2014, the Advisory Committee, consisting of experts inside and outside the university, has been set up in each of the Research Centers, Research Hubs, and Research Divisions, and has been playing a key role in developing R&D activities from a broader perspective.

Among Tokyo University of Science that aim to make progress "From TUS in Japan to TUS in the World", Research Institute for Science and Technology will continue to make further efforts to contribute not only to academia but also to society through the development of ambitious research activities from a global perspective.

We appreciate the cooperation and support of everyone involved.

March, 2024

Hiroshi Nishihara
Director.
Research Institute for Science and Technology (RIST)
Tokyo University of Science

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History and current status of Research Institute for Science and Technology

(1) Objectives and Features of Research Institute for Science and Technology

In order to respond to changes and advances in academia, and to meet the needs of society, Research Institute for Science and Technology (RIST) aims to develop an interdisciplinary and cross-disciplinary comprehensive research system through the cooperation of teachers in several disciplines, and to create and disseminate outstanding research benefits through active collaboration with non-academic experts and industrial and administrative agencies. It also aims to contribute significantly to society through the sustainable development of the academic and educational research system in this academy and the realization of an upgraded environment for human resources development.

RIST is a cross-linking organization that connects Faculty of Science Division I, Faculty of Science Division II, Faculty of Pharmaceutical Sciences, Faculty of Engineering, Faculty of Science and Technology, Faculty of Advanced Engineering, and School of Management. RIST emphasizes not only domestic but also international collaboration, and actively promotes activities as a research base both domestically and internationally.

(2) History of Research Institute for Science and Technology

Research Institute for Science and Technology was originally General Research Institute established in 1981. It later became the Tokyo University of Science General Research Institution in November 2005, In April, 2015, with the establishment of the Organization for Research Advancement with the aim of enhancing the research promotion system, it was reorganized into the Research Institute for Science and Technology. General Research Institute had been active as the university's only cross-disciplinary comprehensive research organization and accumulated many achievements. In the 25 years up to 2005 from 1981, 17 research departments were established, and the university played an important role as a pioneer of cross-disciplinary research groups and a parent body for many research organizations. In 1989, Research Institute for Biological Sciences was established from Biosystems Division, and in 1996, Organization for Information Science Education and Research was established from Computational Mechanics Division.

On March 31, 2004, the "Report on the Ideal Form of Research Institutes, etc., at the Tokyo University of Science" was compiled, and based on this, on April 25, 2005, "Proposal for establishment of Tokyo University of Science General Research Institution (Final Report of the Future Plan for the Tokyo University of Science Institute for General Research) was compiled. On November 10, 2005, the "Report of the Preparatory Committee for the Establishment of the Tokyo University of Science Research Organization" was compiled, and based on it, General Research Institution consisting of 10 centers and 5 research divisions was established.

In the 10 years up to 2015, the Research Equipment Center and Research Administration Center were established, the Research Center for Fire Science and Technology was recognized as a Joint Usage/Research Center, and the Global Fire Science and Technology was newly established through the "Global COE Program", and Photocatalysis International Research Center.

(3) Organization of the Research Institute for Science and Technology

Research Institute for Science and Technology established under the Organization for Research Advancement in 2015 consists of Research Centers, Joint Usage/Research Center, Research Hubs, Research Divisions, and the Open Innovation Projects.

Research Reports by Research Center/ Research Hub/Research Division

Center for Fire Science and Technology

Center for Fire Science and Technology

1. Overview

The Center for Fire Science and Technology was established in 2003 when its predecessor, the Research Division of Fire Science Research within the Research Institute for Science and Technology, was selected as a core organization for the 21st Century COE Program (program name: the Center of Excellence for Promoting Leading Research on Building Fire Safety Engineering) by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. In 2008, the MEXT Global COE Program (program name: the East Asia Center of Education and Research for Leading Fire Safety Engineering) was subsequently accepted. Through the ten years of these two COE (Center of Excellence) programs, we have promoted not only cutting-edge research but also activities to contribute to the development of fire science from various perspectives by organizing international symposia/seminars, publishing a peer-reviewed international journal, and making full use of the Laboratory for research projects with industry and government. The journal, International Journal for Fire Science and Technology, was launched in 1981 and now publishes papers on the J-stage platform, which people worldwide can freely access. In particular, we have contributed to developing human resources by promoting foreign education/research institutions. The activities include the analysis of fire risks and safety measures to reduce them in Asian (mainly East Asian) cities, holding intensive lectures, accepting early-career researchers for short-term stays, and joining the Sakura Science Plan promoted by JST. Further, in 2013, MEXT adopted our proposal of a project to support the formation of a strategic research infrastructure for private universities (project name: Formation of an Asian Fire Safety Information Center Based on Sharing Specialized Knowledge—a New Direction of Fire Safety in the Information Society). Asian cities, which are modernizing with the increasing number of high-rise buildings at an unexperienced rate and scale, need scientific analyses and taking appropriate safety measures against the threats posed by emerging fire risks. We aim to reduce fire risks and improve the city's safety levels by utilizing the Internet to identify fire hazards in Asian cities, building a fire-information network to share such information with related parties, and utilizing the results of TUS research. Specifically, we have the following two research themes:

1) Fire risk analysis of Asian cities based on the formation of the fire safety information center
2) Analysis of fire hazards and incidents in Asian cities

The former is to establish a mechanism in the Asian region to collect fire-incident information and to share specialized knowledge of fire engineering. The latter is to discuss how to investigate the causes and safety measures for the emerging fire risks associated with modernization and urbanization. Consequently, the Center aims to function as a research center for sharing expertise in fire safety engineering, analyzing fire incidents in Asian cities, and deploying information in combination with safety measures to reduce fire risk in the region as a whole. The Center has been established as a permanent organization indefinitely since 2018; it was also accredited as a designated performance-evaluation organization by the Ministry of Land, Infrastructure, Transport, and Tourism in 2020, utilizing the facilities and equipment of the Laboratory.

Furthermore, the "Research Center for Fire Safety Science" was accredited by MEXT as a joint usage/research center in 2009, promoting joint research in cooperation with researchers inside and outside TUS. Its primary objective is to contribute to minimizing potential fire risks that increase with available new spaces associated with urbanization and new materials associated with industrialization and energy conservation.

2. Organization and Facilities

As shown in Fig. 1, building fire safety engineering research covers fire phenomena, smoke flow, fire spread, evacuation behavior, and heating properties of structural members. The research scope also includes fire safety in cities as a set of buildings and underground spaces. The Center considers interrelationships among these diverse research subjects, as shown in Fig. 2, and expands research activities. Putting "fire safety engineering corresponding to changing space and material utilization" as the vital theme, the Center develops research activities in the following four areas: (1) physical and chemical phenomena in fires, (2) human behaviors (psychology, physiology, and behavior) during fires, (3) performance-based fire safety design technology, and (4) establishment of fire-safety performance evaluation and design systems corresponding to changing space and material utilization," which aims to integrate each element for practical use. The Fire Research and Test Laboratory, one of the world's largest university-based fire-science research laboratories, plays a crucial role in these research activities. The Laboratory capabilities have been enhanced by installing large-scale facilities and equipment. Figure 3 and Photo 1 show their names and the layout using floor plans.

Fig. 1. A schematic of building fire safety engineering research.
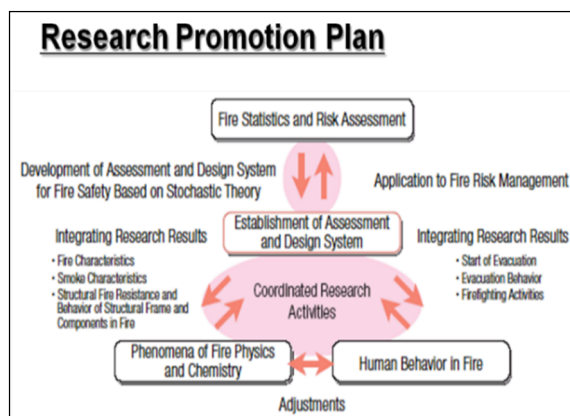
Fig. 2. Interrelationships of research areas and structures.

① Cone calorimeter and FTIR gas analyzer etc.
② Medium-scale structural fire-resistance furnace (inner size: W1.5 x D1.5 x H1.5 m)
③ Radiation panel (ICAL apparatus)
④ Smoke collection hood (fixed, 5m x 5m) (with Room corner testing unit)
⑤ Full-scale fire compartment model with a watering system
⑥ Multi-purpose horizontal loading furnace (inner size: W3 x D4 x H3.5 m, the maximum load: 500 MN)
⑦ Exterior material heating test equipment
⑧ Large-scale wall fire-resistance furnace (inner size: W3.5 x D1.0 x H3.5 m)
⑨ Secondary furnace (exhaust-gas treatment system)

Fig. 3. Floor plans and facilities/equipment of the Fire Research and Test Laboratory.

(i) ⑥Multi-purpose horizontal loading furnace　　(ii) ⑧Large-scale wall fire-resistance furnace
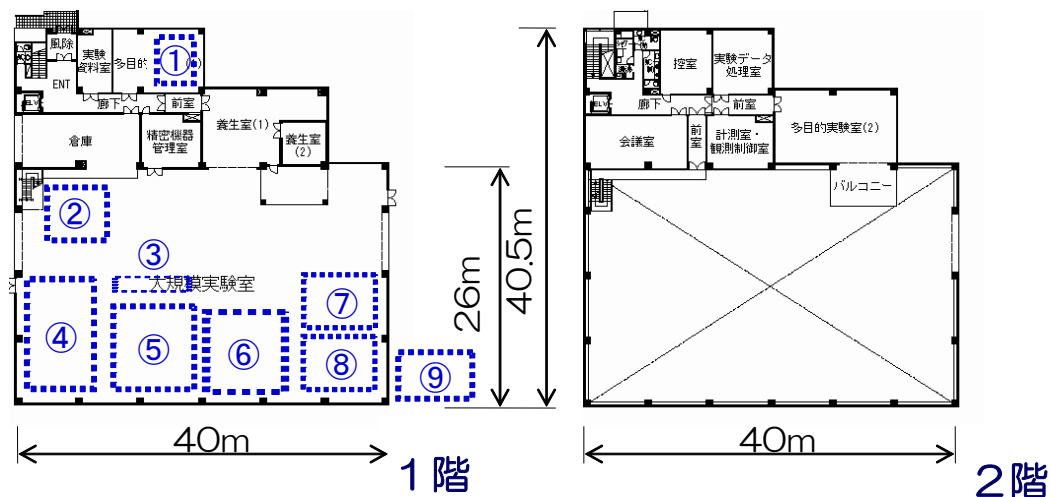
Photo 1. Fire Research and Test Laboratory.

3. Activity Reports

3. 1. Area of Fire Dynamics

In the Fire Dynamics Research Area, fundamental studies are conducted to elucidate the phenomena related to fire, combustion and explosion. In this issue, results of research on toxicity gas test and strategies for early detection of signs of such state changes are reported.

In Japan, the toxicity gas test for combustion product of building materials currently conducted is the mouse test. This test method has some major problems such as not provide quantitative analysis of decomposition and combustion product gases specific to building materials. To solve these problems, we focused on a method to determine toxicity from gas analysis using FT-IR. In order to reveal thet relation between the results of the gas analysis by FT-IR and the standards test, some experimental studies focused on each concentration of HCN and HCl have been carried out. These results indicate that asphyxiating gases affect the cessation of animal behavior due to combustion product gases, while irritant gases do not. In addision, it is found a possibility that the toxicity of combustion product gases can be determined by analysis of asphyxiating gases.
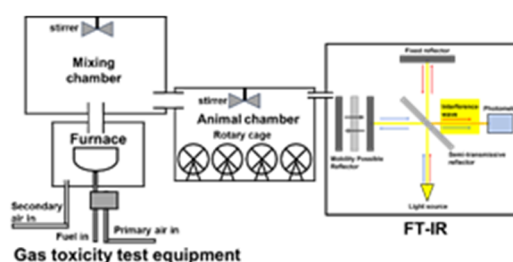
Fig. 4. Experimental set up.

In fire and explosion phenomena, significant damage can be caused by a sudden state change, such as the transition from smoldering to flaming or the thermal runaSumoSway of a chemical reaction. We examined strategies for early detection of signs of such state changes. The figure below shows an FDS numerical simulation of a flashover. Analyzing the data obtained from the numerical simulation, we proposed an anomaly detection marker that can detect the signs of flashover.
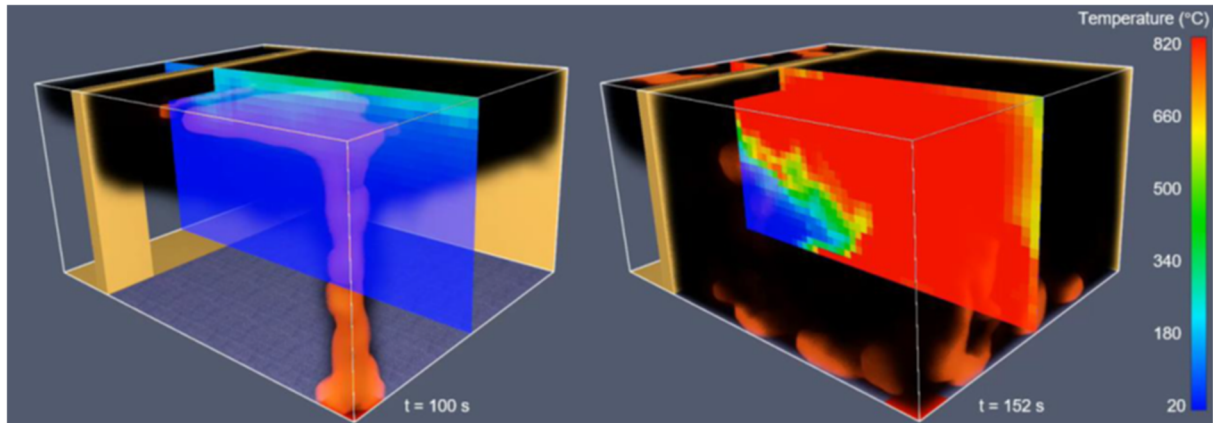
Fig. 5. The occurrence of a flashover simulated using FDS.

3. 2. Area of Evacuation and Human Behavior

This area covers not only evacuation safety during fires, but also occupational safety of firefighters at fire sites. Here, we introduce the results of our research on the following two points.

(Occupational Safety of Firefighters) Firefighters are exposed to various risks on a daily routine as they respond to fires and other severe disaster situations. As an outcome of FY2023, we worked on the development of a method to estimate autonomic nervous system fluctuations from a simplified wearable device. Autonomic fluctuation is a useful indicator for quantifying physical and psychological load since changes can be observed in various physiological indicators such as stress and the function of the respiratory and circulatory systems. On the other hand, existing methods have the problem that they require laboratory measurements. In this research project, we succeeded in estimating autonomic nervous system fluctuations even during exercise using data obtained from a wristwatch-type device.
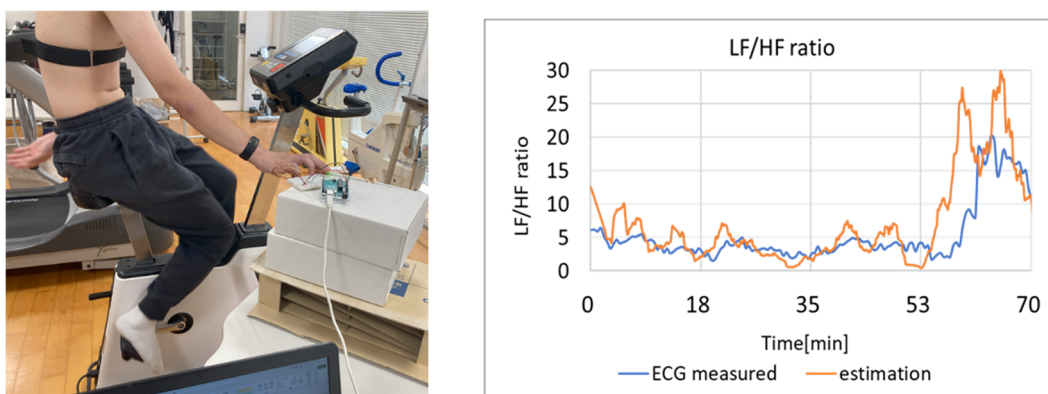
Fig. 6. View of the measurement (left). Measurement results showing the approximation between the actual values measured by the ECG meter (ECG measured) and the values estimated by the wearable device (estimation) (right).

(Study on the passage methods through fire doors installed at corridors by wheelchair assistants) In the fire evacuation plans of elderly welfare facilities, it is effective to introduce temporary refuge areas for horizontal evacuation by installing fire doors at corridors closed by fire detector activation. Due to their larger size compared to regular doors, passage through the fire doors may pose difficulties for wheelchair assistants. In the previous studies, it was experimentally analyzed that wheelchair users opened and passed through normal-type fire doors, but there is no apparent analysis of passage behavior through fire doors by wheelchair assistants. In this study, it was analyzed that wheelchair assistants operated wheelchairs with persons to pass through the fire doors installed and closed at corridors. The participants consisted of 31 caregivers working at three facilities in Tokyo and three employees (with caregiving experience) from the companies operating these facilities, totaling 34 individuals. We recorded the actions of the assistants (participants) passing through a total of four fire doors installed at corridors in each facility while operating wheelchairs, analyzed the behavior during door passage, and measured passage times using video recordings. The analysis revealed that moving backward for pushing the door to open it and moving forward for pulling the door to open it were relatively preferable methods of passage. Moreover, as the number of passages increased, passage times shortened, indicating the significant effect of experience, highlighting the importance of regular training and experience in daily practices.

The assistant pushes the door with his/her back while moving backward to pass through the fire door.
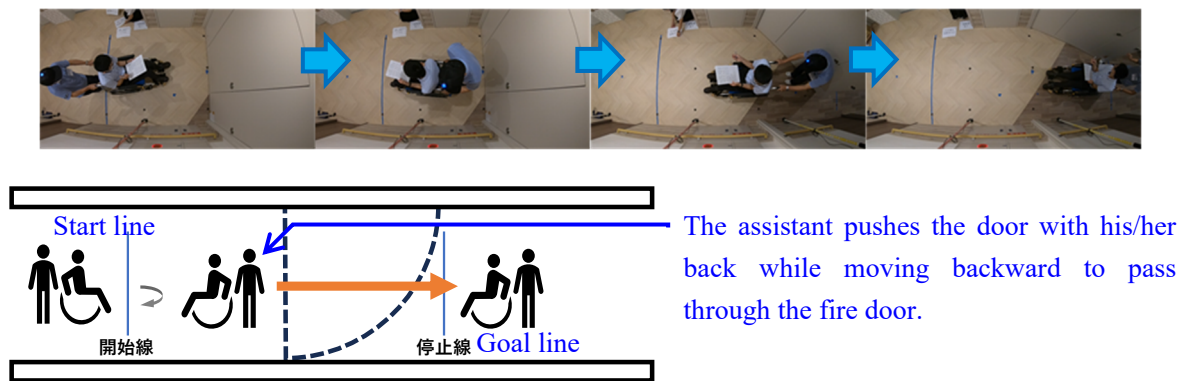
Fig. 7. An example of passing through the fire door under the condition of pushing the door open and moving backward.

3. 3. Area of Fire Resistance for Structural Members and Materials for Disaster Prevention

The fire safety of building components and frames, as well as the fire safety of materials used for interior finishes, fixtures, and furniture have been the primary focus in this area. In FY2023, we continued our previous work by analyzing the fire behavior of fire-protected steel beams using a finite element analysis method, with experimental results from several cases used as a benchmark. In particular, we investigated a finite element analysis method that considers high-temperature creep of steel for beams with higher strength (700 MPa tensile strength) or higher yield points (400 MPa and 500 MPa yield points) compared to ordinary steel (yield point of 325 MPa or lower and tensile strength of 490 MPa or lower).
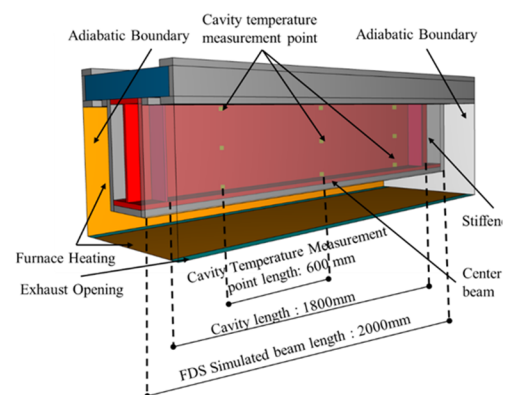
Fig. 8. FDS simulation model for temperatures in cavity of protected steel beam.

These steel grades were developed by Japanese steel manufacturers for advanced seismic design, and their fire resistance performance is still unknown. This research theme is unique and made possible by TUS's advanced experimental facilities, analytical capabilities, and collaboration with industry groups.

In terms of material research, we conducted experiments to simulate an entire fire in a compartment under conditions that replicate the type of materials used in the surrounding structure, such as walls, floor, and ceiling. We also accumulated quantitative data on the effective value of the thermal inertia of materials.

Furthermore, we examined methods to evaluate the functional degradation of buildings caused by natural disasters and the recovery time from such degradation. We conducted resilience analysis of buildings with different collapse modes, which will lead to the development of a seismic performance analysis method from the perspective of the resilience of the city as a collection of buildings. This research aims to address the vulnerability of urban functions to natural disasters, as exemplified by the paralysis and confusion of the capital city of Tokyo after an earthquake, which is currently the most socially feared issue in Japan. This theme is a characteristic research area of TUS, which conducts research on safety against multiple hazards, including fire and earthquakes.

3. 4. Area of Firefighting, Fire Prevention, and Industry Fires

Research is conducted from the viewpoints of "using science and technology to enhance firefighting activities" and "protecting against industrial fires caused by chemical substances."

We have been conducting research on the development of a system to assess the physical and mental condition of firefighters in order to prevent occupational accidents. In cooperation with the fire department, firefighters on duty were asked to put on a wearable device 24 hours a day to quantify their workload based on their heart rate and autonomic nervous system function. Stress conditions were also monitored based on biochemical analysis of saliva samples during work. In addition to this, we developed methods to reduce the burden of firefighting equipment, as well as physiological and biochemical measurements to enhance heat tolerance. These results will contribute to comprehensive safety management.

Photo 2. Measuring the workload of firefighters

Perchlorate can explode even with the slightest shock or heat, but the detailed mechanism of its explosiveness remains unknown. Therefore, we developed a method to extract the characteristics of intermolecular interactions within crystals using deep learning based on the structures of salen complexes registered in crystal structure databases. Using this method, we investigated the cause of the explosive properties of salen complexes. As a result, they found that the salen moiety had no distinctive characteristics, suggesting that the explosive properties are likely due to the chemical bonds and structure of the perchlorate moiety.

Glass wool has been gaining attention as a fire-resistant thermal insulation material. We are investigating the relationship between the internal structure and the thermal insulation performance of insulation materials laminated with a mixture of glass wool and a small amount of inorganic additives used as a binder. As a result of measuring the thermal conductivity, it was shown that the heat transfer characteristics differ when heat is transferred through the laminated glass wool layers (in the thickness direction) compared to the direction along the laminated surface (fiber direction). The thermal conductivity in the thickness direction was found to be smaller than that in the fiber direction. Furthermore, the fiber orientation was quantified using X-ray CT, and the heat transfer coefficient was quantitatively evaluated in relation to the thickness direction.

4. Challenges and Prospects

Research activities were initiated in four new areas in 2021, reflecting the diversification of fire phenomena in recent years. These days, fires such as gasoline arson, or more specifically, "unexpected fires," have frequently been occurring, and the current fire prevention measures may not be sufficient to ensure human safety. These circumstances forced us to initiate research activities in a new, updated framework. Research is conducted by first analyzing characteristic fire phenomena and then identifying and discussing issues in each area. Such efforts will require time to produce satisfactory outcomes. We will continue to solve common problems through close collaboration among the research areas, which will lead to the reduction of fire damage. Furthermore, we would like to strengthen our research network further through active collaboration within the field. In the "Joint Usage/Collaborative Research Center," the number of research projects has been stagnant for the past few years due to the spread of the new coronavirus but finally recovered to the previous activity level in 2023. In the future, we intend to conduct active research activities, including joint research with overseas partners.

5. Conclusion

The Center's research organization has carried out two COE programs promoted by MEXT for ten years. It has also carried out the Strategic Research Infrastructure Formation Support Program for Private Universities (project name: Formation of Asian Fire Safety Information Center Based on Sharing Expertise—A New Approach to Fire Safety in the Information Society) for five years since 2013. Recognizing these achievements, the Center has been positioned as a research center with no fixed term from 2018. We will continue to analyze information on fire accidents, mainly in Asia, and produce research outcomes that contribute to fire risk reduction while promoting them by sharing information with relevant parties in Asia. Furthermore, in Japan, the Center will actively promote and implement its services as a designated performance evaluation institution by the Minister of Land, Infrastructure, Transport and Tourism.

The "Research Center for Fire Safety Science" operated by the Center has been accredited by the Ministry of Education, Culture, Sports, Science and Technology as a Joint Usage/Collaborative Research Center. Therefore, it has the mission to fulfill further its role as the core of fire science research in Japan. Overseas collaboration has been sluggish over the past few years due to the COVID-19 pandemic but has recovered to the previous activity level. We will conduct joint research with more overseas institutions in the future and continue to expand our global activities as a center for fire science and fire safety engineering in Asia.

As for internationalization efforts, it is worth mentioning that, since 2012, the Center has taken the lead in establishing the Forum on Fire Science Research/Education in Asia (Fire FORUM), organizing a symposium/seminar every year. In the past few years, due to the impact of the coronavirus outbreak, the event has been canceled or held online, but a face-to-face meeting was held in Hanoi, Vietnam, in November 2023. So far, discussions have focused on establishing an educational system on fire science, but in the future, the participating institutions of Fire FORUM plan to actively promote international joint research by applying for and being accepted by the Core-to-Core program.

Major Research Achievements (FY 2023)

Academic Papers

1. Gravity effects on the minimum explosive concentrations in 1-D dust explosion, K. Kuwana, S. Yazaki, W. Kim, T. Mogi, R. Dobashi, Combustion Science and Technology, 195(7), pp. 1622-1636, 2023.4 (Peer-reviewed)

2. Fundamental study on relationship between inter-story drift angle and labor amount caused by seismic damage of RC buildings, Suzuki Y, Kinugasa H., Mukai T., Choe H., AIJ journal of technology and design, Vol. 29, No.72, pp.777-782, 2023.6 (in Japanese) (Peer-reviewed)

3. STUDY ON BEHAVIOR OF OPENING FIRE PLUME EJECTED FROM HORIZONTAL OPENING, Shuo ZHANG, Yu-Hsiang WANG, Kodai IMAMURA, Yoshifumi OHMIYA, AIJ J. Technol. Des., Vol. 29, No. 72, pp. 829-833,2023.6 (in Japanese) (Peer-reviewed)

4. Fire whirls: a combustion science perspective, K. Kuwana, K. Matsue, Y. Fukumoto, R. Dobashi, K. Saito, Combustion Science and Technology, 195(13), pp. 3003-3020, 2023.8 (Peer-reviewed)

5. Research on the construction of a CFD analysis model targeting thermal plumes in commercial kitchens (Part 1) Experimental details and study of inflow heat ratio at the bottom and side of the pot, Ariga Mizuki, Hiroki Kimura, Takashi Kurabuchi, Toshihiro Nonaka, Jeongil Kim, Yoshihiro Toriumi, Sihwan Lee, Yuki Shimanuki, Yasumi Kudo, Ryuichi Tominaga, Summaries of technical papers of Annual Meeting Architectural Institute of Japan, 40721, pp.1497-1498, 2023.9 (in Japanese)

6. Research on building a CFD analysis model targeting thermal plumes in commercial kitchens (Part 2) Verification of an analysis model targeting thermal plumes when using a pot, Hiroki Kimura, Mizuki Ariga, Takashi Kurabuchi, Jeongil Kim, Toshihiro Nonaka, Yoshihiro Toriumi, Sihwan Lee, Yuki Shimanuki, Yasumi Kudo, Ryuichi Tominaga, Summaries of technical papers of Annual Meeting Architectural Institute of Japan, 40722, pp.1499-1500, 2023.9 (in Japanese)

7. Critical ignition conditions for propane/air premixtures impinging on electric heated surfaces: an experimental study, T. Imamura, H. Sakuma, M. Nakazawa, K. Kuwana, Fire Safety Journal, 140, 103897 (9 pages), 2023.10 (Peer-reviewed)

8. Deep-learning prediction of safety moiety of salen-type complex crystals towards explosive perchlorate salts, T. Akitsu, Y. Takiguchi, S. Suda, D. Nakane, FirePhysChem, in press. DOI : 10.1016/j.fpc.2023.12.004 (Peer-reviewed)

9. Wearable Ion Sensors for the Detection of Sweat Ions Fabricated by Heat-Transfer Printing, Isao Shitanda, Naoki Muramatsu, Rio Kimura, Nanami Takahashi, Kazuki Watanabe, Hiroyuki Matsui, Noya Loew, Masahiro Motosuke, Takahiro Mukaimoto, Momoko Kobayashi, Taketo Mitsuhara, Yamato Sugita, Kensuke Matsuo, Shinya Yanagita, Tatsunori Suzuki, Hikari Watanabe, and Masayuki Itagaki, ACS Sensors, Vol 8, 2889 – 2895, 2023

10. Air-Bubble-Insensitive Microfluidic Lactate Biosensor for Continuous Monitoring of Lactate in Sweat, Isao Shitanda, Yuro Ozone, Yuki Morishita, Hiroyuki Matsui, Noya Loew, Masahiro Motosuke, Takahiro Mukaimoto, Momoko Kobayashi, Taketo Mitsuhara, Yamato Sugita, Kensuke Matsuo, Shinya Yanagita, Tatsunori Suzuki, Tsutomu Mikawa, Hikari Watanabe, and Masayuki Itagaki, ACS Sensors, Vol 8, 2368-2374, 2023

11. 4. Exposure to Benzo[a]pyrene Decreases Noradrenergic and Serotonergic Axons in Hippocampus of Mouse Brain, Walaa Slouma Hamouda Abd El Naby, Cai Zong, Alzahraa Fergany, Frederick Adams Ekuban, Saleh Ahmed, Yousra Reda, Harue Sato, Sahoko Ichihara, Natsuko Kubota, Shinya Yanagita and Gaku Ichihara, INTERNATIONAL JOURNAL OF MOLECULAR SCIENCES, Vol. 24(12), 2023

12. 実験動物用埋め込み型運動量計へのワイヤレス電力伝送システム ―送受電間の角度変化を考慮した送電コイルの試作―, 葛西徳一, 久保田夏子, 柳田信也, 山本隆彦, 日本 AEM 学会誌, 31 巻, 2 号, pp238 – 243, 2023 (in Japanese)

13. Estimation of heat release rate based on analysis of flame spread behavior in mattresses, Kye-Won Park, Masayuki Mizuno, Chang-Geun Cho, Jong-Jin Jeong, Fire and Materials, 1-12, 2023 (Peer-reviewed)

14. Scale model experiments of toxic gas production from the combustion of polymers when applied with different droplet sizes of water mist, Nicharee Thinnakornsutibutr, Masayuki Mizuno, Kazunori Kuwana, Progress in Scale Modeling, Vol. 4 (1), 1-12, 2023 (in Japanese) (Peer-reviewed)

15. Numerical analysis and validation on the phased evacuation time in high-rise buildings, Guan-Yuan Wu, Masayuki Mizuno and SeongKyung Park, Indoor and Built Environment, Vol. 33 (3), 501-520, 2023 (Peer-reviewed)

16. Numerical model of heat transfer for protected steel beam with cavity under ISO 834 standard fire, Hoang Long Nguyen, Mamoru Kohno, Fire Safety Journal, Vol. 140, P. 8, 2023（Peer-rerviewed）

17. Early Detection of Thermal Runaway of Exothermic Reactions, Thinnakornsutibutr, Kazunori Kuwana, Masayuki Mizuno, Tateo Ushijima, Naritoshi Yazaki, , Jaoan Society for Safety Engineering, Vol. 63, No. 1, pp. 25-30, 2024 (in Japanese) (Peer-reviewed)

18. 連続体モデルと点熱源モデルによる粉塵爆発における重力の影響評価, 桑名一徳, 日本実験力学会誌「実験力学」, 第 24 巻, 第 1 号, pp. 17-22, 2024.3 (in Japanese) (Peer-reviewed)

19. COMPATIBILITY BETWEEN ENHANCEMENT OF FIRE RESISTANCE PERFORMANCE AND CROSS-SECTION REDUCTION OF WOODEN FIRE-RESISTANT STRUCTURAL BEAM, Tomoyo Hokibara, Yuto Akama, Koki Watanabe, Daisuke Kamikawa, Ryo Takase, Ken Matsuyama, J. Environ.. Eng., AIJ, Vol. 89, No. 817, 101-110, Mar., 2024 (in Japanese) (Peer-reviewed)

Books
1. 魔法の「動作感覚つくりの運動」, 森田哲史, 佐藤哲史, 柳田信也, 明治図書, 2023 (in Japanese)
2. Guidelines for Building Evacuation Safety Planning, Yoshifumi Ohmiya 7 others, The Building Center of Japan, 2023 (in Japanese)

Invited Lectures
1. Takashiro Akitsu: "Inorganic Chemistry Perspectives in Radio-volatile RuO4 Studies", World Science Congress ~Joint with The 14th International Science Conference~ (2023.9.26) Bangladesh (Online).
2. Takashiro Akitsu, Daiki Shimonishi : "Chemistry in Wild fire and Air Pollution", The 15th International Science Conference (2024.2.29) Chaudhary Charan Singh University, Meerut, India (Online).
3. 高層・超高層建築物における避難戦略を考える, 水野雅之, 日本火災学会, 2024 年 3 月 21 日 (in Japanese)

Public Relations
1. 河野 守, 防耐火関係の性能評価をめぐる諸情勢, 建材試験情報, 第 59 巻, pp. 14-15, 一般財団法人建材試験センター, 2023 年 9・10 月（in Japanese）
2. 萩原一郎, 大阪北新地放火火災から 2 年ビル改修支援に関するコメント, 産経新聞, 2023.12.16（in Japanese）
3. 萩原一郎, 大牟田市の飲食店街火災についてコメント, 西日本新聞, 2024.1.27（in Japanese）
4. 水野雅之, 火災で死者 相次ぐ, 上毛新聞, 2023.12.10（in Japanese）

Awards

1. Shinya Yanagita, JSPESS Award, Japan Society of Physical Exercise and Sports Science, 2023
2. Y. Mizutani, Y. Mochizuki, A. Sakuma, M. Okoshi, K. Matsuyama, Paper Award of the Japan Institute of Materials Life Society, 2023
3. A. Tanno, Y. Oka, K. Matsuyama and H. Oka, Best Poster Award, The 14th International Symposium on Fire Safety Science, 2023

Individual Research Topics

Takashiro Akitsu
"Prediction of explosive sites of perchlorate compounds using deep learning"

Perchlorate can explode even with the slightest shock or heat, but the detailed mechanism of its explosiveness remains unknown. Therefore, we developed a method to extract the characteristics of intermolecular interactions within crystals using deep learning based on the structures of salen complexes registered in crystal structure databases. Using this method, we investigated the cause of the explosive properties of salen complexes. As a result, they found that the salen moiety had no distinctive characteristics, suggesting that the explosive properties are likely due to the chemical bonds and structure of the perchlorate moiety.

Shiro Ichimura
"Epidemiological survey of heart disease in Japanese firefighters during work time"

On American firefighters, deaths caused heart disease during work time are very high, averaging 43% of all deaths over the past decade (7% for police officers and 11% for emergency medical workers). In particular, the greatest risk is during or immediately after firefighting and the frequency reported to be 10 to 130 times greater than during other fire department operations. However, it is not clear how many Japanese firefighters have heart disease during work time. Therefore, we conduct an epidemiological survey of heart disease during work time in Japanese firefighters.

Yoshifumi Ohmiya
"Study on fire spread prevention system during a building fire"

Assuming a fully-developed fire in a building, the conditions of combustible materials and architectural conditions are used as parameters, and experiments are conducted on the properties of fire plume through the openings. In this study, we quantitatively grasp the influence on the properties of the fire plume when unburned combustible gas blows out from the opening and burns outside, and proposes an evaluation method considering the water discharge system for preventing the spread of fire in building.

Masaki Kato
"Study on thermal stress at occurrence of spalling behavior in high-strength concrete under fire environment"

Concerns about spalling of high strength concrete members in fire have been raised. The purpose of this study is to clarify the main factors that cause spalling by focusing on the thermal stress. In this year, analytical investigations were conducted on members using high strength concrete.

Manabu Kanematsu
"A study on evaluating the durability of fire-retardant-treated wood"

In recent years, fire-retardant-treated wood has been increasingly used as an exterior material for building facades due to its fire-prevention properties. However, concerns have been raised regarding the possibility of the fire-retardant agent leaching out when exposed to rain, which can cause a loss of its required performance over time. This study aims to establish a fire performance evaluation method for fire-retardant-treated wood for exterior use in Japan while taking into account its long-term deterioration characteristics, as well as to clarify the degradation mechanism of fire-retardant-treated wood and develop an accelerated degradation test method by repeated dry-wet cycles.

Hideyuki Kinugasa

"Study on urban functional recovery in the event of natural disasters"

The importance of assessing seismic performance from the perspective of building resilience (i.e., "loss of functionality" and "recovery time" during an earthquake) has recently increased. Against this backdrop, we obtained the loss of functionality and recovery time changes due to increased deformation of the building to demonstrate that there are certain regularities in the resilience behavior induced by increased damage. This resilience assessment defines the loss of functionality in terms of "repair work area" (the floor area that will be unavailable during repair work) and recovery time in terms of "repair time."

Takashi Kurabuchi

"Study on CFD prediction of thermal plume from gas stove and capture efficiency by exhaust Hood"

Standard k-ε model tends to overestimate the exhaust capture efficiency of an exhaust hood of a gas stove on which a pot is placed. It is known that there is a problem with the consistency of the turbulence model, and an attempt was made to apply GGDH, which takes into account temperature and velocity gradients in lateral directions to predict the turbulent heat flux. We are aiming at high-precision prediction by CFD simulation of the exhaust capture efficiency when a pot is placed on a gas stove.

Kazunori Kuwana

"Modeling reactions of combustible solids"

Improving the accuracy of fire and explosion simulations is crucial for quantitative risk assessment and developing efficient firefighting strategies. This study aims at developing mathematical models of combustible-particle reactions during dust explosions and smoldering-to-flaming transitions. Further, dynamical markers for the early detection of transition phenomena are being investigated.

Mamoru Kohno

"Study on the fire resistance performance of building structural members"

Experimental and analytical investigations were conducted on the members that make up buildings, such as beams and floors. Specifically, a finite element method (FEM) analysis technique was developed and analyzed, taking into account creep behavior during fires of columns using high-yield-point steel. The study also constructed a finite element analysis procedure benchmarked against measured temperatures from heating experiments on composite slabs made of concrete and steel decks with various shapes. Additionally, using the developed method, a simplified evaluation formula for fire resistance time related to thermal insulation was proposed.

Atsushi Shono

"Study on thermophysical properties of thermal insulation materials"

For the development of lightweight insulation materials, evaluating their thermal insulation performance is crucial. Thermal conductivity is a key indicator in this regard. We focus on insulation materials composed of glass wool laminated with a small amount of inorganic compounds serving as a binder. The aim of this study is to elucidate the relationship between thermal conductivity and the internal structure of the insulation materials, including fiber orientation, fiber length, fiber diameter, porosity, void shape, and continuous porosity. We will discuss the correlation between the thermal conductivity values obtained from heat flux measurements and the parameters derived from X-ray CT scanner analysis. Additionally, we will examine the equation used to estimate thermal conductivity.

Ichiro Hagiwara

"Study on criteria for firefighting support performance"

The purpose of this study is to clarify the firefighting support performance that buildings should have, and to organize it as a fire safety standard. In past fire incidents, it is often the case that damage has increased because it is difficult to enter in the fire building. This year, the requirements are proposed for emergency rescue openings in each fire compartment, depending on the size.

"Security measures for evacuation safety"

A field survey of security measures such as access control on evacuation routes, which have been increasing in recent years, will be conducted, accidents and failures that are expected to occur will be analyzed, and countermeasures will be considered to ensure evacuation safety. This year, experiments were conducted to operate four types of breakable locks, and data such as the time for unlocking and the force required was measured. Problems related to the operation of breakable locks have been clarified.

Ken Matsuyama

"Study on gas toxicity testing using FT-IR"

In Japan, toxicity testing on combustion product gases of building interior materials has been carried out by qualitative methods using mice. In this study, an experimental study was conducted to establish a quantitative test method using FT-IR. Experiments focused on HCN and HCl concentrations as representative examples of combustion product gases. In particular, the purpose of the study is to find out a relationship between them.

Masayuki Mizuno

"Consideration of evacuation planning methods for full building evacuation from high-rise office buildings"

Evacuation of entire buildings from high-rise structures is a scenario that may arise during disasters, necessitating the consideration of strategies to execute it smoothly and safely. A study was conducted on the evacuation flow within staircases during evacuation drills adopting new sequential evacuation scenarios. Instances of floors not complying with evacuation instructions were observed, and prolonged delays occurred due to scenarios prone to congestion. Future analysis will focus on the duration of such delays.

"Study on the validity assessment of evacuation behavior analysis utilizing VR technology"

In recent years, research utilizing VR technology for evacuation behavior analysis has been actively pursued. This study compared experiments conducted in real space and replicated in VR space focusing on interactions such as passing and overtaking between individuals. Avoidance distances between subjects and others were comparable between walking in VR space and real space, while movements via VR controllers were smaller than those in real space. This is attributed to the absence of physical sensations like body sway in VR space during controller operation.

Shinya Yanagita

"Physiological analysis for the prevention of heat stroke in firefighters"

To improve the safety of firefighters in fire and rescue operations, physiological measurements of physical and psychological stress during actual firefighting activities are being conducted. Currently, heat acclimatization and body cooling experiments are being conducted in an environment that simulates an actual fire site, with heat stroke prevention as a research target.

"Quantifying the physical and mental workload of firefighters"

Not only do firefighters work in a time-consuming environment, such as 24-hour shifts, but they also respond to disasters and accidents, which is an occupation with an extremely high mental and physical workload. To maintain their occupational safety, we are analyzing the physical and mental conditions of firefighters using physiological measures. In addition, comparative verification by region is being conducted throughout Japan.

Water Frontier Research Center (WaTUS)

Water Frontier Research Center (WaTUS)

1. Overview

Water Frontier Research Center (WaTUS) established in April 2021, is a successor research organization of Water Frontier Science and Research Center which was launched in November 2016 for promoting Research Branding Project "Formation of an Interdisciplinary Research Center for Water at Material Surfaces and Interfaces," supported by the Ministry of Education, Culture, Sports, Science and Technology, Japan. Our research center focused on "water" which is essential for all the lives and their various activities. Especially, interaction between water and materials' surface, namely "water interface", is generally very complicated and particularly difficult to be fully understood. Our aim is to tackle these complicated issues related on "water interface."

We, WaTUS, aims to pursue leading-edge researches and developments relating to "Water Interface" with multi-disciplinarily collaborative researches. Our mission is to perform following missions:

(1) Pursuit of state-of-the-art science and technologies of water interface by collaboration and technical excellence
(2) Establishment of international research core of excellence
(3) Provision of "one-stop service" of water researches for industries
(4) Visualization of TUS through our research activities

Formation of research and development hub for "Water Interface" through our researches means to create the place where researchers all over the world can join and to establish research organization which can provide practical solutions to industries.

To carry our above-mentioned missions, highly intensive collaborations of fundamental researches and technical developments with researchers inside and outside of the center become a key.

2. Organization and Facilities

WaTUS promotes interdisciplinary collaborative researches to achieve our goals. We consist of matrix-based research units with approaches (Materials development, Measurement & Analysis, and Theory & Simulation) and targets (Materials & Water, Life & Water, and Environment & Water). In this 3×3 matrix-based research unit (Fig. 3), our center encourages researchers who develop novel materials with high functionality, ones who develop cutting-edge measurement and analysis techniques, and ones who perform advanced theoretical consideration and simulation, to perform intensively flexible collaborative studies expecting synergetic effects. Also, more flexible style of collaboration involving ones outside of the center are appreciated in this center.

- Materials and Water: this unit pursues research and development considering relation between water and materials from atomic to macroscale
- Life and Water: this unit pursues research and development contributing to human beings and medical diagnostics or medical and biological engineering
- Environment and Water: this unit pursues research and development for environment and industries. Earth science and energy conservation is also included in this unit

WaTUS has advanced facilities with state-of-the-art analytical systems for pursuing leading-edge researches of "water interface"; for example, (i) heterodyne sum frequency generator, (ii) atmosphere-controlled scanning probe microscopy, (iii) sputtering equipment, (iv) interfacial fluorescence microscopy, and (v) high-speed camera system. Also, we have been released a newly-developed multi-level water

simulator, which provide intuitive connection between quantum mechanics, molecular dynamics, and fluid dynamics calculations for water on materials interface.

3. Activity Reports

As mentioned above, our research center consists of three research units, "Materials and Water," "Life and Water," and "Environment and Water." Each units perform research activities with mutual cooperation. Below we report on some of our recent research activities.

3. 1. Water Molecular Model Representing Shear Viscosity

Despite the simple chemical composition of water, consisting of two hydrogen atoms and one oxygen atom, it remains difficult to reproduce the various experimental properties of bulk water in computer simulation. Researchers must choose an appropriate model among a number of different models depending on their purposes. In this study, using molecular dynamics, shear viscosity was calculated and compared in the temperature range from 273 K to 373 K using various water molecule models such as OPC and OPC3 models, TIP4P/2005, TIP4P-FB, and TIP3P-FB models (Fig. 1). The results show that the OPC and OPC3 models have the best performance. This result can provide a fundamental and

Fig. 1. Molecular dynamics simulation of water molecules.

important finding for many researchers relating transport phenomena of water molecules and biological simulations where water dynamics is relevant.

3. 2. Hydrogels Aiming for Medical Applications

Hydrogels can absorb exudates from skin tissues and maintain a moist environment to promote wound healing. It has been said that these wound healing gels need "adhesiveness" to follow skin movement and "swelling" to absorb exudate. However, when the gel absorbs exudate and swells while adhering to the skin, the wound is pulled along with the gel, causing wound expansion. In this study, we succeeded in developing a gel with low skin adhesion and low swelling using alginate for the wound healing that is gentle to the wound and has higher functionality. This gel can be prepared by adding carbonated water to a mixed solution of potassium alginate and $CaCO_3$, and has high biocompatibility. In order to evaluate the performance of the developed hydrogel, the adhesive properties and wound healing effect of the gel on NHDF cells (human dermal fibroblasts) and mouse skin tissue were confirmed, and it was found to have high healing effect with low adhesiveness and swelling. Alginic acid, the base of the gel, can be extracted from seaweed, making it an inexpensive, simple, and environmentally friendly material.
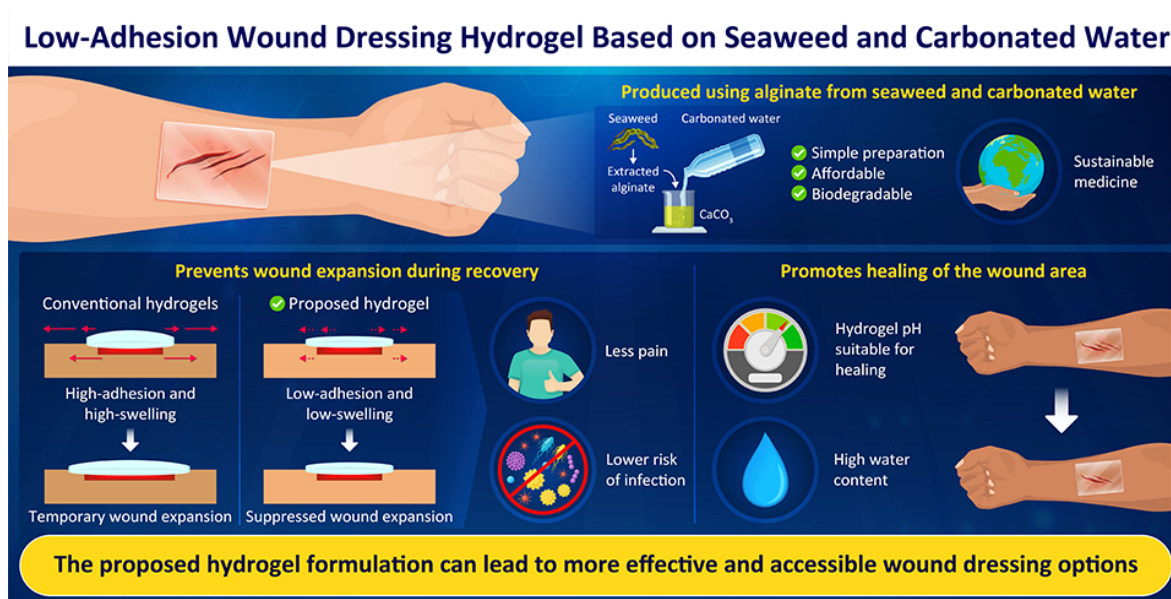
Fig. 2. Newly-developed wound healing hydrogel.

3. 3. High-throughput Cancer Cell Assay Technology

Cancer is the primary cause of death today in Japan, and its early diagnosis is extremely important. Physical properties of cell membrane and cytoplasm would change when the cells become cancerous, but the evaluation of individual cells is extremely complicated, cumbersome and time-consuming. A cell evaluation method with high throughput is required. In this study, we developed a novel assay technology called continuous-flow electrorotation (cROT), which can evaluate the electrical properties of many cells in a label-free manner, and developed a device and system. This method utilizes the phenomenon that cells rotate in response to the polarization characteristics when cells are subjected to a rotating AC electric filed with a certain frequency range. Furthermore, individual cells are automatically manipulated to the analysis site. The analysis is completed simply by pouring cells into the microfluidic channel. The effectiveness of the system was demonstrated by analyzing cancer cells (HeLa and A549) as the measurement of the permittivity of the cell membrane and the conductivity of the cytoplasm. The developed cell analysis system automates a series of tasks to detect cells from images of flowing cells, measure their rotation speed by image processing, and evaluate their electrical properties. This technology has a potential to become a highly functional assay technology capable of evaluating more cells through future improvements.
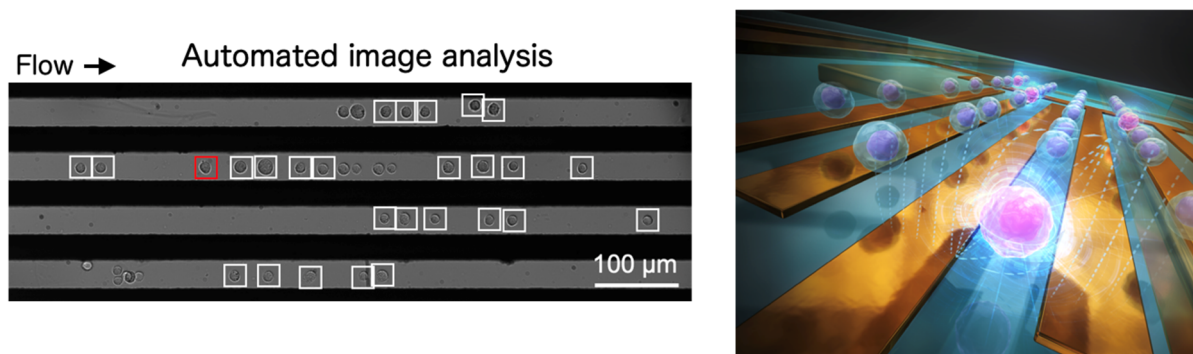
Fig. 3. High-throughput Cell Assay System for Electrical Properties.

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3. 4. Other Activities

We held a number of events. In addition to two evening seminars, which are mainly organized by young researchers, three special seminars and one workshop were held by prominent researchers to promote mutual research exchanges with researchers inside and outside. Moreover, we have participated in two exhibitions to promote our research center, research activities, to a wide range of people.

4. Challenges and Prospects

As an interdisciplinary research center for "water," we hope to be a leading organization tackling social issues, in addition to promoting cutting-edge research through mutual collaboration among physics, chemistry, and engineering fields. In addition to research, in 2022, we started an educational class of "Advanced Water Science" for all the graduate students in Tokyo University of Science, and more than 250 students were enrolled.

As an interdisciplinary research center for "water," we, WaTUS, hope that this research center will not only promote cutting-edge research through collaboration among faculty members in physics, chemistry, and engineering that transcends disciplinary boundaries, but also become a center that responds to social issues and leads the university. We would like to hold events that promote interaction among faculty members and students within the center and enhance new collaborations.

5. Conclusion

New joint researches and collaborations have started while on-going projects has actively continued. Therefore, further progress is expected. Also, a multi-level water simulator was partially released. We, Water Frontier Research Center (WaTUS), intend to continue both research and educational activities with high enthusiasm.

Major Research Achievements (FY 2023)

Academic Papers

1. Continuous-flow electrorotation (cROT): improved throughput characterization for dielectric properties of cancer cells, Kazuka Yoda, <u>Yoshiyasu Ichikawa</u>, <u>Masahiro Motosuke</u>, Lab on a Chip, Vol. 23, pp.4986-4996, 2023 (Peer-reviewed)

2. Coexistence of slow and fast dynamics in interfacial water around a carbon nanotube, Yusei Kioka, Takemi Hara, Yuki Maekawa, Kenji Sasaoka, <u>Yoshikazu Homma</u>, <u>Takahiro Yamamoto</u>, Japanese Journal of Applied Physics, Vol. 62, No. 8, 085003, 2023 (Peer-reviewed)

3. Shear viscosity of OPC and OPC3 water models, <u>Tadashi Ando</u>, J. Chem. Phys., Vol. 14, pp 101102, 2023 (Peer-reviewed)

4. Capillary-driven horseshoe vortex around a micro-pillar, Kogen Ozawa, Hayate Nakamura, Georg F. Dietze, Harunori N. Yoshikawa, Farzam Zoueshtiagh, <u>Kizuku Kurose</u>, Lizhong Mu, <u>Ichiro Ueno</u>, Journal of Colloid and Interface Science, 642, pp. 227-234, 2023 (Peer-reviewed)

5. Multicellular structures in thin free liquid films induced by thermocapillary effect, akahiro Homma, Tokiya Yamashita, Ryohei Wada, Koki Kawazu, <u>Kizuku Kurose</u>, <u>Takahiro Tsukahara</u>, <u>Ichiro Ueno</u>, Journal of Colloid and Interface Science, 641, 187-196, 2023 (Peer-reviewed)

6. Three-dimensional co-culture model employing silica nonwoven fabrics to enhance cell-to-cell communication of paracrine signaling between hepatocytes and fibroblasts, Shohei Ishikawa, Kazutoshi Iijima, Kohei Sasaki, Masaaki Kawabe, <u>Shigehito Osawa</u>, <u>Hidenori Otsuka</u>, Biotechnology and Bioengineering, 120(7), pp. 1961-1974, 2023 (Peer-reviewed)

7. Enhanced removal of photoresist films through swelling and dewetting using pluronic surfactants, Masaki Hanzawa, Taku Ogura, <u>Masaaki Akamatsu</u>, <u>Kenichi Sakai</u>, <u>Hideki Sakai</u>, Langmuir, 39(41), pp. 14670-14679, 2023 (Peer-reviewed)

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9. Air-bubble insensitive microfluidic lactate biosensor for continuous monitoring of lactate in sweat, <u>Isao Shitanda</u>, Yuro Ozone, Yuki Morishita, Hiroyuki Matsui, Noya Loew, <u>Masahiro Motosuke</u>, Takahiro Mukaimoto, Momoko Kobayashi, Taketo Mitsuhara, Yamato Sugita, Kensuke Matsuo, Shinya Yanagita, Tatsunori Suzuki, Tsutomu Mikawa, Hikari Watanabe, Masayuki Itagaki, ACS Sensors, 8(6), pp. 2368-2374, 2023 (Peer-reviewed)

10. Wearable ion sensors for the detection of sweat ions fabricated by heat transfer printing, <u>Isao Shitanda</u>, Naoki Muramatsu, Rio Kimura, Nanami Takahashi, Kazuki Watanabe, Hiroyuki Matsui, Noya Loew, <u>Masahiro Motosuke</u>, Takahiro Mukaimoto, Momoko Kobayashi, Taketo Mitsuhara, Yamato Sugita, Kensuke Matsuo, Shinya Yanagita, Tatsunori Suzuki, Hikari Watanabe, Masayuki Itagaki, ACS Sensors, 8(7), pp. 2889-2895, 2023 (Peer-reviewed)

11. Droplet duos on water display pairing, autonomous motion, and periodic eruption, <u>Yutaka Sumino</u>, Ryo Yamashita, Kazuki Miyaji, Hiroaki Ishikawa, Maho Otani, Daigo Yamamoto, Erika Okita, Yasunao Okamoto, Marie Pierre Krafft, Kenichi Yoshikawa, Akihisa Shioi, Scientific Report, 13, pp12377-1-10, 2023 (Peer-reviewed)

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15. Deposition of layered double hydroxide on non-pretreated carbon cloth using lactate salts as raw materials, Shingo Machida, Kaishi Hasegawa, Kenichi Katsumata, Atsuo Yasumori, International Journal of Cerammic Engineering and Science, Vol. 5, e10190, 2023 (Peer-reviewed)

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22. Technique for estimating the charge number of individual radioactive particles using Kelvin probe force microscopy, Yukimi Shinke, Tatsuhiro Mori, Ayumi Iwata, Muhammad Aiman bin Mohd Nor, Keiichi Kurosawa, Makoto Inagaki, Shun Sekimoto, Koichi Takamiya, Yuichi Oki, Tsutomu Ohtsuki, Yoasuhiro Igarashi, Tomoaki Okuda, Aerosol Science & Technology, 57(8), pp. 758–768, 2023 (Peer-reviewed)

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24. Equilibrium molecular dynamics evaluation of the solid-liquid friction coefficient: role of timescales, Haruki Oga, Takeshi Omori, Laurent Joly, Yasutaka Yamaguchi, Journal of Chemical Physisics, Vol. 159, pp. 024701_1-11, 2023 (Peer-reviewed)

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Invited Lectures
1. Advanced nanoparticle control and detection in water, Masahiro Motosuke, Materials Research Meeting (MRM), Kyoto, 2023
2. Novel "Photo-Switchable" Molecular Assemblies, Sakai, H.,FORMULA XI, Lille, France, July 6, 2023
3. Deep learning estimation of scalar source in turbulence, T. Tsukahara, AJKFED2023 (The ASME-JSME-KSME Joint Fluids Engineering Conference), Osaka, 2023

Public Relations

1. Exhibition of Water Frontier Research Center, 23rd International nanotechnology exhibition, 2024 (in Japanese)

2. TUS evaluates exercise loard by sweat, Nikkei, August 9, 2023 (in Japanese)

Individual Research Topics

Masahiro Motosuke
"Nanoparticle manipulation using plasmonic bubble"

In this study, the manipulation of nanomaterials suspended in water using plasmonic heating with themophoresis and interfacial flow around a photothermal bubble is investigated. It is found that frequent modulation in the heating provides significant difference in the accumulation pattern of nanomaterials. This would suggest that an itnteraction between heat dissipation and bubble dynamics including the onset of the interfacial flow grealy influence the accumulation phenomena.

Kenichi Sakai
"Effects of counterion on the formation and hydration behavior of α-form hydrated crystals"

The hydration or water sorption of amphiphilic materials in water vapor was assessed using a humidity-controlled quartz crystal microbalance with dissipation monitoring (QCM-D) technique. The amphiphilic materials used in this study were hexadecyl phosphate salts neutralized with L-arginine (C16P-Arg), CsOH (C16P-Cs), KOH (C16P-K), and NaOH (C16P-Na). The key conclusion is that the significant hydration ability of C16P-Arg and C16P-Cs promotes the formation of the corresponding α-form hydrated crystals.

Yoshikazu Homma
"Evaluation of structure and physical properties of water confined in nanospace of nanocarbon"

We use molecular dynamics simulations to analyze phase changes in two-dimensional nanostructured water existing on the surfaces of carbon nanotubes (CNTs) and graphene, and in one-dimensional nanostructured water existing in the internal space of CNTs. We aim at construction of phase diagrams of low dimensional water confined in nanospace.

Takahiro Yamamoto
"Two state coexistence and dynamical heterogeneity of water in a nanotube"

Using classical molecular dynamics (MD) simulations, we investigated the polarization of water when a gated electric field is applied to water inserted between an hBN substrate and graphene placed on top of it. We concluded that the polarization of water does not affect the electrical transport properties of graphene under the weak electric field as used in the device.

Hiroharu Yui
"Laser spectroscopic measurements of adosorbed water molecules and thier dynamic wetting on material's surfaces"

We have developed original laser spectroscopic methods utilizing phase-sensitive detection. We applied them to invesitigate adosorbed water molecules and thier dynamic wetting on material's surfaces. We clarified heterogeneous stuructures of adosorpted water on glass surfaces depending on thier chemical composition. In addition, we succeeded in measuring dynamic wetting front with nanometer-thickness in-situ by real-time phase-contrasted laser imaging techniques.

Tadashi Ando

"Shear viscosity of OPC and OPC3 water models"

Water is a unique and abundant substance in biological and chemical systems. Considering its importance and ubiquity, numerous water models have been developed to reproduce various properties of bulk water in molecular simulations. Therefore, selecting an appropriate water model suitable for the properties of interest is crucial for computational studies of water systems. OPC and OPC3 are water models that reproduce numerous properties of bulk water with high accuracy. However, the shear viscosity of these water models had not been reported. In this study, we evaluated the shear viscosity of these water models using the Green-Kubo formula at different temperatures ranging from 273 K to 373 K. Both models showed good agreement with the experimental results above 310 K, but underestimated the shear viscosity below 310 K, showing values 20% lower than the experimental values at 273 K and 10% lower at 298 K.

Yoshiyasu Ichikawa

"Measurement of complex flow behavior"

This study uses optical flow measurement techniques to reveal the complex flow behavior of viscoelastic fluids. We focused on the flow around micro-obstacles, and the velocity distribution in the low-speed regions between obstacles was obtained. Then, the correlation between each low-speed region's behavior was provided. Additionally, the relationship between the viscosity and shear rate was devised.

Ichiro Ueno

"On heat and mass transfer problems near solid-liquid-gas interface"

Dealing with (i) capillary-driven local acceleration of contact line after interaction with micropillar, (ii) high-density heat removal by subcooled boiling, and (iii) coherent structure formation by low-Stokes number particles in closed systems.

Shu-hei Urashima

"Hydrogen-bonding networks of water on material surfaces and interfaces"

Adsorbed water on material surfaces under atmospheric conditions drastically changes their properties such as friction, wettability, and electrification. Oil/water interfaces are ubiquitously found in biological system and utilized in solvent extraction processes, where molecules are dynamically crossing through the interfaces. However, we have still little knowledge about how the water molecules at the surfaces/interfaces change their properties and affect the functions and the transport phenomena. The aim of the study is pushing forward our knowledge from the scale of the microscopic changes in the hydrogen-bonding network structures of water at the surfaces and interfaces.

Hidenori Otsuka

"Structural design of novel self-healing interpenetrating polymer network (IPN) gels with hydrazone bond-derived cross-links"

IPN gels with self-healing properties, employing chemical cross-linking formed by hydrazone-dynamic bonding and physical cross-linking formed by peptides, were investigated as in the previous year. When human-derived liver cancer cells were suspended in the self-healing gel and injected with a syringe, they gelated in situ and the cells were loaded into the gel, indicating the possibility of highly efficient retention of the cells in the affected area. In addition, the gel network structure functioned as a scaffold for the cells, and growth, organization, and functional expression of the transplanted cells were confirmed.

Ken-ichi Katsumata

"Development of photocatalytic materials for decomposition of nitrate ion in water"

Photocatalysts with Pd and Cu supported on the composite surface of titanium dioxide (TiO_2) and graphene (GnP) were prepared, and changes in the concentration of nitrate ions in water were measured. the decomposition of NO_3^- was greatly improved by optimizing the mixture ratio of TiO_2 and GnP. It was also inferred that NO_3^- was reduced to NO_2^- and even gas components were reduced. When layered potassium niobate was used as the material, it was found that doping rhodium and ruthenium in the niobate layer improved the decomposition activity.

Kizuku Kurose

"Heat transport characteristics of pulsating heat pipe"

We conduct heat transfer experiments and develop a simulation model to improve the heat transport performance and clarify the complex gas-liquid two-phase flow with boiling and condensation in Pulsating Heat Pipes (PHPs). In the former experiment, the evaluation of heat transfer performance was conducted and the flow patterns were captured using a high-speed camera, elucidating the effects of various parameters on the thermal transport performance. In the latter numerical analysis, the mechanism of transition between oscillating flow and pulsating-circulating flow were proposed based on the simulation results.

Hideki Sakai

"Effect of plant-derived sterol derivatives on the membrane properties and hydration state of phospholipid mixed bilayers"

We investigated the effect of plant-derived sterol derivatives (PSO_4) on the membrane properties of liposomes preparaed by mixtures of saturated (DPPC) and unsaturated (DOPC) phospholipids, which mimic cell membranes. The addition of a small amount of DOPC to DPPC improved the fluidity of the bilayer membrane and the dispersion stability of the liposomes. Furthermore, we found that the addition of PSO_4 decreased the number of membranes in the multilamellar vesicles and significantly increased the retention of water-soluble drugs.

Shinya Sasaki

"Study on friction mechanism by interface nanostructure control"

We are conducting research to control macroscopic tribological properties by imparting nanostructures to friction surfaces. On the friction interface, a lubricant-derived chemical reaction film called a tribofilm is formed, and the macroscopic friction and wear properties are governed by the mechanical properties of this film. In this study, we measured the formation process of the tribofilm using AFM in situ observation method and investigated the effects of additive type and friction conditions on the film formation rate. Additionally, we measured the mechanical properties using AFM and nanoindentation and examined their relationship with macroscopic properties.

Isao Shitanda

"Study on rheo-impedance"

This study proposes a new method to evaluate the dispersibility of carbon dispersion liquids by measuring electrochemical impedance while applying shear stress with a rheometer. The changes in rheo-impedance spectra were measured when a dispersant was added to the carbon dispersion. The appropriate dispersant concentration was evaluated by fitting an equivalent circuit model and calculating various parameters.

Yutaka Sumino

"Pattern formation of a fluidic system under nonequilibrium condtion"

In this research topic, we focused on the pattern formation of fluidic systems with chemical reactions, phase separation, molecular motors, and rheological changes. Such processes have a system under nonequilibrium conditions and create macroscopic patterns. Here, we used a system with droplets that generate flows owing to the Marangoni effect and localization of molecular motors. The convective flow then creates the translational motion of droplets. We also studied liquid crystals and viscoelastic fluids that show fingering patterns.

Makoto Tadokoro

"Study on water molecular clusters confined to one-dimensional nanopores in molecular crystals"

Water molecules confined to hydrophilic one-dimensional nanopores in molecular crystals have a characteristic regular hierarchical structure, which is different properties from those of bulk water. We are conducting research on some gas-storage materials for artificial gas hydrates made by adding methane and Xe to the water clusters, and proton conductive ones such as artificial ion-clathrate hydrates made by adding electrolyte salts.

Takahiro Tsukahara

"Scalar diffusion source estimation by machine learning"

We conducted scalar concentration-diffusion source estimation by machine learning mainly using convolutional neural networks (CNNs), where we estimated the streamwise distance or time from the observation point to the scalar source based on instantaneous local concentration information. It was demonstrated that even under different flow conditions, robust estimation is possible if there is sufficient information (e.g., observation window size).

Eiji Tokunaga

"Study of mechanism and application of the interfacial water Pockels effect"

We are conducting research to elucidate the physical mechanism that can predict the giant Pockels coefficient of water in the electric double layer at the electrode interface and to apply the interfacial water Pockels effect. This year, the Pockels effect of interfacial water on transparent oxide, Cu, and Si electrodes was investigated for two electrodes with an electric field perpendicular to the interface and one electrode with an electric field parallel to the interface. The magnitude and sign of the Pockels signal for the latter case were found to have a systematic dependence on the location on the electrode, reflecting the distribution of the perpendicular electric field on the electrode surface.

Shingo Machida

"Development of techniques for stabilizing powders with functionalities to bulk materials"

Although photocatalysts, adsorbents, and anti-bacterial materials have high expectations from materials besides environmental publication, such as water purification, because powder samples can be hardly handled, I develop techniques for stabilizing powders to bulk materials without detaching them and decreasing their functionalities. Especially, in this fiscal year, the method for the direct deposition of particles with hydrophilicity onto hydrophobic surfaces was developed.

Kazuhiko Miura

"Study on climate effects of atmospheric aerosols"

In order to investigate the effects of anthropogenic and background aerosols, we are conducting observations on the roof of TUS Building No. 1, and on Mt. Fuji, respectively. The particle concentration measured at the summit of Mt. Fuji in summer decreased to about one-third from 2006 to 2019. We have continued year-round observations at Tarobo (1290m) at the foot of Mt. Fuji in order to see post-coronavirus changes, but there was no tendency for a decrease in the total particle concentration in the summer from 2017 to 2023 at Tarobo. I would like to analyze it in detail in future.

Makoto Yamamoto

"Study on numerical simulation of icing phenomenon"

Icing is a phenomenon in which supercooled droplets or ice particles in the atmosphere collide with a wall surface to form an ice layer on the wall surface. When icing occurs on an aircraft, it causes deterioration of aerodynamic performance and mechanical damages due to the collision of shed ice pieces, which causes a serious threat to flight safety. In our laboratory, we are conducting numerical simulation research on the development of simulation methods for accurately predicting icing phenomenon, the evaluation of anti-icing and de-icing technologies, and the clarification of the impact behavior of droplets on walls and the solidification process.

Masaaki Akamatsu

"Study of controling water wettability by anion adsorption at water interface"

Anion–π interaction is an attractive interaction between an anion and an electron-deficient aromatic ring. In recent years, it has been found that its contribution to interfacial phenomena such as bioadhesion. We have demonstrated that anion adsorption is the driving force for the improvement of water-wettability on polymer brush substrates with naphthalenediimide (NDI) units. We assume this is due to the increase in charge density and hydration near the interface associated with anion adsorption. It is expected to be applied in selective sensing and liquid transport technology.

Yuki Araki

"Nanoscopic wetting of glass surfaces"

We evaluated the coexistence of nano water droplets and nano water film on glass surfaces in a humid environment using frequency modulation atomic force microscopy (FM-AFM) and peak force tapping AFM. We found that nano water film are initially formed under low humidity conditions, with nano water droplets forming on top in high humidity. The formation of silica gel-like layer on the glass surface by the nano wáter film may contribute to nano wáter droplet formation. We will observe changes in the fine structure of glass surfaces due to humidity using FM-AFM and further investigate the gel layer on the glass surfaces.

Shigehito Osawa

"Building locally concentrated state of metal complexes in aqueous milieu based on polymer chemistry toward biomaterial applications"

Metal complexes installed on polymer chains would be under a locally concentrated state because the diffusion of the metal complexes is limited on inside of polymer conformation even though the metal complexes total concentration is quite low. During chemical reaction, the locally concentrated state would promote formation of the reaction intermediates composed of the multiple metal complexes, eventually changing catalytic activity of the metal complexes. We develop the polymers having metal complexes toward biomaterial applications through investigations and evaluations on the catalytic activity and molecular recognition properties of the locally concentrated state of metal complexes under physiological circumstances.

Koichiro Kato

"Integration of data science and molecular simulation to study water on material surfaces and in polymer membranes"

Molecular simulation and data science will be used to study the structure of water at the micro and mesoscale. Microstructural analysis of water on graphene surfaces using persistent homology has successfully revealed the transition from surface water to free water, and these methods will be extended to other material surfaces. In addition, mesoscale phase-separated structural analysis of polymeric materials and water by coarse-grained simulation and persistent homology will be initiated.

Shouhei Kawada

"Effect of water molecule on active friction control"

Reducing friction and wear can contribute to improved energy efficiency and reduced carbon dioxide emissions over the entire life cycle of materials. The microstructure of the lubricant at the friction interface dominates the macro-friction. Therefore, we are attempting to control the microstructure of lubricants by surface potential. However, adsorbed water at the friction interface and water in the air are mixed in the lubricant. Since these water molecules are also adsorbed in response to surface potential, it is very important to visualize the dynamics of water molecules. In this year's study, we clarified how water molecules reach the friction interface by using hydrophobic and hydrophilic lubricants through spectroscopic analysis and friction tests. The results showed that water molecules remove the adsorption film of lubricant-derived lubricants in the hydrophilic lubricants.

Kengo Manabe

"Development of functional surfaces using wettability"

Our research is being conducted on elucidating phenomena at surface interfaces, focusing on surface wettability, and on the creation of functional composite materials using these phenomena. In the 2023 fiscal year, a surface exhibiting Zwitter-wettability, a seemingly contradictory property combining hydrophobicity at the outermost surface and water absorbency, was developed. Additionally, while self-healing phenomena in hydrophilic and highly water-absorbent polymers had been confirmed previously, precise control of surface wettability enabled the first realization of self-healing phenomena in Zwitter-wettable surfaces.

Tatsuhiro Mori

"Seasonal charge distributions of submicron atmospheric particles in Yokohama, Japan"

The number concentrations of non-charged and charged particles within the 0.3–0.5 µm diameter (D) were measured at Keio University in Yokohama, Japan, from June 2022 to January 2023 by combining a parallel-pate particle separator and optical particle counters to investigate critical parameters controlling the charging state of atmospheric particles. The measurement uncertainties in the average charge number per particle (p_{ave}) and the standard deviation (1σ) were within 15%. The monthly median values of 1σ increased in summer and decreased in winter and correlated with the water vapor amount and wind speed. The 1σ values in summer and winter were close to those from the theoretically calculated charge distribution of particles within 0.387–0.5 µm D range and with $D = 0.3$ µm, respectively, suggesting that the observed particle charge distributions approached the stationary charge distribution for the effective D. In summer, the frequent transport of water and ions from the Pacific Ocean causes efficient collisions between multiple ions and particles with a larger effective D, which may expand the charge distribution. The polarity ratio, the concentration of positively charged particles relative to that of negatively charged particles, was almost unity. The polarity ratio and p_{ave} changed significantly during lightning events, indicating that the atmospheric particle charge balance broke. Our findings show that the charge distribution of atmospheric particles can be partly controlled by meteorological parameters (e.g., absolute humidity) and the microphysical properties of the particles.

Yasutaka Yamaguchi

"Microscopic and macroscopic physics of liquid-solid interface regarding wetting and friction"

We examine the physics of liquid-solid interface regarding wetting and friction using molecular dynamics analysis. Specifically, we focus on the water wetting on silica and graphene surface and on the method to extract liquid-solid friction from the equilibrium fluctuation of the shear force between liquid and solid.

Ken Yamamoto

"Research on soft matter dynamics"

We conduct experimental research aimed at understanding the dynamic behavior of soft matter, such as the drop impact or sphere rolling motion on a granular bed and Leidenfrost droplets. In our experiments, we use multiple measurement techniques including high-speed visualization, interferometry, and thermography, to approach the understanding of the phenomena through multimodal measurements.

Naoki Watanabe

"Release of water-interface integrated simulator"

We have developed a water-interface integrated simulator that allows for easy execution of numerical simulation analysis on the structure, behavior, and properties of water molecules on material interfaces. With the GUI of this simulator, water molecules can be arranged on the material interface, and by pressing the execute button for molecular dynamics calculations, the resulting calculations are analyzed and displayed on the screen. This includes the contact angle of water droplets, viscosity, surface tension of water, network diagram showing shape characteristics of hydrogen bonding, and persistent diagram showing cavity characteristics of water molecules. We began publicly releasing this simulator to the general public via the WaTUS website.

Research Center for Space System Innovation

Research Center for Space System Innovation

1. Overview

By bringing together our research and education activities related to space development and space environment utilization at Tokyo University of Science, we have established a research center for comprehensively studying various technological issues, ranging from basic research to ways of traveling into space.

Specifically, with the following goals in mind, we aim to build a place for co-creation where cross-disciplinary technologies and human resources can be brought together to form a virtuous cycle between the earth and space, in order to solve various issues common to both space and earth (Fig. 1).

- By utilizing photocatalytic technology, which is one of the specialties of our university, we aim to develop life-support technologies in space and to realize a safe and comfortable living environment on earth.
- We will work on demonstrating technologies in space using suborbital spaceplanes under development and the International Space Station, and develop a new "space" market in partnership with industry.
- The Research Center for Space Colony, which has been researching and developing space-stay technologies, will shift its focus to "dual development on earth and in space and the development of space vehicles to bridge the two," to achieve further strategic development.
- We will provide a place for education based on these research opportunities connected to space, secure and foster Ph.D students and young researchers, and build an environment where they can experience "real" research.
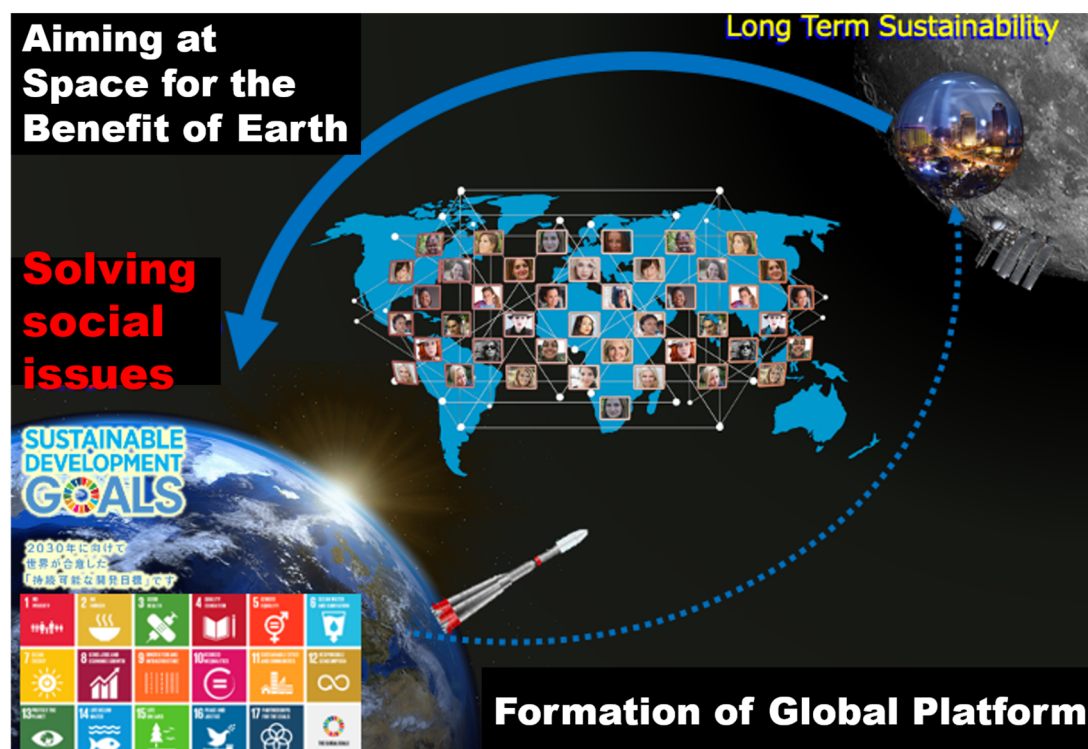

Fig. 1. Dual development on earth and in space.

2. Organization and Facilities

The Research Center is engaged in collaborative research between its four units and coordinates the technologies produced by its research and development processes (Fig. 2). The technologies are rapidly transferred to applications which can effectively utilize them and realize technological advancement that can be used on Earth as well as in the future for usage in space.

Education Unit
"Education utilizing "real" technology and experience that leads to actual use in space"
Utilizing the technologies and research of Tokyo University of Science, such as flight missions, rocket launches, theoretical research in astrophysics, and astronomical observations, for the purpose of education is a great incentive for both researchers and students. In addition to participating in a number of missions, we will work in close cooperation with domestic and international space development organizations, space venture companies, and space development companies, and will actively utilize the results obtained for education.

Photocatalysis International Unit
"Solving resource and environmental problems based on photocatalysis"
Photocatalysts, such as titanium dioxide, are effective for decomposing organic pollutants and have antibacterial and disinfecting properties, due to their strong oxidative decomposition power. In addition, research on artificial photosynthesis using photocatalysts (hydrogen production by water decomposition and generation of valuable substances by carbon dioxide reduction) is being actively conducted. By advancing these studies, we will tackle existing issues on earth that must also be overcome when entering space, such as environmental purification and energy production.

Space Colony Unit
"Advancement of space-stay technologies and promotion of social use, with a focus on space habitation"
We will conduct cross-disciplinary research and development of various technologies related to clothing, food, and housing that have not been directly related to space so far, as well as infrastructure construction technologies in closed environments, such as electric power and telecommunications. In addition, we will collaborate with companies and research institutes on the applied development of space-stay technology designed to allow humans to stay in an extreme closed environment for a long time, aiming to solve social issues such as disasters and food problems on earth, which are common issues for humanity.

Spaceplane Unit
"Development of spaceplanes that allow anyone to travel to and from space"
The Spaceplane Unit conducts research and development on system integration, including system optimization technology, fault-tolerant systems, LOX/LNG engine operation, autonomous navigation technology, composite airframes and propellant tanks, and the legalization of commercial space transportation, all of which are necessary to allow anyone to travel freely to and from space using spaceplanes just like using an airplane, under the slogan "Space is for everyone."
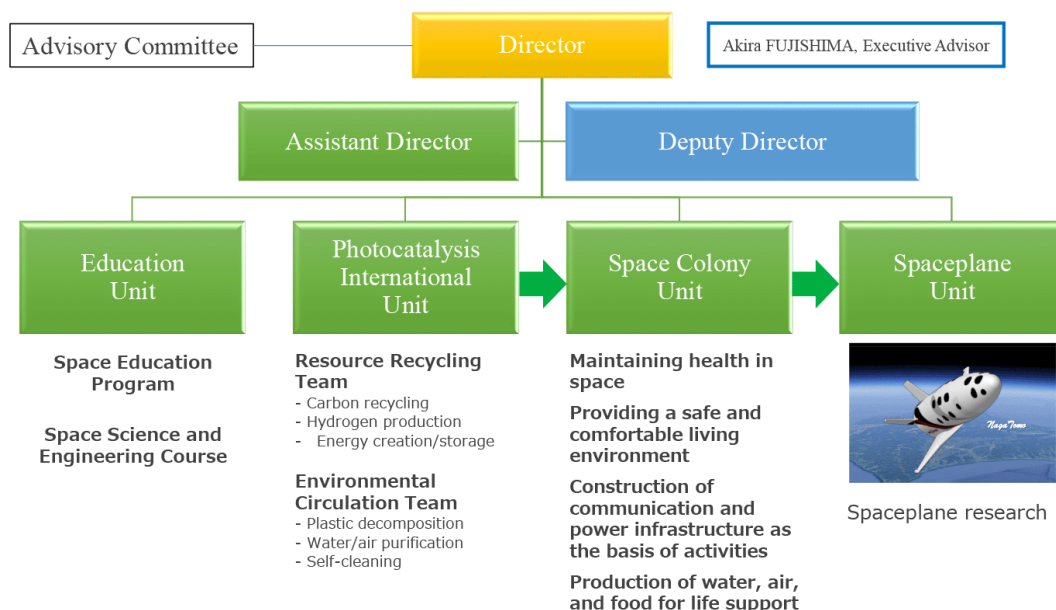
Co-create by forming a virtuous cycle between earth and space.

Fig. 2. Research Center for Space System Innovation's structure.

The facilities of the Research Center for Space System Innovation include Building 22 of the Research Center for Space System Innovation, which is comprehensively engaged in research on resource circulation and environmental cleanup.

3. Activity Reports

3. 1. Education Unit

The Education Unit participates in propagating active-learning educational programs in cooperation with the Space Education Program. The program was started as the Interdisciplinary Study of Space Humanities program (a Commissioned Expense for Promoting Space Aeronautics and Technology by the Ministry of Education, Culture, Sports, Science and Technology (MEXT)) as educational material. As a result, multiple educational events have been implemented such as SPACE HIKE space events, space events performed by the Adachi City, and visiting space classes for Hoshino High School —spun off from the "Space Education Program" and rolled out by the Academic Venture Business called "Ucyunomanabiya Seed." It has also implemented "Space Education Program Lectures" and "Space Education Program Presentations" that have been newly constructed as courses of the Graduate School of Science and Engineering.

3. 2. Photocatalysis International Unit

The symposium on Photocatalysis was held on 6th March 2024, with the concerted efforts of this unit. Total number of participants was 225. Based on a rigorous review process, the student poster awards were selected, in order to encourage the young researchers.

Photo 1. Student poster awards.

3 .3. Space Colony Unit

The Space Colony Unit is engaged in technological development for future long-term space habitation and is built on five pillars: (1) Health maintenance, (2) Radiation measurement and protection, (3) Environmental Control and Life Support Systems (ECLSS), (4) Food production, and (5) Communication and energy infrastructure.

In research results from 2023, using the photocatalytic odor removal experimental device returned from the ISS, organic compounds adsorbed to the activated carbon filter and shirasu adsorbent were analyzed under two conditions: with and without titania photocatalyst. As a result, we were able to obtain information about the air components inside the ISS, and at the same time, we were able to confirm changes in the amount of adsorption of some organic substances depending on the presence or absence of photocatalysts.

In addition, through the activities of the "Ground-Space Dual Development Type Near Future Urban Function Research Center" selected for the COI-Next fostering type, we will hold workshops, "MIRAI2022/2023 Japan Visit Program" and "International Workshop on Space Habitation". Exchanges were held.

In addition, during space habitation R&D in the development of inflatable habitation modules—which was performed jointly between Shimizu and Taiyo Kogyo and intended for the construction of space colonies—has been phased up from a Feasibility Study (FS) to a Research Study (RS) of the StarDust Program of the Japan Cabinet Office. It has shifted to full-on research and development.

Relatedly, the Moonshot Project's "Homeostatic Inflatable Autonomous Structure (HIDAS)" achieved homeostasis, adaptability, and activity by constructing an inflatable structure with autonomous decentralized cells. A HIDAS experimental site was constructed on the Noda campus and a full-scale model was constructed.

Furthermore, in GUNDAM Open Innovation, "TEAM SPACE LIFE", which promotes research and development on future space habitation, was certified as an official project, focusing on three technologies: creating living space, controlling a comfortable environment, and sustainable resource circulation. We are conducting research and development. Regarding the environment, we have developed a small autonomous decentralized environmental sensor and are conducting research with a view to conducting a demonstration experiment on the ISS in early 2025.

3. 4. Spaceplane Unit

Regarding the research and development of unmanned suborbital space planes for scientific missions and small satellite launch missions, the Ministry of Education, Culture, Sports, Science and Technology's "SBIR (Small Business Innovation and Research) Space Field (Development and Demonstration of Private Rockets)" was announced in September 2023. After being selected (Phase 1: 2 billion yen until September 2024), we are collaborating with Kawasaki Heavy Industries, IHI, Toray Carbon Magic, Air Water Hokkaido, and nearly 40 domestic and international companies, universities, research and development organizations, etc. In a collaborative system, we proceeded with the development of innovative technology and at the same time began full-scale basic design. From July 2024, we will proceed to detailed design with the aim of starting manufacturing.

In the "flight demonstration of LNG propulsion system using the small experimental rocket aircraft WIRES", which has been carried out as a joint research between Tokyo University of Science and JAXA, we have begun manufacturing the experimental winged rocket aircraft WIRES#015, and will be approved by the Ministry of Defense in the summer of 2024. There are plans to conduct a recovery system test using a helicopter at the Self-Defense Force training range, and an avionics system test over Lake Biwa in Shiga Prefecture in the winter.

We are collaborating with the German Aerospace Center DLR Augsburg to develop the world's first composite liquid oxygen tank using a liquid oxygen compatible composite material for which we have applied for an international patent, and with the German Fraunhofer Research Institute to develop a composite liquid methane tank. We are proceeding with prototype production, and plan to conduct performance evaluation tests for both from 2024 to 2025.

4. Challenges and Prospects

The Research Center for Space System Innovation is a large-scale research center with over sixty associated researchers. These researchers have been active in the Educational, Photocatalytic, Space Colony, and Spaceplane Units. These people have produced significant science and technology and achieved remarkable results (See the Important Research Results page). For this term, we have selected several large-scale projects in the space field: the "JST COI-NEXT Program for Creating Innovation through Interaction among Core Technologies," the "JST Moonshot Research and Development Program," and the "GUNDAM Open Innovation -TEAM SPACE LIFE-" are prom fostering type oting research and development on space habitation. Unfortunately, JST COI-NEXT ended as a, but companies aiming for space came together and formed the Space Colony Research and Development Union. To continue and success of these projects and union activities is recognized as a vital task in realizing the vision of the directors of the Research Center for Space System Innovation.

Next year, the organization's goal is to construct systems conducive to cooperation both inside and outside the school by implementing the same research activities as this year and by presenting the technological capabilities of the Research Center to the outside world by enhancing its activities on a global platform.

5. Conclusion

The Research Center for Space System Innovation is aiming to construct a global platform capable of aggregating cross-disciplinary technologies and people of talent by forming "A virtuous cycle between earth and space."

We are accelerating our initiatives for the realization of future space habitation. In addition to the "Space Innovation through Partnership and Acceleration of Collaboration and Technology Program (StarDust Program)"; the "Advanced Technology for Space Development through Utilization of Unmanned Construction" of the Ministry of Land, Infrastructure, Transport, and Tourism; and the GUNDAM Open Innovation "SPACE UTILITY PROJECT" for realizing the "Space Century" (directed by Bandai Namco,) we have accelerated our future space habitation programs, starting with the "JST COI-NEXT Program for Creating Innovation through Interaction among Core Technologies" and the "JST Moonshot Research and Development Program."

The key to human space venture is proactive cooperation with universities, research institutes, and private enterprises, both in Japan and overseas. Innovation is fostered by bringing experts together. We will continue to become a new platform for collaboration and a global platform for the aggregation of various technologies and talents, centered around the Research Center for Space System Innovation.

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4. Printed biosensors and biofuel cells for monitoring body fluids, I. Shitanda, Young Researchers Society for Flexible and Stretchable Electronics, 5th event,Yokohama National University, Bldg. S1-2, 101 (Plenary lecture), 2023_5_19

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Patents

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1. M. Kanesi (M2) Best Presentation Award, (2023_9_30), 31st Turbulent Flow Control Conference

2. Taisei Hattori, Takuto Maeda, Mutsumi Sugiyama, 22nd The Japan Society of Applied Physics Poster Award: The 84th JSAP Autumn Meeting, "Investigation of flexible CO_2 gas sensors based on transfer of SnO_2 thin film with NaCl sacrificial layer" (November 2023).

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7. Yasushi Idemoto, Kota Shima, Chiaki Ishibashi, Naoya Ishida, Naoto Kitamura, Supplementary Cover (ACS Appl. Energy Mater.), "Rate Dependence of Average Crystal Structure and Electronic Structure of $0.5Li_2MnO_3$-$0.5LiMn_{10/24}Ni_{7/24}Co_{7/24}O_2$ for Lithium-Ion Battery Positive Electrode Material in Steady State", 2023

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10. Shinichi Komaba, Highly Cited Researchers 2023

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12. Motoharu Kusano, Gaku Murakami, Hikono Furuichi, Kizuku Kurose, Masato Sakurai, Yusuke Sakamoto, Seiji Kamiyoshi and Ichiro Ueno, Second Best Mohri Poster Award at 35th Conf. of the Japan Society of Microgravity Application (Oct. 2023, Okinawa): On-orbit Experiments via CBEF aboard the ISS on Sloshing Phenomena under Normal and Reduced Gravity Conditions

13. <u>Akihiko Kudo,</u> The 76th The Chemical Society of Japan, The Chemical Society of Japan, 2023

14. Rintaro Yamanaka, <u>Noboru Katayama</u>, Isao Yondenda, and Koya Yokoi, YPC Encouragement Award: Analysis of the DC Model and Optimization of Electrode Shape for Paper-Based Lactic Acid Biofuel Cells, Proceedings of the Institute of Electrical Engineers of Japan Conference on Power and Energy, (September 2023)

15. Shinya Yanagita, JSPESS Award, Japan Society of Physical Exercise and Sports Science, 2023

Individual Research Topics

Sinich Kimura

"Space colony system design and the implementation of related technology in space"

Technology from a range of fields is necessary to maintain the space-colony closed environment that turns the concept into reality. We have developed high-performing space equipment using commercial-off-the-shelf technologies as it is inefficient to develop the underlying technology to be used only in space. We aim to build space colonies using ground-based technology, turning it into technology that can also be used in space.

Hideyuki Suzuki

"Supernova neutrinos and diffuse supernova neutrino background"

Large-scale multidimensional numerical simulations on supernova neutrinos are currently being conducted. I am aiming towards a comprehensive understanding of diffuse supernova neutrino background and cosmic chemical evolution by combining a simplified model that qualitatively reproduces the results of the multidimensional simulations with population synthesis calculations.

Makoto Yamamoto

"Study on numerical simulation of icing phenomenon"

Icing is a phenomenon in which supercooled droplets or ice particles in the atmosphere collide with a wall surface to form an ice layer on the wall surface. When icing occurs on an aircraft, it causes deterioration of aerodynamic performance and mechanical damages due to the collision of shed ice pieces, which causes a serious threat to flight safety. In our laboratory, we are conducting numerical simulation research on the development of simulation methods for accurately predicting icing phenomenon, the evaluation of anti-icing and de-icing technologies, and the clarification of the impact behavior of droplets on walls and the solidification process.

Koichi Yonemoto

"Winged reusable space transport system (spaceplane)"

We are researching a winged, reusable space transport system, commonly known as "spaceplane," to replace conventional expendable rockets. The ultimate goal is to create a future in which space travel is as accessible and effortless as air travel for everyone. In cooperation with universities, research institutes, and enterprises inside and outside Japan, we are engaged in basic research on system optimization technology, advanced guidance and control technology, and cryogenic propellant tanks made of composite materials. Additionally, we are developing small experimental aircraft and performing flight demonstrations and tests on our emerging technologies.

Chiaki Mukai

"Lunar medicine and space QOL"

I am promoting research and development in Space Medicine for lunar exploration, based on the knowledge of space medical research (physiological countermeasures, psychiatric and psychological support, radiation exposure management and protection, spacecraft environment maintenance, on-orbit medical system development) that has supported the health of astronauts on the Space Shuttle Program and the International Space Station. In doing this, we are adding to the medical and life science fields considering the lunar environment (e.g. variable gravity physiology, effects of regolith on the human body, protection from regolith, development of living space) to the existing space medicine performed in earth orbit.

Kozo Fujii

"Research on moving means in dilute gas"

I am engaged in research on propulsion means for outer space and flight technologies enabling transport in thin atmospheres such as Mars, which is the next destination after the moon. This year, I have engaged in foundational experiments and numerical simulations on wing-equipped missile shapes and similar features, which may enhance lift.

Kyoko Matsushita

"Research on experiential space education in collaboration with space education programs"

By capitalizing on the expertise in space education that we have accumulated, I have cooperated with new programs to develop new materials, in tandem with promoting examinations for curriculum formation in the graduate school, where I have held lectures since 2022.

Kazuo Watanabe

"Research on formation mechanisms for noble gas hydrides"

The presence of cations of various noble gas hydrides such as ArH^+ and HeH^+ in outer space has been well known. In contrast, the presence of neutral gas hydrides that do not have an electric charge has been almost unknown. However, by irradiating a noble gas ion beam onto a metal substrate surface and further exposing it to hydrogen gas, we have detected neutral noble gas hydrides such as ArH and KrH. We are currently studying their formation mechanisms by using thermal desorption spectroscopy.

Takashi Kurabuchi

"A study on contaminant diffusion behavior under zero gravity conditions using numerical simulation Technique"

In zero-gravity conditions, natural convection driven by buoyancy does not occur, so the diffusion of contaminants is greatly restricted compared to the environment where gravity acts, and the air environment inside the spacecraft may deteriorate due to localized stagnation. Fundamental study is carried out with the aim of clarifying this problem by combining numerical simulation and ventilation efficiency evaluation techniques.

Mikio Hasegawa

"6G interconnecting terrestrial and satellite networks"

We propose optimization algorithms for 6G networks that utilize space, air, and ground networks. Communication capacity can be improved by interconnecting terrestrial and satellite networks and optimizing network routing. We showed that the overall throughput can be improved by optimization using machine learning.

Tomoaki Tatsukawa

"A study of multi-objective design optimization with severe constraints using evolutionary computation"

Selection of colony construction sites and various space exploration missions have extremely harsh constraints in addition to a multitude of parameters, and it is difficult to efficiently find feasible solutions that simultaneously satisfy multiple performance indicators. I am engaged in research on advanced multi-objective optimization techniques that can be applied to multi-objective problems. This year, I performed basic verification of the efficacy of existing techniques using benchmark problems and actual problems.

Ichiro Ueno

"Interfacial thermo-hydrodynamics in the space environment"

We have performed research on thermal and material transport using space environments such as surface tension-driven convection and phase change heat transfer. Since 1999, we have been joint researchers in interfacial thermo-hydrodynamics experiments on the Japanese Experiment Module of the International Space Station. We are currently developing environmental control system under micro- and low-gravity conditions.

Takayoshi Kohmura

"Development of sensor for space radiation monitoring and its evaluation of radiation durability"

On the airless lunar surface, electronic devices, such as sensors used in monitoring the ambient environment of space colonies, e.g., the visualization sensors for CMOS, and radiation measurement sensors for monitoring exposure are exposed to solar radiation degrading their performance. Therefore, in this research, I am developing radiation measurement sensors that operate normally under high radiation and I am evaluating their durability.

Yuichi Takaku

"Space colony system design and the implementation of related technology in space"

Technology from a range of fields is necessary to maintain the space-colony closed environment that turns the concept into reality. We have developed high-performing space equipment using commercial-off-the-shelf technologies as it is inefficient to develop the underlying technology to be used only in space. We aim to build space colonies using ground-based technology, turning it into technology that can also be used in space.

Chiaki Terashima

"Development of liquid fertilizer with sterilizing effect for automated plant factories"

In the view of resource recycling, the reformulation of air and water was conducted into liquid fertilisers with anti-algae effects by using of in-liquid technology. The aim is to elucidate the plasma reaction field and make it practical for industrial applications through the present research work under the space system inovation.

Idemoto Yasushi

"Development and structural analysis of next-generation secondary battery materials with high capacity and high safety"

We focused on $Mg_{1.33-y}(V_{1.67-x+y}Mn_x)O_4$ as a cathode material for magnesium secondary batteries and succeeded in improving cathode properties by optimizing the metal composition. In addition, as for high-capacity cathode and anode materials used in lithium-ion batteries, crystal and electronic structures of the synthesised powder and the electrode after charging and discharging were clarified by diffraction and total scattering measurements using quantum beams.

Akihiko Kudo

"Z-schematic water splitting and CO_2 reduction under visible light irradiation using water as an electron donor over the particulate photocatalyst"

Development of efficient photocatalysts as artificial photosynthesis is an important research topic to achieve carbon neutral society. This year, we successfully developed the efficient Z-schematic water splitting and CO_2 reduction systems by application of metal sulfide photocatalysts prepared by the flux treatment instead of the conventional solid-state reaction. In addition, we successfully developed the Au/Cu_3VS_4 photocathode using whole range of visible light for photoelectrochemical CO_2 reduction to produce a syngas.

Shinichi Komaba

"Fundamental study on materials of next generation battery contribution to self-sufficiency of electricity in space"

We study on materials of sodium-ion and potassium ion batteries free from minor and toxic metal elements along with that of lithium-ion battery. In FY2023, we studied on new materials for Na-ion battery, like layered sodium manganese oxide and templated hard carbon. Furthermore, we extended our research target to electrochemical reaction using rubidium ions as charge carrier ions.

Yuichi Negishi

"Creation and evaluation of highly active water splitting photocatalysts with fine metal clusters"

Water splitting photocatalysts, which can produce hydrogen from water and sunlight, have attracted attention as a truly clean hydrogen production method. In order to increase the activity of this photocatalyst, it is effective to load fine metal particles, called cocatalysts. However, it is difficult to precisely control the "size" and "electronic state" with conventional loading methods. In this study, we aim to further increase the activity of water-splitting photocatalysts by establishing a novel method to load ultrafine metal clusters synthesized in the liquid phase on the surface of photocatalysts.

Naoto Kitamura

"Development and structural analysis of next-generation secondary battery materials with high capacity and high safety"

We focused on $Mg_{1.33-y}(V_{1.67-x+y}Mn_x)O_4$ as a cathode material for magnesium secondary batteries and succeeded in improving cathode properties by optimizing the metal composition. In addition, as for high-capacity cathode and anode materials used in lithium-ion batteries, crystal and electronic structures of the synthesised powder and the electrode after charging and discharging were clarified by diffraction and total scattering measurements using quantum beams.

Yumi Tanaka

"Research on inorganic energy conversion materials and related devices"

Electrets expressing the world's highest surface potentials of over 7 kV for bulk (1000 μm) and about 800 V for thin films (1 μm) have been successfully developed using rare earth aluminate-based ceramics. In collaboration with a company, a prototype model of an "edge system" consisting of a ceramic electret-based vibration generator, an LED, an illumination sensor, a microcontroller, and a wireless communication device was created, and the system operation under autonomous power generation (about 500 μW) by vibration generation was demonstrated.

Yuichi Yamaguchi

"Z-schematic water splitting and CO_2 reduction under visible light irradiation using water as an electron donor over the particulate photocatalyst"

Development of efficient photocatalysts as artificial photosynthesis is an important research topic to achieve carbon neutral society. This year, we successfully developed the efficient Z-schematic water splitting and CO_2 reduction systems by application of metal sulfide photocatalysts prepared by the flux treatment instead of the conventional solid-state reaction. In addition, we successfully developed the Au/Cu_3VS_4 photocathode using whole range of visible light for photoelectrochemical CO_2 reduction to produce a syngas.

Tokuhisa Kawawaki

"Creation of fuel cell cathode electrodes using size-controlled platinum clusters"

Fuel cells, which are expected to be a clean power generation material, use a large amount of platinum particulate catalysts because the oxygen reduction reaction at the cathode is the rate-limiting step. However, platinum is an expensive precious metal, so it is important to reduce the use of platinum. In this study, we worked to establish a simple and high-yield method for synthesizing platinum clusters smaller than conventional platinum particles. Furthermore, we aim to create a practical platinum catalyst by applying it to fuel cell cathode electrocatalysts.

Ryoichi Tatara

"Study on next generation Na-ion batteries with earth-abundant elements"

We study on new materials for Na-ion batteries which are free from rare metals and toxic elements. Commercialization plans of Na-ion battery have been released from industry and large-format Na-ion battery is expected to be used for ESS application. In 2022, we studied the layered manganese-based oxide and hard-carbon materials for positive and negative electrodes and their compatibility to all-solid-state Na-ion batteries are demonstrated and K-ion batteries are successfully solidified with dry polymer electrolyte.

Chiaki Ishibashi

"Development and structural analysis of next-generation secondary battery materials with high capacity and high safety"

We focused on $Mg_{1.33-y}(V_{1.67-x+y}Mn_x)O_4$ as a cathode material for magnesium secondary batteries and succeeded in improving cathode properties by optimizing the metal composition. In addition, as for high-capacity cathode and anode materials used in lithium-ion batteries, crystal and electronic structures of the synthesised powder and the electrode after charging and discharging were clarified by diffraction and total scattering measurements using quantum beams.

Makoto Yuasa

"Research on reactive oxygen sensors by biomimetic approach, as well as antioxidants and anticancer drugs"

We examined a sensor of superoxide anion radicals ($O_2^{\cdot-}$), that is, active oxygen species, which are highly useful in space colonies in outer space or on the ground, and can confirm the physical condition of the pre-disease state. In the future, we will consider the construction of $O_2^{\cdot-}$ sensors with higher functionality, improved quantitation, and compatibility with living organisms.

Hideki Sakai

"Photocatalytic synthesis of rare sugars: effect of UV light wavelength"

We have investigated the synthesis of rare sugars from glucono-delta-lactone using titanium dioxide as a photocatalyst and found that the selectivity of erythrose formation with higher rarity was enhanced when rutile-type titanium dioxide was used. In this year, we examined the effect of the wavelength of irradiated ultraviolet light on the production efficiency of rare sugars. We found that the production efficiency of rare sugars was higher when irradiated with light of 254 nm than that of 365 nm when the number of irradiated photons was fixed.

Isao Shitanda

"Development of wearable biosensors for stress monitoring needed in outer space health management"

In this study, I will develop a wearable biosensing system capable of the noninvasive and real-time monitoring of components in sweat when worn in outer space. This year, I performed implementation evaluation tests, particularly of lactate sensors, sodium sensors, and chloride sensors worn on the skin.

Ken-Ichi Katsumata

"Development of photocatalytic materials for decomposition of nitrate ion in water"

Photocatalysts with Pd and Cu supported on the composite surface of titanium dioxide (TiO_2) and graphene (GnP) were prepared, and changes in the concentration of nitrate ions in water were measured. the decomposition of NO_3^- was greatly improved by optimizing the mixture ratio of TiO_2 and GnP. It was also inferred that NO_3^- was reduced to NO_2^- and even gas components were reduced. When layered potassium niobate was used as the material, it was found that doping rhodium and ruthenium in the niobate layer improved the decomposition activity.

Kiyoshi Dowaki

"Practical studies from biohydrogen production system to fuel cell assist bicycle"

In our studies, the team of multiple and cross-disciplinary researchers is researching and developing plant technology for energy conversion, impurity removal, and hydrogen purification, as well as research and development of a fuel cell-assisted bicycle that uses biohydrogen from the perspective of life cycle engineering. The former research is being dynamically evaluated to seek suitable plant operating conditions based on basic tests this fiscal year. In contrast, the latter research on assisted bicycles is being demonstrated through basic tests on thermal management, control, and so on. This year, we successfully conducted the demo test of bike operation.

Takahiro Gunji

"Self-cleaning material using titanium dioxide nano particles supported on a flexible organic polymer thin film"

A suitable structure was investigated by clarifying the relationship between the molecular structure of polysilsesquioxane to support titania nano particles and the physical and chemical properties of self-cleaning film which was prepared by using the materials. In addition, another self-cleaning film was prepared by spin-coating of titanium dioxide nano particles on an organic polymer film having adhesive layer and the durability as photo-catalyst was evaluated. The photo-catalytic ability was increased by pre-treatment of the organic polymer layer by ozone.

Koji Arimitsu

"Grafting of organic silicon polymers to titanium oxide surfaces and application in self-cleaning materials"

I simultaneously prepared titanium oxide macroparticles in a solution containing tetra-isopropyl ortho-titanate and polysilane by sol-gel processing while photochemically grafting the polysilane. I was thereby able to obtain modified titanium oxide particles with smaller particle diameters compared to polysilane-modified titanium oxide particles prepared by conventional solid-phase methods. Furthermore, when I prepared a UV-cured film on which these polysilane-modified titanium oxide particles had been dispersed, I succeeded in preparing a self-cleaning film with higher transparency than conventional films.

Tomonori Suzuki

"Study on analyses of sterilization mechanism of photocatalyst and its application"

Diaminopimelic acid-type peptidoglycan and its constituent amino sugar and diaminopimelic acid enhanced the photocatalytic bactericidal effect. However, this effect was not confirmed for lysine-type peptidoglycan. Bacterial flora and fungal flora were analyzed as a preliminary survey for using photocatalysts to preserve the cultural properties of Nikko shrines and temples. The effectiveness of the wastewater treatment system with photocatalyst diamond electrode was demonstrated, but the presence of resistant bacteria was confirmed.

Kenjiro Fujimoto

"Photocatalysts are anticipated"

A quarter century has passed since we discovered that oxides with a Hollandite crystal structure—which were researched as one-dimensional superionic conductors—function as nitric oxide selective reduction catalysts and photocatalysts. We are attempting to improve the material synthesis process for a higher specific surface area and we are pursuing the differences in catalytic activity performance according to differences in particle morphology, and the novel possibility of carbon monoxide adsorption.

Takashi Kondo

"Research on the development of a conductive diamond powder-packed flow cell"

We have developed a conductive boron-doped diamond powder (BDDP)-packed electrolytic flow cell toward application to efficient water treatment. The BDDP-packed layer was found to act as a porous electrode, and it was able to efficiently decompose an organic substance in an electrolyte via electrolysis. In addition, a repeated electrolysis test revealed excellent long-term durability of the BDDP-packed flow cell.

Shingo Machida

"Development of techniques for stabilizing powders with functionalities to bulk materials"

Although photocatalysts, adsorbents, and anti-bacterial materials have high expectations from materials besides environmental publication, such as water purification, because powder samples can be hardly handled, I develop techniques for stabilizing powders to bulk materials without detaching them and decreasing their functionalities. Such techniques for Earth environment are important when people live in space.

Toshifumi Tojo

"Research on active oxygen sensors and antioxidants/anticancer drugs through a biomimetic approach"

I have been studying the superoxide anion radical ($O_2 \cdot ^-$), the so-called "active oxygen," which would be incredibly useful in space colonies and on earth, and with which it is possible to confirm health conditions in pre-illness states. Going forward, I will examine the construction of $O_2 \cdot ^-$ sensors with greater functionality, superior quantitative performance, and biocompatibility.

Mutsumi Sugiyama

"Research on semiconductor IoT devices for space application"

This study explores the fabrication methods for space-applicable, cost-effective Cu_2SnS_3 (CTS) based solar cells and NiO based transparent solar cells, alongside the enhancement of efficiency and radiation resistance of SnO based gas sensors. Our findings demonstrate that CTS, NiO, and SnO thin film semiconductors exhibit remarkably high resistance to electron and proton radiation, making them promising candidates for practical implementation in space applications.

Takayuki Hamamoto

"A study on image sensing for health monitoring"

We study image sensing technology to understand the health status of space visitors. This study focuses on visible and near-infrared light information. We tackle reconstructing images with low noise and high spatial resolution, even in low-illumination environments, by using visible and near-infrared light images acquired simultaneously. Using the reconstructed image information, we also investigate a non-contact heart rate estimation method even when illumination environments fluctuate significantly.

Yasuo Kogo

"Construction of power generation systems with the indoor/outdoor power differential"

Utilizing temperature differential power generation via the Seebeck effect, we are developing a thermoelectric temperature differential power generation system supplying electric power from the indoor/outdoor temperature differential between day and night that occurs in space colonies. Temperature differential power supply by thermal power generation can realize auxiliary power supply at night and in the shade, when solar cells are unable to generate electricity, as well as during the construction of underground space for a colony. We will therefore develop power supply systems in which solar cell power generation and flywheel power storage are interlinked.

Tsutomu Iida

"Construction of power generation systems with the indoor/outdoor power differential"

Utilizing temperature differential power generation via the Seebeck effect of thermoelectric materials, we are developing a thermoelectric temperature differential power generation system supplying electric power from the indoor/outdoor temperature differential between day and night that occurs in space colonies. Temperature differential power supply by thermal power generation can realize auxiliary power supply at night and in the shade, when solar cells are unable to generate electricity, as well as during the construction of underground space for a colony.

Noboru Katayama

"Practical studies from biohydrogen production system to fuel cell assist bicycle"

Paper-based lactic acid biofuel cells, which generate electricity using lactic acid contained in sweat as fuel, are anticipated for their use as thin, lightweight, and environmentally friendly batteries. One of the challenges is improving power density, but optimization of electrode shape holds promise for improvement. In this research, a two-dimensional simulator that replicates the power generation performance of the battery was developed, and an increase in power density was investigated through shape optimization and topology optimization. So far, a successful increase in power density by 53% has been achieved.

Mitsutoshi Tsukimoto

"Development of chemicals for protection from cosmic radiation"

To protect the body from cosmic radiation, I have performed research on chemicals that protect from and attenuate radiation injury and have discovered a substance that protects bone marrow cells, which are prone to radiation injury. In addition, I am also researching the cellular response to radiation under variations in the gravitational direction.

Shinya Yanagita

"Development of TUS original space fitness"

The decline in physical activity is an issue that needs to be resolved in a super-aged society. On the other hand, there is a large overlap between staying and living in space. We aim to solve this problem by developing an online fitness program that can be used anytime and anywhere.

Takahiro Mukaimoto

"Effects of exercise conditions on resistance exercise on excess post-exercise oxygen consumption"

This study aims to examine examine the effects of resistance exercise on exercise types, intensity, order, and rest time between sets, on oxygen intake and energy expenditure during exercise, and on excess post-exercise oxygen consumption (EPOC). It aims to build useful knowledge for planning efficient resistance exercise training programs.

Takako Akakura

"Development of a distance CSCW system using VR"

We are developing an environment for computer supported cooperative work (CSCW) in distant areas and an environment that gives the feeling of working with someone else even if a man is working alone, using VR. The system that realizes interaction between a real person and a person in VR space (avatar) has been shown to be effective in maintaining motivation and reducing the sense of loneliness.

"A study on measurement of user's fatigue using face, utterance and gaze information"

Mental fatigue is a serious problem during long stays in space under lonely state. Therefore, we are constructing a methodology to estimate the state of fatigue based on the biometric information of fatigue. In addition to 51 facial feature points, such as the eyes and the bridge of the nose, the fatigue state is estimated using the Mel-frequency Cepstrum coefficient, which is a kind of vocal cord feature, and eye gaze information.

Momoyo Gota

"Evaluation of habitability of small enclosed spaces and development on planning of interior spaces for space habitation"

The objective of my research is to develop planning technologies for indoor spaces suitable for human psychology and behavior in space habitation. I am therefore focusing, as basic research, on human psychology and behavior in narrow, enclosed spaces intended for multiple inhabitants, not limited to zero-G, and I have evaluated their performance as a habitation space, and I am investigating/analyzing shapes and arrangements of indoor spaces, as well as human behavior, in actual space habitation.

Masayuki Mizuno

"Study on evacuation behavior under microgravity in space facilities"

Movement of people in micro-gravity condition inside space facilities requires grasping onto handrails attached to walls to move around. In case of hazards such as debris collision or fire, individuals need to evacuate to adjacent modules via a hatch between the modules. This study proposes an effective handrail arrangement for movement during emergency evacuation of individuals or groups according to the results of the past experiments conducted under water.

"Walking experiments using a walking characteristics simulator simulating low gravity conditions on the moon"

The gravity environment is different on the Moon than on Earth, and it is expected that walking on the Moon will be different from walking on Earth. Therefore, the low-gravity walking simulator that NASA used in the Apollo program was recreated on a smaller scale, to analyze the starting and stopping behavior of forward movement with restricted lateral movement. And then, some experiments were conducted using the simulator. Qualitative effects on movement, stopping, and posture control resulting from differences in walking methods are expected to be considered.

Yoshihiro Maeda

"A study on real-time vital sensing by using image infomation"

We study non-contact sensing technology utilizing image information to acquire the vitals of space visitors. In order to acquire vitals in real-time, we also investigate acceleration methods for the image filtering process, which is a fundamental process in image sensing. We tackle constructing a vital sensing system that operates in real time.

Kazuki Kitabatake

"Development of chemicals for protection from cosmic radiation"

To protect the body from cosmic radiation, I have performed research on chemicals that protect from and attenuate radiation injury and have discovered a substance that protects bone marrow cells, which are prone to radiation injury. In addition, I am also researching the cellular response to radiation under variations in the gravitational direction.

Osamu Sakata

"Research on stress accumulation monitoring technology of long-term residents in closed environments"

When human beings stay for a long period of time in a closed environment such as a space colony, lunar base, or Mars base, which is strongly isolated from the general society on Earth, negative mental stress may accumulate and lead to mental and physical disorders. Since many cases of mental and physical disorders resulting from stress accumulation can become serious symptoms, early detection and early response in daily life and work are effective means of preventing the seriousness of such disorders. In this project, we will conduct research on technology to automatically detect the accumulation of negative mental stress of residents in a natural way in their daily lives, based on causality analysis between various physical quantities such as multiple biometric and environmental information.

Shinji Ogiwara

"Research on microscopic damage behavior of fiber-reinforced composite materials"

I have empirically studied the process of microscopic damage occurrence and progression inside materials through various loading forms, focusing on laminated fiber-reinforced composite materials. Furthermore, I have evaluated the effect on the mechanical characteristics of materials accompanying damage occurrence by experiment. I have predicted and compared, by the finite element method and with a damage mechanics model, and studied the validity of the results. I have constructed a foundation for the application of this to material systems with more complex internal structures. I expect my work to contribute to the evaluation of the structural integrity of materials during space operations.

Takahiro Fujikawa

"Research on spaceplane system design and guidance trajectory optimization"

The establishment of system design technologies and autonomous flight guidance technologies are necessary for the development of a spaceplane that can operate like an airplane instead of a disposable rocket. In this study, we have engaged in the development of a multipurpose system optimization technique. We focused on the combination and application of two types of numerical optimization techniques: the gradient method and the evolutionary computation method, as well as a high-speed generation technique for various orbital groups satisfying the terminal constraints.

Jun Koyanagi

"Numerical simulation for the deployment of inflatable structures in space applications"

A numerical simulation of the deployment of an inflatable structure for securing living space on the moon was performed using finite element analysis. In the past, we did not carry out numerical analysis and proceeded with development that relied on experiments. For this reason, the deployment process in outer space could not be tested, and the feasibility was questioned. However, by constructing numerical analysis technology, it became possible to predict the behavior in outer space, and we took a big step towards the realization of development.

Mohammad Fikry

"Study on the mechanical properties and damage behavior evaluation methods of carbon fiber reinforced plastic laminates"

The study aimed to provide guidelines for the development of higher-performance new materials focusing on carbon fiber reinforced plastic (CFRP) laminates by constructing and examining the mechanical properties and damage behavior evaluation methods, along with their modeling. Non-contact and non-destructive methods such as digital image correlation and sampling moiré, as well as in-situ observations using optical microscopes and scanning electron microscopes were utilized to observe and model the detailed process of matrix crack initiation and progression in CFRP laminates. Furthermore, based on these observations, the experimental elucidation of the microscale damage initiation and progression processes in CFRP with complex structures was achieved, and their modeling was also conducted using the finite element method and variational stress analysis.

Research Center for Drug Discovery and Applied Sciences

Research Center for Drug Discovery and Applied Sciences

1. Overview

Most of the products used as medicines by humans comprise carbon-based organic compounds, which are synthesized by combining multiple chemical reactions. However, when it is crucial to perform several reaction steps before achieving the synthesis of the desired compound, considerable time and effort are spent, as well as a considerable amount of waste is generated, thereby adding to the environmental burden.

Our synthetic team is conducting research on reaction methods that can improve the synthetic yield of pharmaceutical products to the maximum, and we have developed a new dehydration condensation agent, namely 2-methyl-6-nitrobenzoic anhydride (MNBA), which can drastically enhance the production efficiency of antibiotics and anticancer drugs.

After the establishment of this new technology, MNBA has been widely used to synthesize new antibiotics, molecular target anticancer drugs, and drugs for diabetes treatment, and more than 14,000 successful results have been reported worldwide.

One of the achievements of this year is the total synthesis of tanzawaic acid B. Tanzawaic acids are organic compounds discovered in 1997 in the Tanzawa mountains area of Kanagawa Prefecture by Professor Daisuke Uemura (then of Shizuoka University) and his colleagues. Tanzawaic acids have antibacterial activity, and various pharmacological activities including antitumor and anti-inflammatory activity have been reported in recent years. We achieved the total synthesis of tanzawaic acid B in 2023 using asymmetric alkylation, asymmetric Mukaiyama aldol reaction, and intramolecular Diels–Alder reaction as key steps. Currently, we were able to establish a method for supplying a large amount of the mother nucleus, which is common to tanzawaic acids, making it possible to develop not only tanzawaic acid B but also antibacterial drugs and anticancer drugs that use tanzawaic acid B as the lead compound. We researched M-COPA, an artificial analog of tanzawaic acid B, and investigated its growth-inhibiting activity on cancer cells.

In 2023, we investigated the ability of compounds obtained to inhibit cell proliferation in multiple cell lines such as lung adenocarcinoma strains NCI-H1650 [EGFR(Δ746-750)], PC-9 [EGFR(Δ746-750)] and breast adenocarcinoma strain (MDA-MB-231). We found that tanzawaic acid B did not have a significant cell line growth inhibition effect, but its analog TDA showed moderate activity. Furthermore, it was revealed that effective the artificial analog M-COPA showed significant cytostatic effects, with $GI_{50} = 85$ nM against NCI-H1650, $GI_{50} = 26$ nM against PC-9, and $GI_{50} = 630$ nM against MDA-MB-231.

As described below, this research center is independently conducting research and development of anticancer drugs using protein intracellular transport inhibitors as molecular target drugs and antiviral drugs developed at our university and is developing applications based on basic research. We are promoting practical research with a strong focus on the development of new drugs through industry-academia collaboration.

2. Organization and Facilities

This research center is a joint organization established in 2023 by progressively reorganizing the chemical biology research department based on practical organic synthesis, whose establishment period expired in 2022. Through close collaboration between the synthetic chemistry group and chemical biology group, we are engaged in research and development aimed at social implementation. The research department head is Professor Isamu Shiina (Department of Chemistry, Graduate School of Science/Department of Applied

Chemistry, Faculty of Science I). The facility is Kagurazaka School Building No. 11 Annex. The Chirality Research Center (2012-2016, Center Director: Isamu Shiina), the predecessor of this research center, purchased a nuclear magnetic resonance measurement device (500 MHz and 300 MHz NMR), a gas chromatograph mass spectrometer, as well as time-of-flight mass spectrometer systems. In addition, the facility is equipped with other analytical instruments such as a single-crystal X-ray structure analyzer and a circular dichroism spectrometer (CD). We made effective use of these high-performance analyzers to promote research.
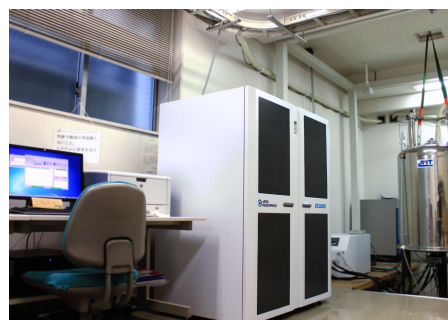
Photo 1. NMR equipment (500 MHz).

3. Activity Reports

3. 1. Area of the Development and Application Group for Practical Organic Synthesis Technology

We have developed research on providing synthetic means, such as practical organic transformations, total synthesis of natural products, asymmetric synthesis using organic catalysts, asymmetric synthesis using metal complexes, dehydration condensation reactions, and asymmetric self-amplification reactions.

3. 2. Area of the Chemical Biology and Drug Development Group

We set a research theme centering on the university's original compound, ridaifen, obtained using the technology of our research center, and proceeded with investigations in the Shiina, Shimonaka, Mano, Higami, and Kuramochi laboratories. In addition, the Shiina, Shimonaka, and Kawasaki laboratories conducted joint research on the evaluation of the biological activity of compounds obtained by asymmetric synthetic technology. In order to expand the application into the research on bioactive compounds, we will practice drug development based on the synthesis of natural products with complex structures. We are conducting research and development of merillianin, which is expected to be applied as a drug for the treatment of nervous system diseases, an antifungal agent based on natural depsipeptide FE399, and an antitumor agent based on tanzawaic acid B and violaceoids.

4. Challenges and Prospects

All the issues set for this year have been resolved. Tumor regression was successfully observed in animal testing by using tanzawaic acid analogs discovered at Tokyo University of Science Shiina Laboratory as novel anticancer agents for cancer types with mutant RTKs that are refractory to existing tyrosine kinase inhibitors (TKIs).

Our projects were adopted as a core organization for AMED [Innovative Cancer Treatment Practical Research Project] in 2022-25. We have established a method for synthesizing tanzawaic acid analogs in a gram scale and have confirmed the effects of anticancer effects on mutated cancers, resistant cancers, and endoplasmic reticulum stress-sensitive cancer cells at a non-clinical level. Currently, to complete the non-clinical studies necessary for the start of clinical trials, we are in the process of acquiring data sets for the preparation of PMDA interview materials. We plan to continue research and development with the aim of social implementation.

5. Conclusion

The Research Center for Drug Discovery and Applied Sciences is an organization that actively supported close collaboration between the organic synthetic chemistry group and the chemical biology group both inside and outside our university, which was launched in 2023, and carried out the project as planned as described above.

During this period, we aimed to make effective use of the organic synthesis methods and compounds developed at our university. We plan to expand our center in aiming to apply them not only to basic research but also to biological research.

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2. 椎名 勇, 令和 6 年度千葉大学真菌医学研究センター共同研究課題選定, 2024 年 2 月 20 日, 千葉大学 (in Japanese)

3. Yuuki Asahara (Shimonaka Lab. 2nd year master's student), TOIN International Symposium on Biomedical Engineering 2023 Poster Award, 2nd Dec. 2023, Toin Gakuen Academium Organizing Committee

4. 仙波悠太（長原研究室：修士 2 年）, 日本薬学会第 143 年会　学生優秀発表賞, 2023 年 4 月 25 日, 日本薬学会 (in Japanese)

5. 川﨑常臣, Chemical Science 誌の Front Cover Article, 2023 年 5 月 7 日、英国王立化学会（RSC）(in Japanese)

6. 加瀬千寛（川﨑研究室：修士 2 年）, 第 85 回有機合成化学協会関東支部シンポジウム　優秀発表賞, 2023 年 11 月 26 日, 有機合成化学協会 (in Japanese)

7. 井上拓実（川﨑研究室：学部 4 年）, 日本化学会第 104 春季年会（2024）元素川柳コンテスト最優秀賞, 2024 年 3 月 26 日, 日本化学会 (in Japanese)

Individual Research Topics

Isamu Shiina and Takatsugu Murata
"Development of anticancer agents from naturally occurring products"

Tanzawaic acids are organic compounds discovered in 1997 in the Tanzawa mountains area of Kanagawa Prefecture. Tanzawaic acids have various pharmacological activities such as antibacterial activity, antitumor activity, and anti-inflammatory activity. We achieved the total synthesis of tanzawaic acid B in 2023 by using asymmetric alkylation, asymmetric Mukaiyama aldol reaction, and intramolecular Diels–Alder reaction as key steps. We are currently investigating the biological activity of tanzawaic acid B, and in the future, we will synthesize an artificial analog of tanzawaic acid B, and design and synthesize new tanzawaic acid-related compounds based on the molecular structure of natural products. We plan to conduct these experiments and investigate their anti-proliferation effects on cancer cells.

Tsuneomi Kawasaki
"Search for chiral bioactive compounds and BNCT carrier compounds using Strecker amino acid synthesis"

Amino acids are one of the typical chiral compounds that make up living organisms, and they consist of only the L-enantiomer of the L- and D-enantiomers (homochirality). In a study aimed at elucidating the reaction pathway leading to homochirality in biologically relevant compounds, we elucidated the asymmetric generation and amplification mechanism of aminonitrile, an intermediate in the synthesis of Strecker amino acids. we conducted a cell proliferation inhibitory activity test using amino acid derivatives prepared by the Strecker synthesis, and we found a novel compound that does not affect the proliferation of not only cancer cells but also normal cells. In FY2023, we expanded our compound library to conduct contract evaluations of compounds at external collaborating organizations (companies) accompanying joint research with our center.

Kouji Kuramochi
"Synthesis and evaluation of biologically active compounds using novel *N*-alkylphenazines and phenazinones"

We are developing a method to synthesize new *N*-alkylphenazines and phenazinones by utilizing regioselective intermolecular coupling reactions. In 2023, we conducted a human cancer cell growth inhibition activity test using the compound. Furthermore, we have expanded our compound library to conduct biological activity tests such as antifungal, plant growth inhibiting, and insecticidal properties at external collaborating organizations (companies) accompanying joint research with our center.

Motoyuki Shimonaka

"Screening of novel boron compounds for boron neutron capture therapy (BNCT)"

Various boron-containing compounds, including boronophenylalanine analogues were synthesized by means of asymmetric synthesis in the Shiina and Kawasaki laboratories. The toxicity to cancer cells, normal skin cells, and other cancer cells were examined, and the synthesized compounds were classified into two groups according to the presence or absence of cytotoxicity. As a result of the examination, in addition to the novel compounds that do not affect the proliferation of both cancer cells and normal cells, we also successfully obtained novel compounds that are selectively toxic to certain cancer cells. In FY2023, we conducted a comparative study of the cell growth inhibition ability of M-COPA and new tanzawaic acid analogs using multiple cell lines such as lung cancer cell lines. As a result of *in vitro* tests, tanzawaic acid B did not have a significant cell line proliferation inhibitory effect, but its analog TDA had moderate activity. Furthermore, it was revealed that the artificial analog M-COPA exhibited a remarkable cell proliferation inhibitory effect and exhibited effective proliferation inhibition with $GI_{50} = 85$ nM against NCI-H1650, $GI_{50} = 26$ nM against PC-9, and $GI_{50} = 630$ nM against MDA-MB-231.

Yoshikazu Higami

"Biologically activity test of novel cholesterol accumulation-inducing compound (lipoprofen)"

In order to demonstrate the cholesterol-lowering effect of a new cholesterol accumulation-inducing compound (lipoprofen) found in the Shiina laboratory on the animal level, lipoprofen was intraperitoneally administered to diet-induced obesity model mice for 3 weeks. As a result, lipoprofen administration reduced the total cholesterol level in the blood by about 30%. Furthermore, in the liver of the treated group, an increase in the gene expression of the LDL receptor, which is important for cholesterol uptake, was confirmed, but the cholesterol level did not change. This suggests that lipoprofen lowers blood cholesterol by promoting cholesterol uptake into the liver and promoting its metabolism in the liver. A preliminary in vivo test was performed by oral administration to support the above biological activity, and a similar decrease in blood total cholesterol could be observed. We are currently conducting a study to investigate dosage and usage in order to finalize the dosing protocol.

Yasunari Mano

"Pharmacokinetic study of novel cholesterol accumulation-inducing compound (lipoprofen)"

As a result of single intravenous and single oral administration of lipoprofen to male Wistar rats, blood and urine samples were collected over time, and the pharmacokinetics were analyzed, the elimination half-life was found to be approximately 2 to 3 hours. It was revealed that it is a hepatically metabolized drug with moderate clearance and large distribution volume. Bioavailability was approximately 20%.

Furthermore, we investigated the pharmacokinetics after transdermal administration using the "PassPort® System," a transdermal administration device that opens temporary micropores in the stratum corneum of human skin. An in vivo study in rats using the PassPort® System through dermal administration revealed for the first time that the drug was absorbed into the systemic circulatory system and maintained its pharmacokinetics in the blood for a long time. As a result of verifying the dosing protocol and conducting experiments jointly with the Higami Laboratory, we were able to find a dosage and usage method in which this compound, which maintains its blood concentration and transfers to the blood circulation system, exerts its medicinal effects through transdermal administration using the "PassPort® System."

Carbon Value Research Center

Carbon Value Research Center

1. Overview

Due to the concern about climate change and global warming, the movement toward decarbonized society is being accelerated globally. In October, 2020, Japanese government announced that Japan would achieve "Carbon neutral" (i.e., net emission of greenhouse effect gas is zero in total) by 2050. The Green Growth Strategy, which connects challenges for carbon neutral with an economical and industrial growth, was formulated. In 2021, the summit among university's presidents on the contributions toward carbon neutral was held and, based on the discussions there, "University Coalition for Carbon Neutrality" was established.

Many efforts are underway around the world to become carbon neutral, a concept that would reduce carbon emissions to virtually zero. The use of renewable energy is a prerequisite for achieving carbon neutrality. This will help to solve the resource, energy, and environmental problems that humanity faces. When it comes to renewable energy use, most people think of solar power and wind power. Looking back at our daily lives, not only electrical energy but also materials such as fuels (chemical energy) and chemical products are indispensable. To synthesize these substances, hydrogen (H) and carbon (C) are needed as the main raw materials. Here, to achieve carbon neutrality, water (H_2O) must be used as the hydrogen source and carbon dioxide (CO_2) as the carbon source. This means that carbon dioxide must be used as a carbon source to synthesize high-value substances such as gasoline, jet fuel, olefins, and alcohols (this is called "Carbon Value").

Based on the social background mentioned above, our university ranked research fields relating to "carbon neutral" as a strategical key area, and then "Carbon Value Research Center", where researchers on artificial photosynthesis, electrochemical CO_2 reduction, secondary batteries, hydrogen usage gathered, was launched in January, 2022.
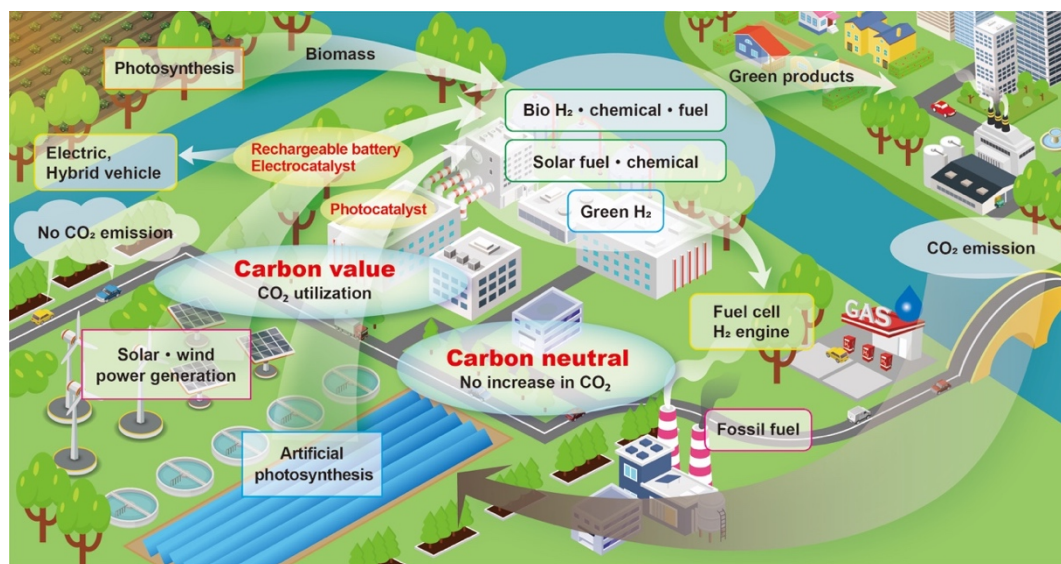

Fig. 1. Future vision that the CV center aims at.

2. Organization and Facilities

The CV center develops original and essential technologies for CARBON VALUE by which CO_2 is converted to valuable products as a carbon source through collaborations. The CV center aims to solve the

resource, energy, and environmental issues by social implementation of the total system based on our basic research through the carbon value technology (Fig. 1).

To convert carbon dioxide into a resource, it is essential to develop science and technology to reduce carbon dioxide (reacting it with electrons or hydrogen) using renewable energy sources such as sunlight. Direct carbon dioxide reduction methods include photochemical and electrochemical methods. Here, light must be solar and electricity must be generated from renewable energy sources (renewable electricity). Another indirect method is the thermocatalytic reduction of carbon dioxide using solar hydrogen (green hydrogen) produced from water using renewable energy. On the other hand, to use renewable electricity, a battery is needed to store it. For this reason, the development of lithium and sodium ion batteries is also an important topic worldwide. Battery technology is not limited to electrolytic synthesis but can contribute to carbon neutrality through its use in electric vehicles and other applications.

Hydrogen is also an essential substance for carbon neutrality. You might think that hydrogen is a clean energy source that fuels fuel cells. Therefore, it must also be linked to fuel cell technology. In addition to this, hydrogen is also essential as a key substance in the chemical industry. Many chemical products are produced chemically using hydrogen as a raw material. One of the most important products is ammonia, which is used in chemical fertilizers. If hydrogen cannot be produced due to depletion of fossil resources, chemical fertilizers cannot be made. This will be a critical issue for humanity. Thus, hydrogen is not only a clean energy source, but is indispensable to support the materials of today's society. In other words, it is no exaggeration to say that anything is possible with hydrogen. The industrial hydrogen production method in modern society is steam reforming, in which fossil resources such as oil, natural gas, and coal are reacted with water at high temperatures. However, this hydrogen production method still has the problems of fossil fuel depletion and carbon dioxide emissions. Running fuel cell vehicles on hydrogen obtained in this way is not a fundamental solution to environmental problems. Therefore, it is desirable to develop a technology to produce hydrogen from water using renewable energy. One such science and technology is artificial photosynthesis, which uses photocatalysis to decomposition of water to produce hydrogen.

The objective of this research center is to develop science and technology to effectively utilize and reduce excess carbon dioxide emissions by converting carbon dioxide, which is an important carbon resource, into valuable substances. Furthermore, we will develop science and technology that will be carbon negative. A typical example of this science and technology is the production of hydrogen through water splitting using renewable energy. Research will focus on the development of photocatalysts, electrocatalysts, and rechargeable batteries necessary for these scientific processes. In addition, we will conduct research and development of fuel cells and bio-hydrogen. We will also proceed with life cycle assessment (LCA: a method for quantitatively evaluating the environmental impact of a product or service over its entire life cycle (resource extraction - raw material production - product production - distribution and consumption - disposal and recycling) at the same time.

2. 1. Research System of the CV Center

About 9 researchers from Tokyo University of Science and 2 visiting scientists belong to the CV center. The researchers collaborate with each other and also outside researchers. We work on developments of photocatalysts and semiconductor photoelectrodes for artificial photosynthesis, electrocatalysts for electrochemical reduction of CO_2 using a renewable electricity, and secondary batteries for storage of the renewable electricity, and minimization of platinum in a fuel cell for usage of green hydrogen. In addition, CO_2 storage and adsorption, biological process, and measurement technology are studied. The collaboration will be expanded to accelerate the research in the future.

2. 2. Main Research Topics in the CV Center

Figures 2 and 3 show research topics and strengths of the CV center.
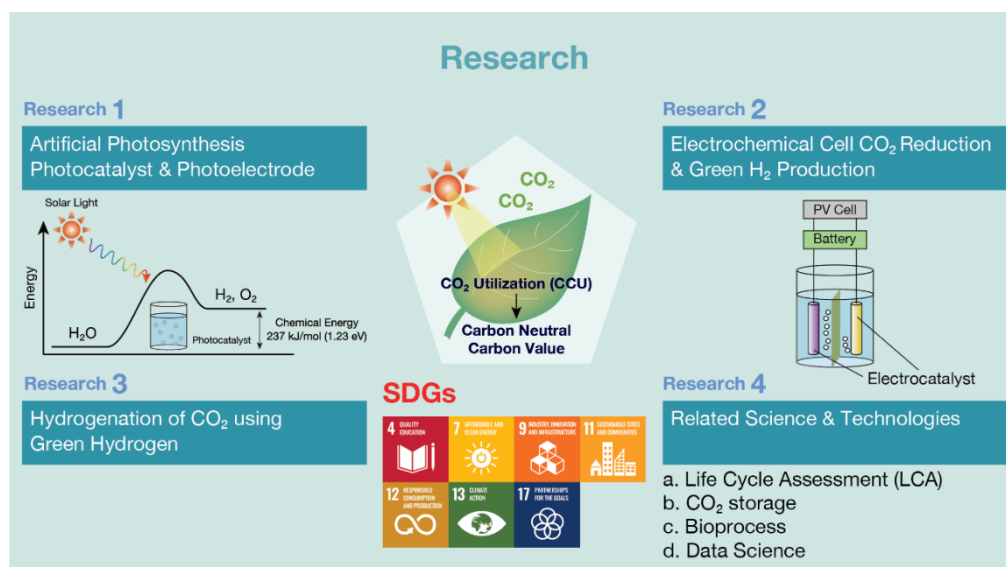
Fig. 2. Research topics of the CV center.
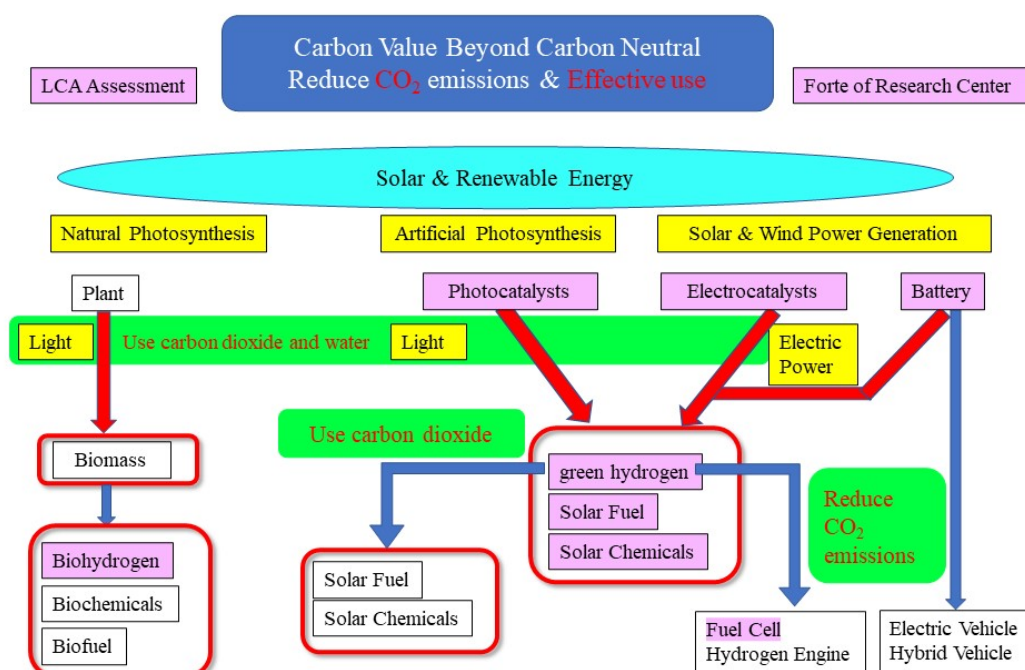
Fig. 3. Strengths of the CV center.

2. 2. 1. Green Hydrogen Production with Renewable Energy

Hydrogen is also an essential material from a perspective of carbon neutral. Because hydrogen burns without emitting CO_2, it is attracted as a clean energy source. In addition, hydrogen is indispensable as a basic material in a chemical industry. Today, an industrial production of hydrogen is based on a steam reforming method, in which fossil fuels (i.e., petroleum, natural gas, and coal) are reacted with water at high temperature. Therefore, consumption of fossil fuels and emission of CO_2 remains still. To achieve carbon neutral, technological development of green hydrogen production from water with renewable energy is

desired. The CV center conducts the research on artificial photosynthesis in which green hydrogen is produced by water splitting using a photocatalyst that is the strength of our university. The green hydrogen can be utilized for a carbon value technology such as hydrogenation of CO_2 to produce valuable compounds in a chemical industry.

2. 2. 2. *Manufacturing of Highly-valuable Products by CO₂ Reduction*

To manufacture highly-valuable products (i.e., gasoline, jet fuel, olefin, and alcohol) from CO_2 as a carbon source, we work on the development of CO_2 reduction technologies. CO_2 reduction by artificial photosynthesis using sun light, H_2O and photocatalysts/semiconductor photoelectrodes, and an electrochemical reaction of CO_2 with renewable electricity are studied for the direct CO_2 reduction.

2. 2. 3. *Development of Batteries Supporting Carbon Neutral Society*

When green hydrogen is considered as a clean energy, the application to a fuel cell technology becomes important. The CV center works on reduction in an amount of platinum and even platinum free in fuel cells, because platinum is rare and expensive. A secondary battery to store renewable electricity is also a key technology for green hydrogen production and CO_2 reduction by electrochemical reactions. Developments of not only lithium but also sodium ion battery are important from a viewpoint of stable supply of the alkali metal resource. The secondary battery contributes to carbon neutral in an electric vehicle.

2. 3. *Facilities*

We organize the following instruments:
Scanning electron microscopy (SEM), X-ray Photoelectron Spectrometer (XPS), Matrix Assisted Laser Desorption/Ionization-Time of Flight Mass Spectrometer (MALDI-TOFMS), Inductively Coupled Plasma Mass Spectrometry (ICP-MS), etc.

3. Activity Reports

In 2023, the CV center organized "The 2nd International Workshop on Carbon Value Science & Technology" (on-line). Leading scientists working on carbon neutral from oversea and Japan, and the member of the CV center gave presentations on Artificial Photosynthesis, Photo/Electrocatalyst, Energy material & CO_2 reduction, and Rechargeable Ion Battery. About 140 participants attended the workshop from universities and companies in domestic and overseas.

We also co-organized "the 28th Recent development of photocatalytic reactions" with Photofunctional Material Society and Research Center for Space System Innovation (RIST, TUS). There were 4 invited talks and 62 poster presentations. We had 225 of participants in person and on-line.

Groups of the center have mainly studied development of green hydrogen production and construction of hydrogen utilization system, production of valuable compounds by carbon dioxide reduction, and secondary battery. We published our achievements in various journals and cover pictures with high impact factors.

3. 1. *Photocatalyst Group*

This group developed various photocatalysts for waters splitting to produce green hydrogen and CO_2 reduction using water as an electron donor. A semiconductor photocatalyst-molecular catalyst hybrid system was developed for highly selective CO_2 reduction with a collaboration of Dr. Morikawa's group at Toyota Central Laboratory. This group published a paper by collaboration with University of California, Irvine.

3. 2. Cluster Catalyst Group

Facet-selective loading of metal nanoclusters on water-splitting photocatalysts was This group proposed a method to synthesize ultrafine metal clusters in the liquid phase and support them on the surface of the photocatalyst facet-selectively, thereby creating a water-splitting photocatalyst with precisely controlled particle size and electronic state.

3. 3. CO_2 Conversion Group

Photothermal catalysts for carbon recycling was studied. The synthesis of solar-thermal CO_2 conversion materials and the development of reaction processes were examined.

3. 4. Secondary Battery Group

Materials of next generation battery for efficient utilization of electricity was studied focusing on materials of sodium-ion and potassium ion batteries free from minor and toxic metal elements along with that of lithium-ion battery.

3. 5. Biomass Group

Research on the secondary decomposition of tar in the pyrolyzer and reformer using sewage sludge was conducted. The behavior of secondary decomposition of light tar was measured with an online mass spectrometer.

3. 6. Physical Property-control Group

This group developed design concepts for high surface potential electrets based on ceramics and created a vibration power generation device using these electrets in collaboration with a company.

3. 7. CO_2 Capture Group

Sustainable carbon-recycle with sunlight was studied. The phase-transition CO_2 absorbent that switches highly efficient CO_2 absorption with precipitation and CO_2 release through dissolution based on the photo-responsive structural changes was modified.

4. Challenges and Prospects

Individual studies were mainly conducted by the member, while collaborations among the members were not enough still. The CV center is planning some seminars by the member and researchers outside to exchange information and opinion to accelerate the collaboration. The 3rd international workshop will also be arranged to have a relationship with international collaborators. We will continue to study our research topics with aiming at output with high impacts in a social society.

5. Conclusion

Research by our member is steadily progressing on carbon value and carbon neutrality. However, relationship among members and researchers out-side should further be made strong. We have been studying to make excellent achievements with our originality and strength and will contribute to the establishment of carbon neutral society.

Major Research Achievements (FY 2023)

Academic Papers

1. Single-Particle Measurements Reveal the Origin of Low Solar-to-Hydrogen Efficiency of Rh-Doped $SrTiO_3$ Photocatalysts, B. Zutter, Z. Chen, L. Barrera, W. Gaieck, A. S. Lapp, K. Watanabe, A. Kudo, D. V. Esposito, R. B. Chandran, S. Ardo, A. A. Talin, ACS Nano, 2023, 17, 9405-9414 (Peer-reviewed)

2. Understanding the reaction mechanism and kinetics of photocatalytic oxygen evolution on CoOx-loaded bismuth vanadate, Y. Matsumoto, K. Nagatsuka, Y. Yamaguchi, A. Kudo, J. Chem. Phys., 2023, 159, 214706 (Peer-reviewed)

3. Highly selective CO_2 electrolysis in aqueous media by a water-soluble cobalt dimethyl-bipyridine complex, T. M. Suzuki, K. Nagatsuka, T. Nonaka, Y. Yamaguchi, N. Sakamoto, T. Uyama, K. Sekizawa, A. Kudo, T. Morikawa, Chem. Commun., 2023, 59, 12318-12321 (Peer-reviewed)

4. CH_4 Synthesis from CO_2 and H_2O of an electron source over Rh-Ru cocatalyst loaded on $NaTaO_3$:Sr photocatalyst, W. Soontornchaiyakul, S. Yoshino, T. Kanazawa, R. Haruki, D. Fan, S. Nozawa, Y. Yamaguchi, A. Kudo, J. Am. Chem. Soc., 2023, 145, 20485-20491 (Peer-reviewed)

5. Water Splitting and CO_2 Reduction over $AgSr_2Ta_5O_{15}$ Photocatalyst Developed by Valence Band Control Strategy, T. Takayama, A. Iwase, A. Kudo, Chem. Commun., 2023, 59, 7911-7914 (Peer-reviewed)

6. Carbon Nitride Loaded with an Ultrafine, Monodisperse, Metallic Platinum-Cluster Cocatalyst for the Photocatalytic Hydrogen-Evolution Reaction, D. Yazaki, T. Kawawaki, D. Hirayama, M. Kawachi, K. Kato, S. Oguchi, Y. Yamaguchi, S. Kikkawa, Y. Ueki, S. Hossain, D. J. Osborn, F. Ozaki, S. Tanaka, J. Yoshinobu, G. F. Metha, S. Yamazoe, A. Kudo, A. Yamakata, Y. Negishi, Small, 2023, 19, 2208287 (1 of 12) (Peer-reviewed)

7. Metal Single-Atom Cocatalyst on Carbon Nitride for the Photocatalytic Hydrogen Evolution Reaction: Effects of Metal Species, Y. Akinaga, T. Kawawaki, H. Kameko, Y. Yamazaki, K. Yamazaki, Y. Nakayasu, K. Kato, Y. Tanaka, A. T. Hanindriyo, M. Takagi, T. Shimazaki, M. Tachikawa, A. Yamakata, Y. Negishi, Adv. Functional Mater., 2023, 33, 2303321 (Peer-reviewed)

8. Clarifying the Electronic Structure of Anion-templated Silver Nanoclusters by Optical Absorption Spectroscopy and Theoretical Calculation, Y. Horita, S. Hossain, M. Ishimi, P. Zhao, M. Sera, T. Kawawaki, S. Takano, Y. Niihori, T. Nakamura, T. Tsukuda, M. Ehara, Y. Negishi, J. Am. Chem. Soc., 2023, 145, 23533-23540 (Peer-reviewed)

9. Progress and Prospects in the Design of Functional Atomically-precise Ag(I)-thiolate Nanoclusters and Their Assembly Approaches, S. Biswas, S. Das, Y. Negishi, Coord. Chem. Rev., 2023, 492, 215255 (Peer-reviewed)

10. Ultra-high growth rate of boron-doped diamond films with optimized growth parameters using in-liquid microwave plasma CVD, Y. Tominaga, Y. M. Hunge, N. Kubota, N. Ishida, S. Sato, T. Kondo, M. Yuasa, H. Uetsuka, C. Terashima, Diam. Relat. Mater., 2023, 140, 110543/1-110543/12 (Peer-reviewed)

11. Synergistic effect of Ag decorated in-liquid plasma treated titanium dioxide catalyst for efficient electrocatalytic CO_2 reduction application, K. Takagi, N. Suzuki, Y. M. Hunge, H. Kuriyama, T. Hayakawa, I. Serizawa, C. Terashima, Sci. Total Environ., 2023, 902, 166018/1-166018/10 (Peer-reviewed)

12. Impact of Ti and Zn Dual-Substitution in P2 type $Na_{2/3}Ni_{1/3}Mn_{2/3}O_2$ on Ni-Mn and Na-Vacancy Orderings and Electrochemical Properties, K. Kubota, T. Asari, S. Komaba, Adv. Mater., 2023, 35, 2300714 (Peer-reviewed)

13. In situ Observation of Evolving H_2 and Solid Electrolyte Interphase Development at Potassium Insertion Materials within Highly Concentrated Aqueous Electrolytes, Z. T. Gossage, N. Ito, T. Hosaka, R. Tatara, S. Komaba, Angew. Chem. Int. Ed., 2023, 62, e2023074 (Peer-reviewed)

14. Electrochemical intercalation of rubidium into graphite, hard carbon, and soft carbon, D. Igarashi, R. Tatara, R. Fujimoto, T. Hosaka, <u>S. Komaba</u>, Chem. Sci., 2023, 14, 11056-11066 (Peer-reviewed)

15. New Template Synthesis of Anomalously Large Capacity Hard Carbon for Na- and K-Ion Batteries, D. Igarashi, Y. Tanaka, K. Kubota, R. Tatara, H. Maejima, T. Hosaka, <u>S. Komaba</u>, Adv. Energy Mater., 2023, 13, 2302647 (Peer-reviewed)

16. Impact of electrolyte decomposition products on the electrochemical performance of 4 V class K-ion batteries, T. Hosaka, T. Matsuyama, R. Tatara, Z. T. Gossage, <u>S. Komaba</u>, Chem. Sci., 2023, 14, 8860-8868 (Peer-reviewed)

17. Ion dynamics in P2-Na_xCoO_2 detected with operando muon spin rotation and relaxation, K. Ohishi, D. Igarashi, R. Tatara, I. Umegaki, J. Nakamura, A. Koda, M. Mansson, <u>S. Komaba</u>, J. Sugiyama, ACS Appl. Energy Mater., 2023, 6, 8111-8119 (Peer-reviewed)

18. Discussions on the heat transfer performance of the indirect pyrolysis plant using CFD modeling, M. Hamazaki, K. Torii, M. Shan, M. Kameyama, J. V. L. Mercado, <u>K. Dowaki,</u> IOP Conf. Series: Earth and Environmental Science, 2023, 1187, 012026 (Peer-reviewed)

19. Dynamic LCA of H_2S adsorption from bio-syngas using mine residues, K. Torii, S. Kumon, K. Sato, S. Kato, <u>K. Dowaki</u>, IOP Conf. Series: Earth and Environmental Science, 2023, 1187, 012033 (Peer-reviewed)

20. Development and Research of Inorganic Energy Conversion Materials and Devices-The Effect of Carbonate Ions on the Ionic Conduction of B-type Carbonated Apatite-, <u>Y. Tanaka</u>, S. Yatsugi, S. Iwasaki, ELECTROCHEMISTRY, 2023, 91, 121001-1-121001-6 (Peer-reviewed)

Invited Lectures

1. Heterogeneous Photocatalysts for water splitting and CO_2 reduction, <u>Akihiko Kudo</u>, (Invited), The conference on Catalyst Design Strategies for Photo- and Electrochemical Fuel Synthesis (ECAT), Keele University Events and Conferencing, UK, 2023.

2. Heterogeneous photocatalysts for artificial photosynthesis aiming at carbon neutral, <u>Akihiko Kudo</u>, (Keynote), The 31st International Conference on Photochemistry (ICP2023), Sapporo, 2023.

3. Creation of Active Water-splitting Photocatalysts by Controlling Cocatalysts Using Atomically Precise Metal Nanoclusters, <u>Yuichi Negishi</u>, International Congress on Pure & Applied Chemistry (ICPAC) Bali 2023.

4. Fabrication of Charge Accumulation Ceramics and Their Applications, <u>Yumi Tanaka</u>, ICMAT 2023 Post Symposium "Interface Ionics for All-Solid-State Batteries", Singapore, 2023.

Patents

1. <u>Yumi Tanaka</u>, Yoshihiro Kozawa, Noriyuki Matsushita, Kazuhiko Kanoh, US patent, ELECTRET, 11917919, 2024.

2. <u>Tatsushi Imahori</u>, Ryo Motoyama, European Patent registrated, compounds, carbon dioxide absorption/release agents, carbon dioxide collection methods and carbon dioxide collection devices, No.3932903, 2023.

Awards

1. <u>Akihiko Kudo</u>, The Chemical Society of Japan (CSJ) Award, The Chemical Society of Japan, 2024.

2. <u>Yuichi Negishi</u>, The 34th Mukai Award, Tokyo Ohka Foundation for The Promotion of Science and Technology, 2023.

3. <u>Yuichi Negishi</u>, Symposium Award 2023, INSTITUT KIMIA MALAYSIA, 2023.

4. <u>Shinichi Komaba</u>, Clarivate Highly Cited Researchers 2023.

Individual Research Topics

Akihiko Kudo and Yuichi Yamaguchi
"Development of photocatalysts aiming at production of green hydrogen and highly efficient CO_2 reduction using water as an electron donor"

Production of green hydrogen and CO_2 reduction using water as an electron donor are important research topics to achieve carbon neutral society. This year, we successfully developed novel metal oxide photocatalysts showing the activity for sacrificial hydrogen evolution under visible light irradiation by doping tiny amount of Ir. In addition, the novel visible-light-driven photocatalysts composed of Ag showing the activity for sacrificial oxygen evolution under visible light irradiation were successfully developed by using a ball-milling device. Also, highly efficient CO_2 reduction over metal oxide photocatalysts was achieved by loading with various dual-cocatalysts.

Yuichi Negishi and Tokuhisa Kawawaki
"Facet-selective loading of metal nanoclusters on water-splitting photocatalysts"

Water-splitting photocatalysts, which can produce hydrogen from water and sunlight, are attracting attention as a clean hydrogen-evolution method. To increase the activity of this photocatalyst, it is effective to support nano metal particles called cocatalysts. In this study, we proposed a method to synthesize ultrafine metal clusters in the liquid phase and support them on the surface of the photocatalyst facet-selectively, thereby creating a water-splitting photocatalyst with precisely controlled particle size and electronic state.

Chiaki Terashima
"Photothermal catalysts for carbon recycling"

CO_2 reduction technology, which views CO_2 as a resource and converts it into a useful resource, is attracting attention. In artificial photosynthesis, TiO_2 photocatalysts can only utilize about 6% of the sunlight, and the R&D into visible light responsiveness is underway. Photothermal catalysts, on the other hand, have a potential to utilize more than 50% of sunlight. Therefore, the synthesis of solar-thermal CO_2 conversion materials and the development of reaction processes will be addressed.

Shinichi Komaba
"Study on materials of next generation battery for efficient utilization of electricity"

We study on materials of sodium-ion and potassium ion batteries free from minor and toxic metal elemetns along with that of lithium-ion battery. In FY2023, we studied on new materials for Na-ion battery, like layered sodium manganese oxide and templated hard carbon. Furthermore, we extended our research target to electrochemical reaction using rubidium ions as charge carrier ions.

Kiyoshi Dowaki
"Research on the secondary decomposition of tar in the pyrolyzer and reformer using sewage sludge"

Continuing from the previous year, research and development of hydrogen production by pyrolysis and gasification of biomass resources such as sewage sludge are being conducted in collaboration between industry and academia. This year, the behavior of secondary decomposition of light tar (mainly naphthalene from cellulose and benzene from lignin) was measured with an online mass spectrometer (decomposition rate was calculated from the amount of hydrogen generated in response to temperature change). After analyzing the decomposition rate on the kinetics, the behavior of tar in the gasifier was analyzed using a dynamic fluid dynamics model (CFD).

Yumi Tanaka

"Research on inorganic energy conversion materials and related devices"

Electrets expressing the world's highest surface potentials of over 7 kV for bulk (1000 μm) and about 800 V for thin films (1 μm) have been successfully developed using rare earth aluminate-based ceramics. In collaboration with a company, a prototype model of an "edge system" consisting of a ceramic electret-based vibration generator, an LED, an illumination sensor, a microcontroller, and a wireless communication device was created, and the system operation under autonomous power generation (about 500μW) by vibration generation was demonstrated.

Tatsushi Imahori

"Sustainable carbon-recycle with sunlight"

The phase-transition CO_2 absorbent that switches highly efficient CO_2 absorption with precipitation and CO_2 release through dissolution based on the photo-responsive structural changes was modified, which accomplished energy-saving fastest CO_2 direct air capture with sunlight. As a utilization of the captured CO_2, a new catalytic C-C bond formation reaction of CO_2 and terminal alkynes was developed using again sunlight as the energy source.

Research Center for Multi-hazard Urban Disaster Prevention

Research Center for Multi-hazard Urban Disaster Prevention

1. Overview

In Japan, in addition to geographical and social conditions that allow multi-hazards to occur, there is concern that the damage to infrastructure will become more serious due to the denser urban structure. Based on this background, in order to create and put into practice a new urban disaster prevention science and build a safe and secure society that is sustainable, takes diversity into account, and leaves no one behind, the research center for multi-hazard urban disaster prevention has been established in the RIST on August 1, 2023. The purpose of this center is the following three points.

– We elevate previous research for single hazard such as natural disasters, large fires, and the spread of new infectious diseases into an academic system that can handle multiple hazards. Researchers from different fields collaborate and fuse to create comprehensive breakthroughs in urban disaster prevention.

– While keeping in mind urban disaster prevention based on building a resilient, safe, and secure society, we aim to realize people's well-being by being sustainable (energy saving), environmentally friendly (SDGs), comfortable, improving QOL, and taking health into consideration.

– We actively collaborate with government agencies and private companies from the beginning of research in order to socially implement the academic knowledge and results obtained.

In order to achieve these objectives, while it is natural for individual researchers to promote research on urban disaster prevention and mitigation as has been the case in the past, we will place the utmost importance on actively promoting cross-disciplinary collaboration and fusion between different fields. With this in mind, the center's activity policy is based on the following four points.

-We promote research in urban disaster prevention, especially in the multi-hazard field and disaster prevention informatics field, by collaborating with researchers and engineers outside the university and researchers in our university who specialize in urban disaster prevention of various hazards, data science, and materials.

– The center's activities will not be limited to the "addition" of the research results of individual researchers, but will actively promote horizontal collaboration and fusion among researchers in different fields, resulting in the "multiplication" of research results.

– We actively promote collaboration with local governments and private companies and greatly contribute to improving local disaster prevention and mitigation capabilities.

– We deepen collaboration with leading domestic and international researchers and form an international joint research center related to urban disaster prevention.

2. Organization and Facilities

The members in our center as of the end of 2023 is shown in Table 1. From 2024 onwards, we plan to gradually increase the number of on-campus members and also include researchers from outside the university.

Table 1. Member list

No.		Affiation	Job title	Name
1	Director	Department of Civil Engineering, Faculty of Science and Technology	Professor	Yasuo Nihei
2	Vice Director	Department of Global Fire Science and Technology, Graduate School of Science and Technology	Professor	Ken Matsuyama
3	Vice Director	Department of Physics,Faculty of Science Division I	Professor	Takahiro Yamamoto
4		Department of Architecture,Faculty of Engineering	Professor	Takumi Ito
5		Department of Architecture,Faculty of Science and Technology	Associate Professor	Yuji Miyazu
6		Department of Industrial and Systems Engineering, Faculty of Science and Technology	Professor	Aya Ishigaki
7		Department of Applied Mathematics,Faculty of Science Division I	Professor	Takashi Seo
8		Organization for Research Advancement, Research Institute for Biomedical Sciences, Research Division	Professor	Masato KUBO
9		Department of Civil Engineering, Faculty of Science and Technology	Assistant Professor	Jin Kashiwada
10		Department of Civil Engineering, Faculty of Science and Technology	Professor	Yoshitaka Kato

3. Activity Reports

At this center, we have three units. Normally, research activities should be carried out by each unit, but since collaborative activities and exchanges between center members were carried out, there were no reports on activities as a unit, and the activities of each member are summarized at the end of the report. Please refer to them. On the other hand, we carried out activities as a whole, so we will briefly summarize them below.

3. 1. Seminars

Sponsored by this center, the "Multi-Hazard Urban Disaster Prevention Research Seminar" was held three times in 2023. An overview is shown below.

1) First session, Tuesday, October 17, 2023, 13:00-14:30 (Participants: 37 off-campus, 21 on-campus)
   • Theme: Overview of the 2023 heavy rain disaster and home recovery methods
   • Lectures: 1) Yasuo Nihei (Professor, Tokyo University of Science), 2) Kenichi Hasegawa (Professor, Akita Prefectural University)

2) Second session, Tuesday, December 8, 2023, 16:00-17:30 (Participants: 5 off-campus, 23 on-campus)
   • Theme: Multi-hazard research focusing on fire damage and urban fire research
   • Lectures: 1) Ken Matsuyama (Professor, Tokyo University of Science), 2) Keisuke Himoto (Ministry of Land, Infrastructure, Transport and Tourism, National Institute of Research, Chief Researcher)

3) Third session, Thursday, January 11, 2024, 16:00-17:30 (Participants: 11 off-campus, 20 on-campus)
   • Theme: preArch, a startup from Tokyo University of Science aiming to realize disaster prevention DX
   • Lectures: 1) Takahiro Yamamoto (Professor, Tokyo University of Science), 2) Takahiro Okita (Representative Director, BosaiTUBE Co., Ltd.)

3. 2. Promoting Extramural Collaboration

In order to carry out exchanges with people outside the university, which is one of the activity policies of this center, we promoted research exchanges with the following two institutions.

1) National Research Institute for Earth Science and Disaster Resilience
   • Date and time: October 5, 2023.

• Participants: Director Nishihara, Nihei, Yamamoto, Ito, Ishigaki, 2 students, 2 people from Noda Research Promotion Division (titles omitted)
• Content: Disaster prevention science research tour and seminar participation

2) Katsushika Ward Office
• Date and time: 2023/11/16, 2024/1/17, 3/27
• Participants: Ito, Takase, Nihei, URA: Okamoto, Uzawa (titles omitted)
• Content: Joint research meeting

3. 3. Promoting Intra-campus Collaboration

In order to steadily promote research exchange among members of this center, we promoted research exchange both online and in person.

1) Preparation of 100 science papers

100 Papers is a site devised by Professor Miyano of Kyoto University, which aims to facilitate the exchange of opinions and interactions between researchers. We created a website where each member can write about (1) research overview, (2) research interests, things they want to try, and (3) current issues with diagrams, and view them and interact with each other using the chat function.

2) Research exchange meeting

After the online exchange in 1), a real face-to-face exchange meeting was held on March 12, 2024. All participants had a 5-minute research introduction and discussion. After this exchange meeting, each member created a research proposal based on the collaboration, and preparations for research exchange for the next year were completed.

4. Challenges and Prospects

This center has only been established for a short period of time, just over half a year, and has produced almost no research results. However, we are slowly progressing with research exchanges and collaborations both inside and outside the university, and we are also increasing the number of center members to establish a research structure. On the other hand, we have not been able to obtain competitive funding, and this is a challenge for next year and beyond. Furthermore, we have not achieved anything in terms of international expansion and collaboration, which is one of the activity policies of this center, and we will gradually move forward with international expansion through holding international symposiums and other activities.

5. Conclusion

This center was just established in August 2023 and has not produced any notable research results, but we plan to strengthen collaboration both within the university (among members) and outside the university (with national research institutes, the government, and private companies). We plan to conduct research in this area, and preparations are underway.

Major Research Achievements (FY 2023)

Academic papers

1. Subgrid Model of Fluid Force Acting on Buildings for Three-Dimensional Flood Inundation Simulations, R. Kubota, J. Kashiwada and Y. Nihei: *Water, 15(17), 3166,* 2023 (Peer-reviewed)

2. 洪水と地震のマルチハザードに関する事例研究, 二瓶泰雄, 第 16 回日本地震工学シンポジウム要旨集, 6 ページ, 2023 (in Japanese)

3. Subgrid Model of Water Storage in Paddy Fields for a Grid-Based Distributed Rainfall–Runoff Model and Assessment of Paddy Field Dam Effects on Flood Control, Y. Nihei, Y. Ogata, R. Yoshimura, T. Ito and J. Kashiwada, *Water, Vol.16, No.2,* 255, 2024 (Peer-reviewed)

4. 河川流・氾濫流一体解析に基づく破堤幅の時間変化と家屋被害状況の関係〜2015 年鬼怒川氾濫を例として〜, 吉井祥真・窪田利久・柏田仁・鎌田直樹・鈴木聡佑・二瓶泰雄, 土木学会論文集, Vol.80, No.16, 23-16010, 2024 (in Japanese) (Peer-reviewed)

5. 三次元河川流・氾濫流一体解析法に基づく令和 2 年球磨川洪水における橋桁抵抗影響評価, 窪田利久, 柏田仁, 井上隆, 二瓶泰雄, 土木学会論文集, Vol.80, No.16, 23-16157, 2024 (in Japanese) (Peer-reviewed)

6. 亀高拓海, 劉虹, 二瓶泰雄, 永野正行：都市型複合災害に対する東京23 区における超高層集合住宅を対象とした空間分析, 2024年度日本建築学会大会学術講演会梗概集, 2024 (in Japanese)

7. 災害状況を考慮した震災鉄骨造の復旧工程に関する基礎的研究, 保坂賢, 横山真広, 崎山夏彦, 伊藤拓海, 2024 年度日本建築学会大会学術講演会梗概集（投稿済）, 2024 (in Japanese)

8. 電場を利用した煙制御方法に関する研究　〜煙粒子の帯電挙動について〜, 奥野博明, 松山賢, 安全工学研究発表会予稿集, pp.59-60, 2023 (in Japanese)

9. Evaluation of vibration properties of an 18-story mass timber–concrete hybrid building by on-site vibration tests, Y. Miyazu and C. Loss, *Journal of Civil Structural Health Monitoring*, 2024 (Peer-reviewed)

10. 滑り基礎構造を適用した実大 2 層木造軸組の振動台加振実験, 富田愛, 宮津裕次, 東城峻樹, 青木崇, 脇田健裕, 永野正行, 日本建築学会構造系論文集, 89(816), pp.168-179, 2024 (in Japanese) (Peer-reviewed)

11. Lateral vibration data of an 18-story timber-concrete hybrid building obtained by on-site vibration tests, Y. Miyazu and C. Loss, Data in Brief, Volume 50, 2023 (Peer-reviewed)

12. Type 2 helper T cells convert to Interleukin-1 13 expressing follicular helper T cells after antigen repriming, Harada, Y., Sasaki, T., Wibisana, J-N., Okada-Hatakeyama, M., Ueno, H., Burrows, P. D., Kubo, M., *Translat Regulat Sci.* Vol. 5 No. 1: 1-12, 2023 (Peer-reviewed)

13. IL-27 regulates the differentiation of follicular helper NKT cells via metabolic adaptation of mitochondria, Kamii, Y., Hayashizaki, K., Kanno, T., Chiba, A., Akeda, Y., Ohteki, T., Kubo, M., Oishi, K., Araya, J., Kuwano, K., Kronenberg, M., Endo, Y., and Kinjo, Y., Proc. *Natl. Acad. Sci.* 121 (9), e2313964121, 2024 (Peer-reviewed)

14. 震災後の道路工事計画を考慮した多期間在庫配送計画問題の設計, 尾崎亘佑, 伊集院大将, 石垣綾, 日本機械学会生産システム部門研究発表講演会 2024 予稿集, pp. 59-63, 2024 (in Japanese)

15. Analysis of the Kokuho Database to Identify regional differences based on complex Health Data of latter-stage elderly, A. Hagimoto, A. Ishigaki, T. Harada, IIAI Letters on Business and Decision Science, Vol. 3, 13, 2023 (Peer-reviewed)

16. Simultaneous Tests for Mean Vectors and Covariance Matrices with Three-step Monotone Missing Data, Sakai, R., Yagi, A., <u>Seo, T.</u>, *Journal of Statistical Theory and Practice*, 18:3, 2024 (Peer-reviewed)

Invited Lectures
1. 近年の激甚化する豪雨災害にどう備えるか, <u>二瓶泰雄</u>, こうよう会 in 神奈川支部, 千葉, 2023 (in Japanese)
2. 激甚化する豪雨災害の現状とマルチハザードへの備え, <u>二瓶泰雄</u>, 山口大ホームカミングデー, 山口, 2023 (in Japanese)
3. 最近の豪雨災害の特徴と備え, <u>二瓶泰雄</u>, 国土文化研究所オープンセミナー, 東京, 2023 (in Japanese)
4. マルチハザード都市防災研究と医理工連携の可能性, <u>二瓶泰雄</u>, 東京慈恵会医科大学・東京理科大学合同シンポジウム, 東京, 2024 (in Japanese)
5. 皮膚より導入されるアレルギー応答において多臓器を繋ぐインターロイキン-13 受容体陽性樹状細胞の役割, <u>久保允人</u>, 第 72 回日本アレルギー学会学術大会 JSA-JSI Joint Session, 東京, 2023 (in Japanese)
6. 皮膚炎症とアレルギーマーチ, <u>久保允人</u>, 第 8 回理論免疫学ワークショップ, 岩手, 2024. (in Japanese)
7. Role of IL-13 in allergic march, <u>Kubo, M.</u>, Tongji Medical College, Huazhong University of Science Technology, China, 2023.

Public Relations
1. 山本貴博, UNWTO.TedQual セミナー・温泉資源の可能性と竹工芸ワークショップ, AMANE RESORT SEIKAI, 2023 (in Japanese)
2. 山本貴博, 【物理】電気エネルギーを作り出そう, 体験型子ども科学館 O-Labo, 2023 (in Japanese)
3. 山本貴博, サイエンスフェス 2023 in 大分「災害時に役立つ最新技術を体験しよう！」, J:COM ホルトホール大分, 2023 (in Japanese)
4. 二瓶泰雄, NHK・ニュースウォッチ９, 研究成果（Lv4 雨量）の紹介, 2023 (in Japanese)
5. 二瓶泰雄, NHK・首都圏ネットワーク, 一宮川水害観測・コメント, 2023 (in Japanese)
6. 二瓶泰雄, NHK・首都圏ネットワーク, 第一回マルチハザードセミナーの紹介, 2023 (in Japanese)
7. 二瓶泰雄, NHK・明日を守るナビ, 千曲川氾濫シミュレーション結果の紹介, 2023 (in Japanese)
8. 二瓶泰雄, 読売新聞, 一宮川流域における令和 5 年台風第 13 号による災害検証会議の紹介, 2023 (in Japanese)

Awards
1. 窪田利久, 第 78 回年次学術講演会優秀講演者賞, 土木学会, 2023（指導教員：二瓶泰雄）(in Japanese)
2. 平本達典, 第 78 回年次学術講演会優秀講演者賞, 土木学会, 2023（指導教員：二瓶泰雄）(in Japanese)
3. 谷口 颯, 第 42 回学術講演会優秀講演者賞, 日本自然災害学会, 2023（指導教員：二瓶泰雄）(in Japanese)
4. 平本達典, 第 42 回学術講演会優秀講演者賞, 日本自然災害学会, 2023（指導教員：二瓶泰雄）(in Japanese)

Individual Research Topics

Yasuo Nihei and Jin Kashiwada
"Research on multi-hazards focusing on flood damage"

As a first step in researching time- and space-linked multi-hazards, we investigated and analyzed case studies of time-linked multi-hazards, and evaluated multi-hazard risks focusing on water treatment plants. Therefore, based on a field survey, we grasped the actual situation of time-linked multi-hazards such as flooding caused by heavy rains in Akita in July 2023, subsequent flooding of water treatment plants, and water outages. Next, we used hazard maps to evaluate the risks of flooding, tsunamis, and landslides at water treatment plants in Tokyo and Akita Prefecture, and clarified the multi-hazard risks at water treatment plants. In addition, we conducted a flood survey (mainly in the Ichinomiya River basin, Chiba Prefecture) due to Typhoon No. 13 in 2023 and conducted a numerical simulation. Furthermore, we advanced the numerical analysis methods necessary for flood damage research and developed new monitoring technology using vehicle data.

Ken Matsuyama
"Smoke exhausting/control systems based on new methodology"

Smoke generated by a fire not only contains components harmful to the human body, but also reduces visibility in evacuation routes. Therefore, effective smoke control and exhausting system is necessary to reduce human casualties during a fire. Smoke particles are known to be weakly charged electrically. The purpose of this study is to establish a smoke control method based on a new concept that takes advantage of this property. As the first step, experimental studies were carried out to clarify the charging characteristics of smoke particles.

Takahiro Yamamoto
"Developing a system for diagnosing the degree of damage to buildings caused by earthquake"

This year, we have developed a vibration sensor that can be integrated into a brace damper, operating autonomously without requiring external power. Additionally, we have designed a network system capable of quickly transmitting acquired data wirelessly, along with a corresponding smartphone application.

Takumi Ito
"Multi-hazard risk assessment at Katsuhika-ku and suvey on post-disaster recovery plans, BCP and mutual support system"

The published hazard maps of Katsushika-ku are collected, while also the database of huge numbers of paper and literature related to multi-hazard are structured. By cross-referencing these with the single hazard maps, the high compound risk area are identified in Katsushika-ku. Through field surveys, the urban structures are modeled. Also, through the numerical simulations, the multi-hazard predictions area is presented.

Furthermore, to investigate the formulation status of recovery plans and BCPs, the actual situation of mutual support system in the field of construction industry, the interview is conducted to general contractors, house manufacturers, and building material suppliers. Form the interview tests, the recovery and reconstruction process are modeled, also, the analytical methods are presented.

Yuji Miyazu

"Evaluation of vibration properties for tall timber buildings"

Lateral vibration tests were conducted on a 18-story timber-concrete hyblid building located in Canada to evaluate its vibration properties. Microtremor acquired by high-sensitive velocity sensors were analysed using stochastic subspace identification method to obtain the natural frequencies, damping ratios, and mode shapes. The findings provide practitioners with an insight into dynamic properties of tall timber buildings and are expected to contribute to enhance their seismic and wind performance.

Masato Kubo

"Study on the effectiveness of vaccination for immunocompromised patients"

Japan has not taken proactive measures against zoonotic diseases. However, the importance of vaccines has been widely recognized by society after the worldwide pandemic caused by a new type of coronavirus. However, the effectiveness of vaccines against vulnerable children, including infants, elderly adults, and immunocompromised patients due to underlying diseases or clinical treatment, has not been thoroughly investigated, and the experience of this pandemic has not been fully utilized. However, it should be a significant lesson for the next contingency in the elderly and immunocompromised populations. Therefore, we investigated whether vaccination given to immunocompromised patients continuously using immunosuppressive agents or targeted drugs as treatment can be as effective as vaccination given to healthy individuals, using the SARS-CoV2 vaccine as a target. We recently found that some cytokine-targeted drugs for allergic diseases and rheumatoid arthritis significantly reduced vaccine efficacy.

Yoshitaka Kato

"Study on the development of a tool to experience the attractiveness of infrastructure engineers"

Japan's population is shrinking, especially the number of people working in the construction industry. Even if technological responses to multi-hazards are in place in the future, they will not be able to be implemented if there are not enough engineers and technicians. The goal of this project is to develop an educational tool to experience the attractiveness of working on infrastructure in order to secure future human resources. This year, we have made preparations for the development of such a tool.

Aya Ishigaki

"Research on the development of decision support systems for urban disaster management"

This study aimed to develop a decision-making support system for the field by structuring and visualizing the phenomenon from multiple perspectives through the analysis of available information. In 2023, we developed a system to provide appropriate health guidance to the elderly based on health-related interviews with doctors and designed a transportation network to deliver goods to evacuation centers using limited transportation resources. The future work is to evaluate the performance of this system in reference to past cases.

Takashi Seo

"Studies of tests for mean vectors and covariance matrices and a test for adequacy in growth curve model with monotone missing data"

This study is concerned with tests of mean vectors and covariance matrices with monotone missing data. In particular, we studied test of a mean vector with three-step monotone missing data, a test of covariance matrix when the covariance matrix has sphericity structure, tests of some types of partial mean vectors, and a test for adequacy in growth curve model with two-step monotone missing data.

Division of Colloid and Interface Science

Division of Colloid and Interface Science

1. Overview

Interface science deals mainly with "particles" (all three dimensions are colloidal dimensions), "lines (wires)" (two dimensions are colloidal dimensions), and "membranes" (only one dimension is colloidal dimension), where at least one of the three dimensions is a colloidal dimension (1 nm - 1 μm). Tokyo University of Science has laboratories specializing in interface science in each faculty. The Division of Colloid and Interface Science has over 40-year history since its establishment in 1981 by interface science researchers from each faculty. This division views the interface as a "spatio-temporal functional expression field that integrates different fields". Starting from the verification and demonstration of conventional interface theories, we aim to create new physical properties, functions, and theories, and ultimately develop unprecedented novel functional materials. Specific research targets are diverse, include soft (mainly organic) materials, hard (mainly inorganic) materials, nanomaterials, and biomaterials. We promote projects from both basic and applied perspectives. Recently, physicists, mechanical engineers in fluid mechanics and tribology, and theoretical scientists have joined the division where most division members were chemists before that. We have developed research activities using a multifaceted approach in the fields of "advanced interface measurement", "stimuli-responsive materials", and "biofunctional interfaces".

From FY 2023, together with the new members, we will promote research development with a focus on "dynamics at interfaces" as the most important issue, based on the achievements accumulated by the division so far. For example, in understanding the dynamic functions of materials formed by molecular assemblies, we will understand the linkage of "dynamics of molecules" → "dynamics of molecular assemblies" → "dynamics of functions of molecular assemblies" and link this knowledge to the "creation of functional materials" based on new ideas. In addition, we will promote activities aimed at turning our university and this division into an international research base in interface science research, through active dissemination of our results overseas, participation in international conferences, and collaboration with overseas universities.

2. Organization and Facilities

In this research division, experts who conduct research in the field of interface science through their specializations in material science, physics, bioscience, mechanical engineering, and theoretical science devote research on interfacial phenomena from basic science to applications through information exchange and collaboration with each other while being aware of "dynamics at interfaces". The main target of each member (underlined: new members) are shown in the figure. One of the features of this division is its collaboration with overseas researchers and industrial researchers.

The division members own or manage various equipment including a light-scattering measurement system, molecular interaction analysis system, atomic force microscope, small-angle X-ray scattering system (SAXS), freeze-fracture transmission electron microscope (FF-TEM), and quartz crystal microbalance with dissipation (QCM-D), interfacial viscoelasticity measuring device, and they are available to other division members. In addition, cryo-TEM and FF-TEM in the Research Equipment Center enable the direct observation of colloidal particles and molecular assemblies
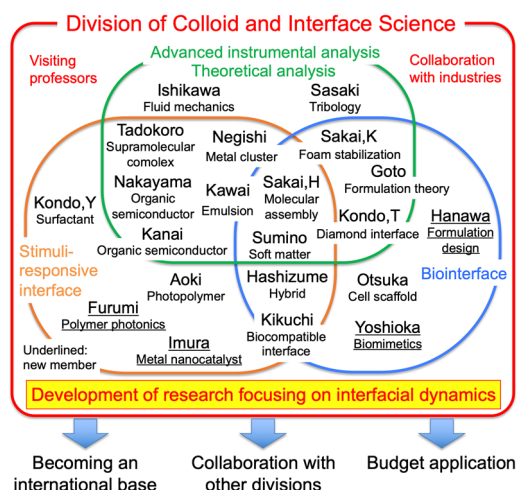
dispersed in solutions. Furthermore, a high-performance small/wide-angle SAXS installed in 2020 enables precise structural analyses of molecular aggregates, emulsions, and catalysts from nanometer to micrometer scale.

3. Activity Reports

Representative activities are as follows.

Summer Symposium 2023, Division of Colloid and Interface Science

Date: August 2, 2023

Venue: Building No. 13 (Morito Memorial Hall) in Kagurazaka Campus + online delivery via Zoom

Summary: Invited lectures were given by Assistant Professor Naoto Iwata (Department of Applied Chemistry, Faculty of Science Division I), Assistant Professor Shuhei Komatsu (Department of Materials Science and Technology, Faculty of Advanced Engineering), and Associate Professor Mafumi Hishida (Department of Chemistry, Faculty of Science Division I), and keynote lecture was given by Professor Emeritus Takahiro Seki (Nagoya University), and lively discussions ensued. In addition, 15 graduate students from the laboratories of the division members and related laboratories gave oral presentations in English (including Q&A sessions). It was a meaningful opportunity not only for the department members but also for the education of the students. The 154 internal and 3 external participants attended the symposium (84 face-to-face, 73 online).

FY2023 Progress Reports, Division of Colloid and Interface Science

Date: March 13, 2024

Venue: Building No. 13 (Morito Memorial Hall) in Kagurazaka Campus + online delivery via Zoom

Summary: Approximately half of the division members (11 people, including presentations by the staff) reported on this fiscal year's achievements. Also, invited lecture by Associate Professor Kenichi Ozawa (Institute of Materials Structure Science, High Energy Accelerator Research Organization), keynote lecture by Professor Hiroshi Nishihara (Research Institute of Science and Technology (RIST)), invited lecture by Professor Cathy McNamee (Graduate School of Engineering, Kyoto University, in English), keynote lecture by Specially Appointed Professor Kazunari Akiyoshi (Graduate School of Medicine, Kyoto University) were given, and very lively discussions took place. Professor Nishihara also introduced RIST to the participants. The 89 internal and 4 external participants attended the symposium (31 face-to-face, 62 online).

Division of Colloid and Interface Science Seminar

We held four seminars given by external lecturers, including overseas researchers, who introduced the latest topics in their related fields. Some of the seminars were also delivered online in order to allow many people to participate.

Others

At the first division meeting (May 20, 2023), in addition to the confirmation of the activity policy and plans, the four newly added members introduced their research. We shared the information for future activities such as joint research among members.

We co-sponsored the courses relating cosmetics in the Open College of Tokyo University of Science and some division members gave lectures (Professor Hideki Sakai, Visiting Professor Kazutami Sakamoto, and Visiting Professor Toshiyuki Suzuki).

International activities

In addition to English presentations at each of the above events, the following activities were carried out as international initiatives.

1) Based on the MOU with the University of Lille in France, our graduate students visited the University of Lille and held bilateral exchanges (Professor Hideki Sakai).

2) We proposed a symposium at the 2025 International Chemical Congress of Pacific Basin Societies (Pacifichem2025), scheduled to be held in 2025, and it was adopted (title: Frontier of Colloid and Interface Chemistry).

3) We planned to publish an English book regarding "dynamics at interfaces". We prepared a proposal that included an outline of the book and a list of authors, and submitted the proposal to the publisher (Springer).

4. Challenges and Prospects

Research results from the perspective of the main theme of "dynamics at interfaces" are not yet sufficient, but this year we were at the stage of starting research in this direction, so we look forward to the results from next year onwards. Although the number of joint research projects between members is still small, we would like to increase this number in the future by sharing information obtained from the progress reports.

Regarding preparations for obtaining a large budget, we decided not to do so this year because there were many items that needed to be considered for a type of project like NEDO, such as searching for target fields, surveying the current situation, and setting specific research content and numerical targets. In the future, we would like to consider large-scale budgets (including international joint research) that can directly utilize current division activities.

5. Conclusion

The year started with a new structure and activity policy, with an emphasis on sharing that direction. From next year onwards, we will strive to disseminate more concrete results.

Major Research Achievements (FY 2023)

Academic papers

1. The pH Responsiveness of Fluorescein Loaded in Polysaccharide Composite Films, K. Takagi, T. Sagawa, M. Hashizume, Soft Matter, 19(46), 8945–8953, 2023 (Selected as Back Cover of the issue) (Peer-reviewed)

2. Nanochannel Water in Molecular Porous Crystals for Methane Storage, H. Matsui, K. Atsumi, M. Tadokoro, J. Phys. Chem. C, 128, 4748-4756, 2024 (Peer-reviewed)

3. Low-adhesion and low-swelling hydrogel based on alginate and carbonated water to prevent temporary dilation of wound sites, R. Teshima, S. Osawa, M. Yoshikawa, Y. Kawano, H. Otsuka, T. Hanawa, Int. J. Biol. Macromolec., 254, 127928, 2024 (Peer-reviewed)

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9. Light-induced reversible destabilization of responsive latex particles prepared via high solids content emulsion polymerization, T. R. Guimarães, R. Othman, R. McKenzie, Y. Takahashi, Y. Kondo*, Per B. Zetterlund*, Colloid Polym. Sci., 301, 979-988, 2023 (Peer-reviewed)

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15. Anion− π Interactions in Monolayers Formed by Amphiphilic Electron-Deficient Aromatic Compounds at Air/Water Interfaces, M. Akamatsu, K. Yamanaga, K. Tanaka, Y. Kanehara, M. Sumita, K. Sakai, H. Sakai, Langmuir, 39, 5833-5839, 2023 (Peer-reviewed)

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22. Droplet duos on water display pairing, autonomous motion, and periodic eruption, Y. Sumino, R. Yamashita, K. Miyaji, H. Ishikawa, M. Otani, D. Yamamoto, E. Okita, Y. Okamoto, M. P. Krafft, K. Yoshikawa, A. Shioi, Sci. Rep. 13, 12377-1-10, 2023 (Peer-reviewed)

Books

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2. CSJ カレントビュー46　持続可能な社会を支えるゴム・エラストマー　－新素材・自己修復・強靭化と最先端評価技術－, 古海誓一, 化学同人, pp 154-160, 2023 (in Japanese)
3. 切って OK? 貼り直して OK? いざ特訓！貼付剤道場, 花輪剛久 企画, じほう, 調剤と情報 29(11), 2023 (in Japanese)

Invited Lectures

1. Creation of Active Water-splitting Photocatalysts by Controlling Cocatalysts Using Atomically Precise Metal Nanoclusters, Y. Negishi, International Congress on Pure & Applied Chemistry (ICPAC) Bali 2023, Bali, 2023
2. Novel "Photo-Switchable" Molecular Assemblies, H. Sakai, H., FORMULA XI, Lille, France, July 6, 2023 (Plenary Lecture).
3. Thermo-sensitive particles as biomaterials, A. Kikuchi, S. Komatsu, T. Asoh, 5th International Bio/Medical Interface Symposium, Taipei, Taiwan, 2024. 3
4. Conductive Nanodiamond Powder for Capacitor Applications, T. Kondo, 7th International Conference on Advanced Capacitors (ICAC 2023), Kamakura, 2023
5. Self-propulsion of floating objects driven by the Marangoni flow induced by the presence of multiple species, Y. Sumino, SPP 2171 Workshop "Wetting of Flexible, Adaptive, and Switchable Substrates" Berlin, 2023

Patents

1. 大塚英典, 大澤重仁, 山村明未, ハイドロゲル、及びハイドロゲルを形成するための組成物, PCT/JP2024/000752 (in Japanese)
2. 酒井秀樹, 坂本一民, 五十嵐優作, 深澤龍太郎, 酒井健一, 膜透過促進剤, 膜透過促進方法, 及び細胞内送達方法, 公開番号 WO2023-027006 (in Japanese)

Public Relations

1. 大塚英典, 日本経済新聞 2023.12.29, 海藻成分と炭酸水から傷治療用ゲル (in Japanese)
2. 根岸雄一, 日刊工業新聞, 2023.4.13, 銀ナノクラスター安定化 新物質探索の指針に (in Japanese)
3. 古海誓一, 日刊工業新聞, 2023.10.13, 再生可能なセンサーシート 加熱成形で復元 (in Japanese)

Awards

1. 田所 誠, 第5回物質・デバイス共同研究賞（基盤共同研究）, 2023 (in Japanese)
2. 根岸雄一, 第34回向井賞, 東京応化科学技術振興財団, 2023 (in Japanese)
3. 佐々木信也, 技術賞, 日本トライボロジー学会, 2023 (in Japanese)
4. 渡辺 啓, 井上東彦, 酒井秀樹, 油脂技術優秀論文賞, 油脂工業会館, 2023 (in Japanese)

Individual Research Topics

Mineo Hashizume

"pH-Responsiveness of molecules loaded in polysaccharide polyion complexes "

We have been conducting functional evaluations of free-standing films made of polyion complexes of oppositely charged polysaccharides. In this fiscal year, the dynamics of molecules loaded in the film were evaluated using the photodimerization reaction of coumarin. It was found that photodimerization of coumarin that covalently grafted to the polysaccharides in the films proceeded faster when the films were in the swollen state than when the films were in the dried state. These results indicated that the swollen state of the film could control the diffusivity and thus the reactivity of the loaded molecules.

Makoto Tadokoro

"Development of high-temperature proton conductors based on hydrogen-bonded metal complexes"

Nafion membranes are used as the solid electrolyte that conducts protons in fuel cells. However, since water molecules are used as the proton transfer medium, proton conductivity decreases significantly at temperatures higher than 100°C. In the research, we aim to create a high-temperature proton conductor using a new hydrogen-bonded metal complex as a proton conductive medium.

Hidenori Otsuka

"Structural design of novel self-healing interpenetrating polymer network (IPN) gels with hydrazone bond-derived cross-links"

By employing chemical cross-linking formed by hydrazone-dynamic bonding and physical cross-linking formed by peptides, we designed an IPN gel with self-healing properties. At the moment of strong strain (strain=60%), the gel showed a sol state with storage modulus G' < loss modulus G'' and recovered the gel state at weak strain (strain=5%). In repeated measurements, G' in the gel state repeated complete recovery, confirming that the mesh density in the gel state does not change, i.e., it has self-healing properties.

Yuichi Negishi

"Creation of novel alloy nanoclusters and evaluation of their catalytic activity"

Metal nanoclusters with a particle size of around 1 nm are being actively investigated as a new nanomaterial, as they exhibit an electronic/geometrical structure different from that of bulk metals. Furthermore, it is expected that the stability and hydrogen evolution activity of such nanoclusters can be improved by replacing some of the metal atoms in the nanoclusters with different metal atoms and by protecting the surface with bidentate ligands. Therefore, this study aims to create metal nanoclusters with a novel stable structure and high hydrogen evolution activity.

Seiichi Furumi

"Reusable and stretchable colloidal crystal elastomer films of colloidal particles"

We successfully fabricated reusable and stretchable elastomer films by hot-pressing colloidal particles surface-modified with block copolymers consisting of amorphous poly(n-octyl acrylate) and crystalline poly(n-octadecyl acrylate) by surface-initiated atom transfer radical polymerization. The reflection color changed reversibly upon stretching and release. Such elastomer films can be used as the flexible materials and sensors in diverse industries.

Satoru Goto

"Dispersion of drugs and their intermolecular interaction in solution"

As drugs is hydrophobic, their solubility dominances the activity and delivery to the target. Enhancement and regulation of the aqueous solubility is widely attempted with cyclodextrin inclusion complexes, quasistable crystals, and amorphous phases. Dissolution of drug required hydrophobic hydration like carbon oxides and methane hydrates, differing from dissolution of inorganic salts. Investigation of the intermolecular interaction between drugs and additives would provide rational strategy and proposals for the aims.

Takehisa Hanawa

"Research on the effect of surfactant addition in mixture milling"

Two-component milling mixtures of pharmaceuticals and water-soluble polymers improve the solubility of poorly water-soluble drugs. However, three-component milling is performed by adding a surfactant to the mixture to improve dispersion stability. Our research focuses on the contribution of the type and concentration of surfactants to the nano-particulate and solubility of pharmaceuticals in the milling process.

Takeshi Kawai

"Mechanochromic emulsion with spontaneous reversion"

We demonstrated a new type of mechanochromic material, an emulsion that imparts dynamic and variable color. It is composed of a surfactant and a co-surfactant; therefore, it can be installed in containers of any shape. The dynamic color change is derived from the lamellar to cubic phase transition of the emulsion. The relaxation time for return to the original color, i.e., the lamellar phase, can be regulated from a few minutes to an hour by changing the temperature, the concentration and chain length of surfactant, and water content. Furthermore, the original and stressed colors could be tuned by varying the surfactant concentration.

Yukishige Kondo

"Synthesis of cyclodextrin derivatives for the development of aqueous scintillators"

2,5-Diphenyloxazole (PPO) is an organic compound that converts synchrotron radiation into fluorescence. In this study, we attempted to improve the aqueous solubility of cyclodextrin (CD) as a solubilizer for dissolving PPO in water. As a result, a new CD derivative was synthesized by modifying β-CD with PEG chains. This compound was found to have higher water solubility than unmodified β-CD, making it a promising candidate for the development of aqueous scintillators.

Hitoshi Ishikawa

"Study of flow control by viscosity change"

The viscosity of CTAB/C4AzoNa solution is increased by irradiation of UV light and decreased by visible light. The solution in small gap of rotating coaxial cylinders was irradiated locally by UV light to measure its torque and flow structure. The circumferential velocity in high viscosity region by local irradiation of UV light is larger than that in low viscosity region.

Shinya SASAKI

"In-situ observation of additive-derived reaction film formation process at friction interface"

In lubricated environments, the reaction film derived from additives formed on friction surfaces governs the macroscopic friction and wear characteristics. We are advancing research on elucidating the reaction mechanisms of additive molecules at the friction interface and exploring methods for controlling them, as well as optimal approaches for additives, by clarifying the formation process of the reaction film through in-situ observation using AFM.

Kaname Kanai

"Elucidation of mechanism of photocatalytic activity of poly(heptazine imide)"

Poly(heptazine imide) (PHI) is a photocatalyst that exhibits a unique function called "dark photocatalytic activity", a phenomenon in which water can be decomposed to produce hydrogen even in dark conditions. Since PHI also exhibits excellent photocatalytic activity in the irradiated state, stable hydrogen collection can be realized by combining it with dark photocatalytic activity. In this project, we will elucidate the mechanism of the dark photocatalytic activity of PHI by directly observing the electronic structure change of PHI induced by light irradiation.

Shinya Yoshioka

"Structural and optical properties of the spherical colloidal cluster"

Colloidal particles with a diameter of around 100 nm that aggregate into spherical structures are called photonic balls, and they are expected to be applied as structurally colored pigment with low angle-dependent iridescence. In this research, we clarified various types of aggregation structures, including face-centered cubic, dodecahedron, icosahedron, and onion structures. Particularly in the face-centered cubic type, we observed the formation of layered domains and conducted detailed studies on their structure and optical properties.

Hideki Sakai

"Bilayer membrane permeation dynamics of lipophilic substances via bile salts"

Lipophilic substances ingested orally are absorbed after being solubilized into micelles formed by bile salts in the small intestine, but the absorption mechanism is poorly understood. We have used giant unilamellar vesicles (GUVs) as a cell model and investigated morphological changes when bile salts are added to them using confocal laser scanning microscopy. In this study, we investigated the morphological changes of GUVs and the permeation behavior of lipophilic substances when a bile salt solution solubilized with lipophilic substances were added.

Akihiko Kikuchi

"Preparation of stimuli-responsive nanoparticles for diagnostic use"

For simple diagnosis of blood glucose levels using dispersibility changes of nanoparticles, we prepared thermoresponsive core-corona type nanoparticles having phenylboronic acid (PBA) at the outermost surfaces with a particle diameter of around 300 nm. The nanoparticles coated films showed structural color. The particle coated surfaces showed color change depending on the glucose concentration. These results suggest the possibility of diagnosis of blood glucose levels using the surface property alteration of the particle surfaces.

Ken'ichi Aoki

"Thermal activation mechanism on photopolymerisation of hydrogen-bonded diacetylene crystals"

Diacetylene crystals with adequate hydrogen bonding sites at both terminals are inactive to photopolymerization when recrystallized from organic solvents, while the heat treatment to the crystals causes the marked improvements of their photopolymerisation activities. The mechanism was investigated in terms of the molecular aggregation behaviors in details.

Yoshiro Imura

"Improving catalytic performance of gold nanoflowers by size-control"

The catalytic properties of gold nanocrystals change depending on their size and shape. Previously, we reported that gold nanoflowers have high catalytic activity for alcohol oxidation reactions compared to spherical gold nanoparticles. In this study, we conducted size-control of gold nanoflowers and exhibited improving catalytic performance by decreasing nanoflower size.

Takeshi Kondo

"Surface-modified conductive diamond-like carbon electrode for sensitive electrochemical sensors"

We investigated surface modification of conductive diamond-like carbon (DLC) electrodes for application to electrochemical monitoring of drug concentrations in blood. Surface of conductive DLC thin film deposited on a silicon wafer substrate was oxidized by UV/ozone treatment to obtain an O-DLC electrode. The O-DLC electrode was found to be useful for highly sensitive and stable electrochemical detection of theophylline. In addition, a linear calibration curve for theophylline detection was also obtained with a conductive DLC electrode formed on a stainless-steel rod substrate.

Kenichi Sakai

"Adsorption and lubrication of glutamic acid-based surfactant with calcium ions"

The adsorption and lubrication of an amino acid-based surfactant were studied in the presence of calcium ions. The anionic surfactant was adsorbed on the hydrophobically modified solid surface. The replacement of the surfactant solution with $CaCl_2$ aqueous solution resulted in the formation of an elastic adsorption film. The adsorption film containing calcium ions lowered the kinetic friction coefficient. The usability of personal care products formulated using amino acid-based surfactants is relevant to such adsorption and lubrication properties.

Yasuo Nakayama

"Design and characterization of well-defined epitaxial molecular semiconductor interfaces"

The functionalities of organic electronic devices such as OLEDs originates from the interfaces where different kinds of organic semiconductor molecules make direct contact with each other, and the structural designs and electronic properties at such interfaces are the key points of the development. In FY2022, our group has proceeded crystallographic and electronic structures of well-defined epitaxial interfaces of organic semiconductor molecules as published in two original papers. We also conducted collaborative researches within this division (Prof. Tadokoro G) and with an outside group (Univ. Tsukuba) for the elucidation of molecular-resolved structures and partial hydrogenation reactions of adsorbed organic semiconductor species at the interface with electrode metal surfaces.

Yutaka Sumino

"Experimental and theoretical studies on active interfaces: pattern and dynamics"

Here, we constructed an experimental system composed of water, hydrocarbon oil, and fluorinated oil. With the air phase, the system comprised four different phases with six different interfaces. By the evaporation of fluorinated oil, the droplet of hydrocarbon and fluorinated oil floating on a water showed merged and concentric ring shape depending on droplet volume. We also found the repetitive transition between these two geometries.

Division of Nucleic Acid Drug Development

Division of Nucleic Acid Drug Development

1. Overview

Developing nucleic acid drugs requires knowledge from a wide range of research fields. Many prominent researchers work on nucleic acid or related research at TUS. Hence, innovative and unique results are highly anticipated through their collaborations. In this division, one of our missions is the development of novel nucleic acid derivatives that overwhelm conventional ones in the viewpoint of efficacy, stability, and safety. Also, we aim to develop novel carrier molecules that bind to nucleic acids to improve their stability and pharmacokinetics in the body and to establish formulation technology. We chose the immune system, metabolic system-related diseases, and cancer as targets. As just described, the development of original nucleic acid drugs targeting unique diseases is highly expected by a gathering of in-house competent researchers in this division.
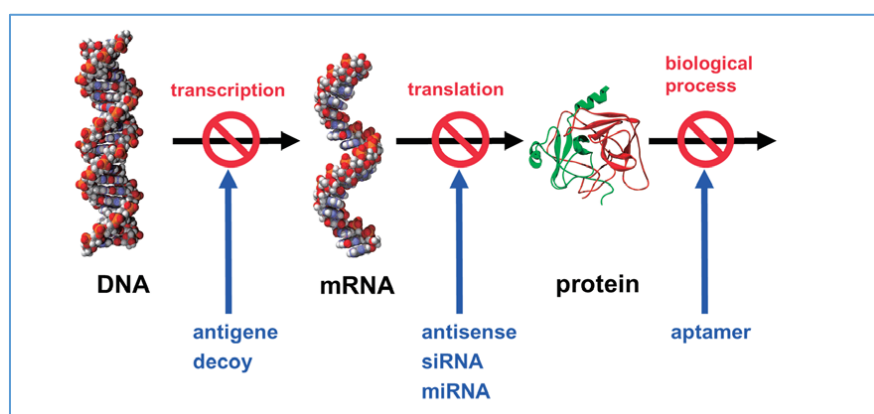
Fig. 1. Oligonucleotides as therapeutic agents.

2. Organization and Facilities

Organization

Faculty of Pharmaceutical Sciences

Takeshi Wada (Organic chemistry)

Makiya Nishikawa (Drug delivery system)

Takehisa Hanawa (Medicinal formulation)

Yoshikazu Higami (Molecular pathology and metabolic diseases)

Kazunori Akimoto (Molecular pathology)

Chikamasa Yamashita (Physical pharmacy)

Yosuke Harada (Immunology)

Kosuke Kusamori (Physical pharmacy)

Faculty of Science

Satoru Miyazaki (Bioinformatics)

Hidetaka Torigoe (Biophysical chemistry)

Hidenori Otsuka (Polymer chemistry)
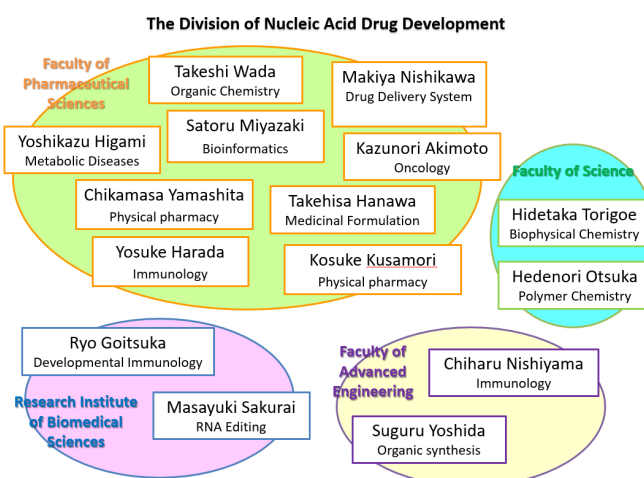
Fig. 2.

Faculty of Advanced Engineering
Chiharu Nishiyama (Immunology, allergy and molecular biology)
Suguru Yoshida (Organic synthesis)
Research Institute of Biomedical Sciences
Ryo Goitsuka (Developmental immunology)
Masayuki Sakurai (RNA editing)

Principal research equipment in the Division of Nucleic Acid Drug Development

Nuclear magnetic resonance (NMR) spectrometer
1. Model   JNM-ECZ400S （JEOL Ltd.）
2. Installation site   Building No.15, Noda Campus
3. Feature

This equipment is a nuclear magnetic resonance spectrometer that can collect ^{1}H, ^{13}C, ^{11}B, ^{19}F, ^{31}P, and other nuclei NMR spectra at a frequency of 400 MHz. Furthermore, 2D NMR experiments such as COSY, HMQC, HMBC, and NOESY are available to characterize synthesized samples and natural compounds.

Mass spectrometer
1. Model   SCIEX X500R QTOF（SCIEX）
2. Installation site   Building No.15, Noda Campus
3. Feature

The equipment measures m/z values of chemical compounds ionized by the electrospray ionization (ESI) method. High-resolution mass analysis and MS/MS analysis are also available.

3. Activity Reports

Joint Symposium of Medical Data Science and Division of Nucleic Acid Drug Development
-Synergy of data science and oligonucleotide therapeutics-
Date: 9/30/2023
Venue: Katsushika Campus, Tokyo University of Science
Summary: Division of Nucleic Acid Drug Development and the newly established Medical Data Science (department head: Prof. Kazunori Akimoto) held a joint symposium. The purpose of the symposium was to deepen mutual understanding among members of the two divisions through the presentation and discussion of their research. Since it was the first in-person symposium held in the post-COVID-19 era, active discussions were conducted.
Invited lecturers: Prof. Akimitsu Okamoto (Research Center for Advanced Science and Technology The
          niversity of Tokyo)
          Prof. Hiroaki Taniguchi (Keio University School of Medicine)

7th Symposium of Division of Nucleic Acid Drug Development
Date: 2/25/2022
Venue: Fujimi Building, Kagurazaka Campus, Tokyo University of Science
Summary: The division members made presentations on their research to strengthen mutual understanding and enhance the opportunity for collaborative research.

Invited lecturers: Prof. Nobuyoshi Akimitsu (Isotope Science Center, The University of Tokyo)

Prof. Fumi Nagatsugi (Institute of Multidisciplinary Research for Advanced Materials, Tohoku University)

4. Challenges and Prospects

While advancing ongoing collaborative research on specific targets such as cutaneous wounds, pancreatic cancer, breast cancer, and COVID-19 using oligonucleotide therapeutics, the new application for controlling immunity and lipid metabolism systems will be investigated in detail.

In addition, the development of a method for the stereoselective synthesis of boranophosphate oligonucleotides, which are promising alternatives for phosphorothioate as antisense oligonucleotides, is in progress, and the examination of their safety and efficacy will be explored.

Moreover, platform technology for highly functionalized oligonucleotides and novel DDS will be established using DNA nanotechnology.

This division will end in March 2023, and will be developmentally reorganized into the Nucleic Acid Drug Discovery Center in April 2024 to further advance research.

5. Conclusions

The division combines the knowledge of in-house researchers engaging in oligonucleotide therapeutics and related research. After this division is reorganized into the Nucleic Acid Drug Discovery Center, the collaborative research will be actively advanced for the development of oligonucleotide therapeutics made at Tokyo University of Science.

Research Achievements (FY 2023)

Academic Papers

1. Internucleotidic bond formation using H-phosphonamidate derivatives and acidic activators, Tsurusaki, T., Sato, K., Wada, T., RSC Adv. Vol. 13, pp 31674–31686, 2023 (Peer-reviewed)

2. Solid-phase synthesis of oligodeoxynucleotides using nucleobase *N*-unprotected oxazaphospholidine derivatives bearing a long alkyl chain, Kakuta, K., Kasahara, R., Sato, K., Wada, T., Org. Biomol. Chem., Vol. 21, pp 7580–7592, 2023 (Peer-reviewed)

3. Obesity-induced PARIS (ZNF746) accumulation in adipose progenitor cells leads to attenuated mitochondrial biogenesis and impaired adipogénesis, Kazuki Hachiya, Yusuke Deguchi, Takuro Hirata, Tomoya Arikawa, Hiroto Fukai, Tatsuhiro Esashi, Kota Nagasawa, Yuhei Mizunoe, Yuka Nozaki, Masaki Kobayashi, Yoshikazu Higami, Sci. Rep., Vol. 13, pp 22990, 2023 (Peer-reviewed)

4. Effect of mitochondrial quantity and quality controls in white adipose tissue on healthy lifespan: Essential roles of GH/IGF-1-independent pathways in caloric restriction-mediated metabolic remodeling, Yuina Otani, Yuka Nozaki, Yuhei Mizunoe, Masaki Kobayashi, Yoshikazu Higami, Pathology international, Vol. 73, pp 479-489, 2023 (Peer-reviewed)

5. High expression of PKCλ and ALDH1A3 indicates a poor prognosis, and PKCλ is required for the asymmetric cell division of ALDH1A3-positive cancer stem cells in PDAC, Kasai T, Tamori S, Takasaki Y, Matsuoka I, Ozaki A, Matsuda C, Harada Y, Sasaki K, Ohno S, Akimoto K, Biochem. Biophys. Res. Commun., Vol. 669, pp 85-94, 2023 (Peer-reviewed)

6. Development of rice bran-derived nanoparticles with excellent anti-cancer activity and their application for peritoneal dissemination, Daisuke Sasaki, Hinako Suzuki, Kosuke Kusamori, Shoko Itakura, Hiroaki Todo, Makiya Nishikawa, Journal of Nanobiotechnology, Vol. 22, pp 114, 2024 (Peer-reviewed)

7. Low-adhesion and low-swelling hydrogel based on alginate and carbonated water to prevent temporary dilation of wound sites, Ryota Teshima, Shigehito Osawa, Miki Yoshikawa, Yayoi Kawano, Hidenori Otsuka, Takehisa Hanawa, International Journal of Biological Macromolecules, Vol. 254, pp 127928, 2023 (Peer-reviewed)

8. GLP-1 derivatives with functional sequences transit and migrate through trigeminal neurons, Tomomi Akita, Mizuki Shimamura, Ayano Tezuka, Marina Takagi, Chikamasa Yamashita, European Journal of Pharmaceutics and Biopharmaceutics, Vol. 195, pp 114176, 2024 (Peer-reviewed)

9. Butyrate, valerate, and niacin ameliorate anaphylaxis by suppressing IgE-dependent mast cell activation: Roles of GPR109A, PGE$_2$, and epigenetic regulation, Kazuki Nagata, Daisuke Ando, Tsubasa Ashikari, Kandai Ito, Ryosuke Miura, Izumi Fujigaki, Yuki Goto, Miki Ando, Naoto Ito, Hibiki Kawazoe, Yuki Iizuka, Mariko Inoue, Takuya Yashiro, Masakazu Hachisu, Kazumi Kasakura, and Chiharu Nishiyama, J. Immunol., Vol. 212, pp 771-784, 2024 (Peer-reviewed)

10. Foxp3 and Bcl6 deficiency synergistically induces spontaneous development of atopic dermatitis-like skin disease, Tai Y, Sakaida Y, Kawasaki R, Kanemaru K, Akimoto K, Brombacher F, Ogawa S, Nakamura Y, Harada Y., Int. Immunol. Vol. 35, pp 423-435, 2023 (Peer-reviewed)

Books

1. 核酸医薬総論と革新的次世代核酸医薬, 和田　猛, BIOSCINECE & INDUSTRY, vol.81 No.5, 一般財団法人バイオインダストリー協会, pp 442-446, 2023 (in Japanese)

2. リン原子の立体化学を厳密に制御した核酸医薬の開発　有効性と安全性を両立する次世代核酸医薬, 和田猛, 化学と工業, 76, 日本化学会, pp 802-804, 2023 (in Japanese)

3. 経鼻投与された神経ペプチド誘導体は三叉神経軸索を介した中枢へ移行する, 秋田智后, 山下親正, Drug Delivery System, 38, pp 259, 2023 (in Japanese)

4. Nanobiomaterials 2nd edition, <u>Hidenori Otsuka</u>, Ami Yamamura, Elsevier, pp 1–20, 2023

5. Interdisciplinary Cancer Research, <u>Hidenori Otsuka</u>, Springer Nature, pp 1–23, 2023

6. Hydrogels for Wound Healing Applications, <u>Hidenori Otsuka</u>, Elsevier, pp 1–25, 2023

Invited Lectures

1. Development of new molecular technologies for siRNA therapeutics, <u>Takeshi Wada</u>, The 3rd International Symposium on Functional Nucleic Acids: From Laboratory to Targeted Molecular Therapy (FNA Perth), Perth, Australia, 2023

2. Solid-Phase Synthesis of Glycosyl Phosphate Repeating Units Using Glycosyl Phosphoramidite Derivatives, <u>Sato, K.</u>, <u>Wada, T.,</u> International Congress on Pure & Applied Chemistry (ICPAC), Bali, 2023

3. PGC-1α and MIPEP, Key regulators of mitochondria function in white adipose tissue, <u>Yuka Nozaki</u>, <u>Yuhei Mizunoe</u>, <u>Masaki Kobayashi</u>, <u>Yoshikazu Higami</u>, The 40th Spring Conference of the Korean Society for Gerontology & Korea-Japan Joint Symposium, 2023

4. Structural Optimization of Oligonucleotide Therapeutics for Targeted or Sustained Delivery, <u>Makiya Nishikawa</u>, Asian Federation for Pharmaceutical Sciences 2023, Hanoi, Vietnam, 2023

Patent

1. 赫多聖, <u>佐藤一樹</u>, <u>和田 猛</u>, 国内優先出願, ヌクレオチドモノマー及び核酸オリゴマーの製造方法, 特願 2023-105223, 2023

2. <u>山下親正</u>, 神経ペプチド配列及び糖鎖を含む糖鎖修飾神経ペプチド誘導体, 医薬組成物, 経鼻・点鼻製剤及び糖鎖修飾神経ペプチド誘導体の使用, PCT/JP2023/40454, 2023

3. <u>山下親正</u>, 眼治療のための生理活性ペプチド誘導体, 医薬組成物, 経鼻・点鼻製剤及び生理活性ペプチド誘導体の使用, PCT/JP2023/40455, 2023

4. <u>西山千春</u>, 後藤有貴, 長田和樹, 平本忠浩, 大田黒晴樹, 国内優先出願, 炎症性サイトカイン調整剤, 特願 2024-032037, 2024

5. <u>櫻井雅之</u>, 楊雨溪, 中山宏紀, 岡田俊平, <u>和田 猛</u>, <u>佐藤一樹</u>, イノシン塩基の標識方法, イノシン塩基の検出方法, 核酸の配列決定方法, イノシン塩基を含む核酸の濃縮方法, イノシン塩基標識剤, 及びキット, 特願 2023-175606, 2023

6. <u>大塚英典</u>, 大澤重仁, 山村明未, ハイドロゲル, 及びハイドロゲルを形成するための組成物, 特願 2023-070135, 2023

Public Relations

1. <u>秋田智后</u>, 長井記念薬学研究奨励支援事業から得られた自信と経験, ファルマシア Vol.60, No.2, 2024

2. <u>西山千春</u>ら, 食物繊維でアレルギー抑制, 日刊工業新聞, 2024

3. 手島涼太, 大澤重仁, 河野弥生, 花輪剛久, 菊池明彦, <u>大塚英典</u>, 果実の皮成分と炭酸水で高機能なハイドロゲルを創製〜環境負荷を低減しつつ, 医療分野に応用可能な材料〜, プレスリリース, 2023

Awards

1. <u>佐藤一樹</u>, 東京糖鎖研究会（GlycoTokyo）奨励賞, 東京糖鎖研究会（GlycoTokyo）, 2023

2. <u>草森浩輔</u>, ポスター奨励賞, 第 3 回細胞シート工学イノベーションフォーラム, 2023

3. <u>秋田智后</u>, 日本薬学会関東支部　2023 年度関東支部奨励賞受賞, 2023

4. Ryota Teshima, Shigehito Osawa, Yayoi Kawano, Takehisa Hanawa, Akihiko Kikuchi, <u>Hidenori Otsuka</u>, ACS Omega, Supplementary Cover, American Chemical Society, 2023

Individual Research Topics

Takeshi Wada
"Efficient synthesis of Phosphorodiamidate Morpholino Oligonucleotides"

Phosphorodiamidate Morpholino Oligonucleotides (PMOs) are valuable antisense oligonucleotides and have been approved as Duchenne muscular dystrophy drugs. However, a conventional synthetic method for PMOs suffers from a low eficiency due to a poor reactivity of monomer units. Under these circumstances, a novel method for the synthesis of PMOs using an *H*-phosphonate derivative was developed. By using phosphonium type condensation reagent, which was developed in our laboratory, the internucleotidic bond formation reaction proceeded in a shorter time and this method enabled block condensation reactions, namely reaction of oligomers, to give PMOs up to 8mer. This is the first example for the synthesis of PMOs using block condensation reactions.

"Synthesis of oligonucleotides without nucleobase protections"

The synthesis of oligonucleotides are mainly conducted by the phosphoramidite method and the monomers for the method generally have an amino protecting group on a nucleobase to enhance solubility in organic solvents and prevent the side reaction of a phosphoramidite and a nucleobase. We found that an oxazaphospholidine derivative bearing a branched long alkyl chain exhibited substantial solubility in organic solvents and the condensation reaction of the oxazaphospholidine monomer and the hydroxy group proceeded in a chemoselective manner. Oligomers up to dodecamers were successfully synthesized by using the monomer.

Kazuki Sato
"Synthesis of *P*-modified DNAs using boranophosphate DNA as a precursor"

Boranophophoshate DNAs (PB-DNAs) are attractive antisence oligonucleotide candidates because PB-DNAs exhibit high nuclease resistance and low cytotoxicity. Meanwhile, it was found that a glycosyl boranophosphate afforded various *P*-modified glycosyl phosphate analogs via an acyl phosphite intermediate. Hence, we investigated the synthesis of *P*-modified DNAs from PB-DNAs. The method was applicable for the synthesis of *P*-modified DNAs including doubly modified ones, whose synthesis is difficult by the exsisting synthetic methods.

Yoshikazu Higami, Yuka Nozaki, Yuhei Mizunoe
"Research on caloric restriction, ageing and mitochondria"

Caloric restriction (CR) increased mitochondrial biosynthesis in white adipose tissue in an SREBP-1c-dependent manner, and CR induced metabolic improvement, anti-aging and lifespan extension. At the same time, we found that SREBP-1c promotes the maturation of SIRT3, a deacetylase that enhances the function of many proteins in mitochondria, and that one of the mitochondrial signal peptidases, MIPEP, is involved in promoting this maturation (Fujii et al., *Aging cell*. 2017; Kobayashi et al., *FEBS lett*. 2017). Mitochondria are intracellular organelles with a variety of functions, including energy metabolism, which themselves contain DNA. The quality of mitochondria is thought to be regulated by proteostasis (protein homeostasis), biosynthesis, mitophagy (mitochondrial degradation) and dynamics (fission and fusion). We are currently funding research into these mitochondrial quality control mechanisms.

"Studies in animal models of obesity and autophagy"

Hypertrophic adipocytes increase in the adipose tissue of obese patients. Hypertrophied adipocytes secrete bioactive substances (cytokines) that induce inflammation and attract inflammatory cells. We found that the protein WWP1 is induced in obese adipose tissue in a TP53-dependent manner and acts as a defence against adipocyte dysfunction (Kobayashi et al., *BBRC*. 2019; Hoshino et al., *FEBS Open Bio*. 2020; Nozaki et al., *FEBS Open Bio*. 2023). We are currently analysing the mechanism of WWP1 defence against adipocyte dysfunction. We have also found that in the early pathology of obesity, although autophagy is activated, autophagosomes accumulate due to impaired lysosomal function caused by an imbalance in the cathepsin group, a hydrolytic enzyme found in lysosomes (Mizunoe et al., *Autophagy*. 2017; Mizunoe et al., *Sci Rep*. 2020). We are currently investigating the relationship between mitochondrial function, autophagosome accumulation and mitophagy (mitochondrial selective autophagy). We have also elucidated the mechanism by which trehalose, which is known to induce autophagy, induces antioxidant capacity and that taurine induces autophagy (Mizunoe et al., *Redox Biology*. 2018; Kobayashi et al., FEBS Open Bio. 2021)

Kazunori Akimoto, Shoma Tamori
"Identification of cancer prognostic markers and elucidation of molecular functions in cancer stem cells using cancer genomics databases"

To identify the biomarkers for the early detection and targeted molecules in refractory cancers, we have analyzed cancer genomics databases by data science techniques to isolate prognostic marker candidates and therapeutic target molecules for oligonucleotide therapeutics. In 2023, we isolated p62 as a new candidate molecule. Furthermore, we also proceeded with the function analysis in cancer stem cells of prognostic marker candidates isolated by 2022 and therapeutic target molecule candidates of oligonucleotide therapeutics. In 2024, we will continue to aim to isolate new candidates and advance the functional analysis of molecules that have already been isolated.

Makiya Nishikawa, Kosuke Kusamori, Shoko Itakura
"Elucidation of factors regulating the pharmacokinetics of heteroduplex oligonucleotides"

We attempted to elucidate the factors that determine the pharmacokinetics of cholesterol-modified heteroduplex oligonucleotide (Chol-HDO), which exhibits high knockdown activity in many organs including the brain after intravenous administration to mice. Using mice and cultured hepatocytes, we found that Chol-HDO strongly binds to lipoproteins and serum albumin in the blood and that the protein binding strongly inhibits its uptake by hepatocytes.

Talehisa Hanawa
"Application of water-soluble polymeric nanogels as drug carriers"

The research on hydrogel formulations containing nucleic acid drugs for wound healing will be continued. At the same time, research on the preparation of nanogels composed of water-soluble polymers by nanoparticulate hydrogels will be undertaken for drug delivery to wounds with more complex geometries.

Kaoru Hirose
"Research on the Application of Thermoresponsive Tamarind Seed Gum as a Drug Carrier"

The mechanism of thermoresponsive tamarind seed gum, which can change its properties in response to changes in ambient temperature, will be investigated in detail. The potential application as a drug carrier for nucleic acid drugs will also be examined.

Satoru Miyazaki

"Design of anti-sense DNA sequences for COVID19 genome by use of sequences which do not existe in human genoma genes"

We implemented machine learning methods based on Markov process theory for human miRNA genes. This machine learning suggest that human miRNA sequence data have 3rd or 4th Markov property. We also found that almost all short sequences in COVID19 genome are not fit Markov property of human miRNA's one. However some of them, which have low occurrence in human genome, still have same Markov property of human miRNA genes. Therefore, those sequences are quite better candidate of for COVID19. These methods are available for any other virus genome.

Yoshio Nakano

"Development of therapeutic drugs for SARS-CoV-2 using infrequent sequences in human genes"

This study attempts to search for effective nucleic acid therapeutics against SARS-CoV-2. In this filed, studies have been focused on the sequence specificity of RNA, however, few studies have been conducted with off-target effects from the design stage. Therefore, to develop targets for nucleic acid therapeutics, bioinformatics is used to investigate sequences present in the SARS-CoV-2 genome and less abundant in human pre-mRNAs, ncRNAs, and mRNAs.

Chikamasa Yamashita, Tomomi Akita

"Development of dry powder inhalation of active vitamin D3-encapsulated functional nanoparticles aiming at radical treatment of COPD by alveolar regeneration"

In our previous study, active vitamin D3 (VD3) encapsulated in functional lipid (SS-OP) nanoparticles succeeded to deliver VD3 efficiently to the site of action and reduce the side effects in a mouse model of COPD. Therefore, we aimed to develop lyophilizates for dry powder inhalation of VD3-encapsulated in SS-OP nanoparticles for the clinical application as a radical treatment for COPD. As a result, we could develop lyophilizates for dry powder inhalation with Design of Experiments and a genetic algorithm to determine the optimal excipient dose.

Hidenori Otsuka

"Preparation of nanogel with target-directed properties using glycopolymers and their application in immunotherapy"

In order for cytotoxic T lymphocytes (CTLs) to be induced, antigen-presenting cells (APCs) such as dendritic cells must take up antigenic proteins, degrade them intracellularly, and present the generated peptide fragments on MHC class I molecules. In this study, we prepared core-shell Mannose-modified nanogels with a rich aqueous environment as protein carriers that can be stably active targeted in vivo, and confirmed their selective uptake by Mannose receptor-bearing dendritic cells.

Hidetaka Torigoe

"Development of quadruplex nucleic acid-based methods to artificially repress target gene expression"

G-rich sequences of nucleic acids can form quadruplexes. The quadruplexes are formed through the stacking of the G-quartets, where four guanines are aligned with each other in a square planar configuration. G-rich sequences in some regions of the SARS-CoV2 virus RNA genome and in the promoter region of HIV-1 DNA genome may form quadruplexes, although their stability is low. When quadruplex-stabilizing ligand was added to these unstable quadruplexes, proteins to be involved in gene expression may not be able to access the stabilized quadruplexes due to their steric hindrance, and then the expression of the downstream gene was decreased in a ligand-concentration dependent manner.

Chiharu Nishiyama, Kazuki Nagata

"Anti-allergic effects of short-chain fatty acids"

We found the involvement of GPR109A, PGE2, EP3, and histone deacetylase inhibitory activity in the molecular mechanism by which short-chain fatty acids suppressed IgE-dependent mast cell activation, and demonstrated that administration of short-chain fatty acids or nicotinic acid, which exert GPR109A ligand activity, alleviate pathogenesis of anaphylaxis in mice (*J. Immunol.* 2024).

"Anti-inflammatory effects of gKetoC, a gut bacteria-generated polysaturated fatty acid metabolite"

We identified gKetoC as the most effective anti-inflammatory compound among the intesitinal bacteria metabolites of polysaturated fatty acids. We found that GPCRs and the antioxidant stress response master transcription factor NRF2 were involved in the suppressive effects of gKetoC on inflamatory response of dendritic cells. In addition, we demonstrated that oral administration of gKetoC improved the pathogenesis of DSS-induced colitis, but no effects of gKetoC was observed in NRF2 deficient mice (*Front. Immunol.* in press).

Yohsuke Harada

"Mechanisms of intestinal epithelial barrier disruption caused by Treg abnormalities"

It is well known that dysregulation of regulatory T cells (Treg) causes intestinal inflammation. Inflammation of the intestinal tract is thought to cause disruption of the intestinal epithelial barrier, leading to further exacerbation of inflammation. We found that the intestinal epithelial barrier disruption caused by Treg dysfunction is ameliorated by IL-4Rα deficiency. These results suggest that IL-4Rα may be an effective therapeutic target for inflammatory bowel disease.

Suguru Yoshida

"Click chemistry for the chemical modification of biofunctional molecules"

We have developed efficient methods for the chemical modification of biofunctional molecules such as nucleic acids to add multifunctionalities. Indeed, we have synthesized new platform molecules having clickable functional groups, which served in the sequential conjugations by triple click reactions. Further studies for applications including the dual modifications of biomolecules such as nucleic acids are ongoing in our laboratory.

Ryo Goitsuka

"Developmental timing of natural antibody-producing cells in the bone marrow and gut"

IgM and IgA as natural antibodies are mainly produced by plasma cells localized in the bone marrow and intestine, respectively. In this study, we constructed a mouse system that can label and track B cells that develop and differentiate during fetal, neonatal, and adult life, and found that about 80% of IgM plasma cells in adult bone marrow and about 20% of IgA plasma cells in adult intestine originated from fetal and neonatal life.

Masayuki Sakurai

"Unexplored regions of adenosine deamination editing: identification of genomic DNA inosinylation sites"

The genetic code is comprised of four bases, A, G, C, and T(U). However, cells contain an adenosine deaminase ADAR that leads the editing mechanism of adenosine to inosine, which is synonymous with the sequence change from A to G. We recently discovered that ADAR not only acts on RNA but also on DNA. In this study, we have developed an unique inosine identification method, which enables us to label and isolate trace amounts of inosine and to identify inosine sites on DNA comprehensively.

"Regulation of Nucleic Acid-Protein Interactions controlled by A-to-I Editing"

Focusing on the dynamics of dsRNA and DNA:RNA hybrid strands in cells, the project aims to establish the concept of the Nova Epinucleome, a gene network connected by nucleic acid base modifications, as a system to optimize gene expression by altering nucleic acid structure, sequence function, and binding factors through A-to-I editing by ADAR. In particular, we are focusing on DNA damage repair mechanisms and RNA-dependent transcriptional regulation mechanisms that lead to cell carcinoma.

"Techniques for introducing artificial A-to-I DNA editing at arbitrary target genomic sites"

This research aims to unravel the molecular mechanisms of A-to-I RNA and DNA editing and to develop a new technology for editing genomic DNA sequences by harnessing these mechanisms. Moreover, we aim to develop A-to-I editing guide nucleic acids that will be effective for genetic engineering, cancer mutation, single gene mutation disease, and antiviral technology.

Division of Synthetic Biology

Division of Synthetic Biology

1. Overview

The Division of Synthetic Biology, which consists of researchers in the biological field of the Faculty of Science, the Faculty of Engineering Science, the Faculty of Science and Engineering, and the Research Institute for Biomedical Sciences at the Tokyo University of Science, is a cross-disciplinary unit. We promote the research to achieve the clear goal of creating "Hybrid cells" among organism species. This division will make the most of the strengths of our university, where outstanding researchers in the fields of biology and medical science are enrolled. By sharing state-of-the-art biological technology, synergistic effects can be expected to create breakthrough research.

Synthetic biology elucidates the working principle of life through artificial cell production and DNA synthesis. Pet animals such as dogs and cats, horticultural crops such as orchids sold at flower shops, livestock such as mules and chickens, and agricultural crops such as wheat and fruits are hybrids created by crossing among related species. Since ancient times, human beings have created and utilized hybrid organisms without being conscious of genome crossbreeding and genome transplantation. Current technological innovations have enabled genome crossing and genome transplantation of species other than closely related species. In order to create frontier areas from this new biotechnology, we will promote research by making use of the strengths of our university, where excellent life scientists gather.

2. Organization and Facilities

Analysis of hybrid cells by synthetic biology requires not only experimental biological approaches but also informatics approaches using computers and artificial intelligence. By analyzing the three-dimensional distribution of heterologous genomes in hybrid cells, network analysis of gene expression, changes in epigenetic states, etc., we will analyze the coexistence, competition, and collaboration of heterogeneous genomes. By integrating and analyzing the huge amount of bioinformatics data obtained by deep sequencing, we will clarify the molecular and cellular events in newly synthesized cells.

The research division is mainly composed of three groups: the plant genome transplantation group, the genome transplantation group among related species, and the cell creation group that leads to drug discovery and medical treatment.

3. Activity reports

Synthetic biology always needs to be aware of the ethical, legal and social issues (ELSI). We conduct research with ELSI while always being conscious of "what do we want to know and for what purpose?" We are working on the following three research themes for establishing genome transplantation technology with sufficient safety measures, which will lead to the production of useful substances and medical application in the future. The achievements of each group in this fiscal year are described below.

3. 1. Plant Genome Transplantation Group
Tatsuya Tomo (Liberal Arts), Hisataka Ohta (Liberal Arts), Takuya Sakamoto (Kanagawa Univ.), Sachihiro Matsunaga (Univ. Tokyo), Shigeo Sugano (AIST), Yusuke Kazama (Fukui Pref. Univ.), Keizo Nishida (Kobe Univ.)

In the Tomo Laboratory, research is being conducted on chlorophyll (Chl) and molecular hydrogen, both of which play critical roles in the energy conversion processes of photosynthesis. This fiscal year, the laboratory reported on the characteristics of a new hydrogen-producing cyanobacteria. Additionally, the successful isolation of a photosystem complex that incorporates new chlorophyll has been achieved. This achievement indicates the potential for synthetic biological integration of new chlorophylls into reactions.

In order to reproduce the secondary symbiosis phenomenon using synthetic biology, Sakamoto and Matsunaga laboratories conducted a cell fusion study of algae and cultured animal cells to transfer the genome and were able to construct cultured animal cells that retain the transferred algal genome. From the constructed cell lines, these laboratories selected cell lines that retained more than 95% of the algal genome and performed DNA methylation analysis, which revealed that DNA methylation was accumulated in horizontally transferred algal genome.

The Kazama Laboratory has conducted detailed studies on the inheritance of deletions induced by heavy ion beam irradiation. As a result, it was found that the larger the linear energy transfer (LET) of the heavy ion beam, the larger the deletion size becomes, but the maximum value of the deletion size was determined by the distribution of essential genes on the genome.

Base editing technology using DNA base exchange reactions has been developed by the Nishida Laboratory, enabling the direct introduction of point mutations. In FY2023, the performance of Target-G technology, a new editing technique that creates diversity in specific genomic regions, has been improved and can be applied to plants.

3. 2. Genome Transplantation Group Among Related Species

Takashi Kamakura (BS), Takayuki Arazoe (BS), Kiminori Shimizu (AB), Jiro Toshima (AB)

Drs. Kamakura and Arazoe discovered novel genome maintenance and hybridization mechanisms by analyzing fungal hybrid cells generated though cell fusion. Subsequently, they utilized these mechanisms toward new genome transfer, genome rearrangement, and genome editing. Based on the findings of their study, they have filed a patent application. Additionally, they applied them to the genome editing tool, while analyzing the underlying cell fusion mechanism.

Shimizu Laboratory has analyzed the chemical structure of a secondary metabolite produced by an entomopathogenic fungus, which was considered to be associated with a gene cluster present in the genome. They also functionally analyzed a transcription factor gene within the gene cluster.

Human chemokine receptors are G protein-coupled receptors (GPCRs) that are involved in cancer cell migration, invasion, and metastasis. The Toshima Laboratory generated human-yeast hybrid cells in which the receptor for human chemokine, CCL2 was expressed in budding yeast, and succeeded in improving a screening system for inhibitors of the activation signals of CCL2 stimulation. They also succeeded in preparing fluorescently labeled CCL2 and visualizing the process of CCL2 uptake into the cell.

3. 3. Cell Creation Group that Leads to Drug Discovery and Medical Application

Tomokatsu Ikawa (RIBS), Mahito Sadaie (BS), Toshiki Furuya (BS), Shin Aoki (PS), Yoshikazu Nakamura (BS), So Maezawa (BS), Hiroshi Haeno (RIBS), Kengo Morohashi (Chitose Inst. Sci. Technol.)

The Ikawa laboratory has developed a method to induce the differentiation and the self-renewal of T/NK progenitor cells from hematopoietic stem and progenitor cells in human umbilical cord blood. The T/NK progenitors were capable of generating chimeric antigen receptor (CAR)-NK cells. They also succeeded in identifying the T/NK progenitor-specific marker, which enabled us to easily purify them.

Sadaie Laboratory investigated the mechanism of ATRX expression loss, a characteristic found in telomerase-independent cancer cells, across multiple osteosarcoma-derived cell lines using genome analysis and RNA-seq. The findings revealed that ATRX expression loss can be categorized into several patterns, each associated with genetic and epigenetic changes.

The Furuya Laboratory has worked on the efficient production of vanillin, a fragrance compound, by synthetic biological methods using microorganisms. An enzyme that synthesizes vanillin from ferulic acid was developed by introducing mutations into the active center of the oxygenase.

In Aoki's laboratory, two types of peptide-hybrid compounds that induce programmed cell death in cancer cells. The first is a hybrid of cyclometalated iridium (Ir(III)) complexes with cationic peptide (iridium(III) complex-peptide hybrids, IPHs) and the second is triptycene-peptide hybrids (TPHs). It was found that these hybrid compounds induce paraptotic cell death in cancer cells. We recently discovered that TPHs exhibit potent paraptosis-inducing activity in Jurkat, HeLa S3, and A549 cells and studied the general mechanism involved in paraptosis.

Moreover, they have designed and synthesized boron-containing macrocyclic polyamines for that exhibit high intracellular uptake and efficiency for the use in boron neutron capture therapy (BNCT), which is a potent methods in cancer radiotherapy in collaboration with the Institute for Integrated Radiation and Nuclear Science, Kyoto University.

The Nakamura laboratory has obtained results suggesting that a metabolic enzyme that metabolize phospholipids in the plasma membrane regulate the formation of extracellular vesicles. Additionally, abnormalities resembling human age-related diseases are induced when this enzyme is deficient in mice. Also, they revealed that the levels of specific phospholipids present in the plasma membrane decrease during cellular senescence or mouse aging, implying that these phospholipids exert inhibitory effects on cellular senescence.

The Maezawa Laboratory has developed an experimental framework to regulate active and repressive gene expression simultaneously using the epigenome editing system CRISPRon and CRISPRoff. In addition, we have identified novel transcription factors (TFs), which are indispensable for mouse spermatogenesis, by single-cell ATAC-seq analysis of mouse testis, phenotypic analysis of TFs-deficient mice, and reporter analysis.

In Asians, more than half of non-small cell lung cancers (NSCLC) are induced by epidermal growth factor receptor (EGFR) mutations. To overcome this problem, the Haeno Laboratory constructed a mathematical model based on clinical observations and investigated the optimal schedules for EGFR-TKI therapy. Based on published data on cell growth rates under different drugs, they found that using osimertinib that are efficient for secondary resistant cells as the first-line drug is beneficial in monotherapy, which is consistent with published clinical statistical data. (Yu et al. 2023 Front Oncol)

Flavonoids, which are prevalent in plant-based foods, are thought to be highly beneficial for maintaining good health and preventing disease, as demonstrated by previous epidemiological studies. Despite this, no large studies have been conducted on the molecular targets of flavonoids. To gain a comprehensive understanding of the efficacy of flavonoids, the Morohashi Laboratory constructed a protein-flavonoid network and compared it with drug effects using publicly available data. The findings not only validated previous results at the network level, but also uncovered a new potential benefit of flavonoids.

4. Challenges and Prospects

Research is being vigorously pursued in each research group and individual research topic, but there are many cases where the analysis of newly generated xenogenic genome-transplanted cells and genetically

modified cells for cancer treatment is still in progress. In the future, we would like to further clarify the molecular mechanism for industrial and medical applications.

5. Conclusion

The research division aim to create xenogeneic transplanted cells by cell engineering and contribute to the production of useful substances and medical treatment. In this fiscal year, we succeeded in constructing and maintaining the animal cells that retain the transplanted algal genome. The genome-wide analysis demonstrated that the transplanted genome was highly methylated. In addition, we generated genetically modified immune cells that have antigen-specific cytotoxic activities against several cancer cells, suggesting that this method could be applied for cancer treatment. In the future, we would like to carry out integrated informatics analysis of big data in the life sciences and promote xenogeneic transplantation research using cell engineering technologies such as long-chain DNA synthesis, cell fusion, microinjection, and microlaser technology. While carrying out this research, we will emphasize the ethical, legal, and social impacts, which will allow us to develop genome transplantation technology with sufficient safety measures. We would like to continue to demonstrate the frontier spirit and promote the project to "create cells". In addition, we would like this research division to become a platform for joint research, information sharing, and technology exchange with domestic and foreign synthetic biology researchers.

Major research achievements (FY 2023)

Academic Papers

1. Genetic engineering contribution to developing cyanobacteria-based hydrogen energy to reduce carbon emissions and establish a hydrogen economy, Gulzhanay K. Kamshybayevab, Bekzhan D. Kossalbayev, Asemgul K. Sadvakasova, Ardak B. Kakimova, Meruyert O. Bauenova, Bolatkhan K. Zayadan, Chi-Wei Lan, Saleh Alwasel, <u>Tatsuya Tomo,</u> Jo-Shu Chang, Suleyman I. Allakhverdiev, International Journal of Hydrogen Energy, 54, 491–511, 2024 (Peer-reviewed)

2. Biotechnological production of hydrogen: Design features of photobioreactors and improvement of conditions for cultivating cyanobacteria, Bekzhan D. Kossalbayev, Girayhan Yilmaz,Asemgul K. Sadvakasova, Bolatkhan K. Zayadan, Ayaz M. Belkozhayev, Gulzhanay K. Kamshybayeva, Gaukhar A. Sainova, Ayshat M. Bozieva, Hesham F. Alharby, <u>Tatsuya Tomo</u>, Suleyman I. Allakhverdiev, International Journal of Hydrogen Energy, 49, 413–432, 2024 (Peer-reviewed)

3. Isolation and characterization of trimeric and monomeric PSI cores from Acaryochloris marina MBIC11017, Ryo Nagao, Haruya Ogawa, Naoki Tsuboshita, Koji Kato, Reona Toyofuku, <u>Tatsuya Tomo</u>, Jian-Ren Shen2, Photosynth Res. 157, 55-63 2023 (Peer-reviewed)

4. The plant nuclear lamina disassembles to regulate genome folding in stress conditions, Wang N., …, <u>Sakamoto T.</u>, <u>Matsunaga S.</u>, …, Liu C. (7 others), Nat. Plants, 9: 1081–1093, 2023 (Peer-reviewed)

5. Nuclear pore complex proteins are involved in centromere distribution, Ito N., <u>Sakamoto T*.</u>, …, <u>Matsunaga S.</u>*, (4 others), iScience, 27: 108855, 2024 (Peer-reviewed)

6. Genomic view of heavy-ion induced deletions associated with distribution of essential genes in Arabidopsis thaliana, Ishii, K., <u>Kazama, Y.</u>, Hirano, T., Fawcett, J. A., Sato, M., Hirai, M. Y., ... & Abe, T*., Front. Plant Sci., 15, 1352564, 2024 (Peer-reviewed)

7. Evolution of sex-determination in dioecious plants: From active Y to X/A balance? <u>Kazama, Y.</u>*, Kobayashi, T, Filatov, D.A., BioEssays, 45, 2300111, 2023 (Peer-reviewed)

8. Developmental differences between hermaphrodite and female-like flowers in a non-model horticultural plant Dianthus hybrida, Sanjyaya, A., Kobayashi, T., Nishijima, R., Shinoyama, H., <u>Kazama, Y.</u>*, Cygologia 88, 265-272, 2023 (Peer-reviewed)

9. Evolution of sex chromosomes and gynoecium suppression in plants, Kobayashi, T., Kitoh, M., Filatov, D.A., <u>Kazama, Y.</u>*, Cygologia 88, 91-94, 2023 (Peer-reviewed)

10. Treatment of Silene latifolia flower buds with peptides containing gynoecium- suppressing functions, Kobayashi, T., Kitoh, M., Kawano, S., <u>Kazama, Y.</u>*, Cygologia 88, 89, 2023 (Peer-reviewed)

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Books
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2. 金丸佳織, 中村由和 「実験医学増刊 治療標的がみえてきた脂質疾患学」炎症性皮膚疾患とイノシトールリン脂質代謝 3 章 16 炎症性皮膚疾患とイノシトールリン脂質代謝, 2023 年 10 月 (in Japanese)

3. 波江野洋, 佐伯晃一 「がんの免疫逃避進化のシミュレーションモデル研究」 実験医学, 2024 年 1 月号 p24-p30 (in Japanese)

Invited Lectures
1. Effect of Linear Energy Transfer on Heavy-ion Mutagenesis in Plants, Yusuke Kazama, International Seminar on Radiation Damage Effects and Medical Applications in 2024, Jan. 24th, 2024, online

2. Development and application of base editing technology, Keiji Nishida, The 15th International Association for Plant Biotechnology Congress, Tokyo, June 8th, 2023

3. Development and improvement of precise base editing and diversification tools for plant genome engineering, Keiji Nishida, The 15th International Association for Plant Biotechnology Congress, Daejeon, Korea, Aug. 10th, 2023

4. Base editing tools with new features, Keiji Nishida, Frontiers in Genome Engineering 2023, Goa, India. Nov. 16th, 2023

5. Development and Improvement of Base Editing Tools with Various Features, Keiji Nishida, Asian Synthetic Biology Association (ASBA) 2023. Hyogo, Japan. Dec. 14th, 2023

6. 真菌におけるゲノム編集とその利用, 荒添 貴之, JMAC 第 160 回定例会, 2023 年 9 月 12 日(in Japanese)

7. 出芽酵母におけるエンドサイトーシス経路のイメージング解析, 十島二朗, 十島純子, 第 24 回酵母合同シンポジウム, 2023 年 11 月 16 日, 奈良 (in Japanese)

8. エンドサイトーシス経路における初期 TGN 区画による積荷選別と Rab5 局在区画の形成機構, 十島二朗, 長野 真, 戸島拓郎, 中野明彦, 十島純子, 第 75 回日本細胞生物学会シンポジウム, 2023 年 6 月 30 日, 奈良 (in Japanese)

9. 血液細胞の運命制御におけるポリコーム群タンパク PCGF1 の役割, <u>伊川友活</u>, 第 16 回エピジェネティクス研究会, 2023 年 6 月 19 日, 東京都 (in Japanese)

10. Development of Luminescent Metal Complexes to Induce and Study Programmed Cell Death in Cancer Cells, <u>Shin Aoki</u>, The 18th Annual Congress of International Drug Discovery Science & Technology-2023 (IDDST-2023), 5/8-5/10, 2023, Tokyo, Japan

11. Construction of Enzyme Mimetic Systems by the Combination of Metallosupramolecular Complexes Formed by Functionalized Molecular Blocks and Solvent System, <u>Shin Aoki</u>, The 9th Annual World Congress of Advanced Materials (WCAM-2023), 5/8-5/10, 2023, Tokyo, Japan

12. Design and Synthesis of Macrocyclic Polyamine-Based Boron Carriers for Boron Neutron Capture Therapy (BNCT), <u>Shin Aoki</u>, The 3rd Edition of Unite Scientific Chemistry Conference (USCC-2023), 6/22-6/23, 2023, Rome, Italy + online (Keynote lecture)

13. Development of New Cyclometalated Iridium(III) Complexes Based on Post-Complexation Functionalization for Biomedical and Material Sciences, <u>Shin Aoki</u>, Baltic Fellow Summit, IAAM (International Association of Advanced Materials), 8/28-31, 2023, Baltic Sea + Online (IAAM Scientist Medal Lecture)

14. Development of Peptide-Hybrids of Organic and Organometallics for Induction of Paraptotic Cell Death in Cancer Cells, <u>Shin Aoki</u>, The 13th International Symposium on Bioorganic Chemistry (IsBOC-2023), 12/18-12/20, 2023, Singapore

15. Optical Resolution of Cyclometalated Iridium(III) Complexes and Its Applications, <u>Shin Aoki</u>, The 9th Asian Conference on Coordination Chemistry (ACCC9), 2/19-2/22, 2024, Bangkok, Thailand

16. アシクロビルの化学構造式から見た特性, <u>青木　伸</u>, 第 9 回日本医療安全学会学術総会, シンポジウム「薬の科学的特性から視た副作用マネジメント〜アシクロビルの副作用早期回避に向けて〜」, 3/11-12, 2023, 東京都 (東京理科大学葛飾キャンパス), (in Japanese)

17. 生体内金属イオンと金属タンパクを利用する放射線治療用薬剤の開発, <u>青木　伸</u>, 日本薬学会第 144 年会, 一般シンポジウム「金属錯体・放射線を利用する医薬品と生体イメージングの現在と未来」, 3/28-3/31, 2024, 横浜市(in Japanese)

18. 細胞膜リン脂質の変容と細胞老化の関連, <u>中村由和</u>, 金丸佳織, 京都大学　老化セミナー, 2023 年 11 月 30 日 (in Japanese)

19. 細胞老化制御におけるホスファチジルイノシトール 4,5-二リン酸の役割の解明, <u>中村由和</u>, 第 96 回日本生化学会大会シンポジウム『細胞老化の多様性、その統合と理解』, 2023 年 11 月 1 日 (in Japanese)

20. 上皮細胞の細胞老化制御におけるイノシトールリン脂質の役割の解析, 金丸佳織, <u>中村由和</u> 2023 年度　生理研研究会「上皮膜輸送と細胞極性形成機構の統合的理解を目指して」, 2023 年 7 月 13 日 (in Japanese)

21. Epigenetics and chromatin dynamics in mouse spermatogenesis. The 4th Meeting on "Genome Modality", <u>Maezawa S</u>. Stockholm, Sweden, September 2023

22. MSI-H 大腸癌における免疫逃避進化の数理モデル研究, 波江野　洋, 血液がん・免疫・数理融合研究シンポジウム,東京,2023 年 12 月 2 日 (in Japanese)

Patent

1. 原田裕太, <u>荒添貴之</u>, <u>鎌倉高志</u>, 国内優先出願, 核酸切断酵素, 核酸, ベクター, 核酸改変用キット, 及び核酸の改変方法, 特願 2024-057389, 令和 6 (2024) 年 3 月 29 日 (in Japanese)

2. 新門想太, <u>荒添貴之</u>, <u>鎌倉高志</u>, 国内優先出願, ベクター又は DNA 断片, キット, 及び遺伝子操作された真核細胞の作製方法, 特願 2024-057399, 令和 6 (2024) 年 3 月 29 日 (in Japanese)

3. 山崎真也, 荒添貴之, 鎌倉高志, 国内優先出願, 変異体の作製方法, 遺伝子発現方法, 及び真核細胞, 特願 2024-057393, 令和 6 (2024) 年 3 月 29 日 (in Japanese)

4. 伊川友活, 重廣 司, キメラタンパク質, 核酸, ベクター, Ｔ細胞又はＮＫ細胞, 医薬組成物, 組み合わせ物, 及び組み合わせ医薬, 特願 2023-62411, 2023 年 4 月 6 日(in Japanese)

5. 伊川友活, 鈴木藍彩, TCF3-HLF 型 B 細胞性急性リンパ性白血病の治療剤」特願 2023-082464, 2023 年 5 月 18 日 (in Japanese)

6. 伊川友活, 重廣 司, 抗原を特異的に認識する TCR 又は CAR を発現する免疫細胞の生産方法, 特願 2023-127747, 2023 年 8 月 4 日 (in Japanese)

7. 馬場昌範, 岡本実佳, 外山政明, 青木 伸, 田中智博, 横井健汰, 抗 SARS-CoV-2 薬, (令和 4(2022)年 11 月 11 日出願, 2023 年に PCT 出願) 国際公開番号：WO2023/085392 (in Japanese)

Public Relations

1. Maezawa S, The research was introduced by Kawaijuku "Mirai Book".
   Link: https://miraibook.jp/researcher/k23306

Award

1. 坂本卓也, 第 9 回 CYTOLOGIA 奨励賞, 日本メンデル協会, 2023 (in Japanese)

2. 風間裕介, 重イオンビーム照射技術の開発とそれを用いた植物性決定遺伝子の同定, 福井県科学学術大賞, 2024 年 2 月 7 日 (in Japanese)

Individual Research Topics

Tatsuya Tomo

"Fundamental research for plant genome transplantation"

Photosynthetic light-energy conversion has supported the global environment and life energy. For understanding this reaction, site-specific amino acid substitutions are one of the most important research methods. In this study, perturbations of photosynthetic pigment substitutions are used to elucidate the reaction mechanism.

Hisataka Ohta

"Analysis of transporters in cyanobacteria"

More than 50 ATP-binding cassette (ABC) transporter-related genes have been detected in the cyanobacterium Synechocystis sp. Deletion mutants of the substrate-unknown ABC transporter gene will be screened and analyzed for acid stress sensitivity in low pH media.

Sachihiro Matsunaga

"Synthetic biological studies of transfer of the plant genome to animal sells"

To reproduce the phenomenon of secondary symbiosis using synthetic biology, I will promote research on cell fusion of algae and cultured animal cells to transfer the genome, and develop methods to maintain chloroplasts and algae in animal cells.

Takuya Sakamoto

"Ohm analysis of animal and plant hybrid cells"

Gene expression analysis and genome analysis of animal and plant hybrid cells in which algal genomes are transplanted into animal culture cells will be performed. In addition, DNA interaction analysis of the transplanted genome and host genome will be conducted.

Yusuke Kazama

"Genetic analysis of chromosome rearrangements"

Chromosomal rearrangements including translocations, deletions, duplications, and inversions are important mutations that have been involved in speciation and evolution of organisms. We promote the study on the induction of chromosomal rearrangements to alter gene order, copy number, and the higher-dimensional arrangement of DNA in the cell nucleus.

Keiji Nishida

"Development of non-cleaving genome editing technology"

Base editing technology using DNA base exchange reactions has been developed, enabling the direct introduction of point mutations. In FY2022, the application of base editing was expanded to establish highly efficient point mutation introduction in lactic acid bacteria.

Shigeo Sugano

"Development of highly efficient knock-in method using non-homologous end-joining repair"

We will develop efficient knock-in technology using non-homologous end-joining repair pathway instead of homologous recombination pathway. Using this method, we will investigate whether plant transcription factors can work in animals. We will also apply knock-in technology to plants.

Takashi Kamakura and Takayuki Arazoe

"Generation of hybrid filamentous fungi across species"

Interspecific hybridization is constrained by the "species barrier," even among closely related species. Using genome engineering via cell fusion, here we aimed to generate hybrid filamentous fungi with novel traits that can produce useful products.

Kiminori Shimizu

"Molecular biological study towards functional regulation of microorganisms"

In order to regulate the microbiological function, they employ genetics and molecular biology to drive researches on synthetic biology.

Jiro Toshima

"Development of detection system of human GPCR signals using budding yeast"

More than 900 G protein-coupled receptors (GPCRs) exist in the human genome and they are important target proteins for drug discovery. Among them, the human chemokine receptor, CCR2 is involved in the proliferation and migration of cancer cells. In this study, using human-yeast hybrid cells expressing the human CCR2 receptor and its downstream signaling proteins in Saccharomyces cerevisiae, we are going to develop an efficient detection method for activation signals of CCR2 receptor stimulated by the ligand.

Tomokatsu Ikawa

"Development of a novel immune cell therapy using iLS cells"

Chimeric antigen receptor (CAR)-T cells are attracting attention as one of cancer immunotherapy. However, since patient-derived peripheral blood lymphocytes are used, it is difficult to expand them to a sufficient number, and the cells are exhausted and aged. Therefore, in this study, we use induce Leukocyte Stem (iLS) cells, which are multipotent hematopoietic progenitor cells developed in our laboratory, to generate CAR-NK cells and CAR-T cells that target cancer and infectious diseases and analyzed their functions.

Mahito Sadaie

"Exploring cancer vulnerability and developing strategy to prevent cancers"

Telomere maintenance is essential for cancer cell proliferation. There are two types of cancer cells: those that maintain proliferation in a telomerase-dependent manner, and those that are telomerase-independent. Telomerase-independent telomere maintenance is often observed in refractory cancers, such as sarcomas. In this study, we aim to elucidate the mechanism of action of compounds that inhibit the proliferation of telomerase-independent cancer cells and to identify novel genes that are essential for proliferation to discover therapeutic reagents for telomerase-independent cancer and therapeutic target molecules.

Toshiki Furuya

"Characterization of novel microorganisms and enzymes"

Using synthetic biology techniques, we design and construct new metabolic pathways in microorganisms such as Escherichia coli and establish methods for producing useful substances. Specifically, we aim to efficiently produce rare polyphenols and fragrance compounds.

Shin Aoki

"Development of cancer therapy by modeling and controlling intracellular reactions and irradiation"

Phosphorylation/dephosphorylation is important metabolic and signaling pathways within the cell. In order to catalyze intracellular dephosphorylation reactions, we aim to develop supramolecular phosphatases generated by self-assembly of artificial compounds. We are also designing and synthesizing novel boron-containing drugs for boron neutron capture therapy (BNCT), a neutron-based cancer therapy. We will also examine genetic modification of plant by neutron irradiation.

Yoshikazu Nakamura

"Elucidating the role of biological membrane phospholipids in the regulation of cellular identity"

In the determination of cellular identity, while much knowledge has been accumulated regarding the role of proteins, including transcription factors, the role of lipids remains largely unclear. Thus, the aim of this study is to elucidate the role of biological membrane phospholipids in cellular identity determination. Additionally, we aim to attempt the development of a method for controlling cellular identity through manipulation of biological membrane phospholipids.

So Maezawa

"Epigenome editing-based in vitro spermatogenesis"

Recent advances in developmental biology hold great promise for organ regeneration, stem cell-based therapy, and tissue engineering. In vitro gametogenesis from pluripotent stem cells is currently being developed to overcome infertility, particularly germ cell aplasia. However, the induction efficiency to create functional sperm and egg cells is still low by the existing method. Here we aim to develop the epigenome editing-based in vitro gametogenesis by rewriting germ cell-like epigenome into pluripotent stem cells.

Hiroshi Haeno

"Computational modeling of locoregional recurrence with spatial structure"

Local and regional recurrence after surgical intervention is a significant problem in cancer management. This study constructs a computational model for cancer initiation and recurrence by combining the Moran and branching processes in which cells requires 3 or more mutations to become malignant.

Kengo Morohashi

"Elucidation of life science events by network analysis"

Focusing on the connections and/or networks that exist within living organisms, we conducted to develop bioinformatics analysis techniques and promoted studies that can be useful in synthetic biology.

Development of Superior Cell and DDS for Regenerative Medicine

Development of Superior Cell and DDS for Regenerative Medicine

1. Overview

The objective of this research division is to accelerate regenerative medicine. We aim to develop "Superior Cells" by enhancing the functionality of cells that are administered to the body for therapeutic purposes. We also plan to develop drug delivery systems (DDS) that precisely control the pharmacokinetics of cells and other functional molecules in the body. The therapeutic targets of the developed superior cells and DDS will include the respiratory system, brain, immunological system, cancer, and other disease areas, with the goal of developing therapeutic methods for these diseases.

This research division consists of four collaborative groups that promote research on the development of superior cells and DDS to accelerate regenerative medicine. The "Superior cell/DDS Development Group" will design and develop superior cells and DDS for controlling the pharmacokinetics of cells and various bioactive substances within the body. Superior cells are developed by adding new functions to cells, constructing cell spheroids and organoids, and utilizing extracellular microparticles. In addition, DDS technology will be utilized for superior cells, and its effectiveness will be verified in animal disease models. The "Cell Function Regulation System Development Group" will create new molecules that control cell function and develop functional materials to support regenerative medicine and cell therapy. The "Physical Properties Control and Evaluation Group" will evaluate the physical properties of the various functional molecules and materials developed by the above groups to support the optimization of the functions of the superior cells and DDS. The "Cell/tissue Regeneration Group" will elucidate the mechanisms of organ regeneration and treatment of the lungs, bones, and other organs, as well as the interactions of DDS and the immune system.

2. Organization and Facilities

As shown in Figure, 17 researchers from within and outside the university are participating in this research division, which is organized into four groups to promote research on "Development of Superior Cell and DDS for Regenerative Medicine".

1. Superior cell/DDS Development Group
2. Cell Function Regulation System Development Group
3. Physical Properties Control and Evaluation Group
4. Cell/tissue Regeneration Group

The facilities in our division are located in Building No. 18 on the Noda Campus (former DDS Research Center Building), in addition to the laboratories of participating researchers in the School of Pharmacy and the School of Advanced Engineering. These facilities include an image analysis system, LC/MS system, liquid chromatography system, plasma ionization quantification system, powder characterization system, flow cytometer, ultrafine structure observation system, single crystal X-ray diffraction system, powder X-ray diffraction system, differential scanning calorimetry system, thermogravimetric analysis system, and infrared spectrophotometer, a high-performance respiratory function analysis system, all of which are used jointly within the research divisions to conduct our research topics.
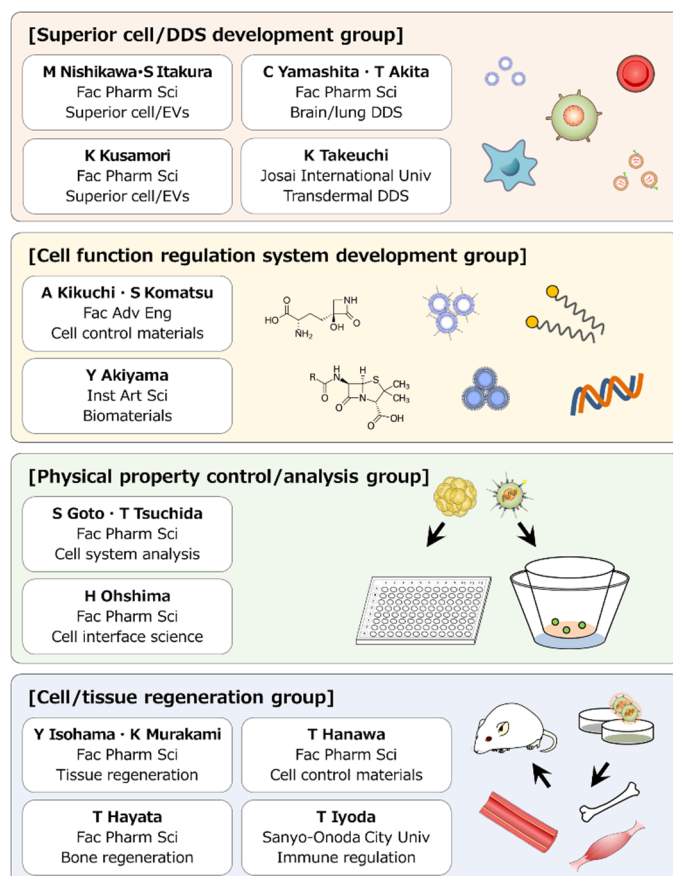
Fig. 1. Members in each group for Development of Superior Cell and DDS for Regenerative Medicine.

3. Activity Reports

On December 8, 2023, the division hosted the "TUS DDS Symposium 2023". In addition to progress reports from each research group, Professor Hideyoshi Harashima (Hokkaido University) gave a special talk entitled "Intracellular Kinetics Control from Drug Kinetics: Creation of Innovative Medicines from Japanese Academia". The symposium was held as a closed meeting and was attended by 76 participants, mainly from the departments within the university.

3. 1. Superior cell/DDS Development Group

This group investigated the structural optimization of the constituent units of DNA hydrogels that can be used as cell-based DDS. Oligodeoxynucleotides capable of forming Takumi-type DNA units by self-assembling were newly designed, and the minimum unit conditions for stable formation of DNA hydrogels were found from evaluation of physicochemical properties and tissue distribution in the body. In addition, for the newly designed functional lipid nanoparticles encapsulating active vitamin D3, we succeeded in developing an inhalation powder formulation that meets clinical dosage requirements by design of experiments and formulation optimization using genetic algorithms. In addition, we succeeded in developing prednisolone-containing nanoparticles using DL-lactide/glycolide copolymers.

3. 2. Cell Function Regulation System Development Group

This group prepared mannose-modified thermosensitive microparticles for the development of drug carriers for selective delivery to macrophages and found that the presence or absence of specific ligands, in addition

to the shape and surface properties of the microparticles, determines the phagocytosis behavior of macrophages. We also prepared double-stranded DNA-loaded gold nanoparticles with a galactose derivative and found that they can be used to detect specific enzymatic activity of tumor markers.

3. 3. Physical Properties Control and Evaluation Group

This group studied the effect of the change in crystal form of indomethacin on its solubility and the mechanism of inclusion of NSAIDs to cyclodextrins and the supersaturation mechanism exhibited by the inclusion. In addition, as a theoretical study on the motion of microparticles, the group submitted a new calculation method for the value of Hamaker constant, which is necessary to evaluate the stability of colloidal dispersion systems.

3. 4. Cell/tissue Regeneration Group

This group found an inhibitory function of apoptosis by aquaporin 5 and found that this protein can be a new therapeutic target for pulmonary edema. The group also developed a coating material using water-soluble polymers such as pectin and alginic acid for wound healing. In addition, we discovered the causative genes in hereditary diseases, and showed the possibility of elucidating the pathogenesis of hereditary bone diseases and osteoporosis and developing new therapeutic strategies. Furthermore, we discovered that intracellular signal changes caused by abnormal cell adhesion may be involved in the accumulation of amyloid-β in the brain and in the regulation of renal mesangial cell function.

4. Challenges and Prospects

The purpose of the division is to accelerate regenerative medicine through a balance of independence and flexible collaboration that allows each of the four research groups to focus on their own research projects for the development of superior cell and DDS. Since its establishment in 2021, the division has been characterized by close collaboration between the divisions, resulting in a shared understanding of the research challenges developed by researchers from different backgrounds in each division. This collaborative approach has led to significant progress not only in intra-group collaborations but also in inter-group collaborations. Furthermore, the research division was granted a two-year extension of its establishment period. The significant research achievements of each group can be used to define a new strategy that includes collaborations with venture companies and international research institutions. Such efforts will lead to the creation of fundamental technologies that will sustainably accelerate the development of regenerative medicine.

5. Conclusion

Since its establishment in 2021, our research division has promoted the development of superior cells and innovative disease treatments through the collaborative efforts of four research groups. Now in its third year, the division has continued to generate steady research output each year. In particular, active collaboration among the research groups has significantly benefited the division, which comprises researchers with diverse expertise, and has generally achieved its initial objectives. We believe that the two-year extension of the research division is a recognition of the efforts of the research division. On the other hand, it may also indicate our expectations for the tasks yet to be accomplished in this research division. Therefore, we will continue our research projects on "Development of Superior Cell and DDS to Accelerate Regenerative Medicine" in collaboration with companies and overseas research institutions. Furthermore, we also intend to continue the challenge of creating a new industrial base using the intellectual property of the patents we have acquired.

Research achievements for 2023

Academic Papers

Makiya Nishikawa, Kosuke Kusamori, Shoko Itakura

1. Investigation of the crystallinity change after the addition of magnesium hydroxides into the calcium phosphate during mechanochemical synthesis; an FTIR spectroscopy, XRD analysis, chemometrics and cell culture, Yuta Otsuka, Daisuke Sasaki, Kosuke Kusamori, Makiya Nishikawa, Besim Ben-Nissan, Journal of the Australian Ceramic Society, vol 59 pp 1373-1380, 2023 (doi: 10.1007/s41779-023-00919-2) (Peer-reviewed)

2. Efficient delivery of mesenchymal stem/stromal cells to injured liver by surface PEGylation, Yukiya Takayama, Kosuke Kusamori, Yuri Katsurada, Shu Obana, Shoko Itakura, Makiya Nishikawa, Stem Cell Research and Therapy, vol 14 pp 216, 2023 (doi: 10.1186/s13287-023-03446-w) (Peer-reviewed)

3. Optimal preparation protocol of cell-encapsulating alginate capsules for long-term cell-based therapy, Ryota Suzuki, Kosuke Kusamori, Kodai Takamura, Yuma Miyakawa, Shu Obana, Shoko Itakura, Makiya Nishikawa, Applied Sciences, vol 13 pp 6676, 2023 (doi: 10.1002/tee.23794) (Peer-reviewed)

4. In situ evaluation of cellular spheroid stiffness by pinching device composed of piezoactuator and strain gauge, Kodai Koyanagi, Kosuke Kusamori, Makiya Nishikawa, Satoshi Konishi, IEEJ Transactions on Electrical and Electronic Engineering, vol 18 pp 1226-1228, 2023 (doi: 10.1002/tee.23794) (Peer-reviewed)

5. Scutellaria Root extract-induced hepatocytotoxicity can be controlled by regulating its baicalin content, Naohiro Oshima, Kosuke Kusamori, Ryo Takasaki, Moe Takeda, Yuri Katsurada, Kazuki Okoshi, Makiya Nishikawa, Noriyasu Hada, Journal of Natural Medicines, *in press* (Peer-reviewed)

6. Survey and Consideration for Evaluation of Tissue Distribution and Plasma/Serum Protein Binding of Approved Oligonucleotide Therapeutics, Shunji Imai, Yasufumi Fukano, Yutaka Niwayama, Naomi Tamura, Mika Miyoshi, Kei Fukuhara, Hiroshi Kodaira, Norihiko Iwazaki, Yosuke Yamanaka, Norihiro Miyazawa, Hideo Takakusa, Kenta Kadotsuji, Akihiko Goto, Shunsuke Shimada, Tokuyuki Yoshida, Satoshi Obika, Makiya Nishikawa, Takao Inoue, 医薬品医療機器レギュラトリーサイエンス, *in press* (in Japanese) (Peer-reviewed)

7. Development of rice bran -derived nanoparticles with excellent anti-cancer activity and their application for peritoneal dissemination, Daisuke Sasaki, Hinako Suzuki, Kosuke Kusamori, Shoko Itakura, Hiroaki Todo, Makiya Nishikawa, Journal of Nanobiotechnology, vol 22 pp 114, 2024 (Peer-reviewed)

8. Hoechst-modification on oligodeoxynucleotides for efficient transport to the cell nucleus and gene regulation , Hiroki Makanai, Tatsuya Nishihara, Makiya Nishikawa, Kazuhito Tanabe, ChemBioChem, vol 25 pp e202300645, 2023 (doi: doi.org/10.1002/cbic.202300645) (Peer-reviewed)

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10. Prediction of critical quality attributes based on the numerical simulation of stress and strain distributions in pharmaceutical tablets, Kozo Takayama, Shoko Itakura, Hiroaki Todo, Kenji Sugibayashi, Chemical and Pharmaceutical Bulletin, vol 71 pp 386-397, 2023 (doi: doi.org/10.1248/cpb.c22-00539) (Peer-reviewed)

Chikamasa Yamashita, Tomomi Akita

1. Efficiency of a lyophilizate for dry powder inhalation system for drug delivery of ghrelin in monkeys, <u>Tomomi Akita</u>, Kahori Miyamoto, <u>Chikamasa Yamashita</u>, Drug Delivery Letters, 2023 in press (Peer-reviewed)

2. Characterization of a spontaneous mouse model of mild, accelerated aging via ECM degradation in emphysematous lungs, Ryosuke Tanino, Yukari Tsubata, Takamasa Hotta, Tamio Okimoto, Yoshihiro Amano, Mayumi Takechi, Tetsuya Tanaka, <u>Tomomi Akita</u>, Mamiko Nagase, <u>Chikamasa Yamashita</u>, Koichiro Wada, Takeshi Isobe, Scientific reports, vol 13 pp 10740-, 2023 (doi.10.1038/s41598-023-37638-4) (Peer-reviewed)

3. Intracellular drug delivery process of am80-encapsulated lipid nanoparticles aiming for alveolar regeneration, <u>Tomomi Akita</u>, Kazuaki Oda, Satoru Narukawa, Yuki Morita, Kota Tange, Yuta Nakai, <u>Chikamasa Yamashita.</u> (2023.6). Pharmaceuticals, vol 16 pp 838 (doi. 10.3390/ ph16060838)

4. 分化誘導を基盤としたCOPD根治治療法の開発, <u>秋田智后</u>, <u>山下親正,</u> Precision Medicine, vol 6 pp 66-69, 2023 (in Japanese) (Peer-reviewed)

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Issei Takeuchi

1. Phosphoric acid triester micelles: characterization and self-assembly, Yuto Yokoyama, Kimiko Makino, Hiroshi Terada, Akihiko Kikuchi, <u>Issei Takeuchi</u>, Kolio Troev, Journal of Oleo Science, vol 72 pp 969-977, 2023 (Peer-reviewed)

Akihiko Kikuchi, Syuuhei Komatsu

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3. Phosphoric acid triester micelles: characterization and self-assembly, Yuto Yokoyama, Kimiko Makino, Hiroshi Terada, <u>Akihiko Kikuchi</u>, Issei Takeuchi, and Kolio Troev, Journal of Oleo Science, vol 72 pp 969-977, 2023 (Peer-reviewed)

4. Physicochemical properties of egg-box-mediated hydrogels with transiently decreased pH employing carbonated water, Ryota Teshima, Shigehito Osawa, Yayoi Kawano, Takehisa Hanawa, <u>Akihiko Kikuchi</u>, Hidenori Otsuka, ACS Omega, vol 8 pp 7800-7807, 2023 (doi:10.1021/acsomega.2c07552) (Peer-reviewed)

Satoru Goto, Tomohiro Tsuchida

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Hiroyuki Ohshima

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Tadayoshi Hayata

1. Identification of a biallelic missense variant in gasdermin D (c.823G > C, p.Asp275His) in a patient of atypical gorham-stout disease in a consanguineous family, Daniela Tiaki Uehara, Tomoki Muramatsu, Senichi Ishii, Hidetsugu Suzuki, Kazuyuki Fukushima, Yasuhiro Arasaki, <u>Tadayoshi Hayata</u>, Johji Inazawa, Yoichi Ezura, *JBMR Plus*, vol 7 pp e10784, 2023 (https://doi.org/10.1002/jbm4.10784) (Peer-reviewed)

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Takuya Iyoda

1. Bioactive TNIIIA2 sequence in tenascin-C is responsible for macrophage foam cell transformation; Potential of FNIII14 peptide derived from fibronectin in suppression of atherosclerotic plaque formation, <u>Takuya Iyoda</u>, Asayo Ohishi, Yunong Wang, Miyabi-Shara Yokoyama, Mika Kazama, Naoyuki Okita, Sachiye Inouye, Yoshimi Nakagawa, Hitoshi Shimano, Fumio Fukai, International Journal of Molecular Sciences, vol 25 pp 1825, 2024 (doi:10.3390/ijms25031825) (Peer-reviewed)

Books

Yamashita laboratory; Chikamasa Yamashita, Tomomi Akita

1. 経鼻投与された神経ペプチド誘導体は三叉神経軸索を介した中枢へ移行する, <u>秋田智后</u>, <u>山下親正</u>, Drug Delivery System (日本 DDS 学会) , vol 38 pp 259, 2023.7

2. インペリアル・カレッジ・ロンドンでの海外留学, <u>秋田智后</u>, 製剤機械技術学会誌, vol 32 pp 55-57, 2023.6.5 (in Japanese)

Oshima laboratory; Hiroyuki Ohshima

1. 分散・凝集理論の系譜, <u>大島広行</u>, 分散・凝集の基礎, 米澤 徹, 武田真一, 藤井秀司, 石田尚之 (編者) , 近代科学社 Digital (東京) , pp 20-30, 2023 (in Japanese)

2. 分散・凝集状態を支配する因子・溶液界面構造と特性, <u>大島広行</u>, 分散・凝集の基礎, 米澤 徹, 武田真一, 藤井秀司, 石田尚之 (編者) , 近代科学社 Digital (東京) , pp 65-107, 2023 (in Japanese)

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Isohama laboratory; Yoichiro Isohama, Kazuhito Murakami

1. 第１３章　呼吸器系に作用する薬物, <u>礒濱洋一郎</u>, パートナー薬理学　改訂第４版, 栗原順一, 田中芳夫, 坂本謙司　編, 南江堂 (東京) , pp 513-528, 2024 (in Japanese)

2. 第１０章　呼吸器疾患に使用する薬物, <u>礒濱洋一郎</u>, 疾患の成り立ちと回復の促進② 臨床薬理学, 赤瀬智子, 柳田俊彦　編, メディカ出版 (東京) , pp 248-263, 2024 (in Japanese)

3. 第６章　呼吸器疾患に使う薬, <u>礒濱洋一郎</u>, くすりがわかる, 柳田俊彦監修, 南山堂 (東京) , pp 254-262, 2023 (in Japanese)

Invited lectures

Nishikawa laboratory; Makiya Nishikawa, Shoko Itakura, Kusamori Laboratory; Kosuke Kusamori

1. Structual Optimaization of Oligonucleotide Therapeutics for Targeted or Sustained Delivery, <u>Makiya Nishikawa</u>, Asian Federation for Pharmaceutical Sciences 2023, Hanoi,vietnam, November 8-10, 2023

2. 構造最適化による核酸医薬品の体内動態制御, <u>西川元也</u>, 日本薬物動態学会 38 年会 シンポジウム 革新的医薬品創出のための DDS 戦略, 2023.9.26 (in Japanese)

3. DNA ハイドロゲルを利用した核酸・タンパク質の体内動態制御, <u>西川元也</u>, 第 8 回 核酸創薬研究部門シンポジウム, 2023.9.23 (in Japanese)

4. 核酸を基盤とするナノ医薬・DDS の開発, <u>西川元也</u>, 薬物動態談話会 9 月例会, 2023.9.22 (in Japanese)

5. 間葉系幹細胞の効率的な肝送達による肝疾患治療効果の増強, <u>草森浩輔</u>, <u>西川元也</u>, 第 39 回日本 DDS 学会学術集会 シンポジウム, 2023.7.28 (in Japanese)

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3. 非定型的ゴーハム病, 原因として Gasdermin D 遺伝子変異を同定－東京医歯大ほか, QLifePro 医療ニュース, 2023.7.4 (in Japanese)

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2. 尾花 柊, 第 39 回日本 DDS 学会学術集会　優秀発表賞, 2023.7.29 (in Japanese)
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5. 草森浩輔, 第 3 回細胞シート工学イノベーションフォーラム, ポスター奨励賞, 2023.11.24 (in Japanese)

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Hayata laboratory; Tadayoshi Hayata

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Individual Research Topics

Makiya Nishikawa, Kosuke Kusamori, Shoko Itakura
"Study on structural optimization of DNA units forming DNA hydrogels"

    In the fiscal year 2023, we focused on the design of DNA nanostructures. We have previously reported that DNA nanostructure-based DNA hydrogels are useful for sustained delivery of cells. For their clinical application, minimizing the DNA units is desirable in terms of production cost and quality control. Therefore, we designed new oligodeoxynucleotides that can form Takumi-shaped DNA units by self-assembly. The conditions for the minimum Takumi-shaped unit that can stably form DNA hydrogels were found based on the evaluation of electrophoresis, thermal stability, viscoelasticity, and persistence after administration to mice.

Chikamasa Yamashita, Tomomi Akita
"Development of dry powder inhalation of active vitamin D3-encapsulated functional nanoparticles aiming at radical treatment of COPD by alveolar regeneration"

    In our previous study, active vitamin D3 (VD3) encapsulated in functional lipid (SS-OP) nanoparticles succeeded to deliver VD3 efficiently to the site of action and reduce the side effects in a mouse model of COPD. Therefore, we aimed to develop lyophilizates for dry powder inhalation of VD3-encapsulated in SS-OP nanoparticles for the clinical application as a radical treatment for COPD.　As a result, we could develop lyophilizates for dry powder inhalation with Design of Experiments and a genetic algorithm to determine the optimal excipient dose.

Issei Takeuchi
"PLGA nanoparticles loaded with prednisolone for the treatment of allergic contact dermatitis"

    We succeeded in developing prednisolone-loaded nanoparticles using poly(DL-lactide-co-glycolide. The particle size distribution of the nanoparticles was controlled by examining the poor solvent and dialysis time during preparation. To evaluate the therapeutic effects of this nanoparticle, we conducted a treatment experiment using an animal model of contact dermatitis. It was found that the expression level of IL-4 in the nanoparticle-administered group was significantly reduced compared to the untreated group. In the future, we will conduct research on the intradermal distribution of nanoparticles to improve therapeutic effects.

Akihiko Kikuchi, Syuuhei Komatsu
"Preparation of mannose-modified thermosensitive particles and their interaction with macrophages"

    Macrophages are responsible for early immunity. To selectively deliver drugs to macrophages we have been designing thermosensitive particles with controlled shape and surface properties. In this study, we newly prepared mannose-modified thermosensitive microparticles to clarify the uptake characteristics of particles via cell surface receptors. Shape and surface properties of particles, as well as the presence or absence of specific ligands, mannose, affect the phagocytic behavior of macrophages. Through the control of these physical properties, we discovered the possibility of selective drug delivery to macrophages.

Yoshitsugu Akiyama

"Colorimetric assay of tumor markers using sugar-protruding double-stranded DNA-functionalized gold nanoparticles"

We developed a colorimetric assay of tumor markers using the high colloidal dispersibility of sugar-protruding double-stranded DNA-functionalized gold nanoparticles (AuNP–dsDNA-Gal). The colloidal dispersibility of AuNP–dsDNA-Gal was evaluated with or without β-galactosidase. AuNP–dsDNA-Gal without β-galactosidase maintained high dispersibility even at high salt concentrations. In contrast, treatment of AuNP–dsDNA-Gal with β-galactosidase caused a color change (red to purple) due to the SPR band shift. This is probably because the enzymatic hydrolysis of the protruding sugar moieties in the outermost layer of the nanoparticles reduced the colloidal dispersibility at high salt concentrations. The result strongly suggests that this methodology could be applied to a simple and rapid detection technique for tumor markers.

Satoru Goto, Tomohiro Tsuchida

"Research on physicochemical changes induced by interactions between drugs, or between drugs and cyclodextrins"

In this laboratory, we investigated the effect of crystalline polymorphic transformation from the α-form to the γ-form of indomethacin on its solubility in various aqueous solvents. Additionally, we reported on the inclusion mechanism of 2-hydroxypropyl-β-cyclodextrin for nonsteroidal anti-inflammatory drugs (NSAIDs) and the supersaturation mechanism exhibited by the inclusion complexes. Furthermore, we examined the cyclodextrin inclusion effects on the solubility changes induced by molecular interactions between acidic NSAIDs and H_2 receptor antagonists.

Hiroyuki Ohshima

"Theoretical study on the motion of colloidal particles in a salt-concentration gradient"

We conducted collaborative research with the Department of Mathematics, NIT Durgapur, India on the electrophoresis of droplets and porous colloids. This is a theoretical study on the motion of colloids aimed at applications in DDS.

"Theoretical study on the relationship between the Hamaker constant and the Hansen solubility parameters"

We proposed a new method for calculating the Hamaker constants necessary for evaluating the stability of colloidal dispersions based on the database of the Hansen solubility parameters.

Yoichiro Isohama, Kazuhito Murakami

"Usefulness of aquaporin water channels, as novel drug discovery targets"

Aquaporins (AQPs) water channels are well known to regulate water metabolism in the body. We have found that AQP5 inhibits apotosis, as a new function. In the in vitro experiments, APP5 inhibited Fas ligand-induced cell death dependent on its expression level. In addition, in vivo experiments showed that Tg mice in which AQP5 was highly expressed in lung epithelial cells had improved survival rate, apoptosis of lung epithelial cells, and pulmonary edema associated with sepsis. It is suggested that AQP5 is a new therapeutic target for pulmonary edema.

Takehisa Hanawa

"Development of wound dressing material using water-soluble polymer"

In FY2023, we attempted to prepare a wound dressing mainly composed of water-soluble polymers for the purpose of wound healing (including oral mucositis). By utilizing the fact that pectin, a plant-derived component, and alginic acid, a brown algae-derived component, are gelatinized by the action of divalent ions such as Ca, we succeeded in preparing a prototype of a covering material that remains dry (xerogel) until just before use and forms a hydrogel when water is added before the use, and published the paper. We were able to publish the results in a paper.

Tadayoshi Hayata

"Study on the pathogenesis of musculoskeletal diseases and new regulatory mechanisms of osteoclast differentiation"

We discovered the D275H mutation in the Gasdermin D (GSDMD) gene as the causative gene for hereditary atypical osteolytic Gorham-Stout disease. We found that the RNA-binding protein Cpeb4 localizes to nuclear bodies of cells during osteoclast differentiation and interacts with splicing factors to regulate selective splicing of the transcription factor Id2 mRNA, which is involved in osteoclast differentiation. The results of this study are expected to contribute to elucidating the pathogenesis of inherited bone diseases and osteoporosis and to new therapeutic strategies.

Takuya Iyoda

"Deregulated cell adhesion and age-related diseases"

Accompanied by aging, reconstitution of extracellular-matrix (ECM) would progress gradually. Since abnormal cell adhesion with reconstituted aged ECM might activate abnormal intracellular signaling, there is a possibility that the cells adhered to aged ECM contribute to the progression of age-related diseases. This year, we found that the potentiated and sustained activation of beta1-integrin expressed on renal mesangial cells lead ECM reconstitution, accompanied with deregulated fibronectin production, On the other hand, we found the possibility that the beta-1-integrin activation in macrophages would become an important event in beta-amyloid production and its accumulation.

Renewable Energy Science and Technology Division

Renewable Energy Science and Technology Division

1. Overview

The Photovoltaic Power Generation Technology Research Division has been focusing on research into photovoltaic power generation technology as a clean energy source for the past 13 years, including a reorganization in 2010. Today, however, research and development are not limited to photovoltaic power generation, but also include wind power generation, thermal power generation, and a wide range of other "renewable energies". However, as more and more renewable energies are connected to the grid, the operation of systems and infrastructure for stable power supply have become extremely difficult and important. This division has been reorganized to handle "renewable energies" as a whole by reorganizing the division that has handled only solar energy so far,

    (i) Development of materials to reduce the cost of installation and operation to the same level as power generation using fossil fuels

        → Cross-divisional development of basic technology for the development of other power generation materials through knowledge obtained through solar cell research (solar cells, thermoelectric power generation devices, fuel cells, etc.).

    (ii) Development of high-efficiency management technology for electricity obtained from various power generation methods

        → Joint development of technologies to utilize power obtained from various power generation methods without waste, such as grid interconnection, fault diagnosis technology, and optimization using AI, in a vertical and cross-sectoral manner within the division

    (iii) Development of new materials, new system technologies, etc.

        → Development of budding technologies within the division, such as laminated sheets of solar cells and thermal power generation, integration with agriculture through solar sharing, and integration with energy storage technologies such as chemical batteries and flywheels, and energy storage technologies such as hydrogen production technology.

The department was established in FY2020 with the aim of developing new technologies.

While renewable energy is environmentally friendly, it has serious infrastructure issues such as unstable power supply and high installation and running costs. The goal of this project is to propose a foundation for stable and low-cost power supply through the above four research objectives, and to activate and promote research and development of renewable energy utilization technology at Tokyo University of Science. In FY2023, the following external and student activities were carried out in addition to various joint research projects.

+ *The 4th symposium of the division "Recent Trends in Renewable Energy Technologies*

The symposium on renewable energy technologies was held on January 29, 2024 at the Morito Memorial Hall on the Kagurazaka Campus, mainly in person, with a hybrid session using Zoom online. The lectures were given by leading researchers who are active in these fields. About 100 people from inside and outside the university attended the symposium. In addition, students and others made poster presentations of their research results, and through discussions with researchers and students from inside and outside the university, they were able to gain knowledge that will guide the development of their own research. As described above, we were able to disseminate information on renewable energy technology research at the Tokyo University of Science. In addition, the activity subsidy was used to pay the honorarium for the invited speakers at the symposium.

+ *Exhibition of RENEWABLE ENERGY 2024*

The 18th Renewable Energy World Exhibition & Forum RENEWABLE ENERGY 2024, one of the largest renewable energy-related exhibitions in Japan, was held on January 31 – February, 2024, at the West Hall of Tokyo Big Sight. We exhibited research results and demonstration machines related to various renewable energy material systems unique to the Tokyo University of Science, and disseminated information on renewable energy technology and research at the Tokyo University of Science both domestically and internationally. The departmental activity fund was used to pay for the preparation of flyers and transportation expenses for the explanation staff to hold this exhibition and presentation.)

+ *Summer day camps for face-to-face interaction*

A half-day day camp was held in Building No. 7 on the Noda Campus, mainly to promote interaction among students from each laboratory. Random groups were formed, and after group work, presentations were made on the future of renewable energy and the creation of new global warming prevention projects from the students' viewpoints. Awards were given to groups that came up with outstanding ideas. For the students, it was a good opportunity to learn about the cutting edge of renewable energy technology outside their own laboratory and to get to know other students.

+ *Research progress reports among faculty members*

The research progress of all faculty members has been presented and reported online once every four months. Sharing information among faculty members with different fields and areas of expertise not only deepened knowledge of the latest renewable energy technologies, but also resulted in beneficial debriefing sessions, such as the creation of new joint research projects.

Through these activities in FY2023, the division's research results and activities were widely disseminated, and suggestions were obtained on how to proceed with future research.

2. Organization and Facilities

The members of the division and their areas of expertise are as follows;

Affiliation of key role	Job title	Name	Main research field
Faculty of Science and Technology Department of Electrical Engineering	Professor	Mutsumi Sugiyama	Semiconductor material engineering / thin film photovoltaic cell
Faculty of Science Division II Department of Chemistry	Professor	Takashiro Akitsu	Coordination chemistry / Photofunctional fuel cells of organic/inorganic hybrid materials
Faculty of Science Division II Department of Physics	Professor	Zhao Xinwei	Semiconductor nano-material engineering / Thin film photovoltaic cell
Faculty of Engineering Department of Electrical Engineering	Professor	Yuzuru Ueda	Electricity and energy engineering / Photovoltaic system
Faculty of Engineering Department of Industrial Chemistry	Associate professor	Morio Nagata	Organic photovoltaic cell, Artificial photosynthesis

Faculty of Science and Technology Department of Electrical Engineering	Associate professor	Junji Kondoh	Photovoltaic power system / Power conditioning system
Faculty of Science and Technology Department of Electrical Engineering	Associate professor	Noboru Katayama	Fuel cells / Hydrogen storage / Diagnosis for energy devices
Faculty of Advanced Engineering Department of Applied Electronics	Associate professor	Takashi Ikuno	Surface and interfaces / Photovoltaic devices / Nanogenerators
Faculty of Science Division II Department of Chemistry	Junior Associate Professor	Tomoyuki Haraguchi	Coordination chemistry / Dye sensitized solar cell
Faculty of Science and Technology Department of Electrical Engineering	Junior Associate Professor	Yuka Takagi	Ferroelectric Materials / Energy Storage, Metamaterials
Faculty of Science Division II Department of Chemistry	Assistant Professor	Daisuke Nakane	Coordination chemistry / Bioinorganic chemistry / Catalytic chemistry
Faculty of Engineering Department of Electrical Engineering	Assistant Professor	Cui Jindan	Photovoltaic system / Energy management system
Faculty of Engineering Department of Architecture	Assistant Professor	Kohei Terashima	Solar heat utilization / Photovoltaic system
Suwa University of Science	Visiting professor	Yoichi Hirata	Photovoltaic power generation system / Wind-power generation / Micro grid
Suwa University of Science	Visiting professor	Yasuyuki Watanabe	Molecular electronics & Bioelectronics / Photosynthetic engineering
Ehime University	Visiting professor	Sho Shirakata	Semiconductor material engineering / Thin film photovoltaic cell, CIGS solar cell
National Institute for Environmental Studies	Visiting researcher	Satoru Ohnishi	Energy economics / Low carbon city management
University of Tsukuba	Visiting researcher	Daisuke Kodaira	Smart grid, energy storage system management, PV generation forecasting
Nagaoka University of Technology	Visiting researcher	Ayaka Kanai	Thin film photovoltaic cell / Optical Properties of Semiconductor

The division's laboratory is located on the 4th floor of Building No. 10 at the Tokyo University of Science's Noda Campus, and has been conducting joint research within the division, focusing on research and development of solar cells and transparent conductive films.

3. Activity Reports

As a center for research and development of renewable energy technologies, the division is generally divided into the "Renewable Energy Materials Group" and the "Energy Management Group" to realize new renewable energy materials and power generation systems through vertical integration of technologies, as well as to educate the next generation of researchers and disseminate the technologies to society.

3. 1. About the Renewable Energy Materials Group

With the goal of developing materials to reduce the cost of installation and operation to the same level as power generation using fossil fuels, the knowledge gained through solar cell research will be used as the basic technology for developing other power generation materials (solar cells, thermoelectric power generation elements, fuel cells, etc.), which will be jointly developed across the division in FY2023. Activities have been carried out by each laboratory to reduce the risk of novel corona infection among faculty and students.

Sugiyama have been working on the development of a device that integrates a hydrogen-generating photoelectrode and a solar cell using $Cu(In,Ga)Se_2$: CIGS compound semiconductor, allowing hydrogen to be produced simply by immersing it in water and exposing it to sunlight without the need for an external power source. He demonstrated that by adding a co-catalyst to the surface of CIGS and adjusting the semiconductor deposition conditions, they could freely control the energy band, contributing to improving the efficiency of hydrogen generation in the photoelectrode. Zhao developed perovskite type active layer for the use in the perovskite solar cells. The optimal design for the active layer was theoretically carried out and synthesized. In the next year, a practice perovskite solar cell will be fabricated. Akitsu et al. continued to study metal complex for biofuel cell cathode materials. Depending on physical properties, azo-Schiff base copper(II) complex may act as an excellent mediator between biofuel cell electrodes and laccase. For example, in the CV experiment results for phosphate buffer solutions containing the complex alone (pH 6.5, 7.5, 8.0), the change in current amount was significant. The arginine moiety of the ligand has a guanidine group that easily protonates under acidic conditions and is sensitive to pH changes. For this reason, it is thought that on the basic side, the amount of current tended to increase, although the change in redox potential was small, due to changes in the molecular structure associated with the elimination of protons. Nagata developed a composite catalyst is synthesized to achieve the gas-phase decomposition of low-concentration hydrogen sulfide under visible light. By combining carbon nitride (g-C_3N_4) with a cadmium sulfide (CdS) photocatalyst, a g-C_3N_4/CdS catalyst is obtained, which reduces 10 ppm H_2S to less than 1 ppm. Ikuno engaged in research aimed at enhancing the output of triboelectric generators, which are anticipated to offer low power generation costs. In this device, which generates electricity through the contact and separation between a polymer film and a metal foil, he dramatically increased the output by controlling the geometric structure of the polymer film. Furthermore, he created an artificial synapse that uses time-series light as input, applying it to physical reservoir computing, a form of non-Von Neumann computing. Haraguchi easily constructed crystal-oriented films of metal-organic complexes (MOFs) using colloidal solutions of metal complex nanosheets for applications such as solar cells, and found that oriented crystalline films could be constructed for various MOFs such as Cu(BDC). Takagi fabricated thick films of ferroelectric composites ($BaTiO_3$ and

polyvinylidene fluoride, PVDF/ poly L-lactic acid, PLLA) for the development of new energy storage devices. The material microstructure morphology was quantitatively characterized by multifractal analysis, revealing the size effect of $BaTiO_3$ particles on the electrical properties. Nakane confirmed the methanol oxidation ability to formaldehyde by dioxygen catalyzed by the Fe(III) complexes synthesized as anodic electrode catalysts for direct methanol fuel cells. He also modified the Fe(III) complexes on platinum and gold substrates and evaluated their electrochemical properties. Furthermore, he investigated the methanol oxidation catalyzed by the Fe(III) complexes under various condition and mentioned their methanol oxidation mechanism. Watanabe fabricated an organic thin-film solar cell (OPV) with an active layer that absorbs near-infrared light to improve the efficiency of OPVs, and in collaboration with the Sugiyama Laboratory, fabricated a translucent organic thin-film solar cell (ST-OPV) using ITiO, a transparent electrode that transmits near-infrared light, as the middle electrode in a tandem device. Furthermore, he developed a system that can simultaneously measure the power generation characteristics of OPVs at multiple points when installed in farmland, and designed a circuit that can drive a temperature/humidity sensor using the power generated by the OPVs. Shirakata initiated the establishment of a deposition apparatus and evaluation equipment for heterogeneous semiconductor films aimed at solar cell material research in the upcoming fiscal year and beyond. Kanai prepared Cu_2SnS_3 (CTS) and $Cu_2Sn_{1-x}Ge_xS_3$ (CTGS) solar cells as a next-generation light-absorbing material under different conditions. The electrical properties of the CTS and CTGS solar cells are evaluated at various temperatures to investigate the changes in leakage current and interface defects in the device structure. As a result, the efficiency of CTGS solar cells dramatically improved by suppressing the interface defects and reducing the leakage current in the cells through the sulfurization process by facing tin sulfide powder during growth in thin films.

3. 2. About the Energy Management Group

Based on the plan to jointly develop technologies to utilize power obtained by various power generation methods without waste, such as the development of highly efficient management technologies for power obtained by various power generation methods, grid interconnection, fault diagnosis technologies, and optimization using AI, across the division, in FY2023. Each laboratory has been working on its own activities for this purpose.

Ueda is participating in a NEDO project that started in FY2021 to develop technology to create raising adjustment power by systematically suppressing and controlling power generation at solar power plants. He is developing a planning method for imbalance control based on the creation of tertiary adjustment power (2) by forecasting the next day's power generation and spot market prices, and securing two sources of boosting capacity: one to accommodate forecast errors and the other for suppression for boosting adjustment power. Kondoh proposed autonomous control of load power consumption based on rate of change of frequency df/dt as a countermeasure to the problem of increased fluctuations in system frequency f due to the reduction of the system inertia caused by the installation of large amounts of photovoltaic and wind power generation, and showed that the system inertia can be increased in a pseudo manner. Katayama developed a large-scale data measurement system for analyzing the impedance characteristics of lithium-ion batteries using machine learning. This system can simultaneously perform charging, discharging, and impedance measurements on multiple lithium-ion batteries, and is designed to be easily scalable. Cui developed an algorithm to secure the headroom to absorb the forecast error for the generation of photovoltaic adjustment power for a photovoltaic power plant that does not take into account the installation of storage batteries. A statistical model based on historical data, a machine learning Support Vector Regulation (SVR) model, and a combined model of these two models were created, and an imbalance evaluation of each model was conducted. She also examined the VI-SVR model by changing the initial values, analyzed the importance of each predictor, and updated the

model. Terashima designed a PV/T solar panel system that combines a PV module and a solar heat collector. A system with an ejector refrigeration cycle that can use collected hot water for cooling in summer and a system with PV/T solar panels installed in a house with a large heat storage capacity were studied, respectively, and their energy-saving effects were clarified. Hirata conducted a simulation of power interchange and showed that by sharing power between the storage batteries of two houses, it is possible to keep the SoC of the storage batteries within a moderately effective range. Ohnishi conducted environmental, economic, and social assessments for biomass utilization in Mishima-cho, Fukushima Prefecture, as well as surveyed and analyzed the current state of industrial clusters in Hamadori, Fukushima Prefecture, and designed a heat and electricity supply system using renewable energy. A model was constructed to estimate the utility facilities and energy consumption patterns of new factories, and a design method for a biomass utilization system that balances supply and demand was developed. Kodaira constructed a demonstration facility for a battery storage control algorithm using deep reinforcement learning. A system that acquires meteorological information from Tsukuba University in real-time and performs power generation forecasting was established. Furthermore, for the demonstration of deep reinforcement learning, a demonstration system that can remotely control home batteries via the cloud was constructed through joint research with the University of Tokyo's Institute of Industrial Science.

4. Challenges and Prospects

The objectives of this research division are (i) development of materials to reduce the cost of installation and operation to the same level as power generation using fossil fuels, (ii) development of high-efficiency management technology for electricity obtained from various power generation methods, and (iii) development of new materials and system technology. Continue to promote research and development of renewable energy technologies by leveraging synergies from the vertical integration of technologies, with a focus on (i) the development of high-efficiency management technologies for electricity generated by various power generation methods, and (ii) the development of new material and system technologies. We will activate joint research within the division and create novel concepts for future renewable energy technologies by creating technology roadmaps and other means. Continue to hold symposiums and participate in exhibitions to promote the division's research results to society and exchange technical information on renewable energy for the benefit of future research. In addition, strengthen cooperation among students and create an environment for the promotion of joint research.

5. Conclusion

While renewable energy is environmentally friendly, it has serious infrastructure issues such as unstable power supply and high installation and running costs. This research division is actively promoting the development of fusion research fields, devices, and processes through the active exchange of researchers with different areas of expertise, proposing a foundation for stable and low-cost power supply, and activating and promoting the research and development of renewable energy utilization technology at Tokyo University of Science. We would like to promote Tokyo University of Science as a center for research and development of renewable energy technologies by proposing the foundation for stable and low-cost power supply.

Major Research Achievements (FY 2023)

Academic Papers

1. Effect of monolithic photovoltaic photoelectrochemical integrated Cu(In, Ga)Se$_2$ related co planar device on water splitting reaction, K. Ueda and <u>M. Sugiyama</u>: Japanese Journal of Applied Physics, 63 (2024) 011005 (Peer-reviewed)

2. Effect of the energy band bending on surface by Cu-poor layer of Cu(In, Ga)Se$_2$-related photoelectrode for water splitting, K. Ueda and <u>M. Sugiyama</u>, Journal of Physics D: Applied Physics, 57 (2024) 135103 (Peer-reviewed)

3. Synthesis and characterization of a novel oxovanadium complex and stability of azo groups in the presence of laccase, N. Katsuumi, R. Miyazaki, D. Nakane, M. Azam, <u>T. Akitsu</u>, J. Mol. Struct., 1285 (2023) 135465 (Peer-reviewed)

4. Catalytic Oxidation of Methanol to Formaldehyde Catalyzed by Iron Complex with N3S3-type Tripodal Ligand, Masaki Kubo, <u>Daisuke Nakane</u>, Yasuhiro Funahashi, Tomohiro Ozawa, Tomohiko Inomata, Hideki Masuda, Chemistry A European Jounal, 2024 (2024) e202303955 (Peer-reviewed)

5. Synthesis and Conductivity Characterization of Anti-Perovskite Na3OX Solid Electrolytes for All Solid Na-Ion Batteries, Wei Shi, Masataka Ohta, Hiroaki Asakawa, Yuki Osaki1, Mariko Murayama, Xinwei Zhao, Optics and Photonics Journal, 13 (2023) 189 (Peer-reviewed)

6. Annealing Temperature-Dependent Luminescence Color Coordination in Eu-Doped AlN Thin Films, Yingda Qian, Mariko Murayama, Sujun Guan, Xinwei Zhao, Journal of Materials Science and Chemical Engineering, 2024 (2024) 12 (Peer-reviewed)

7. Effect of the thicknesses of asymmetric TiO2/polydimethylsiloxane films on the triboelectric output power, Qingyang Zhou and Takashi Ikuno, Jpn. J. Appl. Phys.,63 (2024) 01SP01 (Peer-reviewed)

8. Disposable and Flexible Paper-Based Optoelectronic Synaptic Devices for Physical Reservoir Computing, Hiroaki Komatsu, Norika Hosoda, Toshiya Kounoue, Kazuyasu Tokiwa, and Takashi Ikuno, Adv. Electron. Mater. (2024) 2300749 (Peer-reviewed)

9. A hybrid of iterative Gauss–Newton and one-dimensional convolutional neural network for high-resolution electrical impedance tomography, Keiya Minakawa, Keigo Ohta, Hiroaki Komatsu, Tomoko Fukuyama, Takashi Ikuno, AIP Advances 14 (2024) 015210 (Peer-reviewed)

10. Optimization Bidding Strategy on Day Ahead and Balancing Market of PV Generator Considering Battery Integration, Bo Jie, Jindan Cui, Xue Fang, Takashi Oozeki, Yuzuru Ueda, IEEJ Transactions on Electrical and Electronic Engineering, 18 (2023) 1983 (Peer-reviewed)

11. Absorption of PV Power Prediction Errors with Headroom Control by Statistical, Machine Learning and Combined Models, Jindan Cui, Bo Jie, Xue Fang, Takashi Oozeki, Yuzuru Ueda, IEEJ Transactions on Electrical and Electronic Engineering, 19 (2023) 200 (Peer-reviewed)

12. Visible-Light-Driven Gas-Phase Hydrogen Sulfide Decomposition using Organic–Inorganic Hybrid Photocatalysts, Tomofumi Katayama, Morio Nagata, ChemistrySelect, 8 (2023) e202302709 (Peer-reviewed)

13. Influence of Sacrificial Reagents on the Photodeposition Reaction of Cocatalysts, Ayako Inaguma, Haruki Nagakawa, Sora Kamata, Morio Nagata, Advanced Energy and Sustainability Research, (2024) 2300295 (Peer-reviewed)

14. Validity of wind power for heavy winter demand in eastern Japan power systems, J. Kondoh, Frontiers in Energy Research, 11 (2023) 1185961 (Peer-reviewed)

15. Low-temperature sintering mechanism and electrical properties of CuO-added $(Bi_{0.5}Na_{0.5})TiO_3$ ceramics, Kota Ojima, Kanaka Iwasaki, Seiji Harada, Yuka Takagi and Hajime Nagata, Journal of the Ceramic Society of Japan, 131 (2023) 209 (Peer-reviewed)

16. Reactivity and electrical properties of (Bi0.5Na0.5)TiO3 ceramics fabricated by hydrothermal synthesis using Bi and Ti oxides, Seiji Harada, Yuka Takagi, Hajime Nagata, Journal of the Ceramic Society of Japan, 131 (2023) 202 (Peer-reviewed)

17. PV/T solar panel for supplying residential demands of heating/cooling and hot water with a lower environmental thermal load, Kohei Terashima, Haruki Sato, Toshiharu Ikaga, Energy and Buildings, 297 (2023) 113408 (Peer-reviewed)

18. Solar radiation intensity characteristics and temperature characteristics of red fluorescent sheets, Koji Mizuno, Yoichi Hirata, 2024 National Conference of the Institute of Electrical Engineers of Japan.

19. System design considering BMS power consumption in microgrid control, Sota Mineshita, Noboru Ando, Yoichi Hirata, 2024 IEEJ National Conference

20. Green-light wavelength-selective organic solar cells for agrivoltaics: dependence of wavelength on photosynthetic rate, Seihou Jinnai, Naoto Shimohara, Kazunori Ishikawa, Kento Hama, Yohei Iimuro, Takashi Washio, Yasuyuki Watanabe and Yutaka Ie, Faraday Discuss 250 (2024) 220 (Peer-reviewed)

21. Photoluminescence properties of Cu-poor Cu2Sn1-xGexS3 thin films with varying Ge/(Ge+Sn) ratio, Ayaka Kanai, Ryoma Hata, Mutsumi Sugiyama, Kunihiko Tanaka, Journal of Physics D: Applied Physics 56 (2023) 265102 (Peer-reviewed)

22. Influence of (NH2)2CS concentration during depositing CdS layer on electric properties of Cu2SnS3 solar cell, Ayaka Kanai, Soichiro Saito, Araki Hideaki, and Kunihiko Tanaka, Journal of Physics D: Applied Physics 57 (2024) 025502 (Peer-reviewed)

23. Effects of the growth process on surface morphology of Cu2(Sn1−xGex)S3 thin films, Ayaka Kanai, Rei Ohashi, Kunihiko Tanaka, Hideaki Araki, Mutsumi Sugiyama, Journal of Materials Science: Materials in Electronics 35 (2024) 526 (Peer-reviewed)

24. Life cycle environmental and economic assessment of Tetra Pak recycling technologies, Dong H., Yu F., Bi Z., Zhang C., Liu X., Geng Y., Ohnishi S., Li H. Resources, Conservation and Recycling, 202 (2024) 107355 (Peer-reviewed)

25. Optimal Control of Battery System by Reinforcement Learning Considering Profitability, T. Goto and D. Kodaira, in International Conference on Power and Renewable Energy Engineering (PREE), 2023

26. Development of an efficient vehicle-to-grid method for massive electric vehicle aggregation, M. Seo, D. Kodaira, Y. Jin, H. Son, and S. Han, Energy Rep., 11 (2024) 1659 (Peer-reviewed)

27. Design and implementation of power management system integrated with cooperative systems for an apartment building, M. Cho, H. Aki, and D. Kodaira, Journal of Building Engineering, (2023) 106809. (Peer-reviewed)

Books

1. SDGs Foundation of Inorganic Chemistry, Kiyoshi Isobe, Keisuke Umakoshi, Masako Kato, Isamu Kinoshita, Akira Kinoshita, Makoto Tadokoro, Ho-CHOL Chang, Hidetaka Nakai, Hiroshi Nishihara, Akihiro Nomoto, Masaaki Haga, Hideki Hashimoto, Tomoyuki Haraguchi, Yutaka Hitomi, Shou Fujii, Miho Yamauchi, Mihoko Yamada, Takeshi Yamamura, Shigenobu Yano, Baifukan, 2023

2. Formation of multi-walled carbon nanotube wirings on polypropylene plastic films at room temperature under atmospheric pressure, Takashi Ikuno, Kinozairyo, Jan. 2024

Invited Lectures

1. Fabrication of visible-light-transparent devices using NiO thin films, <u>Mutsumi Sugiyama</u>, TACT2023 International Thin Films Conference, National Taipei University of Technology, Taipei, Taiwan, Nov.12–15, (2023), A-I-66 (Invited oral)

2. Coordination and photoisomerizaiton of azobenzene-amino acid Schiff base Cu(II) complexes binding to lysozyme, <u>Takashiro Akitsu</u>, The 8th Int'l Conference on Physical Chemistry (CPC 2023), Kunming, China, April 21, 2023, Online

3. Optoelectronic physical reservoir devices based on nanocomposite films, <u>Takashi Ikuno</u>, 36th International Microprocesses and Nanotechnology Conference (MNC 2023), Sapporo, November 17th, 2023

4. Development of dye-sensitized solar cells using upconversion, <u>Morio Nagata</u>, CSJ Chemistry Festa2023, 2023/10/17

5. Study on New Material Design of Bismuth-Based Ferroelectric Ceramics by Quenching Effect, <u>Yuka Takagi</u>, Annual Meeting 2024 The Ceramic Society of Japan, Kumamoto University Kurokami Campus, 2024/03/16

6. Solar Matching Technology that Combines Photosynthesis and Photovoltaics, <u>Yasuyuki Watanabe</u>, Maywa Forsyth K.K., Seminar (ZOOM), June 6, 2023

7. Development of wavelength-selective organic solar cells for agricultural greenhouse applications that transmit light necessary for photosynthesis, <u>Yasuyuki Watanabe</u>, JST "Solving Emerging Social Issues" Area Event: University Trade Fair 2023 - Innovation Japan Seminar "The Challenge to Solve Changing Social Issues: Looking to the Future of Food, Energy and Ecosystem Services Challenges to Solve Changing Social Issues: Looking to the Future of Food, Energy, and Ecosystem Services, Tokyo Big Sight, August 24, 2023

8. Deposition Technology of Active Layer by Charged Droplet and Device Characteristics of Organic Thin Film Solar Cells, Masayuki Egashira and <u>Yasuyuki Watanabe</u>, 2023 IEEJ Basic, Material and Common Division Meeting, Aichi Institute of Technology, September 7, 2023

9. Farming Photovoltaic Power Generation using Organic Photovoltaic Cells as Shading Films, <u>Yasuyuki Watanabe</u>, Women in Photovoltaics subcommittee meeting (WinPVJ) Tour of Agricultural PV Facilities in Shizuoka Prefecture and the 1st Workshop in FY2023, Workopia Iwata, The Photovoltaic Society of Japan, Oct. 2, 2023

10. Current Status and Issues of Compatibility of Power Generation and Agriculture by Organic Photovoltaic Cells, <u>Yasuyuki Watanabe</u>, KISTEC Innovation Hub 2023 Solar Cell Forum, Kanagawa Science Park, November 16, 2023

11. Organic thin-film solar cells transmitting light necessary for crop cultivation, <u>Yasuyuki Watanabe</u>, 5th Frontier Solar Cells Seminar, Takeo City Cultural Hall (Takeo City, Saga Prefecture), December 14, 2023

12. Solving the Problem of Farming Photovoltaics! Eco-Design Photovoltaic Technology in Harmony with the Landscape, <u>Yasuyuki Watanabe</u>, Haramura Environmental Study Meeting, Haramura Central Community Center Auditorium, January 16, 2024

13. Solar Matching Technology for Crop Cultivation and Photovoltaic Power Generation by Organic Thin Film Solar Cells Utilizing Shading Property, <u>Yasuyuki Watanabe</u>, 2023 Nagano Prefecture Farm Managers Association Family Exchange Seminar, Hotel RACO Hananoi, February 7, 2024

14. Development of Light Transmitting Organic Photovoltaic Cells for Compatible Photovoltaic Generation and Photosynthesis, <u>Yasuyuki Watanabe</u>, Academia Composition Symposium of Nagoya University Future Society Creation Organization Project, Nagoya University, February 16, 2024

15. Current status of earth abundant Cu2SnS3-based materials for next-generation solar cells, A. Kanai, T. Tosuke, M. Sugiyama, H. Araki and K. Tanaka, The 29th International Society of Functional Thin Film Materials & Devices (AM-FPD23), Kyoto, Japan, Jul. 4-7 (2023)

16. Evaluation of light-absorbing layer materials in copper sulfide solar cell by observation of optical properties, K. Tanaka, A. Kanai, H. Araki, M. Sugiyama; The 71st The Japan Society of Applied Physics Spring Meeting 2024, Tokyo City University, 2024/03/22.

17. The 2023 Ulsan International Symposium for Carbon Neutrality, Carbon Neutrality Strategy of Fukushima Prefecture by innovative urban symbiosis, Satoshi Ohnishi, Ulsan Korea, 2023/11/23.

Awards

1. <u>Ayaka Kanai</u>, Ozawa・Yoshikawa memorial award, "Improving the efficiency of next-generation environmentally Cu2SnS3 solar cells using a liquid-phase growth method", Ozawa-Yoshikawa Electronics Research Grants, (April 2023)

2. <u>Kohei Terashima</u>, Haruki Sato, Oshida Award: Japan Solar Energy Society, "Proposal of net-zero energy house by introducing environmentally friendly PV/T solar panels", (May 2023)

3. Rintaro Yamanaka, Noboru Katayama, Isao Yondenda, and Koya Yokoi, YPC Encouragement Award: "Analysis of the DC Model and Optimization of Electrode Shape for Paper-Based Lactic Acid Biofuel Cells," Proceedings of the Institute of Electrical Engineers of Japan Conference on Power and Energy, (September 2023)

4. Qiyuan Zhang, <u>Tomoyuki Haraguchi</u>, Best Poster Award: The 18th International Conference on Molecule-Based Magnets – ICMM2023, "Fabrication of Oriented Crystalline Pillared-Layer-Type MOF Thin Film by the Casting Method and Evaluation of The Spin-Crossover Behavior. (September 2023)

5. Mayu Okajima, Hina Nakagawa, <u>Mutsumi Sugiyama</u>, Best poster presentation award: The meeting of Japansese Sciety of Agricultural, Biological and Enviromental Engneers and Science 2023 Toyohashi, "Analysis of Cultivation Environment Response Using Electrochemical Impedance Spectroscopy on Leaf Surfaces for Direct Plant Monitoring", (September 2023)

6. Keigo Ota, Keiya Minakawa, <u>Takashi Ikuno</u>, Outstanding Poster Presentation Paper Award: Japan AEM Society, "Development of Post-Processing for High-Resolution Electrical Impedance Tomography" (November 2023)

7. <u>Yuka Takagi</u>, CerSJ Awards for advancements in ceramic science and technology: "Study on New Material Design of Bismuth-Based Ferroelectric Ceramics by Quenching Effect" (November 2023)

8. Taisei Hattori, Takuto Maeda, <u>Mutsumi Sugiyama</u>, 22nd The Japan Society of Applied Physics Poster Award: The 84th JSAP Autumn Meeting, "Investigation of flexible CO_2 gas sensors based on transfer of SnO2 thin film with NaCl sacrificial layer" (November 2023)

Individual Research Topics

Mutsumi Sugiyama

"Research on realization of hydrogen generation Device using Cu(In,Ga)Se$_2$ compound semiconductors"

    The study focused on developing thin-film devices capable of generating hydrogen by immersing them in water and exposing them to sunlight, without the need for an external power source. This was achieved by monolithically integrating a photoelectrode for hydrogen generation and a solar cell using Cu(In,Ga)Se$_2$:CIGS compound semiconductor. By adjusting the deposition conditions of the CIGS semiconductor with high light absorption coefficient, we were able to control the energyband. Additionally, it was revealed that adding a co-catalyst to the CIGS surface to suppress defects contributes to improving the hydrogen generation efficiency of the photoelectrode.

Zhao Xinwei

"Research on perovskite solar cells"

    In this year, we theoretically designed the active layer which coveing to the visible wavelength region and has a band gap energy of 2 to 3 eV. The thin films having these narrow band gaps were also fabricated and demonstrated. Our results have been submitted to journal and was under the reviewing process. eveloped perovskite type active layer for the use in the perovskite solar cells. In the next year, a practice perovskite solar cell will be fabricated.

Takashiro Akitsu

"Hybrid material of laccase and chiral azo-amino acid Schiff base copper complexes"

    Laccase is an enzyme that catalyzes the four-electron reduction of oxygen to water. Taking advantage of this property, laccase is used as a cathode catalyst in enzymatic biofuel cells. Azo-Schiff base copper(II) serves as an excellent mediator between biofuel cell electrodes and laccase. Azobenzene is known as the most commonly used optical switch because of its high quantum yield, stability, and easy synthesis of derivatives. We newly synthesized an amino acid derivative Schiff base copper(II) complex containing an azobenzene moiety, and investigated the pH and temperature dependence of cis-trans photoisomerization and redox potential while comparing it with the amino acid derivative complex serving as a mediator.

Yuzuru Ueda

"Research on photovoltaic power generation systems"

    In FY2023, we are developing technology to predict and evaluate the amount of electricity generated by photovoltaic power plants, and developing a system for energy management using photovoltaic power generation systems as distributed power sources on the customer side. In FY2023, we are participating in a NEDO project to develop technology to predict and evaluate the amount of electricity generated by photovoltaic power plants, and to research operational methods to create a regulating power in addition to the amount of electricity generated.

Morio Nagata

"Research on organic solar cells and artificial photosynthesis"

A composite catalyst is synthesized to achieve the gas-phase decomposition of low-concentration hydrogen sulfide under visible light. By combining carbon nitride (g-C_3N_4) with a cadmium sulfide (CdS) photocatalyst, a g-C_3N_4/CdS catalyst is obtained, which reduces 10 ppm H_2S to less than 1 ppm. In addition, the other paper on Influence of Sacrificial Reagents on the Photodeposition Reaction of Cocatalysts was selected for the Front Cover of the Journal of Wiley.

Junji Kondoh

"Pseudo increase of system inertia by autonomous load control"

In power systems where large amounts of solar and wind power generation have been introduced, the proportion of interconnected synchronous generators decreases, resulting in a decrease in inertia and an increase in fluctuations in the system frequency f. As a countermeasure to this problem, it was proposed to artificially increase system inertia by performing autonomous control of load power consumption based on df/dt. Experiments in a small-scale isolated power system using a 5kW engine generator and resistive loads (including autonomously controlled loads) showed that the frequency fluctuation characteristics were similar with the system that had large inertia.

Noboru Katayama

"Application of machine learning to energy technologies"

Research is being conducted on methods that combine impedance spectroscopy and machine learning, as well as on energy management using reinforcement learning. The use of electrochemical impedance spectroscopy has been challenging for state estimation in actual use environments due to its significant dependence on the measurement environment and the need to construct equivalent circuit models specific to the device. Currently, successful simultaneous measurement of temperature and charge capacity of lithium-ion batteries has been achieved. Additionally, successful control in simulations using reinforcement learning for energy management has been accomplished, and currently, practical tests with actual equipment are being advanced.

Takashi Ikuno

"Research on low-cost vibrational power generation devices and artificial photoelectronic synaptic devices"

Research and development have been conducted on triboelectric generators that generate electricity through the contact, separation, or friction of dissimilar materials. By incorporating high-dielectric particles into the polymer film used in triboelectric devices and controlling the film's geometric structure, a significant improvement in output voltage was achieved. Future efforts will focus on enhancing the surface charge density of the polymer to further improve output. In addition, a polymer film embedded with a semiconductor particle array was created to realize an artificial optoelectronic synaptic device that mimics the brain and eyes. This device, responsive to time-series light inputs, has been demonstrated to recognize handwritten digits with approximately 90% accuracy. Future plans include device design aimed at integration with renewable energy systems.

Tomoyuki Haraguchi

"Construction of printable oriented crystalline metal-organic framework thin films"

We have investigated the application of metal-organic frameworks (MOFs) to dye-sensitized solar cells, etc. We found that various MOFs such as Cu(BDC) can be used to construct oriented crystalline films. In the future, we will control the structure and HOMO/LUMO energy levels hierarchically by changing the components, and aim to create dye-sensitized solar cells that absorb light at a wide range of wavelengths and transport electrons with high efficiency.

Yuka Takagi

"Morphology of material organization and electrical properties in ceramic filler/ferroelectric polymer composites"

For the development of new energy storage devices, we fabricated thick films of ferroelectric composites ($BaTiO_3$ and polyvinylidene fluoride/poly-L-lactic acid) composed of ceramic filler and polymer matrix, and examined quantitative evaluation of their morphology of material organization by multifractal analysis. As a result, we found the size effects of $BaTiO_3$ particles on the electrical properties. This year, I have set up my own laboratory and am gradually preparing my experimental environment.

Daisuke Nakane

"Development of Fe(III) complex catalysts for anodic electrode of direct methanol fuel cell"

Novel molecular catalysts composed of inexpensive iron ions as catalysts for anodic electrode of direct methanol fuel cells were synthesized and their various spectroscopic properties were clarified. The electrochemical properties of these Fe(III) complexes suggest that they have sufficient catalytic ability for methanol oxidation. The reactions between the Fe(III) complexes and methanol under an oxygen atmosphere at room temperature revealed that these Fe(III) complexes catalyzed methanol oxidation by the oxidizing power of dioxygen, as in the methanol fuel cell. Furthermore, we succeeded in modifying these Fe(III) complexes on a platinum and gold substrates.

Cui Jindan

"Headroom control for generating regulating power from photovoltaic power generation"

The promotion of photovoltaic power generation, which is greatly affected by weather conditions, requires the securing of regulating power. In addition, the expansion of photovoltaic power generation is expected to lower the market price of electricity during the daytime, and selling electricity only to the spot market is not profitable. Based on these two points, we studied headroom control to create ΔkW value in addition to the energy (kWh) value of photovoltaic power generation. We developed an algorithm that solves the problem in two stages: the problem of absorbing the error in the generation forecast and the problem of ratio of the forecasted values to the two markets. For the forecast error absorption problem, a simple statistical model and a machine learning model were studied, and for the plan value ratio problem, a model using linear programming was studied to maximize the profit.

Kohei Terashima

"Research on PV/T solar panel systems"

A system using a PV/T solar panel which combines a PV module and a solar heat collector was designed. This year, a system with an ejector refrigeration cycle which converts hot water into cold water was studied, and the energy saving effect when using the collected heat for cooling in summer was clarified. In addition, when the PV/T solar panels were installed in a house with a large heat storage capacity, it was found that the room temperature could be controlled within a comfortable temperature range during winter using only the collected hot water, with little use of auxiliary heat sources.

Yoichi Hirata

"Creation and testing of software simulation for power interchange in DC microgrid systems"

Assuming two DC microgrids, we established a simulation system in which when one storage battery is insufficient, power is transferred from the other storage battery. By doing so, we confirmed that the period during which the storage battery's SoC can be kept within a certain range can be extended.

Yasuyuki Watanabe

"Investigation of tandem organic photovoltaics with transparent oxide electrodes"

It is known that tandem solar cells can achieve higher conversion efficiency than single solar cells due to the broadening of the light absorption wavelength. In this study, we investigated a two-terminal tandem-type organic photovoltaics using ItiO as the photosensitive electrode and the middle electrode. The use of ItiO, which has superior transmittance in the long-wavelength region compared to ITO, enables the use of near-infrared light for power generation, confirming the superiority of ItiO and the improvement of PCE by tandem operation.

Sho Shirakata

"Research on narrow-gap chalcopyrite semiconductors"

The growth of bulk single crystals and thin films of complex semiconductor materials, which are candidates for new thin-film solar cells, is conducted. Measurements of their basic properties, including crystal structure, bandgap, absorption coefficient, and Raman scattering, are performed. Based on these measurements, a comparison of the characteristics of bulk and polycrystalline materials is conducted. In the fiscal year 2023, the relocation and launch of the deposition and evaluation equipment mentioned above were carried out. In the future, deposition and evaluation of various semiconductor materials are planned.

Satoru Ohnishi

"Design and evaluation for appropriate introduction of renewable energy to the industrial sector, mainly through biomass heat utilization"

The appropriate introduction of renewable energy into the industrial sector, mainly through biomass heat utilization, is an important issue for realizing regionally driven decarbonization. We will support actual community development by developing a system of public-private-academic collaboration to create a vision and business model for the introduction of renewable energy with a view to regional planning and social implementation in industrial cities, mountainous areas, and earthquake recovery areas, and by setting up and evaluating the system according to regional characteristics.

Ayaka Kanai

"Next-generation CTS-based solar cells combining low cost, non-toxicity, and high efficiency"

   To realize the next generation of Cu_2SnS_3 (CTS)-based solar cells, which are inexpensive, non-toxic, and highly efficient, the optimization of the growth methods of CTS and $Cu_2Sn_{1-x}Ge_xS_3$ (CTGS) thin films was investigated last year. This year, the electrical properties of fabricated CTS and CTGS solar cells will be studied in detail by *J-V* and *C-V* measurements. In addition, issues in the solar cells (e.g., information on interface defects, bulk defects, band offsets, etc.) will be discussed, and a guideline for improving the efficiency of CTS-based solar cells will be established.

Daisuke Kodaira

"Automatic control of battery charging and discharging via cloud based on deep reinforcement learning"

   In this research project, the constructed control algorithm for the battery decides the control amount for the next day in advance, based on the predicted values of the next day's PV generation and electricity prices. This fiscal year, we constructed a system for remotely operating actual household batteries. Although the communication standards for household batteries comply with specifications such as ECHONET Lite, the actual operation varies among individual manufacturers. Therefore, it is necessary to sequentially check the operation during operation. As a specific example, after sending a charge operation command from a PC terminal to the battery's communication gateway, it is necessary to confirm whether the battery is actually performing the charging operation. This fiscal year, we signed a joint research agreement with the University of Tokyo's Institute of Industrial Science and constructed a system to monitor the difference between command signals from the terminal and the actual operations via the cloud.

Division of Implementation of Sustainable Technology in Society

Division of Implementation of Sustainable Technology in Society

1. Overview

In order to realize a sustainable society, it is important to maintain a balance in all aspects—economic, social, and environmental—that will allow people to continue to prosper from the present to the future. This involves considering various factors, including resource and energy conservation, technological development, and social structural reforms. This division aims to converge the collective wisdom of all members to provide not only ideas but also real products of practical technology to realize a sustainable society, especially in the fields of medical welfare, agriculture, civil engineering, production, industry, and resources and energy, which are directly related to our daily lives. To this end, we will create opportunities to develop new markets through the prototyping of innovative integrated systems, their verification and durability testing, and their commercialization and marketing. We emphasize practicality and application beyond just publishing papers, encouraging startup entrepreneurship, patent applications, and product launches, which will lead to further development.

2. Organization and Facilities

This division is currently composed of one director and 23 researchers as shown in Table 1. Members include faculty staff from Tokyo University of Science (TUS) and participants from external institutions, covering a wide range of specialties and backgrounds.

Table 1. List of division members

[Director] 　Faculty of Engineering, TUS	Prof.	Hiroshi Kobayashi
[Vice director] 　Faculty of Engineering, TUS	Assoc. Prof.	Takuya Hashimoto
[Researcher] 　Faculty of Engineering, TUS	Prof.	Masayoshi Wada
Faculty of Advanced Engineering, TUS	Prof.	Taketoshi Mori
Faculty of Advanced Engineering, TUS	Prof.	Eiichi Yoshida
Faculty of Advanced Engineering, TUS	Prof.	Yoshio Matsumoto
Faculty of Engineering, TUS	Prof.	Kuniharu Ushijima
Faculty of Science and Technology, TUS	Prof.	Hiroshi Takemura
Faculty of Engineering, TUS	Assoc. Prof.	Ryuzo Hayashi
Faculty of Advanced Engineering, TUS	Assoc. Prof.	Hiroaki Hobara
Faculty of Engineering, TUS	Assoc. Prof.	Takuya Hashimoto
Faculty of Science and Technology, TUS	Assoc. Prof.	Shogo Arai
Research Institute for Science & Technology, TUS	Assoc. Prof.	Tomohiko Hayakawa
Research Institute for Science & Technology, TUS	Jr. Assoc. Prof.	Huang Shouren
Research Institute for Science & Technology, TUS	Jr. Assoc. Prof.	Leo Miyashita
Faculty of Engineering, TUS	Assist. Prof.	Kenta Matsumoto
Faculty of Engineering, TUS	Assist. Prof.	Kenta Nagano
Research Institute for Science & Technology, TUS	Assist. Prof.	Satoshi Tabata
Faculty of Advanced Engineering, TUS	Assist. Prof.	Akishige Yuguchi
Faculty of Advanced Engineering, TUS	Assist. Prof.	Tomoya Sasaki
Faculty of Advanced Engineering, TUS	Assist. Prof.	Sooin Kang
Azalee Group, Kokujukai – A Social Welfare Co.	Executive Director (Ph.D., M.D.)	Koji Kurusu
Mito Clinical Education and Training Center, University of Tsukuba Hospital	Prof.	Shuji Matsumoto
Cambridge University	Prof.	Fumiya Iida

Table 2 shows the elemental technologies possessed by each researcher and their specific applications. In this way, we encourage active collaboration with other institutions to promote cooperative research and development with a focus on specific applications as outcomes.

Table 2. Organization for collaborative research and development

Application \ Technology	Medical & Welfare	Life Support	Agriculture	Civil & Production & Industrial	Resource & Energy
	Rehabilitation equipment / Diagnostic equipment / Pathology equipment / Welfare vehicles / Physical support	Physical support / Monitoring / Autonomous driving / Sports	Physical support / Automatic cultivation and harvesting / Genetic modification	Physical support / Digital fabrication / Laboratory automation / Recycling	Binary power generation
Mobility / Vehicle	Kobayashi, Hashimoto, Takemura, Iida, Wada, Kurusu, Matsumoto, Kasai	Hayashi, Wada	Kobayashi, Iida, Arai	Arai	
Mechanism / Device	Kobayashi, Hashimoto, Takemura, Iida, Arai, Hobara, Hayakawa, Kasai	Kobayashi, Hashimoto, Takemura, Matsumoto, Iida, Wada, Nagano, Hobara, Kurusu, Matsumoto	Kobayashi, Takemura, Iida, Arai, Hobara	Kobayashi, Hashimoto, Arai	Kobayashi
Image & Signal Processing	Kobayashi, Takemura, Ushijima, Iida, Wada	Hashimoto, Takemura, Hayashi, Matsumoto, Arai, Hobara, Miyashita, Tabata	Takemura, Iida, Arai, Hobara	Takemura, Iida, Arai, Hobara	Arai
Analysis / Control	Yoshida, Iida, Arai	Kobayashi, Hashimoto, Takemura, Hayashi, Matsumoto, Wada, Nagano	Iida, Arai	Hashimoto, Yoshida, Ushijima, Iida, Arai	Ushijima, Arai

3. Activity Reports

We have been able to establish one startup company (CoreHealth Inc.), launch 2 products, and 5 patent applications or registrations. Additionally, a commissioned project by NEDO (New Energy and Industrial Technology Development Organization) has started, with some members of this division participating. The following reports on the overview of this NEDO project, its achievements, and activities of the entire division including seminars and tours, in FY2023.

3. 1. NEDO Project Research Group

Within the NEDO's commissioned project "Development of Basic Technology to Process E-Waste for an Advanced Resource Circulation System", we are working on a research topic titled "Development of Advanced Resource Recycling Process Technology – (1) Development of Product Disassembly System." Specifically, we are tackling the challenge of developing an autonomous sorting system that segregates hazardous materials (such as oil, flammable gases, and lithium-ion battery-powered devices) from the stockyard of small home electronics located outside the recycling plant (Fig. 1). For this purpose, we have organized small teams for development task: (1) a target location detection system, (2) an omnidirectional vehicle development and control system, (3) a small appliance pickup mechanism, (4) a small appliance identification and classification system, and (5) a power cable cutting mechanism. Each team conducts prototyping and holds a debriefing session every two weeks.

3. 2. Activities of the Division
    (1) Research seminar 1 (Fig. 2)

        Date: August 24, 2024, 13:00-14:00

        Location: Room #103 in Lecture Bldg. at Katsushika Campus

        Lecturer: Fumiya Iida (Cambridge University)

        Title: Advanced Scientific Communication

    (2) Research seminar 2 (Fig. 3)

        Date: January 20, 2024 (Saturday), 9:00-10:30

        Location: Conference Room at Atagawa Prince Hotel

        Lecturer: Toshiaki Tsuji (Saitama University)

        Title: Force Control and Machine Learning for Contact-Rich Tasks

    (3) Tour of binary power generation & posture correction using Muscle Suits® (Fig. 4)

        Dates: January 19, 2024 (Friday), 15:30-17:30 and January 20, 2024 (Saturday), 10:30-12:30

        Location: Atagawa Prince Hotel

        Description: As part of the efforts to commercialize the division's research outcome, we toured the binary power generation facility using the Atagawa hot spring as a heat source (Fig. 4) and checked the progress. Additionally, we conducted a posture correction experience using Muscle Suits® as a new application.

| **Fig. 2** | **Fig. 3** | **Fig. 4** |

4. Challenges and Prospects

Despite achieving some synergistic collaboration, our department has faced challenges in fully utilizing the diverse potential of our members due to a lack of joint projects. Future plans include increasing opportunities for interaction and communication among researchers and applying for large grants to enhance synergistic research and development.

Additionally, we are committed to not only advancing research but also to the commercialization of research outcomes. In the future, we will continue to build a strong foundation to support start-ups by organizing entrepreneurship seminars and encouraging participation in business competitions.

We will involve students in these activities, enhance entrepreneurial education, and create an environment where students can take the initiative to start their own businesses. We will also strive to cultivate talent that will support the future of Japan.

5. Conclusion

The division will continue to work toward realizing innovative technologies and their implementation in society to enrich human life while respecting the environment and resources by leveraging advantage of the strengths of Tokyo University of Science (TUS). To this end, we will create an environment in which researchers collaborate and stimulate each other to achieve unique outcomes owing to the synergy effect. The division will also expand its efforts toward commercialization, which is a characteristic of this division, and actively promote commercialization and practical application of products that directly lead to solving social issues, even at a university. These activities will make our division a distinctive feature of TUS.

Major Research Achievements (FY 2023)

Academic papers

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2. Study on an Add-on Type Electric Wheelchair Using Active Caster with the Differential Mechanism, T. Nakayama and <u>M. Wada</u>, Journal of Robotics and Mechatronics, Vol.35, No.1, pp 99-112, 2023 (Peer-reviewed)

3. ディープラーニングと精神科治療, <u>森 武俊</u>, 臨床精神薬理, 26 巻, pp 86-88, 2023 (in Japanese) (Peer-reviewed)

4. Blood vessel detection using skin impedance tomography and spectroscopy, <u>S. Kang</u>, <u>T. Mori</u>, 45th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2023, DOI:10.1109/EMBC40787.2023.10340703 (Peer-reviewed)

5. Social skills training using multiple humanoid robots for individuals with autism spectrum conditions, K. Takata, Y. Yoshikawa, T. Muramatsu, <u>Y. Matsumoto</u>, H. Ishiguro, M. Mimura, and H. Kumazaki, Frontiers in Psychiatry, vol 14, no. 1168837, 2023 (Peer-reviewed)

6. Fast Inverse Kinematics Based on Pseudo-Forward Dynamics Computation: Application to Musculoskeletal Inverse Kinematics, K. Ayusawa, A. Murai, R. Sagawa, and <u>E. Yoshida</u>, IEEE Robotics and Automation Letters, Vol.9, No.8, pp 5775-5782, 2023 (Peer-reviewed)

7. Topology optimization using the lattice Boltzmann method for unsteady natural convection problems, Y. Tanabe, K. Yaji, <u>K. Ushijima</u>, STRUCTURAL AND MULTIDISCIPLINARY OPTIMIZATION, Vol.66, No.103, DOI: 10.1007/s00158-023-03522-y, 2023 (Peer-reviewed)

8. Robotic endoscope with double-balloon and double-bend tube for colonoscopy, T. Takamatsu, Y. Endo, R. Fukushima, T. Yasue, K. Shinmura, H. Ikematsu, <u>H. Takemura</u>, Scientific Reports, Vol.13, 10494, 2023 (Peer-reviewed)

9. Dynamics of Center of Pressure Trajectory in Gait: Unilateral Transfemoral Amputees versus Non-disabled Individuals, Y. He, M. Hu, A. Jor, <u>H. Hobara</u>, F. Gao, T. Kobayashi, IEEE Transactions on Neural Systems & Rehabilitation Engineering, Vol.32, pp 1416-1425, 2024 (Peer-reviewed)

10. Optimal Projection Pattern for Active Visual Servoing (AVS), <u>S. Arai</u>, Y. Miyamoto, A. Kobayashi, K. Kosuge, IEEE Access, Vol.12, No.1, pp 47110-47118, 2024 (Peer-reviewed)

11. High-Speed Localization Estimation Method Using Lighting Recognition in Tunnels, Y. Moko, Y. Hiruma, <u>T. Hayakawa</u>, Y. Onishi, M. Ishikawa, 7th International Conference on Intelligent Traffic and Transportation (ICITT 2023), ML755:1-ML755:12, 2023 (Peer-reviewed)

12. Human-Robot Interaction and Collaboration Utilizing Voluntary Bimanual Coordination, <u>H. Huang</u>, Y. Cao, K. Murakami, M. Ishikawa, Y. Yamakawa, Proceedings of the 2023 IEEE International Conference on Systems, Man, and Cybernetics (SMC2023), pp 1044-1051, 2023 (Peer-reviewed)

13. Differential Frequency Heterodyne Time-of-Flight Imaging for Instantaneous Depth and Velocity Estimation, Y. Hu, <u>L. Miyashita</u>, M. Ishikawa, SIGGRAPH 2023, Technical Papers (ACM Transactions on Graphics, Vol.42, No.1), 2023 (Peer-reviewed)

14. Development of Human-Size Swallowing Robot, H. Sato, <u>H. Kobayashi</u>, <u>K. Matsumoto</u>, <u>T. Hashimoto</u>, Y. Michiwaki, Journal of Robotics and Mechatronics, Vol.35, No.6, pp 1663-1674, 2023 (Peer-reviewed)

15. 小型高速三次元スキャナの開発, <u>田畑智志</u>, 渡辺義浩, 石川正俊, 日本ロボット学会誌, Vol.42, No.1, pp 82-85, 2024 (in Japanese) (Peer-reviewed)

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2. Prosthetic Developments in Sport; Biomechanics of running-specific prosthesis. <u>H. Hobara</u>, G. Hisano, In 'Applied Sports Science and Exercise in Disability Sports' Routlegde Handbook, 2024

Invited Lectures
1. HEBITREN JAKARTA INTERNATIONAL SEMINAR, <u>H. Kobayashi</u>, Indonesia, 2023.
2. 予防医療の場におけるロボティクス・AI, <u>森武俊</u>, 第 33 回老年学会総会, 横浜, 2023 (in Japanese)
3. ラティス構造の構造解析と設計, <u>牛島邦晴</u>, 公益社団法人 日本設計工学会東海支部 令和 5 年度 設計フォーラム「積層造形により実現するラティス構造の特徴と最新動向」, 愛知, 2023. (in Japanese)
4. Weight transfer strategy during the double limb stance in unilateral transfemoral amputees, <u>H. Hobara</u>, The 19th World Congress of the International Society for Prosthetics and Orthotics, MEX, 2023.
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6. Optical axis control methods for infrastructure inspection, 2nd Intl. Conference Advances in 3OM, OPT23-42., <u>T. Hayakawa</u>, ,2023
7. 高速ビジョンに基づく知能ロボットおよび人間拡張を目指した人間機械協調の実現, <u>黄守仁</u>, 第 10 回日本医科大学・東京理科大学合同シンポジウム, 東京, 2023. (in Japanese)
8. Virtual Material Creation by High-speed Projection, <u>L. Miyashita</u>, International Display Workshops (IDW 2023), PRJ7-1, pp 829-831, Niigata, Japan, 2023

Patents
1. <u>小林 宏</u>, 国内優先出願, 人体サポート装置, 及び, 墜落制止用器具, 2023-220848, 2023 (in Japanese)
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3. <u>森 武俊</u> ほか, 国内共願, 画像評価方法, 画像評価装置, およびコンピュータプログラム, 2023-090404, 2023 (in Japanese)
4. <u>荒井翔悟</u>, 夏井翔太郎, 村上雷伊斗,「自動生産システムの制御方法, 制御プログラム及びセットアップ方法」, 出願番号 2023-102856, 2023 (in Japanese)
5. <u>荒井翔悟</u>, 嵯峨野拓海,「情報処理装置, 情報処理方法, 及びプログラム」, 出願番号 2023-102012, 2023 (in Japanese)

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1. 小林 宏,「装着型ロボ開発加速」, 日刊工業新聞, 2023.4.6 (in Japanese)
2. 小林 宏, イノフィス, 能登半島地震被災者および支援者支援を開始, NIKKEI COMPASS, 2.7.2024 (in Japanese)
3. 小林宏, 東京理科大学ベンチャーエコシステムとビズリーチが連携大学発・技術系スタートアップの事業成長に貢献する経営プロ人材（副業・兼業）を募集, PRTIMES, 10.26.2023 (in Japanese)

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2. 吉田美香子, 森 武俊, 正源寺美穂. 日本老年泌尿器科学会学会賞, 日本老年泌尿器科学会, 2023. (in Japanese)

3. T. Suzuki, T. Okano, Y. Washimi, K. Sasaki, T. Tanimoto. K. Fujita, K. Yokoyama, K. Ushijima, Best Paper Award (Title: Rolling Resistance Evaluation of Non-pneumatic Tire with Linked Zig-zag Structure using Scale Model, Thai Society of Mechanical Engineers, 2023

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Individual Research Topics

Hiroshi Kobayashi
"Development and commercialization of muscle suits for motion support, startup establishment, and development of binary power generation equipment"

    The goal of this division is to commercialize products and acquire rights (patents), and we have achieved these goals with two products: muscle suits that provide movement support. We also founded CoreHealth Co., Ltd. to spread the world's first ultra-quick posture correction business using muscle suits. In order to solve the energy problem that is essential for sustainability, we have been developing a binary power generation device that uses hot springs as a heat source and conducted demonstration tests on-site to demonstrate the possibility of power generation.

Masayoshi Wada
"Research on design and control of omnidirectional movement mechanisms"

    In our Lab., Research on the design and control of omnidirectional mobile mechanisms is conducted to realize a robotic vehicle that can move in any direction, turn, and travel around curves very precisely. In particular, we have proposed the wheel power transmission design with two motors, and motor control methods with multiple drive wheels, called an active caster, that has a caster structure where the wheel axle and steering axis do not intersect to achieve omnidirectional movement. We are also studying autonomous driving systems and remote-control systems for omnidirectional vehicles.

Taketoshi Mori
"Research on image sequence processing of portable ultrasonic image and online identification"

    Development of compact and portable ultrasound equipment is progressing. These devices are designed to send measured video to a computer or tablet at any time, and image processing at the destination is a prerequisite. Because portable ultrasound echo machines are designed for portability, the produced images are coarse and noisy. Generally, they are used for medical judgment, fault determination, and anomaly detection based on the subjective judgment of a trained person, but automatic image identification methods are being introduced. We are developing a method for detecting regions of high anomaly likelihood in video images based on deep machine learning of images correctly annotated with human-assigned anomalies.

Eiichi Yoshida
"Research on contact estimation from motion via vector quantization learning"

    We have developed a method for learning symbols as a discrete representation that relates a motion with a contact sequence through vector-quantized variational autoencoder (VQ-VAE) and self-attention mechanism. We have demonstrated that contact forces and states can be reconstructed from input motion by applying the proposed method to the walking motion as an example. We have also shown that the reconstructed contact force and states can be utilized for dynamic analysis such as joint torque computation during the motion.

Yoshio Matsumoto

"Research on communication support technologies using robot"

We are researching the use of social robots to assist people in the fields of medicine, nursing care, welfare, and education. Specifically, we are developing technologies to screen for delirium and cognitive decline based on voice (acoustic and linguistic features) and facial image (gaze and facial expression features) data obtained while interacting with the robot, and are conducting workshops on social robot programming to improve the social skills of children with ASD.

Kuniharu Ushijima

"Research on reducing rolling resistance in airless tires using a linked zigzag structure"

We propose a new design of a non-pneumatic tire (NPT) that makes use of a linked zig-zag structure to achieve low rolling resistance characteristics. With this specially designed structure, the proposed NPT possesses a rolling resistance coefficient (RRC) about 30% lower than that of the conventional NPT, as verified by the finite element analysis (FEA) technique. It is explained that the linked zig-zag structure can transfer applied load from the bottom to the top through intermediate rings. This reduces the local stress concentration of the structure, especially that in the elements near the ground.

Hiroshi TAKEMURA

"Research on maintenance robots at recycling factories"

In actual automation operations, it is not only necessary to autonomously control equipment and systems but also to have a mechanism that automatically and autonomously resolves frequent minor problems such as clogging in equipment. Therefore, the initial device for maintenance robots and the principal prototype design of the maintenance robot is started.

Ryuzo Hayashi

"Research on path generation methods considering terrain features using deflection curves of discrete element beam model"

As a technique for defining driving lanes in high-precision digital road mapping for automated vehicles, this study proposed a method for generating a route for road sections with no demarcation lines, such as those within intersections. The proposed method uses a deflection curve of a discrete element beam model, which generates paths with a small bulge and takes into account geographic features. This study also examined the ride comfort and controllability of the vehicle when it is driven along a route created with the proposed method.

Hiroaki Hobara

"Research on human mobility reconstruction using biomechanical methods"

In this year, biomechanical studies to quantify and evaluate the asymmetric gait mechanics in individuals with functional impairments were conducted. First, the asymmetric trajectories of the center of foot pressure (COP) during walking in individuals with lower limb amputation were identified. Further, asymmetric anteroposterior force production through running-specific prosthesis was found in individuals with unilateral transfemoral amputation. We also performed a systematic review to evaluate orthotic intervention on running kinematics and kinetics.

Takuya Hashimoto

"Research on swallowing function evaluation and its clinical application"

The decrease in swallowing function notably affects QOL, but the quantitative assessment of its function is challenging as it is an in vivo motion that cannot be directly observed. To address this problem, we have been developing a device using PVDF film to simultaneously measure muscle activity, swallowing sounds, and laryngeal elevation during swallowing. We are now focusing on devising a method to automatically identify swallowing intervals from various signals measured in daily activities using this device, aiming for practical applications.

Shogo Arai

"Research on automated consumer electronics dismantling system"

The number of discarded consumer electronics is increasing every year, and we need to improve the recycling rate to promote the resource recycling process. On the other hand, unlike manufacturing processes, dismantled objects are small in quantity and of various types. Therefore, the conventional teaching-and-playback method using positioning jigs in the dismantling process cannot be expected to promote the resource recycling process. Therefore, a general-purpose automated disassembly system that does not require positioning jigs is essential. This research aims to construct an automated disassembly system for consumer electronics to contribute to the achievement of the SDGs.

Tomohiko Hayakawa

"Research on high-precision imaging in mobile environments"

When capturing images with a camera during high-speed traveling, movements can lead to blurring and a decrease in image quality. To address this issue, we are developing an imaging system that utilizes mirror rotation for optical axis control, enabling image capture comparable to stationary conditions.

This system can be installed on vehicles and has been shown through experimental results to be capable of capturing images with high quality even while traveling at speeds of up to 100 km/h on public roads. Furthermore, it can be utilized for inspecting fine cracks, such as those measuring 0.2mm, on tunnel ceilings.

Huang Shouren

"Research on human-machine cooperation via 2D/3D gaze control interfaces"

I am engaged in research on human-machine integration and collaboration aimed at enhancing human functionality by combining human cognition with robots. Specifically, in order to improve the welfare of people with severe sensory-based motor disorder or musculoskeletal disorders, a robotic assistance method is proposed to realize extended sensing, locomotion as well as manipulation for a user to interact with the environment utilizing a 2D/3D gaze interface. Specifically, the proposed method focuses on the situation where a user desires to explore the environment beyond their physical perception capability, requiring the robotic assistance of realizing extended sensing. The proposed 2D/3D gaze interface is wearable, unrestrained to users, and straightforward to give commands for robot control.

Leo Miyashita

"High-speed motion sensing technologies and dynamic projection mapping"

Recent AI is going to establish the foundation for industrial and technological innovation that will enable various tasks without human intervention and build a sustainable society. In this context, sensing as input to AI systems, and display as output are becoming increasingly important. Then, this year I researched high-speed motion sensing technologies for understanding dynamic environments and a projection technology for moving objects.

Kenta Nagano

"Research on actuator control for collaborative robots with humans"

A study on force control of actuators for robots collaborating with humans was conducted. We proposed compliance control without force sensors by utilizing angle sensors attached to the input and output sides of the gearbox that constitutes the actuator. The proposed method achieved position tracking and flexibility against external forces due to force control by dynamically changing the virtual impedance according to external forces. Furthermore, a reduction in the force generated during contact was achieved by controlling the contact force with the environment based on angle sensor information.

Satoshi Tabata

"Research on High-speed 3D Measurement and Display System"

In this research, a real-time high-speed 3D scanning system has been developed by combining high-speed 3D shape measurement using a segmented pattern with high-speed 6DoF tracking based on small-displacement assumption. Moreover, high-speed 3D display based on dynamic anamorphosis has also been realized by using the cylindrical mirror.

Akishige Yuguchi

"Research on life-support robots through interaction"

With a focus on human-robot interaction, I conduct research on life support robots and understanding human behavior and actions using robotics and information engineering technologies, aiming to realize robots that can coexist with humans or are easy to handle. Specifically, I develop devices and methods for measuring and analyzing caregiving skills and evaluating their effects on humans through psychological experiments to adapt such skills to robots.

Sooin Kang

"Research on the electrical analysis and measurement of human hemodynamics"

For continuous and non-invasive vascular observation under various conditions, we have successfully developed an impedance tomography method and established an image reconstruction technique utilizing spectroscopy data. We aim for accurate estimations of vascular states using a localized impedance tomography approach that considers morphological characteristics specific to each vessel and develop an arm robot for automatic vascular tracking assistance using skin impedance.

Research Alliance for Mathematical Analysis

Research Alliance for Mathematical Analysis

1. Overview

This division has been established in April 2020, as the succession of Division of Mathematical modeling and mathematical analysis. The aim of our division is to make alliance research over mathematical analysis, numerical analysis, physics, chemistry, biology and engineering.

We make research alliance based on Three groups (Group of mathematical physics, Group of mathematical biology and Group of mathematical engineering).

Group of mathematical physics

The aim of the group is to establish original numerical method for Schrödinger equations based on representation of solutions via wave packet transform by K. Kato et al. and apply it to condensed matter physics. We have succeeded in establishing original numerical method and are applying it to computing numerical solutions of Schrödinger equations.

Group of mathematical engineering

This is a research group focused on mathematical analysis of various phenomena in continuum mechanics and applying to inverse problems. Especially, we study fracture phenomena for elastic structures, motion of vortex filaments, faulting rupture in seismology and so on. As regards inverse problems, we deal with reconstruction problems for discontinuity embedded in a medium, such as cracks, cavities, inclusions and obstacles, from observed data, which are arising from non-invasive tests for a living body, non-destructive tests in engineering and inversion of source process in seismology. The aim of the group is to provide theoretical foundations and their numerical implementation.

Group of mathematical biology

We investigate asymptotic behavior of solutions of mathematical models including epidemiological models and Keller–Segel system for cancer invasion. One of our study is a free boundary problem that describes the spatial propagation of a transmitted disease. By a joint work among E. Ishiwata, T. Ushijima, Y. Enatsu, we have obtained a new result for existence and nonexistence of a traveling wave solution (a solution propagating in a direction with the same profile and the same speed). Starting February 2018, we have organized regular seminars relating to infectious diseases in Kagurazaka campus. In the seminar, talks on infectious diseases are given by researchers in the field of mathematics, biology, medical science.

2. Organization and Faculties

We have 19 members from our university (8 members from Department of Mathematics, 1 member from Department of Physics, 2 members from Department of Applied Mathematics, Faculty of Science, 2 members from Department of Information and Computer technology, Faculty of Engineering, 4 members from Department of Mathematics, Faculty of Science and Technology, 2 members from Institute of Arts and Sciences.

URL of our web-page is the following:

https://www.rs.tus.ac.jp/ma-alliance/index.html

3. Research Activities

3. 1. Group of mathematical physics

We try to apply the representation of the solutions to Schrödinger equations by Kato et al. to condensed matter physics. We have succeeded in numerical computation by using our representation for Schrödinger equations in one space dimension with some potentials. Since October 2021, Kato and Ushijima have been trying to develop numerical computation with our representation for application to physics.

3. 2. Group of mathematical engineering

The purpose of this group is to conduct mathematical analysis of various phenomena in continua (elastic bodies and fluids) and to study inverse problems as their application to engineering and other fields. In FY2023, we considered mathematical analysis of some viscoelastic models with elastic moduli depending on mechanical pressure, as well as coupled poroelastic problems of a non-penetrating crack with cohesive contact stemming from hydraulic fracturing. Then we obtained a qualitative theory, including the existence of solutions. These results were published in international academic journals. We also studied the motion of a vortex filament by use of the generalized Hasimoto transformation. Furthermore, we carried out joint research projects with research teams in France and Finland, on numerical simulation of the obtained results of inverse problems. Moreover, we have conducted activities such as providing a forum for exchange among young researchers in Japan and abroad in the field of inverse problems.

3. 3. Group of mathematical biology

Our group studies dynamics of mathematical models in biology, including epidemiological models and Keller-Segel models.

E. Ishiwata, T. Ushijima, Y. Enatsu, and K. Kato organized a seminar on infectious diseases that has started in 2018 in Kagurazaka campus. We invited Dr. Shinji Nakaoka (Hokkaido University) to give a talk on a mathematical model of zoonotic diseases. We discussed analysis and numerical simulations for a renewal equation, preclinical diagnostic data and infection dynamics for COVID-19.

We held a HyFlex workshop on applied mathematical sciences that aims at student education. The organizers are E. Ishiwata, T. Ushijima, Y. Enatsu, and T. Suzuki. We provided researchers and students from both inside and outside the university with an opportunity to give a presentation on applied mathematical sciences. There were a lot of participants and students actively interacting with each other. We are planning to hold this workshop next year.

On a joint work for a diffusive epidemiological model with a free boundary, E. Ishiwata, T. Ushijima, and Y. Enatsu have regular discussions. We investigate the existence of semiwave (a traveling wave spreading in a half space) and speed of the semiwave. For a diffusive SI (Susceptible-Infected) epidemiological model with a free boundary, we have obtained a partial result on the existence of the semiwave when there are no diffusion terms for susceptible individuals. Applying fixed point theorems, we also investigate the existence of the semiwave when there are diffusion terms both for susceptible individuals and infected individuals.

Major Research Achievements (FY 2023)

Academic Papers

1. Estimates on modulation spaces for Schrödinger operators with time-dependent sub-linear vector potentials, <u>Keiichi Kato</u>, Ryo Muramatsu, Hokkaido Math. J., 53 (2024)

2. Well-posedness of the governing equations for a quasi-linear viscoelastic model with pressure-dependent moduli in which both stress and strain appear linearly, <u>Hiromichi Itou</u>, Victor A. Kovtunenko, Kumbakonam R. Rajagopal, Zeitschrift für angewandte Mathematik und Physik, 75, 22, 2024

3. A generalization of the Kelvin-Voigt model with pressure-dependent moduli in which both stress and strain appear linearly, <u>Hiromichi Itou</u>, Victor A. Kovtunenko, Kumbakonam R. Rajagopal, Mathematical Methods in the Applied Sciences, 46 pp. 15641-15654, 2023

4. Poroelastic problem of a non-penetrating crack with cohesive contact for fluid-driven fracture, <u>Hiromichi Itou</u>, Victor A. Kovtunenko, Nyurgun P. Lazarev, Applications in Engineering Science, 15 100136, 2023

5. Hunting cooperation in a prey-predator model with maturation delay, <u>Yoichi Enatsu</u>, Jyotirmoy Roy, and Malay Banerjee, Journal of Biological Dyanmics, 18 (2024), no. 1, 2332279

6. Upper estimates for blow-up solutions of a quasi-linear parabolic equation, Koichi Anada, Tetsuya Ishiwata, <u>Takeo Ushijima</u>, Japan Journal of Industrial and Applied Mathematics, 41 (2024), 381-405

7. Behavior in time of solutions of a Keller-Segel system with flux limitation and source term, Monica Monica, Stella Vernier-Piro, <u>Tomomi Yokota</u>, NoDEA Nonlinear Differential Equations Appl. 30, Paper No. 65, 27 pp., 2023

8. Boundedness and weak stabilization in a degenerate chemotaxis model arising from tumor invasion, Sachiko Ishida, <u>Tomomi Yokota</u>, J. Differential Equations 371, pp. 450–480, 2023

9. Avoiding critical mass phenomena by arbitrarily mild saturation of cross-diffusive fluxes in two-dimensional Keller-Segel-Navier-Stokes systems, Michael Winkler, <u>Tomomi Yokota</u>, J. Differential Equations 374, pp. 1–28, 2023

10. Transverse Field Dependence of the Ground State in the Z2 Bose-Hubbard Model, Yuma Watanabe, Shohei Watabe, and <u>Tetsuro Nikuni</u>, JPS Conference Proceedings, Vol. 38, 011012, 2023

11. Embedding All Feasible Solutions of Traveling Salesman Problem by Divide-and-Conquer Quantum Search, Rei Sato, Kazuhiro Saito, <u>Tetsuro Nikuni</u>, Shohei Watabe, 2023 IEEE International Conference on Quantum Computing and Engineering (QCE), 270, 2023

12. 1hydrodynamic and collisionless regimes, Hoshu Hiyane, Shohei Watabe, <u>Tetsuro Nikuni</u>, Phys. Rev. A, Vol. 109, 033302, 2023

13. Hunting cooperation in a prey-predator model with maturation delay, <u>Yoichi Enatsu</u>, Jyotirmoy Roy, and Malay Banerjee, Journal of Biological Dyanmics, 18 (2024), no. 1, 2332279

14. Upper estimates for blow-up solutions of a quasi-linear parabolic equation, Koichi Anada, Tetsuya Ishiwata, <u>Takeo Ushijima</u>, Japan Journal of Industrial and Applied Mathematics, 41 (2024), 381-405

15. Existence for a nonlocal Penrose-Fife type phase field system with inertial term, <u>S. Kurima</u>, Electron. J. Differential Equations (2023), Paper No. 40, 18 pp

16. p-Adic Time-Frequency Analysis and Its Properties, <u>Toshio Suzuki</u>, Analysis, Applications, and Computations pp 715–723

17. An improvement for image compression using the discrete wavelet transform and the linear quantization, Kouta Yamamoto, <u>Toshio Suzuki, Emiko Ishiwata,</u> Proceedings the 42nd JSST Annual International Conference on Simulation Technology Conference, Aug, 2023

18. The Representation of p-adic Fourier Transform of a Locally Constant Test Function, Munehiro Kobayashi, <u>Toshio Suzuki</u>, Proceedings the 42nd JSST Annual International Conference on Simulation Technology Conference, Aug, 2023

Books

1. 工科系のための偏微分方程式入門 (Introduction to Partial Differential Equations for engineering), Yasuyuki Oka, HIroyuki Hirayama, <u>Toshio Suzuki</u> and Kensuke Fujinoki, Gakujutsutosho-shuppan, 2023 (in Japanese)

2. Theory of elastic wave propagation and its application to scattering problems. CRC press (ISBN 9781032170770), <u>Terumi Touhei,</u> 2023

Invited Lectures

1. Construction of solutions to Schrödinger equations with potentials of quadratic or sub-quadratic growth, Keiichi Kato, Regularity and Singularity for Geometric PDE and related topics, Kumamoto-Jo Hall, 2024, Jan

2. 非線形シュレディンガー方程式に対する定在波の強不安定性解析 (Strong non-stability of standing wave solutions to non-linear Schrödinger equations), Masahito Ohta, 日本数学会 2024 年度 年会 函数方程式論分科会 特別講演 (Japan mathematical Society 2024, invited lecture), Osaka Metropolitan University, 2024, March (in Japanese)

3. Boundedness in a Degenerate Chemotaxis System for Tumor Invasion, <u>Tomomi Yokota</u>, Nonlinear Phenomena in Biology, Ecology, Physics and Mechanics, Azerbaijan State University of Economics, Baku, 2023, October

4. Global existence of solutions to a singular nonlocal phase field system with inertial term, <u>Shunsuke Kurima</u>, The 13th AIMS Conference on Dynamical Systems, Differential Equations and Applications,USA (Wilminton), 2023, June

5. Global existence for a singular nonlocal phase field system with inertial term, <u>Shunsuke Kurima</u>, ICIAM 2023 Tokyo, Waseda University, 2023, August

6. Global existence of weak solutions to a singular nonlocal phase field system with inertial term, <u>Shunsuke Kurima</u>, RIMS Symposia(open)"Evolution equations and related topics –Energy structure and Quantitative Analysis–", Kyoto University, 2023, October

7. Existence of weak solutions to a singular nonlocal phase field system with inertial term, <u>Shunsuke Kurima</u>, Workshop on Nonlinear Partial Differential Equations — China-Japan Joint Project for Young Mathematicians 2023, Shanhai, 2023, November

8. Semi wave solutions for a diffusive SI model with free boundary, <u>Yoichi Enatsu</u>, International Conference on Nonlinear Phenomena in Biology, Ecology, Physics and Mechanics, Azerbaijan State University of Economic, Baku(Azerbaijan), 2023, October

Individual Research Topics

Keiichi Kato
"Representation of solutions to Schrödinger equations via wave packet transform"

We have the representation of solutions to Schrödinger equations via wave packet transform in 2011. Our subject is to apply the representation to physics. Recently we develop numerical computation using the representation with Ushijima who is a member of our division from October, 2021.

Masahito Ohta
"Studies on stability of standing waves for nonlinear Schrödinger equations"

We studied standing wave solutions for nonlinear Schrödinger equation with an attractive delta-function potential, a repulsive cubic nonlinear term, and an attractive quintic nonlinear term in one spatial dimension. We obtained some results on the stability of standing wave solutions.

Tomomi Yokota
"Study of chemotaxis models"

In a joint work with Ph.D student Yutaro Chiyo, a result on the classification of boundedness and blow-up of solutions to quasilinear attraction-repulsion chemotaxis systems by the size of the powers of the attraction and repulstion terms was obtained. Also, in a joint work with Professor Sachiko Ishida (Chiba University), a stabilization result for weak solutions to degenerate Keller-Segel sytems was established. Moreover, in a joint work with Professors Monica Marras and Stella Vernier-Piro, a result on finite-time blow-up and estimates for the blow-up time was obtained.

Tetsuro Nikuni
"Research on Theoretical Analysis of Quantum Many-Body Systems and Applications of Quantum Computers"

We study quantum many-body dynamics in ultracold atomic gases using analytical methods and numerical simulations. We are also conducting theoretical research on the application of quantum search using quantum walks to optimization problems and on the application of NISQ (Noisy Intermediate-Scale Quantum Computer)devices.

Hiromichi Itou
"Study on theoretical analysis of mathematical model of viscoelasticity and inverse problems related to nondestructive testing"

We considered mathematical analysis of viscoelastic models describing porous materials such as rock and concrete, as well as crack problems of coupled poroelastic models stemming from hydraulic fracturing. In consequence, we established a qualitative theory, including the existence of solutions. Also, the inverse problem of cracks in linear elastic bodies related to nondestructive testing was studied, deepening the previous reconstruction method. For these applications, numerical simulations and experiments of the obtained results, as well as collaboration with other fields, are planned.

Atsuhide Ishida

"Study on spectral theory, scattering theory and inverse problems for non-local Schrӧdinger operators"

Non-local Schrödinger operators are appeared in a lot of physical models and have the rich mathematical backgrounds. For such non-local Schrödinger operators, I will conduct research on spectral and scattering theory that are basic topics in quantum physics. Moreover, I will apply these results to inverse problems determining the uniqueness of the interactional potential functions.

Mieko Tanaka

"Nonlinear eigenvalue problems for p-Laplacian and (p,q)-Laplacian''

I analyzed the kth eigenvalue of the spherically symmetric p-Laplacian with Ryuji Kajikiya and Satoshi Tanaka. We obtained results on the behavior of eigenvalues when p moves, and on the monotonicity and non-monotonicity of the eigenvalues. In the joint work with Vladimir Bobkov, we succeeded in showing the existence of multiple solutions in partial differential equations related to the (p,q)-Laplacian eigenvalue problem. In addition, we have also analyzed the eigenvalues of p-Laplacian, which are characterized a little differently from the variational eigenvalues.

Yoichi Enatsu

"Dynamical analysis of epidemiological models and prey-predator models"

My research theme is stability of stationary solutions of epidemiological models and prey-predator models. For epidemiological models, the current interest lies in the existence of semiwave of diffusion equations with a free boundary and stability analysis of delayed models. For prey-predator models, we study stability and bifurcation theory for the case where hunting cooperation among predators.

Masashi Aiki

"Research on Vortex Motion"

Research on fluid motion has many aspects, and vortex motion is one of the most fundamental factors which determine the motion of fluids. My research is concerned with the mathematical analysis of the motion and interaction of vortex rings. A vortex ring is a thin vortex structure, for which its motion can be approximated as the motion of a closed curve in space. Specifically, we consider motions of multiple vortex rings aligned on a common axis and construct mathematical models which describe such motions. We also analyze the model to investigate the possible motion patterns of the rings and study the stability/instability of particular patterns.

Shunsuke Kurima

"Study of proving existence of solutions and using time discretization methods for phase-field systems"

I could confirm that existence of solutions to a nonlocal phase-field system with inertial term can be proved by using a time discretization method. Also, I could verify that we can prove existence of solutions to a singular (local) phase field system of conserved type by convergence from a singular nonlocal phase field system of conserved type.

Toshio Suzuki

"Time-frequency analysis"

Time-frequency analysis is a well-known method for simultaneously analyzing the time and frequency information of a signal. The windowed Fourier transform and the wavelet transform are well-known transforms of this method, and various transforms are constructed according to the features of the signal.

In this study, we investigate the characteristics of these transforms and their relationship to other transforms relevant to time-frequency analysis. We also study time-frequency analysis for functions over p-adic fields.

Noriyoshi Fukaya

"Study on solitary wave solutions for nonlinear dispersive equations"

I study the properties of solitary wave solutions for nonlinear dispersive equations. In particular, I deal with equations without scale invariance or Galilean invariance, such as cases with potentials, cases with double power nonlinearities, and systems, to investigate the properties of the profiles of solitary waves and the orbital stability/instability. In addition, I consider asymptotic stability and strong instability in order to reveal the global dynamics.

Yukihide Tadano

"Spectral and scattering theory of discrete Schrödinger operators"

Discrete Schrödinger operators have two different derivations; one is the tight-binding Hamiltonian in the field of solid state physics, and the other is the discretization of Schrödinger operators. I study these operators by focusing on similarity and dissimilarity of spectral and scattering properties.

Division of Smart Healthcare Engineering

Division of Smart Healthcare Engineering

1. Overview

The Division of Smart Healthcare Engineering originates in the Biosystems Research Division established in April 1983. In April 1988, the Intelligent Systems Engineering Division was established to research a wide range of topics from basic to applied fields based on the principle of "adding intelligence to engineering systems, taking over the Biosystems Research Division. Furthermore, with the reorganization of the Research Institute for Advanced Science and Technology into the Research Organization for Advanced Science and Technology in November 2005, the Intelligent Systems Engineering Division was reorganized, with the new mission of "developing human-friendly and human-like intelligent systems through the mutual collaboration and integration of the fields of software application and network, hardware, energy and environment, and fundamental theory. After the 15-year activity with many achievements based on the principles of "Human-like intelligent systems" and "Research and development for medical and space applications of human-like, autonomous, and human-friendly intelligent systems", the division was temporarily dissolved. Subsequently, in April 2022, the Division of Smart Healthcare Engineering was established with the aim of "creating a society in which all people can lead a high quality of life (QOL) social life as a matter of course," advocating a smart healthcare system that further develops medical applications of intelligent systems (22 members as of March 31, 2024). The division targets elemental technologies for (1) sensing a wide range of biological information, (2) brushing up hardware, (3) energy and information transmission to devices, and (4) stable and pure information communication, as well as cross-sectional collaborative research with a total system in mind.

In FY2023, the second year of its establishment, a workshop on measuring instruments was held jointly with Tokyo Denki Sangyo Co., Ltd. and Yokogawa Test & Measurement Co. on Friday, May 12, and Friday, May 26, mainly for students who had just joined the laboratory and students from laboratories belonging to other departments. In addition, we introduced the current status and challenges of the division with posters at the RIST booth during Homecoming Day on Sunday, November 29, and at the RIST Forum 2023 on Monday, December 25. On Monday, March 11, 2024, the annual research symposium was held, including a face-to-face meeting and a social event, with two special lectures entitled "Biomedical Engineering Using VR/AR/MR Technology" by Professor Tatsuhiko Arafune of Tokyo Denki University and "Machine Learning for Prediction of Radiated Electric Field from Printed Circuit Board" by Hiroaki Ikeda of the Connector Division of Japan Aviation Electronics Industry. Furthermore, seven presentations by representatives of each research group and 37 student posters were presented. The poster presentations were evaluated and voted on by all participants, and awards were given to the most outstanding presentations. Through these activities, we further promoted the enlightenment of students and research exchange among the division members and identified future research topics. We were able to hold a meaningful debriefing session that will lead to the future development of this field and bridge the gap to the next generation.

2. Organization and Facilities

2.1. Composition of division

Figure 1 depicts the future of implantable medical devices that support a society of health and longevity, as an example of the research agenda that this division is pursuing. Patients wearing advanced medical devices such as implantable artificial hearts will be provided with a safe and secure life through constant

remote monitoring and device control by doctors and other medical professionals of their biometric information and device operation status. Such hardware requires highly efficient energy transmission, miniaturized integrated circuits, and low power consumption. In addition, a bi-directional and secure wireless communication system is envisioned for communication and control, which is indispensable for telemedicine. The Smart Healthcare System Research Division consists of the following four groups, which conduct individual elemental technology research and cross-disciplinary collaborative research aiming for a total system.
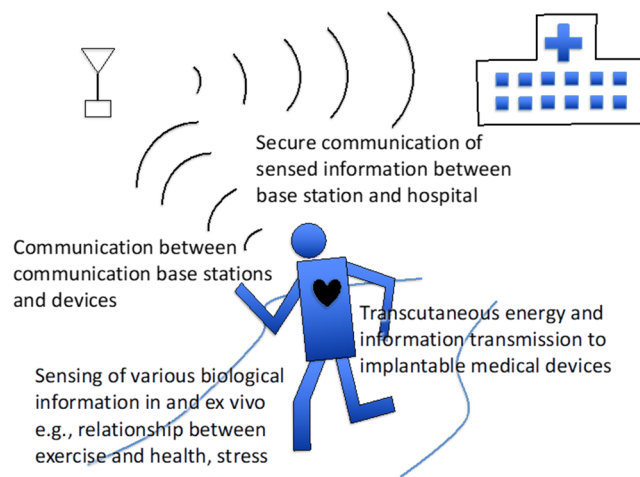
Fig. 1. Examples of research topics in the division.

(1) Sensing of biological information

Exercise has a panacea effect on health and longevity. We have researched to elucidate the mechanism by visualizing "mental health," which is generally difficult to measure, based on the measurement of various non-invasively obtainable biological information such as ECG (Electrocardiogram), PPG (Photoplethysmography), EDA (Electro dermal activity), peripheral body temperature, and respiration.

(2) Integrated circuits and signal processing

The multifunctionality of each system leads to larger device sizes and higher power consumption. Miniaturization and low power consumption of high-frequency analog circuits are indispensable issues to be considered, and research is conducted on miniaturization and low power consumption of high-frequency front ends in the GHz band, including low-noise amplifiers and mixers. Furthermore, in signal processing of information from sensor systems, we aim for higher resolution and lower power consumption of the conversion circuit ADC that converts analog signals to digital signals and the conversion circuit DAC that converts digital signals to analog signals. In addition, we research variation analysis and variation-resistant circuits to improve the yield rate, which is inevitable for supplying integrated circuits at low prices.

(3) Energy and information transmission to devices

We have developed energy and information transmission technologies to drive and control devices implanted in the body, such as implantable artificial hearts and locomotion meters for small animals, percutaneously between inside and outside the body to construct an electromagnetic-environmental-friendly system. In addition, we have investigated the effects of high-frequency magnetic fields generated by percutaneous energy transmission on the body with the sensing group.

(4) Stable and secure information communication

The information and communication environment can be broadly classified into the hardware aspect of communication devices and the software aspect of information exchange via the Internet. In the former, we aim to develop antennas with high radiation efficiency that contribute to low power consumption of the system. For the latter, the division has developed a wireless communication system with high-performance error control and strong communication functions for high reliability, and a VPN connecting multiple

research sites to create a "virtual communication environment unique to this division" using virtual private circuits.

As of March 31, 2024, this division has 22 interdisciplinary researchers including 12 members from Tokyo University of Science and 10 members from external institutes: T. Yamamoto, S. Akashi, K. Higuchi, A. Hyogo, T. Hara, and R. Miyauchi (Faculty of Science and Technology); A. Saito, D. Yamada, and Y. Nozaki (Faculty of Pharmaceutical Sciences); M. Umezawa (Faculty of Advanced Engineering); S. Yanagita (Institute of Arts and Sciences), K. Koshiji (Professor Emeritus); T. Matsuura (Tokyo City University); F. Koshiji (Tokyo Polytechnic University); K. Ota (Nippon Institute of Technology); N. Kubota (Tokyo International University); M. Kobayashi (Ochanomizu University); R. Kishida (Toyama Prefectural University); H. Sato (Tokyo Institute of Technology); I. Hashimoto (Zenkigen); S. Yokobori (Nippon Medical School); C. Umeda (Saitama Medical Center, Jichi Medical University). The group can cover a wide range of fields, including hardware, software, communication/networking, and energy systems, through joint and collaborative research using the facilities and equipment owned by each member.

2.2. Facilities and equipment

The main research facilities and equipment are listed below.

(1) Analog integrated circuit chip analysis equipment

Analog integrated circuit chip analysis equipment (manufactured by Nihon Micronics Co., Ltd.) is capable of measuring and analyzing integrated circuits on unpackaged bare chips, and is equipped with a voltage/current detection unit and a measurement analysis unit (Fig. 2).
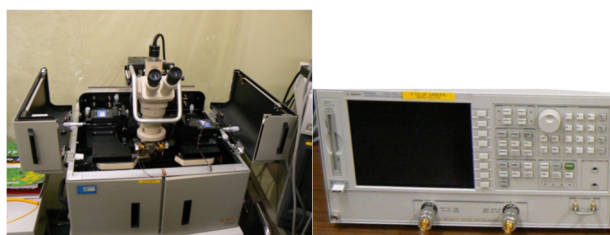
Fig. 2. Analog integrated circuit chip analysis facility. (Left: Voltage and current detection section, Right:

(2) Vector signal generator

This is a synthesized signal generator with high output, low phase noise, and I/Q modulation capability, and is an indispensable measurement device as a reference signal source at high frequencies (Fig. 3).

(3) Oscilloscope (with TDR function)

Waveform observation equipment with a frequency bandwidth up to about 20 GHz is indispensable for evaluating the characteristics of very high-frequency and very high-speed differential signal transmission lines and for measuring the location of reflection sources (TDR). It is useful not only for ordinary signal waveform observation but also for research on microwave imaging for radar and medical applications (Fig. 4).

Fig. 3. Vector signal generator.
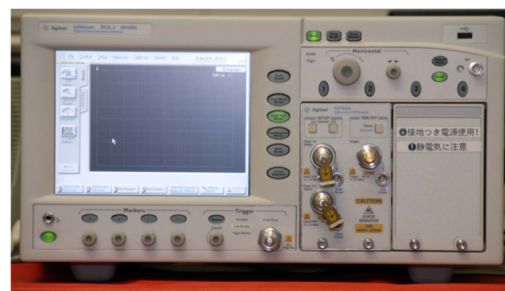
Fig. 4. Oscilloscope with TDR.

(4) Compact near-infrared spectrometer

This compact device integrated with a light source and detector can acquire optical reflectance spectra in

the near-infrared range from 900 to 1700 nm in wavelength by placing it close to a sample. It is possible to measure the wavelength range where information about the deep part of the living body can be obtained without absorption by hemoglobin or water. In particular, this compact device can acquire data in the wavelength region where weak absorption corresponding to overtones and coupling tones overlap in the infrared region where bioorganic molecules show strong absorption, and is expected to be applied to non-invasive estimation and monitoring of in vivo information.

3. Activity Reports

Four groups (Sensing group, Integrated circuits and signal processing group, Device operation and control group, and Information and communication group) conduct individual elementary technology research and interdisciplinary research among the groups. The status of activities and major research topics in each group are described below. The research results of each research topic are published in the Proceedings of the Research Achievement Report Conference of the Smart Healthcare System Research Division in FY2023, major academic conferences, and international conferences.

3. 1. Sensing group

3. 1. 1. Umezawa group

Methods of fractionation is being developed for nano-sized membranous vesicles from biological tissue cells. In 2023, microfluidic devices were developed for concentrating and isolating nanoparticles of interest in cultured cell supernatants by a collaborative work (especially Umezawa and Nozaki) in this Division. This work is aimed at elucidating the intracellular origin of cell-derived membranous vesicles, which may be involved in the pathophysiology of metabolism and aging. In 2024, the effects of the concentration/isolation of the extracellular microvesicles will be investigated. Based on the results, the fractionation devices will be improved for their further applications in the biomedical field.

3. 1. 2. Yanagita group

The following are the main research topics of the Yanagita Group.
- Mechanisms of health promotion and longevity through physical activity
- Development of a device that measures the total amount of physical activity, not just exercise
- Creation of an animal model that simulates increased lifestyle activity

3. 1. 3. Ota group

We have worked on the estimation of speech content in phoneme units based on mouth movement information captured by a camera and the construction of a simple human body movement measurement system. First, for the estimation of speech content based on mouth movements, we searched for a structure suitable for our purpose in deep neural networks, which are also used in ordinary speech recognition, and evaluated it under the condition that the speakers of the evaluation data were not included in the speakers of the training data. As a result, we achieved a phoneme error rate of about 30%. Next, for a simple human body motion measurement system, we performed skeletal detection using openpose on video images captured by two web cameras and realized a three-dimensional motion analysis system using the direct linear transformation (DLT) method. The main research subjects of the Ota Group are listed below.
- A comparison of the accuracy of motion capture using a webcam.
- A comparison of the accuracy of calculating 3D coordinates using a stereo camera.

- An investigation into the influence of the number of speakers, models, and feature points on recognition accuracy in machine lip reading.
- An investigation into the effects of training and generation conditions on synthesized speech accuracy.
- A comparison of the accuracy of emotion estimation using time- and frequency-domain parameters obtained from facial images and skin electric responses.
- An investigation of the influence of acoustic features used for classification of authentic/false speech on the accuracy of classification.
- A comparison of the accuracy of anomalous sound detection using Wave GAN and ensemble learning.
- A consideration of flute playing conditions using an artificial blowing device.

3. 2. Integrated circuits and signal processing group

3. 2. 1. Hyogo, Matsuura, Kishida group
Our main research topic is the proposal of evaluation circuits for hot carrier injection phenomenon with stage switching function.

3. 3. Device operation and control group

3. 3. 1. K. Koshiji group
Research and development of transcutaneous power transmission technology for body implantable devices and construction of systems compatible with the electromagnetic environment.

3. 3. 2. Yamamoto, K. Koshiji group
Yamamoto and K. Koshiji are studying various issues for stable device operation, starting with transcutaneous energy transmission to implanted devices, such as improving the efficiency of energy transmission, information transmission between inside and outside the body, studying the effect of magnetic fields generated by energy transmission on the living body, and developing a simulated living body. In addition, we are working with Umeda to develop devices for preventing accidents in hospitals and conducting field demonstrations. Some research is being conducted in collaboration with Saito, Yanagita, Yamada, Nozaki, and Kobayashi from the Sensing Group, and Yokobori and Umeda from the Clinical Engineering and Medicine Group. The following is a list of major research projects.
- Development of fatty liver equivalent phantom for hyperthermia
- Development of Skin-Equivalent Phantom for Electroencephalogram and Investigation of Environment-Induced Artifacts
- Development of a Novel Traumatic Brain Injury Model and Biochemical Investigation
- Effects of AC magnetic field on the living body using small laboratory animals
- Development of a Prototype Light Stimulator for Small Laboratory Animals Using a Wireless Power Transmission System and Evaluation of Its Performance in Animal Experiments
- Wireless Power Transmission System for Multiple Implantable Locomotion Scales for Small Laboratory Animals
- Evaluation of Transcutaneous Energy Transmission System Using Non-Inductive Cable
- Study on Transcutaneous Energy Transmission System Using Class-E Amplifier
- Investigation of Pasteurization Effect in Low-Temperature Cooking Using Dielectric Heating

3. 4. Information and communication group

3. 4. 1. Higuchi group

The main research subjects of the Higuchi group are listed below.

- Investigation of NOMA-Based Random Access for Massive Machine-Type Communications
- Investigation of Peak Power Reduction of OFDM Signals Using Null Space in MIMO Channel for Massive MIMO Transmission
- Investigation of Highly-Efficient and Low-Latency Scheduling Methods in Round-Trip Communication for Feedback Control
- Investigation of Low-Complexity User-Specific TRP Selection Method in Downlink Distributed MIMO
- Investigation of Autonomous Decentralized Sleep Control of Base Stations for Heterogeneous Networks
- Investigation of Autonomous Decentralized User Association Method to Maximize System-Level Throughout in Co-existing Networks with HAPS and Terrestrial BSs

3. 4. 2. F. Koshiji group

We have been studying optically transparent antennas that can be worn on the body. The radiation efficiency of the obtained antenna is almost equivalent to that of small antennas built into portable and wearable devices. The antenna is practical in terms of both transparency and radiation efficiency.

4. Challenges and Prospects

An interdisciplinary research system is essential to the division's goal of "creating a society in which all people can enjoy a high-quality life as a matter of course," and the division is composed of researchers from various fields within and outside the university. Research meetings, workshops on measuring instruments for students, and research results reporting meetings have been held to promote research exchanges within the division and to further disseminate research results within and outside the university. In the future, a new joint research system will be established to integrate the results of elementary technologies in each field and enable further collaboration.

5. Conclusion

The division started in FY2022 with research on elementary technologies and fusion research on biological information sensing, miniaturization and low power consumption of integrated circuits, power transmission to devices, antennas for communication, and wireless communication methods. In FY2023, the first year of activities, research exchanges among members of the division were conducted through research meetings centered on lectures by departmental faculty and research results reporting meetings to which students and outsiders were invited, to accelerate collaborative research and "plant seeds". With the reclassification of the Coronavirus infection as Class 5, the importance of research in this division has increased and will likely receive renewed attention in the future. Over the next year, the division will seek to develop the results of its activities in tangible ways, such as accelerating collaborative research and attracting external funding through newly formed collaborations.

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Major Research Achievements (FY 2023)

Academic Papers

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2. Temperature imaging inside fluid devices using a ratiometric near infrared (NIR-II/III) fluorescent Y_2O_3: Nd^{3+}, Yb^{3+}, Er^{3+} nanothermometer, Umezawa M, Haraguchi H, Sugawara G, Sato K, Kurahashi H, Oda T, Okubo K, Soga K, Anal. Sci., in press (Peer-reviewed)

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5. Wearable Ion Sensors for the Detection of Sweat Ions Fabricated by Heat-Transfer Printing, Isao Shitanda, Naoki Muramatsu, Rio Kimura, Nanami Takahashi, Kazuki Watanabe, Hiroyuki Matsui, Noya Loew, Masahiro Motosuke, Takahiro Mukaimoto, Momoko Kobayashi, Taketo Mitsuhara, Yamato Sugita, Kensuke Matsuo, Shinya Yanagita, Tatsunori Suzuki, Hikari Watanabe, and Masayuki Itagaki, ACS Sensors, Vol 8, 2889 – 2895, 2023 (Peer-reviewed)

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Book
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2. デシベルから始めるプリント基板 EMC 即答 200 -平衡度とコモンモード発生の関係から偶数波増大の理由まで, 櫻井秋久, 越地耕二, 藤尾昇平, 池田浩昭, 200 問のうち 40 問を執筆, 全 278 頁, ZEP エンジニアリング, 2023（in Japanese）

Invited Lectures

1. Size fractionation method for extracellular vesicles and its application in biomedical research, <u>Umezawa M</u>, Sueyasu S, Sato K, Motosuke M, 5th International Bio/Medical Interface Symposium 2024 (IBMI 2024), Taipei (Taiwan), 2024

2. Fluidic device for fractionating membranous nanoparticles from biological cells and tissues, <u>Umezawa M</u>, Sueyasu S, Sato K, Motosuke M, 10th International Postgraduate Conference on Pharmaceutical Sciences (iPoPS 2024), Noda, 2024

3. 近赤外蛍光ナノ粒子「を」見る，そんなナノ粒子「で」見る，<u>梅澤雅和</u>，第 32 回バイオイメージング学会学術集会，札幌，2023　(in Japanese)

4. Mitochondrial stress in adipose tissue improves LPS-induced acute inflammation, Yuka Nozaki, Yuhei Mizunoe, Masaki Kobayashi, Yoshikazu Higami The 40th Spring Conference of the Korean Society for Gerontology & Korea-Japan Joint Symposium, Korea, 2023

5. IoT 時代に対応するアンテナの高性能化－広帯域化，高利得化，円偏波化，透明化技術に着目して－，<u>越地福朗</u>，エレクトロニクス実装学会システム設計研究会 2023 年度第 2 回公開研究会，Tokyo, Japan, December 2023.　(in Japanese)

Public Relation

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2. 梅澤雅和，からだの中の「ナノ」を知る，理窓（2023 年 9 月号）p.17, 2023 (In Japanese)

Awards

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2. 野崎優香、第 61 回三島海雲記念財団学術研究奨励金, 公益財団法人三島海雲記念財団, 2023 (in Japanse)

3. 小林亮太（指導教官：樋口健一），電子情報通信学会無線通信システム研究活動奨励賞，電子情報通信学会無線通信システム研究専門委員会，May 2023(in Japanese)

4. 阿部倉優太（指導教官：樋口健一），電子情報通信学会無線通信システム研究会初めての研究会最優秀発表賞，電子情報通信学会無線通信システム研究専門委員会，June 2023 (in Japanese)

5. 山崎竜聖（指導教官：樋口健一），電子情報通信学会無線通信システム研究会初めての研究会優秀発表賞，電子情報通信学会無線通信システム研究専門委員会，June 2023 (in Japanese)

6. D. Ishii (Supervisor: K. Higuchi), IEEE VTS Tokyo/Japan Chapter 2023 Young Researcher's Encouragement Award, June 2023

7. D. Kato (Supervisor: K. Higuchi), IEEE VTS Tokyo/Japan Chapter 2023 Young Researcher's Encouragement Award, October 2023

8. H. Kuwahara (Supervisor: K. Higuchi), IEEE VTS Tokyo/Japan Chapter 2023 Young Researcher's Encouragement Award, October 2023

9. 竹田昂平（指導教員：<u>山本隆彦</u>），ライフサポート学会奨励賞，ライフサポート学会，2024 (in Japanese)

Individual Research Topics

Shinya Yanagita
"Optimal physical activity levels to promote brain-organ crosstalk"

We have been clarifying the relationship between physical activity and brain functions (especially antidepressant and anxiolytic effects) using animal models. However, the optimal amount of physical activity for brain function has not been well understood. In addition, the effect of physical activity on the relationship between skeletal muscles, which are the effectors of exercise, and the brain has not been unveiled at all. Therefore, we are conducting an experimental study to clarify the optimal amount of physical activity and the mechanism by which an increase in the amount of physical (lifestyle) activity induces adaptive changes in brain function.

Masakazu Umezawa
"Optical and computational analysis of interactions of nanoparticles with biomolecules"

Changes in the secondary structure and aggregation of proteins on the surface of inorganic nanomaterials dispersed in aqueous environments are investigated using optical (ultraviolet and infrared) and computational (molecular dynamics) techniques. The change in the secondary structure of albumin on the surface of cerium oxide was found to vary depending on the chemical properties of the particle surface. The size effects of nanoparticles are also being investigated.

"Size-specific fractionation and analysis of adipocyte-derived microvesicles"

A microfluidic device was developed for size-specific enrichment and fractionation of adipocyte-derived microvesicles (ADMs). The difference in the types and amounts of mRNAs contained in ADMs by their sizes is becoming unveiled via analysis of the fractionated samples. Furthermore, the fractionation device is being improved with a focus on the possibility that some fractions of ADMs are involved in the cellular regulation of metabolism and stress responses.

Yuka Nozaki
"Age-related transition of adipose-specific mitochondrial stress"

Mitochondrial intermediate peptidase (MIPEP) plays an important role in mitochondrial matrix proteostasis by processing certain mitochondrial matrix proteins. Therefore, MIPEP dysfunction may cause mitochondrial matrix proteostasis disorder. However, studies investigating the difference between short-term and long-term mitochondrial stress responses. Therefore, we generate and analyze adipose-specific Mipep knockout (aMKO) mice to evaluate the differences.

Akira Hyogo, Ryo Kishida, Tatsuji Matsuura
"Research on high linearization of radio frequency (RF) circuits"

Mixers and other components used in radio frequency (RF) circuits are required to be highly linear for next-generation 5G communications. We have proposed a highly linear RF system by developing a circuit configuration called current bleeding. We believe that these studies will become increasingly important as next-generation communications progress in the future.

"Research on noise reduction and efficiency improvement of switching power supply circuits"

Hysteresis control is one of the control methods for switching power supplies, and its advantages are high load response and simple control circuit configuration. On the other hand, hysteresis control has a problem of noise in the audible range at light loads, which makes noise suppression difficult. We have proposed a control method that allows the hysteresis voltage to be varied so that the switching frequency does not overlap with the audible frequency band, thereby reducing audible noise.

Kenichi Higuchi

"Research on high-capacity and high-reliability wireless communication systems"

In order to realize high-capacity and high-reliability wireless communication, which is essential for smart healthcare systems that utilize intercommunication with multiple medical devices and sensors, the wireless communication method with multi-antenna transmission for high capacity, advanced error control for high reliability, and cooperative transmission technologies among multiple communication nodes are studied. By integrating link-level and network-level methodologies, we aim to realize high-capacity and high-reliability wireless communication systems with limited radio resources.

Koji Koshiji, Takahiko Yamamoto

"Development of a liver-equivalent electromagnetic phantom"

An electromagnetic phantom that simulates the electrical characteristics of the human body is useful for testing the electromagnetic compatibility of medical devices that are implanted or attached to the body under conditions similar to those in actual use, taking into account the effects of the human body. In this study, as part of the development of phantoms for various tissues, we are developing a phantom in the 8 MHz band that simulates hyperthermia treatment.

"Research on percutaneous energy and information transmission system for implantable artificial heart"

Non-invasive transmission of driving energy and control information is essential for improving the quality of life of patients with implanted artificial hearts. In order to realize a transcutaneous energy transmission system with an information transmission function, we are investigating the application of a figure-eight information transmission coil with a double-wound outer circumference that is partially cut off from the outer circumference.

"Wireless energy transmission and its biological effects on small laboratory animal tracking systems"

A small locomotion meter is used to measure the locomotion of small laboratory animals. Wireless power transmission to this device is expected to further reduce the size of the device and make it battery-free for long-term measurement. In this study, we are conducting research and development of such a non-contact power transmission device, as well as investigating the effects of exposing living organisms to electromagnetic waves.

Fukuro KOSHIJI

"Research on optically transparent antennas"

In recent years, many antennas (array antennas) have been used on the Internet of Things and fifth- and sixth-generation mobile communication systems to improve communication characteristics. However, the placement of array antennas on the surface of devices and systems causes problems that impair the design of devices and systems. In this study, we aim to realize a high-performance transparent antenna that achieves both optical transparency and electrical characteristics by using a transparent conductive film.

"Research on body area networks and biomedical information sensing"

In body area networks, antennas and electrodes that are in proximity or contact with the living body are key devices in communication and sensing technologies. In this research, the structure and arrangement of antennas and electrodes that enable stable and highly efficient signal transmission in the vicinity of the living body are investigated, and research on biomedical information sensing technology that applies these antennas and electrodes is also conducted.

Kenko Ota

"A Study on speech estimation and measurement of human body movements based on image information"

In recent years, Japan's population has been aging rapidly, and the number of domestic workers is expected to decline. To solve this problem, there is a need for technology to support workers by estimating their psychological state, physical movements, and speech content using various sensors. In this study, we investigated the prospects for new estimation technologies based on image processing and deep learning, mainly using images acquired by cameras.

Division of Biological Environment Innovation

Division of Biological Environment Innovation

1. Overview

Academic experts in the fields of environmental adaptation, biological interactions, molecular evolution, co-evolution, and ecology of living organisms have formed three subgroups "the section of environmental adaptation", "the section of molecular evolution", and the "section of nature symbiosis". In order to create an academic research field that breaks through the classical concepts and barriers of environmental biology, evolutionary science, and ecology, we produced new technological seeds that would contribute to protecting our lives in a global environment that is always changing.

2. Organization and Facilities

<Section of Environmental Adaption>

We explored to find the mechanisms underlying biological sensing of environmental stress, and develop new technologies including environmental stress-adaptive cultivation systems.

▪ Elucidation of the mechanisms underlying the evolution and diversity of lives
▪ Development of significant plant lines adapted for environmental stress tolerance and biological interaction, leading to the creation of next-generation organic cultivation systems using immunostimulants and companion plants that contribute to reduced pesticide use.

Members: Gen-ichiro Arimura, Kazuyuki Kuchitsu, Ryuichi Nishihama, Hisataka Ohta, Fuminori Takahashi, Takuya Uemura, Takumi Tomoi, Takuya Sakamoto, Sachihiro Matsunaga (The Univ. of Tokyo)

Fig. 1. Elucidation and application of environmental sensing mechanisms in various organisms.

<Section of Molecular Evolution>

We analyzed the mechanisms of genomic evolution and biology's central dogma that enable adaptation and diversification of life from the viewpoint of evolution, which had been overlooked in the past. We also aimed to develop new life system technology beyond conventional conceptions.

▪ Elucidation and utilization of minimum components and the mechanism of biological protein synthesis system of life on Earth.
▪ Development of new life system technology based on RNA technology

Fig. 2. Elucidation of the evolutionary process of life and its application to new life system technologies.

Members: Koji Tamura, Toshiki Furuya, Mitsunori Shiroishi, Masayuki Sakurai, Takashi Nakajima, Kazunori Okada (The Univ. of Tokyo), Akiko Soma (Chiba Univ.)

\<Section of Nature Symbiosis\>

We advanced scientific knowledge that contributes to the conservation of ecosystems and biodiversity, and develop technologies for assessing risks of chemical substances to living things and for managing and improving the air, water, and soil environment.

- Elucidation of environmental factors and mechanisms that affect future biological production
- Development of analytical methods for atmospheric molecules and environmental chemicals, and of methods for assessing the effects on living organisms

Members: Shinichi Miyagawa, Shinichi Satake, Yoshitsugu Akiyama, Yutaka Sumino, Takuya Saito (NIES)
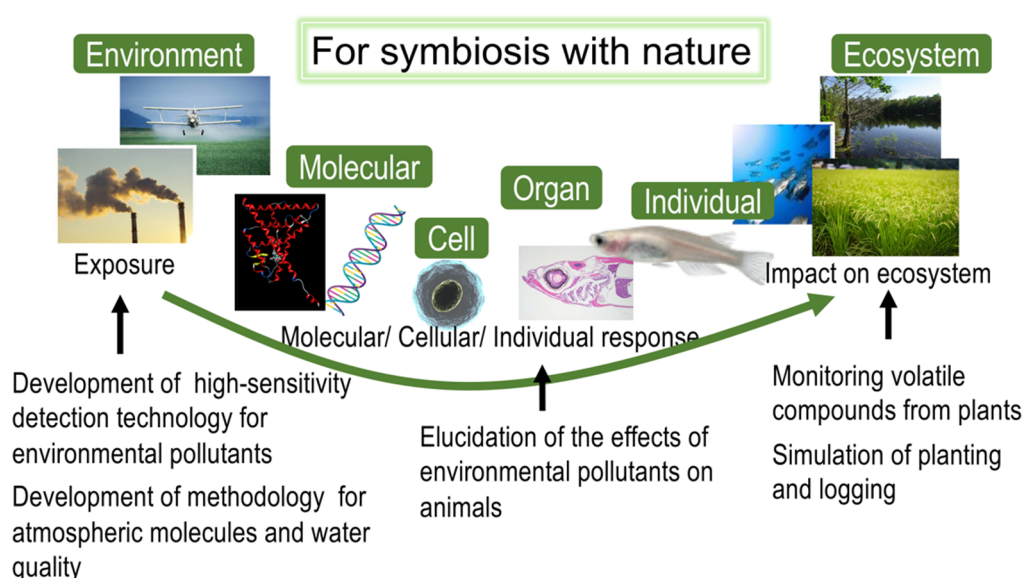
Figure 3 Strategy for the development of applied technologies for symbiosis with nature.

3. Activity Reports

In each research division, members with initiatives in their respective research areas co-worked in terms of "food" and "environment. The following public symposiums and seminars were held as part of the overall activities.

Symposium

October 27, 2023

Outcome: To promote bioenvironmental innovation research, we held a symposium with division members and leading researchers on the theme of "Visualization and quantification of environmental signal responses". The symposium was conducted on stie, and also served as a great opportunity that could be a seed for fusion research unique to the Tokyo University of Science.

2023.7.4

Dr. Kenji Matui (Yamaguchi University)

Title: 植物の葉を潰すと青臭いのはどうして？ (in Japanese)

2023.10.31

Dr. Ivan Galis (Okayama University)

Title: Defense against herbivores: Difficult task resolved by ingenuity of plants

2023.11.13

Dr. Hiroshi Akashi (University of Tokyo)

Title: 地球温暖化に対して生物はどのような応答を見せるのか？」 (in Japanese)

2023.11.27

Dr. Tkashi Seiko (National Agriculture and Food Research Organization)

Title: 野生生物の進化学　(in Japanese)

2023.12.11

Dr. Kenji Toyota (Kanazawa University)

Title: 好奇心駆動型の研究のススメ ~フィールドから分子までを貫く無脊椎動物研究~」

(in Japanese)

4. Challenges and Prospects

We will explore the mechanisms by which life adapts and diversifies, and evolution occurs in a rapidly changing habitat environment. Our aim is also to develop technological seeds that contribute to our food and health quality.

We will create a new revolutionary academic field that has never existed by fusing individually developed research areas such as environmental biology and ecology.

Major Research Achievements (FY 2023)

Academic Papers

1. Molecular anatomy of the class I ligase ribozyme for elucidation of the activity-generating unit, Kasuga M., Mutsuro-Aoki H., Ando T., <u>Tamura K.</u>, Biology, 12, pp 1012, 2023 (Peer-reviewed)

2. Elucidation of productive alanine recognition mechanism by Escherichia coli alanyl-tRNA synthetase, Onoguchi M., Otsuka R., Koyama M., Ando T., Mutsuro-Aoki H., Umehara T., <u>Tamura K.</u>, BioSystems, 237, pp 105152, 2024 (Peer-reviewed)

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4. Large-eddy simulation of cultivated fields with Cyperus malaccensis Lam, Shiraishi M., Hayashi H., Shimada H., <u>Satake S.</u>, Plant Prod. Sci., 26, pp 418-428, 2023 (Peer-reviewed)

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6. The novel potential of rose essential oil as a powerful plant defense potentiator., Kaneko E., Matsui, K., Nakahara R., <u>Arimura G.</u> J. Agri. Food Chem., 72, pp 6526-6532, 2024 (Peer-reviewed)

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12. Recovery of the histamine H3 receptor activity lost in yeast cells through error-prone PCR and in vivo selection. Watanabe A, Nakajima A, <u>Shiroishi, M.</u>, Sci. Rep. 13, pp 16127, 2023 (Peer-reviewed)

13. The plant nuclear lamina disassembles to regulate genome folding in stress conditions, Wang N., <u>Sakamoto T.</u>, <u>Matsunaga S.</u>, Liu C. et al., Nat. Plants, 9, pp 1081-1093, 2023 (Peer-reviewed)

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15. Isolation and characterization of filamentous fungi capable of degrading the mycotoxin patulin, Mita M., Sato R., Kakinuma M., Nakagawa H., <u>Furuya T.</u>, MicrobiologyOpen, 12, pp e1373, 2023 (Peer-reviewed)

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Books
1. Effects of EDCs on female reproductive system in reptiles, In: Carnevali O., Hardiman G. (Eds), Kohno S., Nguyen J., Jakobson C.L., Lange KL., Hafferman AC., Molla MA., Miyagawa S. Academic Press, pp 247-256, 2023

2. Analysis of chromatin accessibility, histone modifications, and transcriptional states in specific cell types using flow cytometry, In: Kaufmann K., Vandepoele K. (Eds), Berendzen KW., Grefen C., Sakamoto T., Slane D., Plant Gene Regulatory Networks. Methods in Molecular Biology, 2698, pp 55-73, 2023

Invited lectures
1. Plant defense system in arabidopsis-Spodoptera interactions, Arimura G., ICAR 2023, Makuhari, 2023
2. メダカ生体に対するエストロゲン様環境化学物質の作用機構, 宮川信一, 日本薬学会第 144 年会, 横浜アリーナ, 2024 (in Japanese)
3. Long-distance signaling under dehydration stress conditions, Takahashi F., Taiwan-Japan Plant Biology, Taipei, 2023
4. バッテリーレス・バッテリー混載型 EH 異常診断システム, 中嶋宇史, 佐藤智浩, 第 71 回応用物理学会春季学術講演会, 東京都市大学, 2023 (in Japanese)
5. 三次元頂端成長の確立とオーキシン ～ゼニゴケの信号伝達経路の役割から探る～, 西浜竜一, 鈴木秀政, 河内孝之, 日本植物学会第 87 回大会, 北海道大学, 2024 (in Japanese)

Patents
1. 有村源一郎, 金子瑛紀, 国内優先出願, 生育植物の免疫応答活性化剤, 及び免疫応答活性化方法, 特願 2023-150302, 2023 (in Japanese)

Public Relations
1. 有村源一郎, 悲鳴？上げるタバコ, 夕刊讀賣新聞, 2023 (in Japanese)

2. <u>有村源一郎</u>, 東京理科大, ローズ精油を利用したトマトの害虫防御技術を開発, 日本経済新聞, 2024 (in Japanese)

Awards

1. <u>坂本卓也</u>, 第 9 回 CYTOLOGIA 奨励賞, 日本メンデル協会, 2023 (in Japanese)
2. <u>Arimura G.</u>, The society awards of the International Society of Chemical Ecology, 2023
3. <u>西浜竜一</u> (他 11 名), 2024 年度 PCP Best Paper Award, 日本植物生理学会, 2024 (in Japanese)
4. <u>相馬亜希子</u>, 2023 年度長瀬研究振興賞, 公益財団法人長瀬科学技術振興財団, 2023 (in Japanese)

Individual Research Topics

Yoshitsugu Akiyama

"Precise design of hairpin DNA-gold nanoparticle monoconjugate with a single-dye molecule for targetable molecular beacon strategies"

The present study exploited a molecular beacon-gold nanoparticle monoconjugate possessing galactose derivatives (Gal-monoMB-AuNP) that specifically recognize asialoglycoprotein receptor on hepatocyte and hepatoma. A remarkable increase in fluorescence intensity of Gal-monoMB-AuNP was observed in the presence of target DNA with partial sequences for diagnostic biomarkers of cancer (TK1 mRNA). Also, WST assay resulted in no toxicity to HepG2 cells. These results will allow to develop *in vivo* cancer targeting and fluorescent bioimaging.

Gen-ichiro Arimura and Takuya Uemura

"Fundamental research for food and environmental conservation learning from biological interactions"

Plants are known to possess solid immune response mechanisms. One such response is "sensing" attack by herbivorous animals. We highlight the major types of elicitors/volatile organic compounds and the underlying cellular signaling, and states that this could spur research on organic farming practices that could prevent the use of harmful pesticides.

Hisataka Ohta

"Application of acid stress response mechanism of cyanobacteria"

Cyanobacteria are capable of producing various substances from carbon dioxide with light energy and have attracted attention as hosts for producing biofuels and bioplastics with low environmental impact. In this study, we identified genetic mutations involved in fat droplet accumulation and genes involved in biofilm formation that play a role in several response mechanisms to acid stress in cyanobacteria.

Kazunori Okada

"Research on the evolution of biosynthetic gene clusters for diterpene-type antibacterial compounds in plants"

Biosynthetic genes for momilactone, a diterpene phytoalexin found in rice, are organized on the rice genome as a gene cluster. In this research project, the existence of the momilactone biosynthetic gene cluster and its induction mechanisms via oxylipin signaling were elucidated from the viewpoint of genomics and biochemistry. This is an important discovery for investigating the evolution of gene clusters in plants and their biological implications.

Kazuyuki Kuchitsu and Kenji Hashimoto

"Physiological functions and target molecules of reactive oxygen species enzymatically produced in the plant cell wall"

Although reactive oxygen species (ROS) are typically considered to be highly toxic substances, ROS generated by the plant enzyme Rbohs are involved in a variety of physiological functions. Genetic and molecular physiological studies using a model liverwort have shown that actively generated ROS are essential for regulating cell elongation, division, differentiation, and morphogenesis as well as stress responses. We have been studying the molecular targets of ROS and molecular mechanisms of ROS-mediated regulation in plant cells.

Takuya Saito

"Biogenic volatile organic compounds in the atmosphere"

Volatile organic compounds (VOCs) emitted from various anthropogenic and natural sources are involved in air pollution and climate change, and also play an important role in stratospheric ozone depletion. Based on field measurements of VOCs emitted from natural sources, we better understood the feedbacks between the biosphere and the atmosphere via VOC emissions.

Takuya Sakamoto and Sachihiro Matsunaga

"Studies on epigenetics and chromatin dynamics in environmental adaptation"

The regulatory mechanism of chromatin dynamics was studied focusing on centromere dynamics, and the novel regulatory complex CII-LINC in plants was identified. In addition, we developed an imaging technique to detect epigenetic alternations induced by environmental stimuli, and succeeded in establishing a technique for live imaging of specific histone modifications.

Masayuki Sakurai

"Studies on deaminating editing of nucleotide adenosine bases in evolutionary adaptation of organisms"

In the Central Dogma of Life, there is a mechanism that modifies the chemical structure of four types of bases in expression regulation. In this study, we are attempting to elucidate the mechanism of modification to inosine bases, which is the result of RNA adenosine base deamination reaction. We have developed a highly accurate inosine identification method and identified 30,000 inosine sites, including 17,000 novel sites, in human brain transcripts with 97% accuracy.

Shin-ichi Satake

"Simulation of cultivated fields with Cyperus malaccensis Lam"

In this study, "honami" of Cyperus malaccensis Lam. was reproduced to establish a simulation technique that can reproduce the waves of it and predict the wind flow over it and in it related to its growth accurately. Vortex structures and vegetation oscillations were visualized.

Mitsunori Shiroishi

"Studies on molecular recognition mechanisms of animal and plant cell membrane receptors and antibodies"

We elucidated the recognition mechanism of doxepin isomers on the histamine H1 receptor. We also analyzed the pH-dependent functions of various GPCRs using Saccharomyces cerevisiae. We constructed an insect cell expression system for cell membrane receptors involved in plant environmental responses. We also performed binding analysis and crystal structure analysis of anti-D-amino acid antibodies and the autoantibody rheumatoid factors (RFs).

Yutaka Sumino

"Spatio-temporal pattern formation induced by rheological change of external/internal media"

Living organisms, especially plants, composed of collective number of cells. Such cells communicate locally, yet establish macroscopic spatio-temporal order spontaneously. This process should be supported by so-call dissipative structure generated under far-from-equilibrium conditions. In our study, we focus on the branching-like pattern formed under injection of fluid owing to the rheological change of external and internal media. We created experimental systems, and extracted essential features of these system using mathematical model.

Akiko Soma

"Identification of tRNA repertoires in plant organelles"

Organelles contain their own gene expression systems, while it is general that insufficient species and copies of tRNA genes are found in the organelle genomes. We analyzed anticodon sequences of organelles of single-cell algae, and found that the some tRNAs are modified to enlarge their decoding capability. Such mechanism allows a small set of tRNA repertoire to decode codons.

Fuminori Takahashi

"Elucidation of long-distance signaling under environmental stress conditions in plants and its application to crop"

We identified sensor modules that recognize drought stress conditions in roots and promote a synthesis of abscisic acid which is required for acquisition of drought stress tolerance in leaves. Especially, we analyzed the downstream signaling of receptors including transcription factors and regulatory factors. We further applied those findings to rice for generating environmental stress resistance crops.

Koji Tamura

"Research on the origin and evolution of the genetic code that lies at the core of bio-environmental innovation"

Aiming to develop new life-system technologies that are unconventional by analyzing the mechanism of action of genome evolution and central dogma that enable adaptation and diversification of life from the perspective of evolution that has been overlooked in the past.

Takashi Nakajima

"Studies on mechanism of piezoelectricity of biopolymers"

Odd-Nylon extracted from castor oil and fibroin contained in silk are known to have piezoelectric properties. These materials are environmentally conscious and are expected to be applied to new sensors and actuators that work in vivo. In this study, the piezoelectric properties of biopolymers were quantitatively evaluated, deepening an understanding of the mechanism of piezoelectricity to apply them to biological systems.

Ryuichi Nishihama

"Studies on the mechanisms of environmental control of plant growth using a liverwort"

We discovered a highly conserved signal transduction pathway in which the phytohormone auxin, which plays important roles in environmental responses and developmental regulation, is perceived at the cell surface, and rapidly regulates cellular activities by phosphorylation. Furthermore, this pathway was found to be mediated by the Raf-like kinase PRAF, which we previously identified as a photosynthesis signaling component. We also found that Marchantia utilizes the conserved pathway for defense signaling and that the activation of a proton pump in stomatal cells is mediated by a newly identified photosynthesis-dependent phosphorylation mechanism.

Shinichi Miyagawa

"Analysis of the mechanisms of interaction between the environment and organisms for symbiosis with nature"

All living organisms are constantly affected in various environment cues and a developing animal ingeniously exploit such external environmental factors to alter its own phenotype to enhance its own survival and the ability of its offspring to reproduce in future. This phenomenon is called phenotypic plasticity. We elucidate the mechanisms of how animals receive environmental factors and translate it into intracellular signals, to understand the interaction between organisms and their environment.

Toshiki Furuya

"Research on utilization of microbial and enzymatic functions"

Microorganisms that activate plant immune responses have high potential for application as biocontrol agents in agriculture, as they function like vaccines in plants without causing unwanted adverse effects. We study a method to detect microorganisms that activate the plant immune system based on plant-microbe interactions. In addition, there is growing interest in environmentally friendly synthetic approach to production of chemicals from the viewpoint of SDGs, and we study bioprocesses using enzymes and renewable resources.

Research Group for Advanced Energy Conversion

Research Group for Advanced Energy Conversion

1. Overview

The development and use of highly efficient energy systems are a matter of urgency, because the exhaustion of petroleum resources and the resultant economic instability are a call to action. The problem is conspicuous in our country since it depends heavily on the import of petroleum. Studies are being carried out in the Division of Ecosystem Research and the Advanced EC Device Research Division, on the development and testing of an electrochemistry device for commercialization purposes.

The United Nations has set 17 targets as global SDGs, and these targets are indispensable for future technical development. The following two relate to our research group:

SDG 7: "Ensure access to affordable, reliable, sustainable, and modern energy for all."

SDG 12: "Ensure sustainable consumption and production patterns."

In our research group, we will study the development and environment-friendly use of new energy, following a product of the Advanced EC Device Research Division, on electrochemical devices, hydrogen energy, heat energy, and light energy.

Our research group consists of two teams: the research team for energy transformation and the research team for energy storage. The research team for energy transformation takes charge of the development of technology and materials for the generation and transformation of energy. The research team for energy storage takes charge of the development of technology and materials on the storage and utilization of energy. Both teams cooperate mutually with the aim of building a system for the generation, transformation, storage, and utilization of energy. When an advanced energy device is created, its development is accelerated by cooperation between group members beyond the limit of their specialty and research fields, to overcome current problems and improve the fundamental knowledge level among group members, furthering collaboration.

Based on "Only at TUS", a researcher on the front line participating in this research should be able to accumulate information and technological know-how from scholars in the various fields and achieve high technical development and originality.

A characteristic feature of our research group is the inclusion of the "Sustainable Energy Systems and Materials" course from the Graduate School of Science and Technology curriculum. The participation of both students and teachers is indispensable for the development of new materials and systems. We plan to hand-down technology and knowledge from generation to generation through research proceeds of students who carry the science and technology of the next

generation, and we plan for an aggressive exchange between students and teachers to achieve the goal of this research group early.
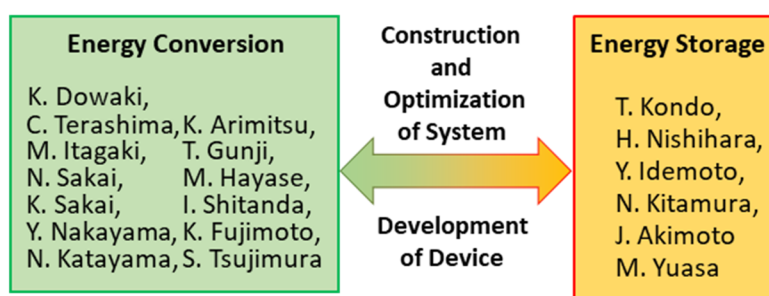
2. Organization and Facilities

<Research on energy conversion>

Based on outcomes from the Division of Ecosystem Research and the Advanced EC Device Research Division, the development of highly efficient, environment-friendly organic synthetic processes, and highly sensitive and functional light-reactive polymers are advancing. One of the aims of this research group is the development of new catalytic reactions for the highly selective reduction of carbonyl groups to methylene groups, to be used in applications for organic compounds made up of elements other than oxygen. Another objective of this group is the development of a polymer that responds to multiple forms of energy, by designing a polymer that reacts stepwise to light and heat. In addition, high-speed material screening will be carried out using a combinatorial experimental method.

The generation and utilization of bio hydrogen will be proposed in relation to SDG 12, based on life-cycle assessment (LCA). A system consisting of the generation of hydrogen from waste wood, its purification, storage, and use in the generation of electricity through fuel cells, as well as in charge storage in capacitors will be built and evaluated based on LCA.

We will manufacture a printable wearable biofuel cell with paper and transfer sheet. For example, a fuel cell that uses organic material in urine as fuel can be used for urine detection (Elderly care, health maintenance). By using lactic acid in sweat as fuel, one can monitor the health of athletes. In order to make the wearable device, we prepare mesoporous carbon materials suitable for use as enzymes, and then develop a printable paper device using the carbon as the electrodes.

In the development of the polymer electrolyte fuel cell, we synthesize a metal-complex-supported conductive diamond as the electrode catalyst and develop a novel silicon-based polymer as the electrolyte.

<Research on energy storage>

We aim to prepare high-capacity electrodes with structures that are well controlled at atomic-to-micro levels and perform high-throughput material screening, and device-oriented electrochemical and structural analyses. For optimization of nano- and micro-structures of the electrodes, we will prepare the powder using liquid-phase synthetic methods like solvothermal synthesis, and then perform a surface coating on the pristine powder.

Atomic configurations of the materials will be simulated computationally for theoretical screening. In addition, we will investigate degradation mechanisms of the batteries under various operation conditions, by means of selected electrochemical techniques such as in-situ analyses of the atomic and electronic structures using neutron and synchrotron X-ray sources and in-situ electrochemical impedance spectroscopy (EIS) by cooperating with energy conversion group. This strategy enables us to produce a customized and appropriate device design based on a working condition and a purpose of use.

3. Activity Reports

In this research group, we also encourage the progress of a joint research by the members in addition to the individual research work by a member.

a) The gas purification of in the Blue Tower demonstration plant (AGM/Advanced Gasification Module) and the development of gas purification by two step PSA. (Dowaki and Gunji)

b) Development of fuel cell system using storage of hydrogen by adsorption aiming the application as a mobile battery. (Dowaki and Katayama)

c) Development of rapid health monitoring system of lithium ion secondary battery. (Itagaki and Katayama)

d) Development and evaluation of wearable bio fuel cell. (Shitanda, Tsujimura, Katayama, and Itagaki)

The homepage of this research group was made in Japanese and English.

This research group is joint to the Energy and Environment Course which is located to the Graduate School of Science and Technology to encourage young researchers. Our members attend the Poster Competition on August, 26, 2022.

4. Challenges and Prospects

a) Promotion of joint research intra- and inter-research group.
b) Setting a target number for joint research and positive promotion.
c) Holding a lecture and a meeting for presenting research.
d) Holding and support of the international conferences.
e) Acquisition of research funds.
f) Management of laboratories. (No. 10 building 4th floor. Research rooms Nos. 4 and 9)

Major Research Achievements

Academic Papers

1. Hydrolysis and condensation behavior of tetraethoxysilane, hexaethoxydisiloxane, and octaethoxytrisiloxane, Y. Sato, A. Sugimoto, T. Iwashina, R. Hayami, K. Yamamoto, <u>T. Gunji</u>, Journal of Sol-Gel Science and Technology, 108, 377–391, 2023. (Peer-reviewed)

2. Manipulating the Morphology and Electronic State of a Two-Dimensional Coordination Polymer as a Hydrogen Evolution Cocatalyst Enhances Photocatalytic Overall Water-Splitting, J. Guan, K. Koizumi, N. Fukui, H. Suzuki, K. Murayama, R. Toyoda, H. Maeda, K. Kamiya, K. Ohashi, S. Takaishi, O. Tomita, A. Saeki, <u>H. Nishihara</u>, H. Kageyama, R. Abe, R. Sakamoto, ACS Catal., 14, 1146-1156, 2024. (Peer-reviewed)

3. Enhanced degradation of ibuprofen using a combined treatment of plasma and Fenton reactions, Y. Hirami, Y. M. Hunge, N. Suzuki, V. Rodríguez-González, T. Kondo, M. Yuasa, A. Fujishima, K. Teshima, <u>C. Terashima</u>, J. Colloid Inter. Sci., 642, 829-836, 2023. (Peer-reviewed)

4. Toughening Ionic Polymer Using Bulky Alkylammonium Counterions and Comb Architecture, D. Aoki, K. Yasuda, <u>K. Arimitsu</u>, ACS Macro Lett., 12, 462-467, 2023. (Peer-reviewed)

5. Rheo-impedance measurements for dispersibility evaluation of electrode slurries I. Shitanda, K. Sugaya, C. Baba, N. Loew, Y. Yamagata, K. Miyamoto, S. Niinobe, K. Komatsuki, H. Watanabe, <u>M. Itagaki</u>, ACS Applied Electronic Materials, 5, 4394-4440, 2023. (Peer-reviewed)

6. Rate Dependence of Average Crystal Structure and Electronic Structure of $0.5Li_2MnO_3$-$0.5LiMn_{10/24}Ni_{7/24}Co_{7/24}O_2$ for Lithium-Ion Battery Positive Electrode Material in Steady State, Y. Idemoto, K. Shima, C. Ishibashi, N. Ishida, <u>N. Kitamura</u>, ACS Appl. Energy Mater., 6, 8327-8335, 2023. (Peer-reviewed)

7. Synthesis of Dithioacetals through Iodine-Promoted Insertion Reactions of Vinylsilane to Disulfides and its Application to Diselenoacetalization, <u>N. Sakai</u>, K. Fukuda, Y. Ogiwara, K. Ishida, Synthesis, 55, 1915-1921, 2023. (Peer-reviewed)

8. Discussions on the heat transfer performance of the indirect pyrolysis plant using CFD modeling, M. Hamazaki, K. Torii, M. Shan, M. Kameyama, J. Victor L Mercado, <u>K. Dowaki</u>, IOP Conf. Series: Earth and Environmental Science, 1187, 012026, 2023. (Peer-reviewed)

9. Simple Low-Temperature GaN/Diamond Bonding Process with an Atomically Thin Intermediate Layer, T. Matsumae, S. Okita, S. Fukumoto, <u>M. Hayase</u>, Y. Kurashima, H. Takagi, ACS Applied Nano Materials, 6, 14076-14082, 2023. (Peer-reviewed)

10. Boron and Nitrogen-Codoped Diamond Electrodes for the Improved Reactivity of Electrochemical CO_2 Reduction Reaction, Y. Miyake, T. Kondo, A. Otake, Y. Einaga, T. Tojo, <u>M. Yuasa</u>, ACS Sustainable Chem. Eng., 11, 8495-8502, 2023. (Peer-reviewed)

11. Enhanced Removal of Photoresist Films through Swelling and Dewetting Using Pluronic Surfactants, M. Hanzawa, T. Ogura, M. Akamatsu, <u>K. Sakai</u>, H. Sakai, Langmuir, 39, 4670-14679, 2023. (Peer-reviewed)

12. High Li-Ion Conductivity in Pyrochlore-Type Solid Electrolyte $Li_{2-x}La_{(1+x)/3}M_2O_6F$ (M = Nb, Ta), A. Aimi, H. Onodera, Y. Shimonishi, <u>K. Fujimoto</u>, S. Yoshida, Chemistry of Materials (Published online28 March 2024) . (Peer-reviewed)

13. Well-ordered molecular heterojunction of epitaxial C_{60} on single-crystal dinaphtho[2,3-b:2',3'-f]thieno[3,2-b]thiophene (DNTT), <u>Y. Nakayama</u>, K. Ito, R. Takeuchi, R. Tsuruta, K. Yamauchi, S. Izawa, M. Hiramoto, R. Kumara, T. Koganezawa, Applied Physics Express, 16, 101001, 2023. (Peer-reviewed)

Books

1. 金属錯体の二次元物質 配位ナノシート, 前田啓明, 福居直哉, 髙田健司, <u>西原 寛</u>, 化学の要点シリーズ 44, 日本化学会編, 共立出版, 2023. (in Japanese)

2. 第 1 章 第 2 節 エポキシ樹脂の光硬化 〜基礎と影部の光硬化〜, <u>有光晃二</u>, エポキシ樹脂の配合設計と高機能化, 技術情報協会, 16-26, 2023. (in Japanese)

3. Wearable Biosensing in Medicine and Healthcare: Printable Wearable Self-Powered Biosensing System Based on Paper-Based Biofuel Cells Using Porous Carbon Material, <u>Isao Shitanda</u>, Springer Nature, 379-398, 2024

4. Hyperordered Structures in Materials: Disorder in Order and Order within Disorder, <u>Naoto Kitamura</u>, Springer, 249-263, 395-410, 2023

Invited lectures

1. QDQ または TDT 構造からなるポリシロキサンの合成とその性質, <u>郡司天博</u>, 下田智也, 山本一樹, 日本セラミックス協会第 36 回秋季シンポジウム, 京都工芸繊維大学（京都府京都市）, 2023/9/6 (in Japanese)

2. Overview of coordination nanosheets, <u>Hiroshi Nishihara</u>, JSPS-EPSRC Workshop on 2D conjugated MOFs and coordination nanosheets, Dresden, Germany, 2023

3. In-liquid plasma processing for synthesizing the functional materials, <u>Chiaki Terashima</u>, Hiroshi Uetsuka, Katsuya Teshima, 5th International Conference on Materials Science, Engineering, Singapore, 27th Feburuary 2024

4. Printed biosensors and biofuel cells for monitoring body fluids, <u>Isao Shitanda</u>, Young Researchers Society for Flexible and Stretchable Electronics, 5th event, Yokohama National University, Bldg. S1-2, 101 (Plenary lecture), 2023/5/19

5. Boron-doped diamond powder/nanoparticle as functional electrode materials, <u>T. Kondo</u>, International Conference on Advanced Technology and Multidiscipline (ICATAM), Online, 2023

6. Phase mapping of pseudo-ternary $LiFePO_4$-$LiMnPO_4$-$LiCoPO_4$ reaction diagrams and electrode properties in olivine-type $LiFe_{1-x-y}Mn_xCo_yPO_4$, <u>Kenjiro FUJIMOTO</u>, 11th International Symposium on Inorganic Phosphate Materials (ISIPM-11), Venezia, Italy, 2023

7. Inter-molecular electronic bands in crystalline organic semiconductors probed by synchrotron radiation photoelectron spectroscopy, <u>Yasuo Nakayama</u>, UVSOR 研究会「明日の放射光光電子分光研究展開のシーズとニーズ 」, 愛知, 2023 (in Japanese)

Patents

1. 積層体, 積層体の製造方法, 及び二酸化チタン担持体, 特許権者　東京理科大学, 発明者　<u>郡司天博</u>, 山本一樹, 特許 7442175 号, 2024/2/22 (in Japanese)

2. 二次電池用負極の製造方法及び二次電池の製造方法, <u>西原 寛</u>, 宮地麻里子, 佐藤正春, 特許第 7431044 号, 2024/1/16 (in v Japanese)

3. 血液成分分離方法及びマイクロ流体デバイスの目詰まり防止剤, <u>早瀬仁則</u>, 水田龍信, 特許第 7284473 号, 2023/5/23 (in Japanese)

4. <u>酒井健一</u>他, アルコール組成物, 特願 2023-129092 (in Japanese)

Public Relations

1. <u>西原 寛</u>, 整流特性を示す新たな面内ヘテロ接合素子の簡便合成に成功 〜電力変換装置や超大規模集積回路の開発・高性能化に寄与〜, 東京理科大学プレスリリース, 2024/2/9. (in Japanese)

2. 四反田功, 「【ヴィランの言い分】 汗」, 2023 年 6 月 10 日, E テレ (in Japanese)
3. 堂脇清志, 片山 昇, ALFALINK 流山スプリングフェスタ, ALFALINK 流山スプリングフェスタ実行委員会主催, 2023.3 (in Japanese)

Awards
1. T. Gunji, Featured Article in Polymer Journal. Polymer Journal, 55, 975–982, 2023
2. H. Nishihara, Back Cover in Angew. Chem. Int. Ed.. Angew. Chem. Int. Ed., 63, e202318181, 2024
3. Isao Shitanda, Masayuki Itagaki, Supplemental cover in ACS Sensors. ACS Sensors, 8, 2368-2374, 2023
4. Yasushi Idemoto, Naoto Kitamura, Supplementary Cover in J. Phys. Chem. C. J. Phys. Chem. C, 127, 10470-10479, 2023
5. N. Sakai, Top Downloaded Paper (European Journal of Organic Chemistry), Wiley, 2023.
6. K. Fujimoto, Science Award, The Society of Inorganic Materials, Japan, 2023 (in Japanese)
7. 山中凜太郎, 片山 昇, 四反田功, 横井亨哉, YPC 奨励賞, "紙基板型乳酸バイオ燃料電池の直流モデルの解析と電極形状の最適化,"令和 6 年電気学会電力・エネルギー部門大会, 2023 年 9 月 (in Japanese)

Individual Research Topics

Takahiro Gunji

"Studies on the polysilsesquioxanes having proton conductivity"

Polysilsequioxanes having phosphonic acid moiety as a side chain was synthesized and the proton conductivity was evaluated as a function of temperature and humidity. Polysilsesquioxanes having phosphonic acid moiety as a side chain was synthesized by the hydrolytic polycondensation of 3-mercaptopropyl(trimethoxy)silane and the following thiol-ene reaction and alcoholysis. The thin film was prepared and the conductivity was evaluated under high-humidity or low-humidity as a function of temperature.

Hiroshi Nishihara

"Studies on metal complex two-dimensional materials 'coordination nanosheets"

Synthesis, structural analysis, elucidation of properties and functions, and application of coordination nanosheets composed of combinations of metal ions and planar organic ligands have been carried out. We found that bis(diimino)copper nanosheets are LIB cathode materials with high energy capacity. As for bis(terpyridine) complex nanosheet M-tpy, we have developed a hetero-laminating method of Fe-tpy and Co-tpy and found that it exhibits rectifying properties. The performance of perovskite solar cells was improved by adding Zn-tpy.

Chiaki Terashima

"Development of diamond photocatalyst for highly efficient CO_2 conversion"

Diamond semiconductor has a potential to reduce the CO_2 molecules with high efficiency due to its wide bandgap energy and the high reduction energy by the conduction band edge. We focused to use the diamond materials in the research work with two strategies. One is to utilize the excimer lamp for ultraviolet wavelength by using of low power, in order to excite the diamond photocatalyst. Second is to modify the diamond nanomaterials with co-catalysts such as Ag, Cu, Sn and their core-shell structures.

Koji Arimitsu

"Synthesis of highly proton-conductive polymer materials"

Synthesis of a silicon-containing polymer was investigated as a substitute material for Nafion^{TM} used in polymer electrolyte batteries. After identifying the structure of the synthesized polymer and examining its heat resistance and thermal decomposition behavior, it was found to be a polymer with high thermal stability.

Masayuki Itagaki

"Studies on the electrochemical methods to evaluate energy transformation devices"

Studies on the electrochemical methods were carried out to evaluate energy transformation devices like lithium-ion battery and polymer electrolyte fuel cell, etc. For example, a precise electrochemical impedance method has been developed to analyze degradation of lithium-ion batteries equipped in aircrafts. And new surface treatments and its evaluation method have been developed for high durability of polymer electrolyte fuel cells.

Isao Shitanda

"Study for wearable biofuel cell"

Paper substrate biofuel cells were fabricated by screen printing on paper substrates. This year, we fabricated a biofuel cell using a novel water-based porous carbon ink. A new carbon ink using polysol as a binder and water as a solvent was prepared. The output power of the new aqueous porous carbon ink was higher than that of the conventional ink with NMP as a solvent and PVdF as a binder.

Yasushi Idemoto and Naoto Kitamura

"Development of new cathode materials for magnesium secondary batteries and investigation of discharge and charge mechanism"

To develop high-capacity cathode materials for magnesium secondary batteries with excellent cycle properties, we investigated the electrochemical properties of spinel-type oxides with various metal compositions, and found that $Mg_{1.33}V_{1.67-x}Mn_xO_4$ exhibited excellent cathode properties. As for some samples, surface modification with Zr compounds was found to be effective in improving cycle properties.

Norio Sakai

"Development of the novel synthetic method of sulfur-containing polycyclic heterocycles toward electroconductive materials"

We focused the development of the effective synthetic method of sulfur-containing polycyclic heterocycles, cyclic sulfide compounds, embedded in the seven-membered ring skeleton, in the hope that the derivatives would be applied to electrochemical devises. It was found that when heating the mixture of a terminal alkyne having a biphenyl group and potassium sulfide with a catalytic system composed of a copper(I) halide and 1,10-phenanthroline as a ligand in N-methylpyrrolidone, the corresponding cyclic sulfide was obtained in a relatively high yield.

Kiyoshi Dowaki

"A system analysis of H₂S adsorbent using mine waste in the bio-hydrogen production system"

Energy production systems, through the combined biomass and fuel cells, can produce clean energy with little environmental impact. However, H_2S in the syngas from the plant causes the performance drop of fuel cells. Therefore, in this study, the removal of H_2S from synthesis gas after the gasification process was investigated through experiments on the adsorption performance using granular neutralized sediment, of which soil discharged from abandoned mines. In addition, the environmental impacts are estimated in terms of life cycle engineering to reduce the environmental impact of hydrogen production.

Masanori Hayase

"Studies on the MEMS type miniature fuel cell"

We are developing a miniature fuel cell with silicon electrodes on which the catalyst layer and the fuel channels are fabricated monolithically. Performance was improved by developing an electrolyte membrane that has adapted shape to the recesses of the catalyst layer. Along with this, water flooding has become conspicuous. Therefore, to observe the behavior of the generated water and promote its discharge, a novel transparent PDMS channel cover was proposed.

Takeshi Kondo and Makoto Yuasa

"Research on aqueous electric double-layer capacitors using conductive diamond powder"

An aqueous electric double-layer capacitor (EDLC) was fabricated using boron-doped nanodiamonds (BDND) as the electrode material and concentrated $NaClO_4$ aqueous solution as the electrolyte, and its durability was evaluated. In a charge-discharge cycle test with a cell voltage of 2.3 V, the capacitance reached 84% of the initial capacitance after 10,000 cycles. In addition, the capacitance was found to retain 97% of the initial capacitance after a 10-hour float test at 2.3 V. Therefore, this aqueous EDLC was found to exhibit sufficient durability even when used at a high cell voltage (2.3 V).

Kenichi Sakai

"Adsorption characteristics and reaction film analysis in mixed extreme-pressure agents"

We characterized the adsorption and desorption behavior of mixed extreme-pressure (EP) agents at an iron oxide/dodecane interface. The two EP agents could adsorb on the iron oxide competitively, and the phosphorus-type EP agent inhibited the adsorption of the sulfur-type EP agent. The phosphorus-type EP agent promoted the formation of an oxidized surface film of sulfur components on steel under sliding conditions. This also contributed to decreased kinetic friction coefficient for the mixed EP agent system.

Kenjiro Fujimoto

"Study on chemical oxidation of cathode materials for lithium-ion batteries"

Chemical oxidation with a mild acid was tried on $LiNi_{1/3}Co_{1/3}Mn_{1/3}O_2$ without the strong oxidant NO_2BF_4. In solid-liquid reaction with carbonated water, no change in Li content was observed after 130 hours, and the maximum amount of Li desorption was 67%. XANES spectra of the acid-treated samples showed an increase in Ni and Co valence compared to pristine. The charge balance due to Li^+ desorption was considered to be an increase in transition metal valence and ion exchange to H_3O^+. Thermal analysis of the powder after 25 hours of treatment with carbonated water (Li=0.53) showed a weight loss around 250 °C, corresponding to a phase change to a spinel structure. Therefore, the heat treatment conditions were fixed at 200 °C for 30 hours, and the valence and initial discharge capacities were compared before and after heat treatment. Although the initial discharge capacity improved after heat treatment, it did not reach the value indicated by pristine, suggesting residual water in the interlayer.

Noboru Katayama

"Diagnosis of Lithium-ion Batteries Using Machine Learning and Electrochemical Impedance Spectroscopy"

In recent years, there has been growing interest in diagnostic techniques for the internal state of lithium-ion batteries. The electrochemical impedance spectroscopy is a non-destructive approach to estimate the internal state of a device. In this study, a method for estimating the internal state that is independent of measurement conditions was proposed using machine learning. Data on the SoC and SoH of lithium-ion batteries were collected through experiments, and a model using a neural network was trained to perform estimation. The results showed that the internal state can be accurately estimated without being dependent on temperature.

Yasuo Nakayama

"Construction and electronic characterization of well-defined molecular semiconductor p-n junctions built on organic single-crystal substrates"

   The functionalities of organic electronic devices such as organic solar cells are rooted in p-n junctions where different kinds of organic semiconductor molecules come into direct contact with each other, and the structural control and electronic properties in such intermolecular junctions are main points for the development of the devices. In FY2022, we have summarized the researches on well-defined molecular semiconductor heterojunctions as a review paper. We have also developed a new method to evaluate the luminescent properties of OLED material molecules promptly and efficiently as a collaborative research with the Joint Graduate School (AIST).

Seiya Tsujimura

"Development of High-Performance Enzyme Electrodes"

   We develope effective interface between enzymes and electrodes to enhance the performance of electrohcemical biosensors and biofuel cells that use enzymes as electrocatalysts. In particular, we focus on the development of organic mediators that facilitate electron transfer between enzymes and electrodes. We are working on immobilization of redox mediator on porous carbon materials and modification of polymers. The obtained materials will be applied to printed electrochemical devices.

Junji Akimoto

"Synthesis, crystal structure and conduction properties of novel lithium ion conducting oxides"

   We focused on Li_4SiO_4-Li_3PO_4 solid electrolytes as lithium ion conducting oxides and optimized the synthesis conditions. The crystal structures of the synthesized samples were investigated in detail, and the correlation between the crystal structure and lithium ion conductivity was examined.

Modern Algebra and Cooperation with Engineering

Modern Algebra and Cooperation with Engineering

1. Overview

It is important for mathematics, which has more than 2000 years of history for research, to interact with other research fields outside mathematics. The research area of pure mathematics is roughly divided into three parts, algebra, geometry, and analysis. One can think that algebra and analysis are two wheels of a cart, via geometry and geometric objects. In its long history, analysis, which treats mainly continuous objects, has been developed in interaction with various engineering technologies. On the other hand, algebra, which treats mainly discrete objects, has interacted with information science, information technology, electrical, mechanical engineering, etc., and produced many essential results and effects for modern human life since the 20th century. Our division based on algebra is going to cooperate with another division "Research Alliance for Mathematical Analysis" and become a basis of science and technology to cooperate with various research areas. Our final goal is to make our division a center of research on algebra and algebra-based engineering.

2. Organization and Facilities

The division consists of various researchers belonging to Tokyo University of Science, whose research fields are number theory, arithmetic geometry, algebraic geometry, commutative algebra, representation theory, automorphic forms, algebraic topology, discrete mathematics, combinatorial design, computational mathematics, computer algebra, cryptology, information security, coding theory, applied algebra, and statistical science.

In the past, these researchers have cooperated with each other in the occasion of seminars, workshops, and international meetings. As an activity of this division, we pursue further cooperative relationships not only inside the division, but also outside the division, and we are going to produce many research collaborations between pure mathematics and engineering.

The division consists of three groups for purely mathematical research and four for applied research. The pure mathematics groups hold seminars, workshops, and symposiums on algebra, algebraic geometry, number theory, etc. The applied research groups make a place for the engagement of researchers in pure mathematics and engineering by proposing and developing many research plans for both sides. Furthermore, the division does cooperative research by continuously pursuing deep cooperation with Research Alliance Center for Mathematical Sciences, Tohoku University.
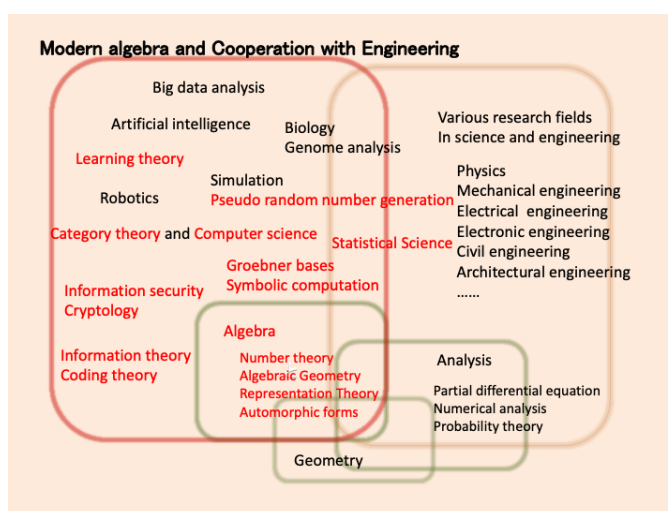

Fig. 1. Research Map.

Name	Job title	Affiliation	Main research field
Hiroyuki Ito	Professor	Department of Mathematics Faculty of Science and Technology	Algebraic geometry Applied algebra
Katsunori Sanada	Professor	Department of Mathematics Faculty of Science Division I	Ring theory
Masanari Kida	Professor	Department of Mathematics Faculty of Science Division I	Number theory
Naoko Kunugi	Professor	Department of Mathematics Faculty of Science Division I	Representation theory
Yosuke Sato	Professor	Department of Mathematical Information Science Faculty of Science Division I	Computer algebra
Hiroshi Sekigawa	Professor	Department of Mathematical Information Science Faculty of Science Division I	Computational Mathematics
Hiroki Aoki	Professor	Department of Mathematics Faculty of Science and Technology	Automorphic forms
Nobuko Miyamoto	Professor	Department of Information Sciences Faculty of Science and Technology	Discrete mathematics Combinatorial designs and their applications
Kouji Tahata	Associate professor	Department of Information Sciences Faculty of Science and Technology	Categorical Data Analysis Analysis for square contingency tables
Takao Satoh	Professor	Department of Mathematics Faculty of Science Division II	Algebra, Geometry
Katsusuke Nabeshima	Associate professor	Department of Mathematical Information Science Faculty of Science Division I	Computer algebra
Yoshitaka Hachimori	Associate professor	Department of Mathematics Faculty of Science and Technology	Algebra Number theory
Toru Komatsu	Associate professor	Department of Mathematics Faculty of Science and Technology	Number theory
Tomokazu Kashio	Associate professor	Department of Mathematics Faculty of Science and Technology	Number theory
Hisanori Ohashi	Associate professor	Department of Mathematics Faculty of Science and Technology	Algebraic geometry
Yasutaka Igarashi	Associate professor	Department of Electrical Engineering Faculty of Science and Technology	Information security Cryptanalysis
Kenta Noguchi	Associate professor	Department of Information Sciences Faculty of Science and Technology	Graph theory
Takashi Nakamura	Associate professor	Noda Division Institute of Arts and Sciences	Analytic number theory
Ayako Itaba	Junior associate professor	Katsushika Division Institute of Arts and Sciences	Algebra Noncommutative algebraic geometry
Genki Koda	Assistant professor	Department of Mathematics Faculty of Science Division I	Algebraic number theory
Yuta Kozakai	Assistant professor	Department of Mathematics Faculty of Science Division I	Representation theory
Yuki Ishihara	Assistant professor	Department of Mathematical Information Science Faculty of Science Division I	Computer algebra
Yuya Matsumoto	Assistant professor	Department of Mathematics Faculty of Science and Technology	Number Theory Algebraic Geometry
Yoshinosuke Hirakara	Assistant professor	Department of Mathematics Faculty of Science and Technology	Number Theory
Makoto Enokizono	Assistant professor	Department of Mathematics Faculty of Science and Technology	Algebraic Geometry

Fig. 2. List of Members.

3. Activity Reports

Our division promotes research through the following two styles.

a) Researchers learn deeply about a wide range of topics close to each other's specialties, share the latest research results, and incorporate useful methods for solving the problems they are pursuing.

b) We solve problems by intensively discussing and cooperating on a single problem or theme.

In 2023, we progressed our research based on the styles above and tried to gradually return to the situation before the Coronavirus disaster by combining face-to-face and online communications.

For Style a), we held a total of 7 algebra seminars, lectures, and ring theory lectures in both Kagurazaka

campus and Noda campus throughout the year, with content related to both research groups. On the other hand, regarding Style b), we invited collaborators from different universities to give lectures on the central topics. We also took time for discussion and intensive research exchanges. In particular, the algebraic geometry/commutative algebra group is making great progress in studying singularities by group scheme quotients. In addition, although we were unable to hold a research meeting co-sponsored with the Collaborative Research Center for Mathematical Sciences at Tohoku University for various reasons this year, we will continue to maintain an ongoing relationship.

4. Challenges and Prospects

After all, it has not been able to act as an active research base like before the Coronavirus disaster. This is partly due to the restrictions imposed by the COVID-19 pandemic, but it is also thought that the peculiarity of mathematics research centered on dialogue and discussion has worked in a negative direction due to the pandemic. On the other hand, although the burden on the organizers has increased due to the new form of combined use of online, it seems that the obstacles to holding the workshop have decreased. Activation is expected by holding research meetings. In addition, it is considered necessary to proceed to the stage of human resource exchange such as cross-appointment, starting with substantial joint research in the collaborative agreement with the Collaborative Research Center for Mathematical Sciences at Tohoku University.

5. Conclusion

The integration of research and research exchanges, which had stagnated due to the Coronavirus disaster, are gradually showing signs of revival as new styles are adopted. The need to devote daily work to deal with the coronavirus induces a delay in our research activities. However, we feel that the situation is gradually returning to the previous situation. We have high hopes for the method that incorporates new changes. Although the department will be established for five years from 2021, we would like to actively engage in activities in the next fiscal year in anticipation of future development.

Major Research Achievements (FY 2023)

Academic Papers

1. Takao Sato: Presentations of Schur covers of braid groups, Toshiyuki Akita, Rikako Kawasaki, and Takao Satoh, Journal of Group Theory 27, 207-222, 2024 (Peer-reviewed)

2. 角度に制限を設けた格子三角形による正方形の三角形分割，青木史也，武田 渉，関川 浩，京都大学数理解析研究所講究録 2255, RIMS 共同研究(公開型)，Computer Algebra—Foundations and Applications, pp. 164-173, 2023 (in Japanese)

3. マンハッタン距離ボロノイ図からの母点探索，山中悠輔，武田 渉，関川 浩，京都大学数理解析研究所講究録 2255, RIMS 共同研究(公開型)，Computer Algebra—Foundations and Applications, pp. 174-183, 2023 (in Japanese)

4. An approximation algorithm for the nearest decomposable polynomial in the Hamming distance, Hiroshi Sekigawa, ACM Communications in Computer Algebra (CCA), Vol. 57, No. 3, pp. 119-122, 2023. DOI: 10.1145/3637529.3637532 (Peer-reviewed)

5. 合成で表現可能な最近接多項式を求める近似アルゴリズム，関川 浩，数式処理, Vol. 30, No. 1, pp. 53-56, 2024 (in Japanese)

6. T. Nakamura, "L-functions with Riemann's functional equation and the Riemann hypothesis", The Quarterly Journal of Mathematics. 74 (2023), no 4, 1495--1504.

7. T. Nakamura and M. Suzuki, "On infinitely divisible distributions related to the Riemann hypothesis", Statistics & Probability Letters. 201 October 2023, 109889.

8. T. Nakamura, "Dirichlet series with periodic coefficients, Riemann's functional equation and real zeros of Dirichlet L-functions", Math. Slovaca. 73 (2023), no. 5, 1145--1152.

9. T. Nakamura, "On zeros of bilateral Hurwitz and periodic zeta and zeta star functions", Rocky Mountain J. Math. 53 (2023), no.1, 157--176.

10. Optimality and constructions of spanning bipartite block designs, Shoko Chisaki, Ryoh Fuji-Hara and Nobuko Miyamoto, Metrika, in press, 2024 (Peer-reviewed)

11. Unknottability of spatial graphs by region crossing changes, Yukari Funakoshi, Kenta Noguchi, Ayaka Shimizu, Osaka Journal of Mathematics, 60, 671-682. (Peer-reviewed)

12. Cubic graphs having only k-cycles in each 2-factor, Naoki Matsumoto, Kenta Noguchi, Takamasa Yashima, Discussiones Mathematicae Graph Theory, 44, 281-296. (Peer-reviewed)

13. Kida, Masanari: Arithmetic equivalence under isoclinism. Communications in Algebra, 2024. published online. https://www.tandfonline.com/doi/full/10.1080/00927872.2024.2312460

14. Kida, Masanari: Arithmetically equivalent fields in a Galois extension with Frobenius Galois group of 2-power degree. Canad. Math. Bull. 66 No.2 (2023) pp.380-394.

15. Inseparable maps on W_n-valued Ext groups of non-taut rational double point singularities and the height of K3 surfaces, Yuya Matsumoto, Journal of Commutative Algebra, 15(3), 377-404, 2023

16. Degeneration of K3 surfaces with non-symplectic automorphisms, Yuya Matsumoto, Rend. Sem. Mat. Univ. Padova, 150, 227-245, 2023

17. Extendability of automorphisms of K3 surfaces, Yuya Matsumoto, Mathematical Research Letters 30(3), 821-863, 2023

18. μ_p- and α_p-actions on K3 surfaces in characteristic p, Yuya Matsumoto, J. Algebraic Geom., 32, 271-322, 2023

19. Geometric Mean Type of Proportional Reduction in Variation Measure for Two-Way Contingency Tables, Wataru Urasaki, Yuki Wada, Tomoyuki Nakagawa, Kouji Tahata, Sadao Tomizawa, Sankhya B : The Indian Journal of Statistics,2024 (Peer-reviewed)

20. Separation of the refined estimator of the measure for symmetry in square contingency tables, <u>Kouji Tahata</u>, Ryohei Auchi, Shuji Ando and Sadao Tomizawa, COMMUNICATIONS IN STATISTICS-SIMULATION AND COMPUTATION,2023 (Peer-reviewed)

21. Y. Shiba, K. Sanada and A. Itaba, Symmetric cohomology and symmetric Hochschild cohomology of cocommutative Hopf algebras, (2023) Journal of algebras and its applications, Online Ready, https://doi.org/10.1142/S0219498824502232. (Corresponding author: A. Itaba)

22. (投稿中, プレプリント公開)A. Itaba, Quantum projective planes and Beilinson algebras of 3-dimensional quantum polynomial algebras for Type S', (2023) arXiv:2304.02242.

23. (英語プロシーディング) A. Itaba, QUANTUM PROJECTIVE PLANES AND BEILINSON ALGEBRAS OF 3-DIMENSIONAL QUANTUM POLYNOMIAL ALGEBRAS FOR TYPE S', Proceedings of the 55th Symposium on Ring Theory and Representation Theory, 26−31, Symp. Ring Theory Represent. Theory Organ. Comm., Matsumoto, (2024).

24. (日本語プロシーディング) 板場綾子, Type S' に対する非可換射影平面と quantum polynomial algebra の Beilinson 多元環について, 研究集会「第 16 回数論女性の集まり (WINJ2023)」 (東京工業大学) 報告集 17-23, 2023 年 10 月 (in Japanese)

25. Relative stable equivalences of Morita type for the principal blocks of finite groups and relative Brauer indecomposability, Naoko Kunugi and Kyoichi Suzuki, Journal of Group Theory, Vol.26, No.6, pp.1157-1184 (2023) (Peer-reviewed)

26. Splendid Morita equivalences for the principal 2-blocks of 2-dimensional general linear groups in non-defining characteristic, Naoko Kunugi and Kyoichi Suzuki, SUT Journal of Mathematics, Vol.59, No.2, pp.117-135 (2023) (Peer-reviewed)

Books
1. 基本群と被覆空間, 佐藤隆夫, 裳華房, 320p, 2023 (in Japanese)
2. (訳本) 暗号と誤り訂正 代数学的基礎とその応用, 三嶋美和子, 宮本暢子, 篠原 聡, 丸善出版, 570 ページ, 2023 (in Japanese)

Invited Lectures
1. 伊藤浩行：On unified p-group scheme actions, 湯布院代数幾何学ワークショップ, 2024 年 12 月 27 日
2. 伊藤浩行：On unified p-group scheme actions and its applications, 晴れ晴れ岡山 代数幾何学シンポジウム, 2024 年 1 月 19 日
3. 伊藤浩行：Quasi-elliptici fibrations on K3 surfaces in characteristic 2, 第 8 回 代数幾何学研究集会 -宇部-, 2024 年 3 月 10 日
4. 加塩朋和：円分 Z2 拡大の極小相対単数について, 加塩朋和, プロジェクト研究集会 2023, ハートピア熱海, 2024 年(in Japanese)
5. 数値数式融合計算, 関川浩, 日本数学会 2024 年度年会, 大阪公立大学, 2024 年 3 月 17 日. (in Japanese)
6. T.Nakamura, "A Mathematical Interpretation of the Pattern of COVID-19 Post-Vaccination Mortality and Excess Mortality", Frontier of Clinical Medicine as Predictive Science, 京都大学医学部 芝蘭会館 稲盛ホール and ZOOM, 2023 5.20.
7. Cubic graphs having only k-cycles in each 2-factor, Kenta Noguchi, The First Shiraz-Yokohama Workshop on Graph Theory, online (Iran and Japan), 2023 (Aug. 8)
8. 木田雅成：Semiabelian extensions について 第 15 回福岡数論研究集会. 立命館アジア太平洋大学. 2023 年 9 月 12 日. 第 15 回 福岡数論研究集会報告集 pp.57--63. (in Japanese)

9. 木田雅成 : ガロア群の同質類とガロア拡大の整数論. 2023 大分宮崎整数論研究集会. 宮崎大学. 2023 年 9 月 16 日. (in Japanese)

10. Kummer 曲面の非分離類似 (in Japanese), 松本雄也, 野田代数幾何学シンポジウム 2023, 東京理科大学, 2023

11. Ordinal quasi-symmetry and its properties for multi-way contingency tables, <u>Kouji Tahata</u>, IMS-APRM 2024, The University of Melbourne's Parkville Campus, 2024

12. 板場綾子, 中心上有限生成な非可換射影平面と Beilinson 多元環, 野田代数幾何学シンポジウム 2023. (東京理科大学野田キャンパス), 2023 年 9 月 4 日

13. A. Itaba, Quantum projective planes finite over their centers and Beilinson algebras, The ninth China-Japan-Korea International Conference on Ring and Module Theory (Incheon National University, Republic of Korea), plenary speaker, 2023 年 8 月 17 日全体講演(英語講演), 韓国, 仁川市

14. A. Itaba, Quantum projective planes finite over their centers and Beilinson algebras, 中国科学技術大学数学科学研究院(呉文俊数学重点実験室代数学系列報告之 234), 2023 年 12 月 12 日(英語講演), 中国, 合肥市

Individual Research Topics

Hiroyuki Ito

"Research on algebraic geometry and singularity theory in positive characteristic and its application to a high-performance pseudorandom number generator. "

I studied quotient algebraic varieties and quotient singularities by finite group schemes of typical types with positive characteristics. Furthermore, I tried to construct a general theory combining Artin-Schreier extensions and purely inseparable extensions of the Frobenius type including many pathological phenomena with positive characteristics. Furthermore, I tried to improve the performance of the pseudorandom number generator using the Artin-Schreier tower of huge finite fields which I invented before.

On the other hand, progress has also been made on quasi-elliptic surfaces, which are closely related to pathological phenomena specific to positive characteristic algebraic geometry. Our detailed investigation of the Mordell-Weil groups in the case of K3 surfaces gave a concrete description of the stratification in moduli space using the Artin invariants.

Katsunori Sanada

"Study on the Lie algebraic structure of complete Hochschild cohomology rings"

We studied defining the Lie bracket product by Gerstenhaber by introducing the BV (Batalin-Vilkovisky) structure to the complete Hochschild cohomology of Frobenius algebras, which is an extension of the ordinary Hochschild cohomology to negative dimension.

Masanari Kida

"Studies on isoclinism classes of Galois groups"

I investigated the arithmetic of number fields based on isoclinism classes of Galois groups and obtained the results on a coincidence of Dedekind zeta functions and semiabelian Galois group.

Naoko Kunugi

"Studies on Morita and Derived equivalences for blocks of finite "groups""

When constructing the Morita equivalences or derived equivalences between blocks of finite groups, there is a method of constructing and lifting stable equivalences of the Morita type. In 2023, we considered relative stable equivalences of the Morita type, which is a generalization of stable equivalences of the Morita type, and developed a method of lifting relative stable equivalences of the Morita type to the Morita equivalences.

Hiroshi Sekigawa

"Research on polynomial decomposition"

If a polynomial f is represented by the composition as f = g(h), where g and h are polynomials, then we can evaluate f with a smaller number of arithmetic operations in general. Unfortunately, almost all polynomials cannot be represented as a composition of polynomials; however, if f−g(h) has few terms, we can use the representation for efficient evaluation of f. In 2023, for a multivariate polynomial f, we began studies on algorithms to find a decomposition of f, and on algorithms to find polynomials g and h such that f−g(h) has few terms when f cannot be represented as decomposition of polynomials.

"Research on polynomial analogues of Wieferich primes"

We consider polynomial analogues of Wieferich primes and call them Wieferich irreducible polynomials. For polynomials over the finite field of order 2, we obtain the following results: if g is the square of a polynomial, then there are infinitely many Wieferich irreducible polynomials in base g; if polynomials g or g+1 are divisible by the derivative of g, then there are only finitely many Wieferich irreducible polynomials in base g.

Hiroki Aoki

"Research on automorphic forms of several variables by using Jacobi forms from an explicit and constructive point of view"

I have been continuously working on the theory of automorphic forms of several variables, which is an important research topic in algebra, especially in number theory. My research is mainly from an explicit and constructive point of view. I also collaborate with my graduate students on related topics on number theory.

Kouji Tahata

"Study of modeling on square contingency tables"

A contingency table is one of the essential tools for analyzing categorical data. Especially for the analysis of the square contingency table, which has the same row and column classifications, we are more interested in considering the symmetry structure than the independence structure. This research aims to assess the modeling of symmetry and asymmetry. Additionally, we reveal the interpretation of the model concerning information theory and properties of goodness-of-fit test statistics. Moreover, we apply the proposed models to a real data set.

Nobuko Miyamoto

"A study on construction and optimality of spanning bipartite block designs"

We proposed a block design called Spanning Bipartite Block Design (SBBD), in which the edge set of a complete bipartite graph is a treatment set and a spanning subgraph is a block, and studied its construction method and optimality. SBBD is a combinatorial structure applicable to the drop-connect method to improve generalization performance in deep learning.

Takao Satoh

"Study of twisted first cohomology groups of the automorphism groups of free groups"

We studied several modules on which the automorphism group of a free group naturally acts without factoring the general linear group on the abelianization of the free group. In particular, we studied its group theoretic properties and unstable cohomology groups.

"Cokernels of the Johnson homomorphisms of the McCool groups and the braid groups"

(Joint work with Naoya Enomoto) We studied the Johnson cokernel of the McCool groups and the Braid groups with trace maps and the representation theory. In particular, we completely determined the structure of the Johnson cokernel of degree up to 4.

Yoshitaka Hachimori

"Research on the mu-invariants of p-adic L-functions for elliptic curves"

A necessary condition for the vanishing of the mu-invariant of the p-adic L-function for an elliptic curve over the rational field associated with the cyclotomic Z_p-extension for a prime p where the curve has a good ordinary reduction is given by a certain uniform distribution of the values of the modular symbols used for a construction of the p-adic L-function. All the values of the modular symbols can be computed from a finite number of data by using the continued fraction expansions of rational numbers. We examined how the values of modular symbols vary when we change the initial data for the elliptic curve of conductor 11 and for some p's.

Tomokazu Kashio

"A Study of Number fields, rings of integers, and unit groups"

I wrote two papers on p-adic periods. The one has been accepted and the other is under submission. In collaboration with Hyuga Yoshizaki, we formulated a conjecture concerning the minimum element of the unit group of Z2-expansions on the rational number field, partially proved it, and provided its application to the class number problem. The paper is in preparation for submission. In collaboration with Yoshinosuke Hirakawa, Naoaki Takada, and Ryutaro Sekikawa, We proved a generalization of the second supplemental law of quadratic reciprocity law. The paper is also in preparation for submission.

Takashi Nakamura

My research interests are Analytic number theory, Zeta functions, L-functions, Value distribution, Complex and real zeros, Universality, Multiple zeta functions and values, Functional equations, Functional relations, Riemann hypothesis, Infinitely divisible distributions, Zeta distributions, and 2010 Mathematics Subject Classification: 11M06, 11M26, 11M32, 11M35, 60E07.

Yuya Matsumoto

"Study on inseparable Kummer surfaces"

We showed that a supersingular K3 surface in characteristic 2 with suitable 16 curves admits an inseparable covering, and hence gives an inseparable analogue of Kummer surfaces.

Kenta Noguchi

"A study on graphs on closed surfaces, particularly for the connectivity, spanning trees, and Hamiltonian cycles"

Since last year, I have researched graphs on closed surfaces, particularly on the connectivity of the dual, homeomorphically irreducible spanning trees, the number of leaves for spanning trees, and Hamiltonian cycles of toroidal directed graphs.

Ayako Itaba

"Study of 4-dimensional Koszul AS-regular algebras obtained by Ore extension of 3-dimensional Koszul AS-regular algebras"

Previously published in 2021 and 2022, Itaba-Matsuno's research conducted an algebraic classification of arbitrary 3-dimensional Koszul AS-regular algebras, but in general, the classification and properties of Koszul AS-regular algebras of 4 dimensions or more are not specific. It is known that all algebras obtained by applying a non-commutative ring expansion called Ore expansion to any 3-dimensional Koszul AS-regular algebras become 4-dimensional Koszul AS regular algebras. In this research, through joint research with Masaki Matsuno of PD (Itaba Lab), Tokyo University of Science, we show that all 4-dimensional Koszul AS-regular algebras obtained as Ore extensions of arbitrary 3-dimensional Koszul AS-regular algebras can be calculated using geometric algebra. It was shown that the condition (G1) regarding the point scheme appearing in the definition is satisfied. Using the previous algebraic classification, we can determine when a concrete 4-dimensional Koszul AS-regular algebra becomes a geometric algebra, that is, when it satisfies the (G2) condition regarding the relation appearing in the definition of a geometric algebra. In this year, results were obtained especially for Type S and Type S'. We have established methods to solve all other cases and are preparing presentations at research conferences and publishing them in academic papers in 2024

"Study of Hochschild cohomology rings and Lie algebras of Beilinson algebras for weighted Down-up algebras of general order"

Previously published in 2021, Itaba-Ueyama's research was based on a weighted down-up of order (1, m). The dimension of the Beilinson algebra A's Hochschild cohomology group of algebra B(A) was determined using an algebraic method. As an application of this, if A and A' are weighted down-up algebras of order (1, m), when m is 2, the bounded derived categories of A and A' are determined using the conditions for the categories D(tails A) and D(tails A') to be triangulated categories equivalent as Abelian categories, and if m is 3 or more, the bounded derived categories D(tails A) and D of A and A'. We showed that (tails A') is not always trigonometric equivalence as an abelian category. In this study, we determined all the Hochschild cohomology groups and ring structures of Beilinson algebras for weighted down-up algebras of general order (n, m), including the Belmans and Itaba-Ueyama results, and the structure of the Lie ring was determined using the following Hochschild cohomology information. Furthermore, we showed the same result as the above for the Itaba-Ueyama abelian category in the case $(n,m) = (2,2)$ and in the case where n,m are both 3 or more. This research is based on joint research with Shu Minamiki, a first-year master's student in the Department of Mathematics, Graduate School of Science (Itaba Lab). We are currently preparing to give a lecture at a research meeting in 2024 and submit our results to an academic paper.

Research Division for Advanced Disaster Prevention on Cities

Research Division for Advanced Disaster Prevention on Cities

1. Overview

Research Division for Advanced Disaster Prevention on Cities was reorganized and renamed from Research Division of Architectures in Advanced Cities in 2021.

"Resolving to the increasingly complex city environment and city life in the 21st century by combining the wisdom of various fields in architectonics", "Seeking the ideal Tokyo as a metropolis in the 21st century from the Sotohori and Kagurazaka areas, where the TUS is based on". In addition to these themes of the former division, we incorporated a new perspective: "How can the city prepare for and overcome the harsh disasters and the catastrophic disasters in the future?" in the reorganization.

We have built modern city systems to make our lives more comfortable. However, the city systems have been occasionally destroyed by natural disasters.

For example, the Kanto Earthquake in 1923 destroyed the most advanced city functions of the time which were built with technologies introduced from Western countries since the opening of Japan. The earthquake and the following disasters exposed the problems of modern cities.

In addition, the 2011 Tohoku earthquake and tsunami destroyed city functions and environments that relied on the Internet and the interrelationships of other cities. Furthermore, the Noto Peninsula earthquake that occurred in January of this year exposed the severe damage caused by liquefaction.

The damage to power plants and other infrastructure facilities by the earthquake and tsunami caused rolling blackouts and disruptions to the transportation network connecting the Tohoku and Kanto regions and indirectly long-term damage to city functions in the Tokyo metropolitan area as well.

Each time we have suffered such catastrophes, we have learned and struggled to protect the city systems.

However, we must prepare against catastrophic disasters surpassing the lessons in the past.

For instance, the inland earthquake in Tokyo has been estimated to have a 100% chance of occurrence within 30 years.

In addition, the Tonankai earthquake was estimated as "Causing catastrophic damages to almost the entire land of Japan and lasts severe paralysis on the functions of the nation".

With these menaces, the division has given greater weight to the theme of "disaster prevention in cities with advanced systems." to build city systems that sustain the culture and functions of entire cities and facilitate their restoration (resilience) in the event of a disaster.

Therefore, the division was reorganized as Research Division for Advanced Disaster Prevention on Cities.

2. Organization and Facilities

1. Responding to the city environment and life that has become increasingly complex and inconsistent with the advanced development of the 21st century, by bringing together the best of various fields of architectural science.
2. Exploring the ideal of "Tokyo as a metropolis of the 21st century" from the Sotobori (Outer Moat) and Kagurazaka areas, the base of Tokyo University of Science
3. Prospecting for modern cities against incoming catastrophic disasters.

As mentioned above, the propositions changed with its reorganization, and the structure of the division itself remains the same as its predecessor.

The division members consist of specialists in each field belonging to the following faculties:

1. Faculty of Engineering,
2. Former Second Faculty of Engineering
3. Faculty of Science and Technology
4. Department of Global Fire Science and Technology

There are three research groups under the division. The interrelationships among them create a reciprocal relationship.
The names and interrelationships of the groups are shown in Figure 1.

1. **Research Group of City Cultures**: Conducting basic architectural research on traditions and city culture to maintain and create unique regional values.
2. **Research Group of City Performances**: Conducting applied research to improve the planning and engineering performance of city functions, especially in disaster prevention.
3. **Research Group of City Designing**: Conducting applied research on architectural and regional renewal model design studies in collaboration with the other two groups above.

Our headquarters are located in the "Research and Promotion Office for Sotobori and Kagurazaka Areas" on the first floor of Building No. 12 of the TUS Kagurazaka Campus. The headquarters exhibit various contents, such as scaled models of Kagurazaka or panels of our proposals. These are updated as needed.

In addition, we held annual presentations and seminars regarding our research studies by inviting residents in Kagurazaka. Additionally, in fiscal 2021, we launched a website, and are now able to disseminate the activities of this division over the internet, and we plan to continue making improvements in the future.

The research and design proposals of this research department are displayed permanently in the form of panels and models, and the exhibition content is updated from time to time. The center also holds various regional research presentations, meetings, and seminars.

Every year, we expand communication equipment, presentation equipment, material production equipment, etc., and in 2023 we will purchase equipment such as computers.
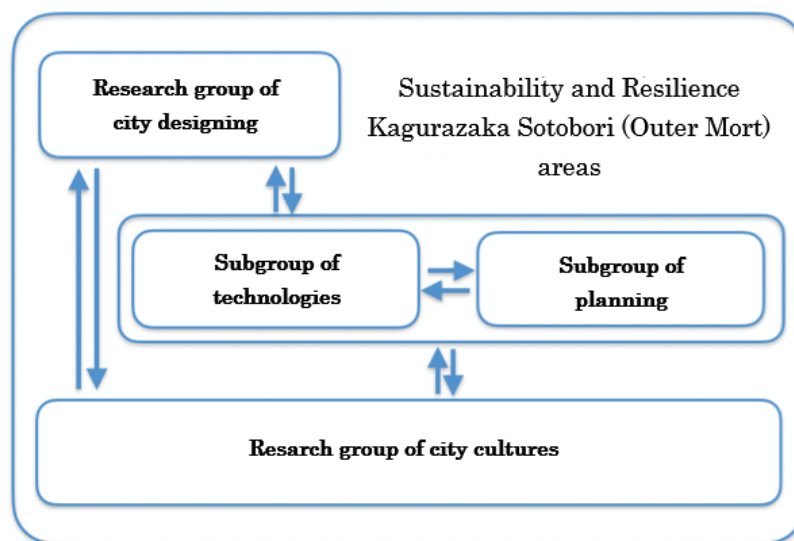
Fig. 1. Research groups in the Division and their interrelationships.

3. Activity Reports

3. 1. Research Group of City Cultures

Hirohisa ITO (Chief of the group), Madoka KAYANOKI:

City planning in the 21st century must consider the importance of research for cultures, heritages, transformations, compositions, and formation of modern and contemporary cities, and traditional construction methods for wooden structures.

By organizing, integrating, and systematizing the accumulation obtained through these studies, we will conduct basic research to build a platform that will contribute to the evaluation of city performance and city design research.

While studying waterfront areas in city centers, we will accumulate knowledge on the formation of future city environments by focusing on layered natural landforms and their changes from time to time.

In addition, we are also conducting research on disaster prevention based on these studies.

3. 2. Research Group of City Performances

▪ **Subgroup of Planning (City Planning · Analyzation)**

Momoyo GOTA (Chief of the group), Kaori ITO:

The Kagurazaka area is characterized by its highly dense low-rise wooden buildings and alleyways that slope toward the Sotobori (Outer Moat) area. This uniqueness creates individuality and attracts customers.

In addition, unique characteristics in those areas can be found in terms of the flow of people and behavior patterns.

These factors of the Sotobori-Kagurazaka area contribute to forming one of the most diverse and unique city spaces in the World.

By analyzing the planning conditions of buildings and cities that contribute to the study of planning, city design, and architectural design in this area, we will compile research and create a proposal of an evaluation of resilience from disasters to the government.

▪ **Subgroup of Technologies (Prevention of Disaster and fire)**

Osamu TAKAHASHI (Chief of the group), Keiichi IMAMOTO, Mamoru KONO,
Ryohei KUMAGAI, Yuji MIYAZU:

We research countermeasure plans for earthquake, fire, and flood damage for high-rise buildings by assuming a case of a university campus and its surrounding areas in Tokyo's central metropolitan district.

Likewise, we are developing, researching, and proposing city planning systems and methods that contribute to improving the disaster-prevention performance of local districts by evaluating the fire-resistance performance of building materials, the disaster-prevention performance of building construction methods, and reinforcement methods for seismic retrofitting of buildings from multiple perspectives.

3. 3. Research Group of City Designing

Motomu UNO (Chief of the group), Kaon KO

We are now researching to propose a definitive consensus regarding city design and development in the metropolitan districts of Tokyo, with sustainability and resilience.

For this purpose, we are examining the vulnerabilities of recent city planning on uneven geological and topographical terrain by referring to the results of revitalization projects in the central areas of Tokyo.

In addition, we are creating draft plans by analyzing, evaluating, or integrating characteristics as follows: forms of cities, materials for buildings, modeling, and planning for disaster prevention.

4．Conclusion

Through the change of division heads and the renewal of divisions and research themes, we have gradually been able to align those areas that were not aligned.

Although there are still some effects, such as delays and restrictions on research surveys due to COVID-19 since 2020, we will continue to promote further research.

In the next fiscal year, we intend to make regional recommendations based on the local disaster prevention performance of the Kagurazaka and Sotobori (Outer Moat) areas, with the following three items pointed out by the Advisory Committee.

1. Compilation and presentation of evaluation and planning methods for appropriate and rational space utilization
2. Evaluation methods for disaster prevention performance and engineering proposals for performance improvement to prepare for disasters
3. Design methods for architectural and city environments that integrate the above and present concrete results in practical application.

Major Research Achievements (FY2023)

(Lab. of Momoyo GOTA) Planning
1. Investing in the social places of heritage towns, Tomoko Kano, Takae Tanaka, Momoyo Gota, "Investing in Disaster Risk Reduction for Resilience Design, Methods and Knowledge in the Face of Climate Change" Elsevier, 2022, 55-76 (Peer-reviewed)

(Lab. Of Madoka KAYANOKI) History
1. 関東大震災と都市の復興(特集 関東大震災から 100 年 ： 過去を振り返る)，日本地震工学会誌 巻号 49 号 2023 年 6 月，p. 36-39，栢木まどか (in Japanese)
2. 関東大震災と都市の不燃化
   (特集 関東大震災百年：近代復興から現代復興へ；帝都復興と市街地整備・住宅政策・経済物流に関する展開) 雑誌 都市計画 日本都市計画学会 巻号 72 巻 4 号(通号 363)
   2023 年 7 月 15 日，p66-69,栢木まどか (in Japanese)
3. 近代和風建築と鉄筋コンクリート造，雑誌 Science forum：東京理科大学科学教養誌
   巻号 40 巻 5 号(通号 437) 2023 年 10 月，p24-29，栢木まどか (in Japanese)
4. 同潤会の建築の考え方とその先進性(特集 関東大震災 帝都復興百年のレガシー) 雑誌 造景，建築資料研究社 巻号 2023，p74-77，栢木まどか (in Japanese)

(Lab. of Kaori ITO) Planning
1. 第 30 回国際地図学会議（イタリア・フィレンツェ及びオンライン）参加報告, 伊藤香織, 太田 弘，若林芳樹，有川正俊，矢野桂司，常泉佑太 60 巻，1 号，94-108 頁, 2022.4，地図 (in Japanese)

(Lab. of Osamu TAKAHASHI) Structure
1. 重ね板バネの制振性能に関する研究—実大実験による性能の比較— 2023 年度日本建築学会大会[近畿] (in Japanese)
2. 新構造技術を用いた実践的挑戦—旧荒屋鉱泉の鉄筋コンクリートブロック塀のポリウレア補強—2023 年度日本建築学会大会[近畿] (in Japanese)
3. 新構造技術を用いた実践的挑戦—焼杉斜め張り耐力壁を用いた耐震改修計画—2023 年度日本建築学会大会[近畿] (in Japanese)
4. ポリウレア樹脂を用いた津波シェルターに関する解析的研究 2023 年度日本建築学会大会[近畿]，第 15 回複合・合成構造の活用に関するシンポジウム，第 18 回 コロキウム構造形態の解析と創生 2023 (in Japanese)
5. Braced Oil Dampers for Buildings: Development and Analytical Modeling, Osamu Takahashi, Atsuki Yokoyama, CRC Press, 2023/9/5, 246 pages

(Lab. of Keiichi IMAMOTO) Materials
1. Biomineralization Analysis and Hydration Acceleration Effect in Self-healing Concrete using Bacillus subtilis natto, Nguyen Ngoc Tri Huynh, Kei-ichi Imamoto, Chizuru Kiyohara, Journal of Advanced Concrete Technology, 2022, 20, 609-623 (Peer-reviewed)

(Lab. of Mamoru KONO) Materials
1. 無耐火被覆小梁を有する鋼構造床架構の火災高温時崩壊挙動評価, 高木次郎, 王 松, 栗原 純, 河野 守, 松山 賢, 日本建築学会構造系論文集(電子媒体), 87 巻.799 号.944-953 頁, 2022 年 9 月，レフェリー付学術論文 (in Japanese)

(Lab. of Yuji MIYAZU) Structure and materials

1. 中層木質ラーメン建築物用の方杖型摩擦ダンパの開発, 下山雅人, 宮津裕次, 宮田雄二郎, 脇田健裕, 石山央樹, 日本建築学会技術報告集, 28 巻, 70 号, 1189-1194 頁, 2022 年 10 月, レフェリー付学術論文 (in Japanese)

Invited Lectures

1. 新材料・新構造で未来の社会を創造する〜国土交通省に認められ実践した新技術〜, 髙橋 治, 第 28 回「震災対策技術展」横浜, パシフィコ横浜, 2023.2 (in Japanese)

Publishments

1. 関東大震災と東京, 栖木まどか,113 巻, 6 号, 4-18 頁, 2022.6, 講演録 (in Japanese)

Individual Research Topics

Motomu Uno, Kaon Ko

"Research on the city architectural design of Kagurazaka, Sotobori (Outer Moat) and its surrounding area"

We are conducting a structural analysis of the topography, historical transition, architectural form, and arrangement of the area surrounding the "Outer Moat" that separates the old city district from the old Edo castle. In addition, design works to examine and adjust the inconsistencies of the area as a modern city.

We are in charge of method research and practice to realize a superior design proposal by integrating elemental technologies and specialized knowledge.

Hirohisa Ito, Madoka Kayanoki

"Historical research of city and architecture on Kagurazaka, Sotobori (Outer Moat) and the surrounding area"

We are now researching the history of cities in Tokyo from the modern transition period of the Meiji and Taisho periods to the Showa period before World War II.

At the same time, we are attempting to discover cultural assets by focusing on festival events found in the neighborhoods of the old city center.

To maintain the presence of the region, we are trying to preserve cultural assets by investigating historical traditions and regional specificities.

Momoyo Gota, Kaori Ito

"Analysis and evaluation technique research of city and architectural planning concerning Kagurazaka, outer moat, and surrounding areas"

This project will study the renewal planning of city zoning and architectural planning techniques to preserve public space appropriately.

In the Kagurazaka area, we conducted a quantitative analysis of the streetscape focusing on the materials and colors of building facades, and route analysis for a two-directional evacuation in particular districts with dead ends.

Mamoru Kawano

"Researches on the capabilities for fire protection and disaster prevention of Kagurazaka, Sotobori and their surrounding areas"

I am researching the performance against fire in cities where wooden houses were constructed densely, such as the Kagurazaka area.

Osamu Takahashi, Hideyuki Kinugasa

"Research on structural performance of buildings in Kagurazaka, Sotobori (outer moat) and surrounding areas"

Under the theme of vibration control structures and seismic isolation structures, we are going to survey and evaluate buildings in the area that use vibration control structures.

In addition, practical research is now being conducted on new high-strength materials that apply to wooden buildings, block walls, and other concrete structures.

Keiichi Imamoto, Yuji Miyazu
"Research on the performance of materials used in buildings in Kagurazaka-Sotobori areas and their surroundings"

From the viewpoint of building materials, we are conducting research on the integrity of wooden buildings and concrete structures in the Kagurazaka area, including exploration of wooden buildings that have deteriorated due to ant damage, and basic studies on reinforcement methods using resin filling.

Ryohei Kumagai
"Research on architectural structures in Kagurazaka-Sotobori area, and their surroundings"

I have researched the exterior and structural characteristics of wooden buildings constructed densely in the Kagurazaka area after World War II.

I am going to study and elucidate the characteristics of the stores and their changes in the densely built wooden building area and the town block.

Division of Medical Data Sciences

Division of Medical Data Sciences

1. Overview

The implementation of "Medical Data Sciences" is indispensable for establishing preventive and therapeutic methods for the complete cure of diseases. This research division aims to solve medical problems by combining data science methods and cancer biological experimental methods. We aim to create Medical Data Sciences at TUS by forming an international scientific network.

2. Research sections

It forms three sub-groups of interdisciplinary research fields, "Data Science Research Section", "Cancer Biology Research Section" and "Connecting Section of Data Science and Cancer Biology" (Fig. 1). We worked on research activities aiming at the creation of interdisciplinary "Medical Data Sciences" by breaking old academic research fields.
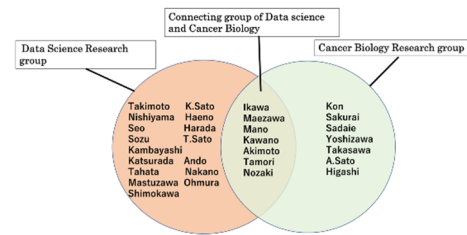
Fig. 1. Division members.

(Data Science Research Section)

Takimoto M., Nishiyama H., Seo T., SozuT., Katsurada K., Tahata K., Matsuzawa T., Ohmura H., Sato K., Haeno H. Harada T., Shimokawa A., Sato T., Kambayashi A., Ando S., Nakano Y.

(Cancer Biology Research Section)

Kon S., Sakurai M., Sadaie M., Yoshizawa K., Takasawa R., Sato A., Higashi K.

(Connecting Section of Data Science and Cancer Biology)

Ikawa T., Maezawa S., Mano Y., Kawano Y., Akimoto K., Tamori S., Nozaki Y.

We used the common facilities of the departments to which each member belongs. In addition, we used Laboratory 8 on the 3rd floor of Building No. 10 on the Noda campus. The experiment space was equipped with a freezer provided free of charge by Noda City, and members' own equipment was brought in as shared equipment. A server for data analysis was used in the server room on the second floor of Building No. 19 (Dr. Haeno as the administrator).
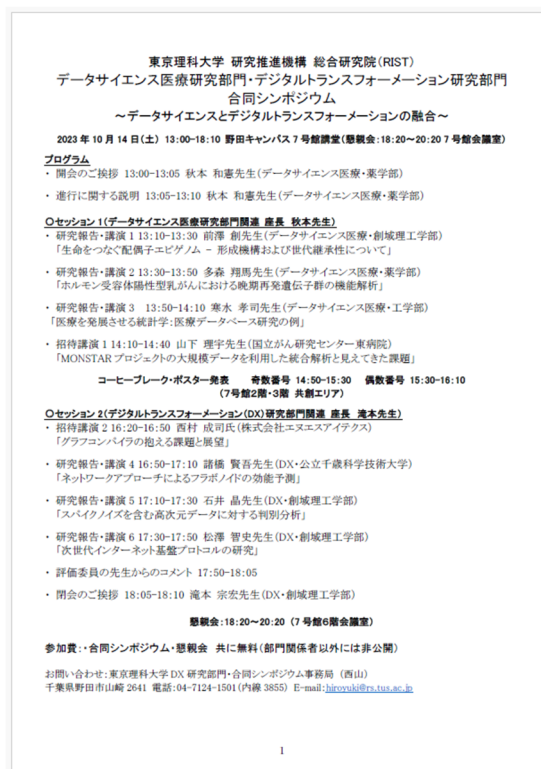
3. Activity Reports

In each research group, division members with initiatives in their research fields gathered and worked on basic research from the aspect of Medical Data Sciences to promote the "global TUS". In addition to creating a division website (for English) to disseminate overall research activities, an entirely face-to-face joint symposium between the Division of Medical Data Sciences and the Division of Digital Transformation was held on October 14, 2023, aiming for a synergistic effect between data science and digital transformation (Fig. 2). It was an exciting opportunity to find seeds of the interdisciplinary research that this research division is aiming for.

3. 1. Data Science Research Section

I) Establishment and verification of specific data science research methods

The group proceeded with the stratification of patients by statistical methods and unique information science methods (AI, XAI, mutual information, PRV (proportional reduction in variation) measure) for public cancer genomics databases to isolate biomarkers of poor clinical outcome and therapeutic targets. Furthermore, using bioinformatics methods, we proposed a mathematical model of cancer progression that takes into account cancer-immune interactions. In addition, in order to reflect our research activities in improving the educational aspects of TUS, we established graduate school courses (Graduate School of Pharmaceutical Sciences, Advanced Medical Data Science (Applied) for PhD students, and Advanced Medical Data Science (Basic) for master students, second semester of 2023).

東京理科大学 研究推進機構 総合研究院（RIST）
データサイエンス医療研究部門・デジタルトランスフォーメーション研究部門
合同シンポジウム
～データサイエンスとデジタルトランスフォーメーションの融合～
2023年10月14日（土）13:00-18:10 野田キャンパス7号館講堂（懇親会：18:20～20:20 7号館会議室）
プログラム
・開会のご挨拶 13:00-13:05 秋本 和憲先生（データサイエンス医療・薬学部）
・進行に関する説明 13:05-13:10 秋本 和憲先生（データサイエンス医療・薬学部）
○セッション1（データサイエンス医療研究部門関連 座長 秋本先生）
・研究報告・講演1 13:10-13:30 前澤 創先生（データサイエンス医療・創域理工学部）
「生命をつなぐ配偶子エピゲノム－形成機構および世代継承性について」
・研究報告・講演2 13:30-13:50 多森 翔馬先生（データサイエンス医療・薬学部）
「ホルモン受容体陽性型乳がんにおける晩期再発遺伝子群の機能解析」
・研究報告・講演3 13:50-14:10 寒水 孝司先生（データサイエンス医療・工学部）
「医療を発展させる統計学：医療データベース研究の例」
・招待講演1 14:10-14:40 山下 理宇先生（国立がん研究センター東病院）
「MONSTARプロジェクトの大規模データを利用した統合解析と見えてきた課題」
コーヒーブレーク・ポスター発表 奇数番号 14:50-15:30 偶数番号 15:30-16:10
（7号館2階・3階 共創エリア）
○セッション2（デジタルトランスフォーメーション（DX）研究部門関連 座長 滝本先生）
・招待講演2 16:20-16:50 西村 成司氏（株式会社エヌエスアイテクス）
「グラフコンパイラの抱える課題と展望」
・研究報告・講演4 16:50-17:10 諸橋 賢吾先生（DX・公立千歳科学技術大学）
「ネットワークアプローチによるフラボノイドの効能予測」
・研究報告・講演5 17:10-17:30 石井 晶先生（DX・創域理工学部）
「スパイクノイズを含む高次元データに対する判別分析」
・研究報告・講演6 17:30-17:50 松澤 智史先生（DX・創域理工学部）
「次世代インターネット基盤プロトコルの研究」
・評価委員の先生方からのコメント 17:50-18:05
・閉会のご挨拶 18:05-18:10 滝本 宗宏先生（DX・創域理工学部）
懇親会：18:20～20:20（7号館6階会議室）
参加費：・合同シンポジウム・懇親会 共に無料（部門関係者以外には非公開）
お問い合わせ：東京理科大学 DX研究部門・合同シンポジウム事務局（西山）
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Fig. 2. Symposium program 2023.

II) Collaboration with the National Cancer Center (NCC)

"Utilization platform for surgical video database, development of AI equipment" and "Large-scale clinical data, SCRUM-Japan MONSTER SCREEN utilization platform" were approved by the Institutional Review Board (IRB) at NCC (May 2023) and were approved by the TUS director (July 2023). Currently, based on the creation of data handling security guidelines and checklists (May 2022) and research plans (November 2022), we are working with URA to create internal regulations for Drs and students to handle NCC data at TUS. It is currently under construction. Furthermore, we are building a cooperative system for NCC researchers in the educational aspect of our university, and from 2023, three NCC-EPOC researchers have given lectures in Career Learning C (first-half elective subject in the third grade) for the Faculty of Pharmaceutical Sciences. In the future, we plan to transition to medical field tours. This will be a valuable opportunity for TUS, which does not have a medical school or hospital.

III) Collaboration with the Jikei University School of Medicine

In cooperation with our university's URA, we are building a joint research system for the purpose of "Improving the infrastructure for integrating data on patients with mental disorders attending four hospitals affiliated with the Jikei University School of Medicine," and we are working with the Tokyo Jikei University School of Medicine Institutional Review Board (IRB) (March 2024). Furthermore, in cooperation with our university's URA, we are building a joint research system for "Elucidation for the signs and characteristics of patients with depression and anxiety, and the effects of treatment, and develop preventive drugs."

IV) Collaboration with other external research institutions

In collaboration with Nippon Medical School, we have established a method for evaluating the prognosis improvement of hysteroscopic uterine septal resection. In addition, we are collaborating with Moonshot Development Research (Prof. Shigeo Ohno at Juntendo University) and are using data technology to research the identification of biomarkers that predict future cancer from a pre-symptomatic state, which is a major

goal of this development research. Young assistant professors and graduate students participated in research meetings and actively presented their research results, making contributions through their methods. This has also made it possible to collaborate with cutting-edge cancer biology research in Japan. Furthermore, we proceeded with establishing a domestic and international joint research system with Juntendo University, Institute of Microbial Chemistry, and the City of Hope Beckman Research Institute.

3. 2. Cancer Biology Research Section

To understand the detail mechanism of the natural history of cancer, we aim to introduce data science methods into experimental methods of cancer biology. In this year, we proceeded with building the academic foundation for this purpose.

3. 3. Connecting Section of Data Science and Cancer Biology

We aim to integrate unconventional data science methods to elucidate the mechanism of action in cancer progression in the natural history of cancer and to identify new biomarkers. This year, we introduced the Shannon-Weiner multiplicity index for the analysis of cancer heterogeneity, and the mutual information of information theory and the person-years method of medical statistics for the isolation of late recurrence biomarker gene clusters of breast cancer. Thus, we proceeded with building the academic foundation of Medical Data Sciences at TUS.

4. Challenges and Prospects

We were able to conduct cross-sectional joint research and exchange information by holding a face-to-face symposium. However, since most division members are on the Noda Campus, it is necessary to collaborate with new members on the Katsushika and Kagurazaka Campuses and with external institutions to widely appeal to the significance of research in this field at TUS to the world. It is also important to strengthen international cooperation. In addition, in order to form a foundation for future medical care that predicts and prevents diseases early and extends healthy lifespans, we are expanding our target diseases to include lifestyle-related diseases (diabetes, hypertension, arteriosclerosis, allergies, dementia, and mental illness). We will also promote intra-university collaboration with multi-hazard disaster prevention research and space system creation research. Furthermore, we aim to acquire a large budget and present more results of joint research among division members in academic conferences and academic papers.

5. Conclusion

Based on the research results until this year, we aim to form a foundation and social implementation at TUS to return the results of a series of "Medical Data Sciences" research activities to society. This is expected to prevent cancer (disease), extend healthy life expectancy, and realize high QOL and social reintegration for cancer patients. Furthermore, we will create a field of "Medical Data Sciences" that has never been seen before in Japan by fusing the research fields that have developed independently, such as data science research and cancer biology research.

Major Research Achievements (FY 2023)

Academic papers

1. High SLC20A1 Expression Indicates Poor Prognosis in Prostate Cancer, Okamoto T, Onaga C, Matsuoka I, Ozaki A, Matsuda C, Kasai T, Xiong Y, Harada Y, Sato T, Nakano Y, Mano Y, Miyazaki S, Ishiguro H, Sato K, Tamori S, Sasaki K, Ohno S, Akimoto K. Cancer Diagn Progn. 3 (4):439-448, 2023 (Peer-reviewed)

2. High expression of PKCλ and ALDH1A3 indicates a poor prognosis, and PKCλ is required for the asymmetric cell division of ALDH1A3-positive cancer stem cells in PDAC, Kasai T, Tamori S, Takasaki Y, Matsuoka I, Ozaki A, Matsuda C, Harada Y, Sasaki K, Ohno S, Akimoto K. Biochem Biophys Res Commun, 669:85-94, 2023 (Peer-reviewed)

3. Foxp3 and Bcl6 deficiency synergistically induces spontaneous development of atopic dermatitis-like skin disease, Tai Y, Sakaida Y, Kawasaki R, Kanemaru K, Akimoto K, Brombacher F, Ogawa S, Nakamura Y, Harada Y, Int Immunol. 35 (9):423-435, 2023 (Peer-reviewed)

4. Luminal B Breast Cancer Coexpressing p62 and ALDH1A3 Is Less Susceptible to Radiotherapy, Ozaki A, Matsuda A, Maemura Y, Tada Y, Kasai T, Nagashima Y, Onaga C, Hara Y, Kitabatake K, Tsukimoto M, Tamori S, Sasaki K, Ohno S, Akimoto K, Anticancer Res. 4, 37-47, 2024 (Peer-reviewed)

5. Co-expression of SLC20A1 and ALDH1A3 is associated with poor prognosis, and SLC20A1 is required for the survival of ALDH1-positive pancreatic cancer stem cells, I Matsuoka, T Kasai, C Onaga, A Ozaki, H Motomura, Y Mamura, Y Tada, H Mori, Y Hara, Y Xiong, K Sato, S Tamori, K Sasaki, S Ohno and K Akimoto, Oncology Letters, 2024, In press (Peer-reviewed)

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8. Association of PSA variability with prostate cancer development using large-scale medical information data: a retrospective cohort study, Ayako Maeda-Minami, Tomoki Nishikawa, Hideki Ishikawa, Michihiro Mutoh, Kazunori Akimoto, Yutaka Matsuyama, Yasunari Mano & Hiroji Uemura, Genes Environ. 45 (1), 25, 2023 (Peer-reviewed)

9. The PKM2 inhibitor shikonin enhances piceatannol-induced apoptosis of glyoxalase I-dependent cancer cells, Manami Inoue, Yuki Nakagawa, Miku Azuma, Haruka Akahane, Ryusei Chimori, Yasunari Mano, Ryoko Takasawa, Genes Cells. 29, 52-62, 2024 (Peer-reviewed)

10. Analysis of the development of gastric cancer after resecting colorectal lesions using large-scale health insurance claims data, Yoshida N, Maeda-Minami A, Ishikawa H, Mutoh M, Kanno Y, Tomita Y, Kobayashi R, Hashimoto H, Inoue K, Hirose R, Dohi O, Itoh Y, Mano Y, Journal of Gastroenterology, 58 (11), 1105-1113, 2023 (Peer-reviewed)

11. Angiotensin II Receptor Blockers Cause Changes in Prostate-specific Antigen Levels: A Retrospective Cohort Study, A Maeda-Mimami, T Nishikawa, H Ishikawa, M Mutoh, Y Makishima, Y Matsuyama, K Akimoto, Y Mano and H Uemura, Anticancer Research, 43 (12), 5629-5636, 2023 (Peer-reviewed)

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4. 医薬品情報学研究の最前線 (教育講演), 真野泰成, 第 25 回日本医薬品情報学会総会・学術大会,京都, 2023 (in Japanese)

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8. Ordinal quasi-symmetry and its properties for multi-way contingency tables, <u>Kouji Tahata</u>, IMS-APRM 2024, The University of Melbourne's Parkville Campus, 2024

9. 「血液細胞の運命制御におけるポリコーム群タンパク PCGF1 の役割」, <u>伊川友活</u>, 第 16 回エピジェネティクス研究会, 東京都, 2023 (in Japanese)

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13. 経口投与医薬品製剤の開発と Physiologically-based Biopharmaceutic Modeling (PBBM)による性能予測研究, 上林　敦, サントリーウェルネス株式会社・社内講演会, 相楽郡精華町, 2023 (in Japanese)

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Award
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4. Hongo W, <u>Ando S</u>, Tsuchida J, <u>Sozu T</u>. Performance evaluation of augmented inverse propensity weighted estimators with penalized regression methods. The 12th conference of the Asian Regional Section of the International Association for Statistical Computing (IASC-ARS). NSW, Australia, December, 6-8, 2023. IASC-ARS 2023 Outstanding Young Researcher/Student Award

5. 奥田 守, <u>寒水孝司</u>, 2023 年度スポーツデータサイエンスコンペティション最優秀賞, 日本統計学会スポーツデータサイエンス分科会, 2023 (in Japanese)

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7. 新見和也, 澤田 隼, <u>桂田浩一</u>, <u>大村英史</u>, FIT 奨励賞, 情報処理学会, 2023 (in Japanese)

8. 肥田歩華, 澤田 隼, <u>桂田浩一</u>, <u>大村英史</u>, 音学シンポジウム学生優秀発表賞, 情報処理学会（MUS/SLP 研究会）, 2023 (in Japanese)

Individual Research Topics

Shoma Tamori and Kazunori Akimoto
"Identification of cancer prognostic biomarkers for breast cancer subtypes by the analysis of cancer genomics databases"

To identify the biomarkers for the early prediction of breast cancer subtypes, we have analyzed cancer genomics databases by data science techniques. Furthermore, we proceeded with the isolation of genes that predict the prognosis of treatment for each breast cancer subtype. In 2023, we isolated the 81 gene signatures as candidate genes for biomarkers of late recurrence. Using cancer biological experimental methods, we revealed that some of these genes are involved in long-term dormancy. Furthermore, we isolated the p62 gene as a prognostic biomarker for radiation therapy for luminal B breast cancer. In 2024, we will try to isolate new candidates of other cancer types and advance the functional analysis of genes that have already been isolated.

Takashi Seo
"Studies of tests for mean vectors and covariance matrices and a test for adequacy in growth curve model with monotone missing data"

This study is concerned with tests of mean vectors and covariance matrices with monotone missing data. In particular, we studied a test of a mean vector with three-step monotone missing data, a test of covariance matrix when the covariance matrix has sphericity structure, tests of some types of partial mean vectors, and a test for adequacy in growth curve model with two-step monotone missing data.

"A study of multivariate normality test problem"

This study is concerned with test statistics and its approximate null distribution using multivariate kurtosis and multivariate skewness for the multivariate normality testing problem. A modified normalizing transformation statistic under complete data and a new test statistic under three-step monotone missing data were proposed. A numerical evaluation for normal approximation was given through Monte Carlo simulations.

Yasunari Mano
"Prediction of prostate cancer development and evaluation of prostate tumor marker (PSA) changes due to angiotensin II receptor blockers (antihypertensive drugs) using medical big data"

Using medical big data, we verified whether it was possible to predict the development of prostate cancer. we clarified the relationship between changes in prostate tumor marker (PSA) and the risk of developing prostate cancer in patients without a history of prostate cancer. In addition, we conducted a retrospective cohort study to determine whether angiotensin II receptor blockers (ARBs), which are antihypertensive drugs, change PSA levels. As a result of examining, ARBs may suppress elevated PSA levels in patients without a history of prostate cancer. This contributes to the prevention of prostate cancer.

Kazumi Yoshizawa, Ph.D.
"Analysis of intestinal microbiota and cancer-related fatigue"

In this study, we analyzed the intestinal microbiota in the feces of tumor-bearing model mice. As a result, mice fed an oligosaccharide-containing diet had an increase in bacteria of the genus Bacteroides, Malvinbriantia, and Barnesiella. These results suggest that short-chain fatty acids produced by the microbiota may be a useful tool for improving cancer-related fatigue.

Takashi Sozu

"Bayesian methods to accelerate drug development process"

It is necessary to develop a clinical trial design that can accelerate the drug development process. This study evaluates and develops new Bayesian methods for study design and data analysis to utilize historical data, assuming the following three situations:

Situation 1: Phase I dose-finding study of a combination of two anticancer drugs

Situation 2: Clinical trials with multiple primary endpoints

Situation 3: Clinical trials utilizing historical data from multiple studies.

Munehiro Takimoto

"Parallelized inductive logic programming based on swarm intelligence"

In this study, I redesign Inductive Logic Programming (ILP), which is a kind of logical AI, based on Particle Swarm Optimization (PSO), which is a kind of Swarm Intelligence, and implement a practical ILP system through parallelizing particles in PSO.

Kouichi Katsurada

"Speech synthesis from articulatory movements"

We propose two models to synthesize speech from articulatory movements which include movement of lips and tongue when producing voices. Although there are several methods for recording articulatory movements, we attempted to synthesize speech sounds from articulatory movements recorded by Electromagnetic Articulography (EMA) and real-time magnetic resonance imaging (rtMRI) in this study. We constructed a model to synthesize speech sounds from EMA through the International Phonetic Alphabet (IPA) and a model to synthesize speech sounds from rtMRI through the Mel-spectrogram and confirmed that the models generated speech sounds with good sound quality.

Kouji Tahata

"Study of modeling on square contingency tables"

A contingency table is one of the essential tools for analyzing categorical data. Especially for the analysis of the square contingency table, which has the same row and column classifications, we are more interested in considering the symmetry structure than the independence structure. This research aims to assess the modeling of symmetry and asymmetry. Additionally, we reveal the interpretation of the model concerning information theory and properties of goodness-of-fit test statistics. Moreover, we apply the proposed models to a real data set.

Hiroyuki Nishiyama

"Estimation of genes affecting late recurrence of breast cancer using machine learning and XAI techniques"

This study aimed to detect candidate genes that influence late recurrence using machine learning and eXplainable AI (XAI). In this study, the research subjects were breast cancer patients with high-dimensional gene expression data. The existing framework of previous studies was extended using optimal dimensionality reduction methods and various XAI. The results showed that our machine learning models performed well for all the subtypes, with the Normal subtype displaying the best performance. We visualized the importance of the features contributing to the Normal subtype using XAI, the genes with high importance were identified and subsequently validated using Kaplan-Meier (KM) curves, which revealed that one out of two genes was significant.

Tomokatsu Ikawa

"Elucidation of molecular mechanisms and search for new therapeutic targets using a mouse model of acute lymphoblastic leukemia"

It is essential to develop new treatments for refractory/relapsed acute lymphoblastic leukemia (ALL) based on elucidation of the pathogenic mechanism. We recently succeeded in creating a mouse model of ALL development using multipotent hematopoietic progenitor cells. Thus, we will elucidate the molecular mechanism of disease onset using this mouse model to identify new therapeutic targets.

Akira Sato

"Analysis of anticancer temozolomide resistance mechanisms in human glioblastoma cells"

We examined the association between the long noncoding RNA TP73-AS1 and TMZ sensitivity regulation in human GBM cells U87MG. We showed that TP73-AS1 expression was reduced in TMZ-resistant U87MG^{RT100} cells compared to that in the parental U87MG cells. We reported that TP73-AS1 knockdown in parental U87MG cells decreased their sensitivity to TMZ.

Tsugumichi Sato

"Pharmacoepidemiological studies using medical information databases"

Pharmacoepidemiological studies using medical information databases were conducted as below: "Identifying drug-induced liver injury by machine learning", "Evaluation of the effectiveness of orphan drugs", "Effect of antidiabetic drugs on the onset of rheumatoid arthritis", "Association between uterotonics use and adverse events in mothers and children", "Analysis of near miss reports in community pharmacies", "Drug utilization study on anti-allergic drugs in children", and "Occurrence of steroid-induced glaucoma in children".

Ryoko Takasawa

"Research on the combined anticancer effect of Piceatannol and Shikonin"

We evaluated the combined anticancer efficacy of Glyoxalase I (GLO I) inhibitor piceatannol plus PKM2 inhibitor, and shikonin in cancer cells. Combined treatment with piceatannol and shikonin synergistically reduced cell viability, enhanced apoptosis rate, and increased extracellular methylglyoxal accumulation compared to single-agent treatment. These results indicate that concomitant use of shikonin potentiates piceatannol-induced apoptosis in cancer cells by augmenting methylglyoxal accumulation.

Kyohei Higashi

"Elucidation of the inflammation mechanism based on the glycan analysis"

Glycosaminoglycans (GAGs) including heparan sulfate (HS), heparin (HP), chondroitin sulfate (CS), dermatan sulfate (DS), and hyaluronan (HA) are linear and acidic polysaccharides that are major components of extracellular matrices. We aimed to elucidate the mechanism of structural change of GAGs caused by ischemic stroke and malignant tumors.

Atsushi Kambayashi

"Research on Physiologically-based Biopharmaceutics Modeling"

Physiologically-based Biopharmaceutics Modeling (PBBM) for virtual bioequivalence (BE) simulations, physiologically-based IVIVC for modified release formulations, clinically relevant dissolution specifications, food effects on drug absorption, and drug-drug interactions in the absorption process.

Keiko Sato

"Identification of genes that predict the risk of early recurrence and the degree of immune cell infiltration in triple-negative breast cancer"

Patients with triple-negative breast cancer (TNBC) have a high rate of recurrence within 3 years of diagnosis and a high rate of death within 5 years compared to other subtypes. The number of clinical trials investigating various new agents and combination therapies has recently increased; however, current strategies benefit only a minority of patients. This study aimed to identify specific genes that predict patients at high risk of recurrence and the immune status of the tumor microenvironment at an early stage, thereby providing insight into potential therapeutic targets to improve clinical outcomes in TNBC patients.

Tomofumi Matsuzawa

"Study of ad hoc network routing between mobile devices"

With the development of IoT, automobiles and home appliances are now connected to the Internet, and it is estimated that the number of IoT devices will exceed about 29 billion by 2030. Current mobile devices communicate with other devices via fixed devices such as base stations, but there is demand for communications that do not (cannot) use base stations, such as during disasters or congestion. We are engaged in research on routing methods that use multiple paths with maximum flow problems and fewer nodes as specific bottlenecks.

Taku Harada

"Distributed control of road traffic signals using deep reinforcement learning for road traffic networks including unsignalized intersections"

In typical road traffic networks, there are some intersections where road traffic signals are not installed. In this study, we proposed a decentralized control method for road traffic signals using deep reinforcement learning, one of the machine learning algorithms, for road traffic networks that include such unsignalized intersections. Simulation experiments showed the effectiveness of the proposed method.

So Maezwa

"Multi-omics approaches for revealing mammalian gametogenesis"

Recent advances in developmental biology hold great promise for organ regeneration, stem cell-based therapy, and tissue engineering. In vitro gametogenesis from pluripotent stem cells is currently being developed to overcome infertility, particularly germ cell aplasia. However, the induction efficiency to create functional sperm and egg cells is still low in the existing method. To develop the epigenome editing-based in vitro gametogenesis by rewriting germ cell-like epigenome into pluripotent stem cells, we aim to clarify the epigenetic regulation during mammalian gametogenesis by multi-omics analysis.

Mahito Sadaie

"Exploring vulnerability of telomerase-independent cancer and developing strategy to suppress cancer"

Telomere maintenance is essential for cancer cell proliferation. There are two types of cancer cells: those that maintain proliferation in a telomerase-dependent manner, and those that are telomerase-independent. Telomerase-independent telomere maintenance is often observed in refractory cancers, such as sarcomas. In this study, we aim to elucidate the mechanism of action of compounds that inhibit the proliferation of telomerase-independent cancer cells and to identify novel genes that are essential for proliferation to discover therapeutic reagents for telomerase-independent cancer and therapeutic target molecules.

Masayuki Sakurai

"Studies on deaminating editing of nucleotide adenosine bases in the evolutionary adaptation of organisms"

In the Central Dogma of Life, there is a mechanism that modifies the chemical structure of four types of bases in expression regulation. In this study, we are attempting to elucidate the mechanism of modification to inosine bases, which is the result of RNA adenosine base deamination reaction. We have developed a highly accurate inosine identification method and identified 30,000 inosine sites, including 17,000 novel sites, in human brain transcripts with 97% accuracy.

Hiroshi Haen

"Mathematical analysis about subclonal accumulation of immune escape mechanisms in microsatellite instability-high colorectal cancers"

We constructed a computational mode of immune escape evolution in microsatellite instability high colorectal cancers (MSI-H CRCs) to show that MSI-H CRCs exhibit higher variant allele frequencies of subclonal mutations than microsatellite-stable CRCs, suggesting that subclonal mutations are subjected to selective sweep. This study showed that MSI-H CRCs acquire immune escape mechanisms even in the relatively late phase of tumor progression, suggesting the effectiveness of early application of immune checkpoint inhibitor-based treatment for patients with MSI-H CRCs (Kobayashi et al. 2023 Br. J Cancer).

Shunsuke Kon

"Identification of cell competition marker"

We aimed to identify cell competition markers by utilizing the sGRAPHIC method. We first successfully labeled the normal epithelial cells adjacent to RasV12-transformed cells. Subsequently, the bulk RNA-seq analysis identified several genes whose expression was significantly elevated in cell competition-committed normal cells.

Asanao Shimokawa

"Construction of a survival tree based on restricted mean survival time"

We considered the restricted mean survival time (RMST) that is paid attention to as an evaluation index of clinical trials with time-to-event outcomes in recent years. We proposed a new splitting criterion that minimizes the prediction error of the RMST for the tree. That criterion consists of the test statistics for RMST estimators between child nodes. The performance of the method was investigated through simulations.

Shuji Ando

"Study on models and measures in square contingency tables"

We proposed some new models with symmetric or asymmetric structures to reveal the relation between the proposed and existing models. Additionally, we proposed some measures for analyzing the degree of departure from the model. We showed the utility of the proposed methods through real data analyses and numerical experiments.

Hidefumi Ohmura

"Searching for applied research using sound"

I have conducted research on music and media art. I have also researched communication and interaction by applying technologies in cognitive science or artificial intelligence. I will integrate and utilize the knowledge obtained through these studies to explore application studies on sound. For example, I am working on sounds for meditation in fitness and the automatic generation of sounds in an ossuary.

Yohei Kawano

"Exploratory research for drug repositioning candidate drugs applicable to malignant tumors"

Drug discovery research has been conducted by targeting abnormalities discovered in pathological or molecular biological studies. However, productivity in drug discovery research remains poor. Recently, with the development of the receipt database (medical big data), an environment has been created in which research can be conducted backward looking to track drug exposure and disease onset in humans over a long period. The research objective is to explore and find drug repositioning candidates through basic research and pharmacoepidemiological studies using medical big data.

Yoshio Nakano

"Development of therapeutic drugs for SARS-CoV-2 using infrequent sequences in human genes"

This study attempts to search for effective nucleic acid therapeutics against SARS-CoV-2. In this field, studies have been focused on the sequence specificity of RNA, however, few studies have been conducted with off-target effects from the design stage. Therefore, to develop targets for nucleic acid therapeutics, bioinformatics is used to investigate sequences present in the SARS-CoV-2 genome and less abundant in human pre-mRNAs, ncRNAs, and mRNAs.

Yuka Nozaki

"Age-related transition of adipose-specific mitochondrial stress"

Mitochondrial intermediate peptidase (MIPEP) plays an important role in mitochondrial matrix proteostasis by processing certain mitochondrial matrix proteins. Therefore, MIPEP dysfunction may cause mitochondrial matrix proteostasis disorder. However, studies investigating the difference between short-term and long-term mitochondrial stress responses. Therefore, to evaluate the differences, we generate and analyze adipose-specific Mipep knockout (aMKO) mice.

Division of Digital Transformation

Division of Digital Transformation

1. Overview

    This research division aims to give high-performance and more accurate big data processing manners with mutual feedback between machine learning systems and statistical analyses of their results, based on mathematical foundations at various levels. They include mathematically redesigning machine learning systems and implementing highly accurate and safe AI. Eventually, they achieve highly confidential big data processing, through statistically analyzing the results generated by the systems. We believe that the challenges of this division will open new horizons for big data processing.

2. Organization and Facilities

2. 1. Research hierarchy
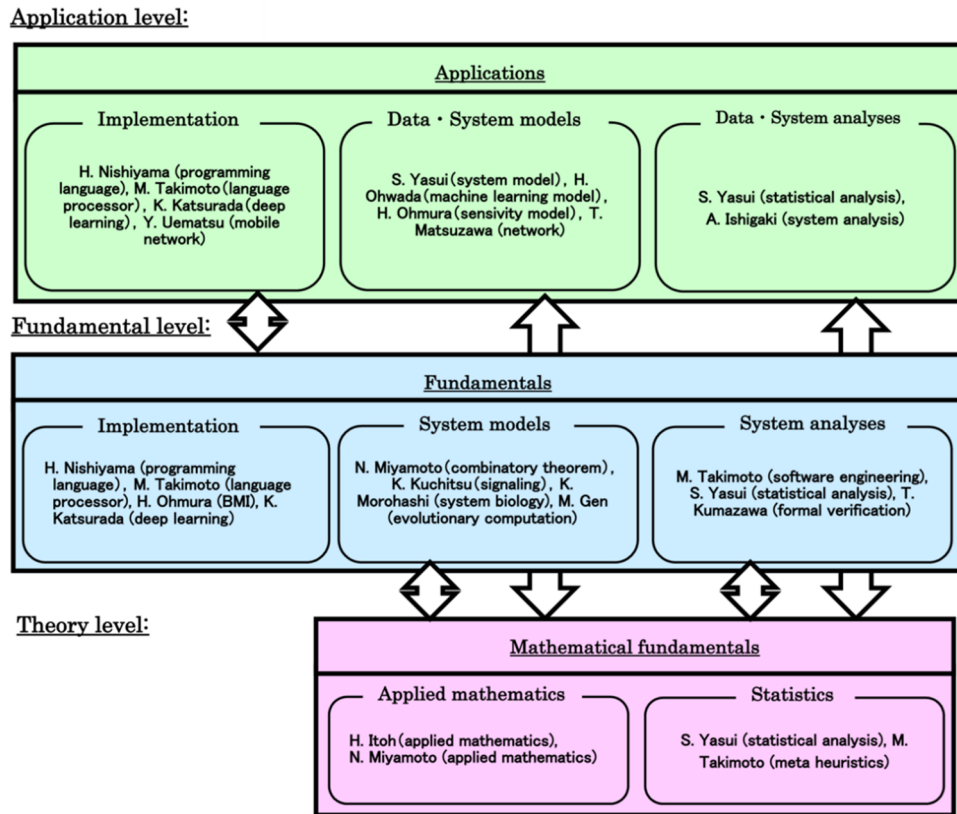
Fig.1. Relations between research areas.

    As shown in Fig.1, we address the issues of big data processing in three hierarchical levels, "applications", "fundamentals, and "theories" as follows:

2. 1. 1. Applications
    At this level, members who are specialists in each application investigate issues of the applications based on their expertise, propose approaches to solve the issues, and check the validity of results given by the solution. In the process, they give new models based on the characteristics of the applications and develop systems implementing the models. The results given by the systems are validated in mathematical methods.

2. 1. 2. Fundamentals

At this level, members directly improve the performance of fundamental techniques such as AI and machine learning and propose new approaches of them. The improvement of performance includes network performance in distributed systems and sensor networks, and the learning performance of AI through parallel and distributed techniques. The new approaches include improvements of parallelism in instruction level on GPU, improvement of accuracy of existing machine learning, and development of new machine learning models based on biological systems. The fundamental techniques and systems developed in the level are validated in mathematical methods.

2. 1. 3. Theories

At this level, members give proofs of techniques with black box parts such as deep learning and machine learning. Furthermore, through knowledges obtained in the process, they propose new methods or system models.

2. 2. Division facilities

● GPGPU parallel computing servers

We introduced them to analyzing the relations between calves for milk cows and the manners of suckling. They consist of high-performance GPGPU machines x5, Pascal Tesla P100 (GPU: P100 x 1, CPU: 6 Cores x 2) x 3, and Pascal Titan X (GPU: Titan X, CPU: 6 Cores x 2) x 2 (Fig. 2). Currently, we are developing a new inductive logic programming that makes parallel learning available on the servers.

Fig. 2. GPGPU parallel computing servers.

3. Activity Reports

We have collected FY2023's achievements of the division members and have made proceedings in March 2024, as shown in Fig. 3. On March 27th, 2024, we held the "Tokyo University of Science Research Institute for Science & Technology (RIST) 2023 Digital Transformation Research Division Results Report Meeting" on the 6th floor of Building 7 on our Noda Campus. In addition, in a joint project with the National Cancer Center (NCC), we held a joint symposium with the Data Science Medical Research Division (representative: Professor Akimoto, Faculty of Pharmacy) on October 14th, 2023, and we also closely shared the latest data science technology and medical data. They are based on research achieving effective prevention or prediction of course through associating advanced data sciences with medical care.

Fig. 3. FY2023's DX

3. 1. Research results report meeting

On March 27th, 2024, we held the "Tokyo University of Science Research Institute for Science & Technology (RIST) 2023 Digital Transformation Research Division Results Report Meeting" on the 6th floor of Building 7 on our Noda Campus. At this research results report meeting, we had four presentations by

members of our research department to report their results, and 15 research results were reported in poster presentations. In addition to members of the research department, students participating in research from each laboratory also participated in this research results reporting session, and active discussions were held in the lecture hall and poster presentation venue with a total of 38 participants. Furthermore, after the results reporting session, a social gathering was held at the poster presentation venue to further discuss the research results.

3. 2. *"Medical care based on cancer genomics and data science"* （Collaboration with NCC） group

This group is progressing multi-grain collaborations with the National Cancer Center (NCC) in manners that make surgery accurate and efficient, and methods that enable data mining to analyze high dimensional big data bases. Currently, ethical reviews for the members and discussions of the access condition to the data base are performed. In addition, on October 14, 2023, we held a joint symposium with the NCC and the related Data Science and Medical Research Division: "Tokyo University of Science Research Institute for Science & Technology (RIST), A joint departmental symposium Data Science and Medical Research Division and Digital Transformation Research Division Joint Symposium -The fusion of data science and digital transformation-", with two invited lectures, six research presentations, and 50 poster presentations.

4. Challenges and Prospects

This research department will enter its third year in 2023, and for the first time, we held a research results report meeting, which had previously been unable to be held due to the spread of the new coronavirus. We have now completed preparations for joint research with the National Cancer Center and held a joint symposium. In the future, we will continue to focus on joint research with the National Cancer Center to achieve concrete results, and we also plan to closely communicate and collaborate with other members on other sub-projects.

5. Conclusion

Through each activity on practical application problems, members belonging to the application level, the fundamental level, and the theory level are integrated to implement safe and reliable data mining systems. In 2024, we have to make the systems available for more practical use, and we need to investigate a manner where to verify each result generated by them.

Major Research Achievements (FY 2023)

Academic Papers

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4. 植物の生き方・人との共生：植物を理解し，環境・食料・エネルギー問題解決に向けてその力を活かす(1), 朽津和幸, 東京理科大学オープンカレッジ, 2023 (in Japanese)
5. 植物の生き方・人との共生：植物を理解し，環境・食料・エネルギー問題解決に向けてその力を活かす(2), 朽津和幸, 東京理科大学オープンカレッジ, 2023 (in Japanese)

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12. Quadratic classifiers for high-dimensional noisy data, <u>Aki Ishii</u>, Kazuyoshi Yata, Makoto Aoshima, The 6th International Conference on Econometrics and Statistics, Tokyo, 2023

13. Recent Advances of Multiobjective Sustainable Closed-loop SCM Network Designs by Metaheuristics, <u>Mitsuo Gen</u>, Keynote talk:, The 17th Inter. Conf. on Management Sci. and Eng. Mgmt., Cape Town, South Africa; Online Conference, Aug. 3-4th, 2023

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15. Hybrid Evolutionary Algorithm and Machine Learning for Scheduling Problems, <u>Mitsuo Gen</u>, Invited talk, Dept. of Mathematical Sciences, Tsinghua Univ., Beijing, China, Dec. 9th, 2023

16. Metaheuristics & Machine Learning for Multiobjective High-Speed Train Scheduling, <u>Mitsuo Gen</u>, Keynote talk, The 6th Inter. Conf. on Uncertainty Theory & The 19th Inter. Conf. on Information & Management Sci., Hilton Hotel & Resort Dali, China, Dec. 15-17, 2023

17. 進化算法と強化学習を活用したハイブリッド算法の開発と生産スケジューリング問題への応用, <u>玄 光男</u>, <u>大和田勇人</u>, 招待講演, 一般社団法人システム制御情報学会 サイバーフィジカル・フレキシブル・オートメーション（CyFA）研究分科会 第 14 回例会,大阪大学 中之島センター 6 階セミナー室, 2024 年 1 月 23 日 (in Japanese)

18. Network Security and Analytics for Reliability, Industrial Mini symposium: Secure Computing, <u>植松幸生</u>, 第 10 回国際産業数理・応用数理会議(ICIAM2023), 東京, 2023

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1. <u>神林 靖</u>, "移動エージェントに基づいたソフトウェアとりわけロボットを制御するソフトウェアの研究", 小野田商工会議所会報「商工おのだ」, 2023 (in Japanese)

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1. 小柴稔輝, 藤村宗一郎, 工藤元樹, Niken P. Martono, 高尾洋之, 山本 誠, <u>大和田勇人</u>, 村山雄一, 石橋敏寛, 第 39 回NPO法人 日本脳神経血管内治療学会学術総会 (JSNET2023), 機械学習を用いた脳動脈瘤コイル塞栓術における最適コイル予測モデルの構築, 2023 年 11 月 24 日, 京都, Poster, [優秀ポスター賞 銅賞] (in Japanese)

2. 安井清一, 上田真也, 石垣 綾, インタラクティブ動画を用いた適応的授業計画とその実装について, 2023PC カンファレンス, 優秀論文賞 (in Japanese)

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4. 中山航希, 秦野 亮, 西山裕之. 学生奨励賞, 情報処理学会第 86 回全国大会, 2024 年 3 月. (in Japanese)

5. 大久保深, 秦野 亮, 西山裕之. 学生奨励賞, 情報処理学会第 86 回全国大会, 2024 年 3 月. (in Japanese)

6. 荒川哲至, 江頭健斗, 鈴木海友, 藤澤健吾, 中川智之, 松澤智史, SDSC2023 優秀賞, 日本統計学会, 2024 (in Japanese)

7. 倉光広人, 鈴木海友, 松澤智史, 優秀研究賞, 情報処理学会, 2023 (in Japanese)

8. Mitsuo Gen, "Lifetime Achievement Award", The 6th Inter. Conf. on Uncertainty Theory & The 19th Inter. Conf. on Information & Management Sci., Dec. 17th, 2023, Research Institute of Uncertainty Theory, Beijing, China.

Individual Research Topics

Munehiro Takimoto
"Parallelized Inductive Logic Programming Based on Swarm Intelligence"

In this study, I redesign Inductive Logic Programming (ILP), which is a kind of logical AI, based on Particle Swarm Optimization (PSO), which is a kind of Swarm Intelligence, and implement a practical ILP system through parallelizing particles in PSO.

Hayato Ohwada
"Applications of machine learning"

I focus on leveraging machine learning and deep learning techniques across various domains. My recent work includes the development of novel in silico screening systems for plant defense activators, efficient estimation of cow's location using sensor data, interpretation of arrhythmia classification, machine learning model development for selecting coils in cerebral aneurysm treatment, and real-time automatic water break detection in mares. Additionally, I have contributed to the development of machine-learning models for medical applications and automated animal behavior classification using wearable sensors. My research emphasizes practical applications of AI for solving real-world problems across agriculture, healthcare, and environmental monitoring.

Hiroyuki Ito
"Research on algebraic geometry and singularity theory in positive characteristic and its application to high performance pseudorandom number generator"

I studied quotient algebraic varieties and quotient singularities by finite group schemes of typical types with positive characteristics. Furthermore, I tried to construct a general theory combining the Artin-Schreier extensions and purely inseparable extensions of the Frobenius type which includes many pathological phenomena with positive characteristics. Furthermore, I tried to improve the performance of the pseudorandom number generator using the Artin-Schreier tower of huge finite fields which I invented before. On the other hand, progress has also been made on quasi-elliptic surfaces, which are closely related to pathological phenomena specific to positive characteristic algebraic geometry. We investigated the Mordell-Weil groups in detail in the case of K3 surfaces and gave a concrete description of the stratification in moduli space using Artin invariants.

Kouichi Katsurada
"Speech synthesis from articulatory movements"

We propose two models to synthesize speech from articulatory movements which include movements of lips and tongue when producing voices. Although there are several methods for recording articulatory movements, we attempted to synthesize speech sounds from articulatory movements recorded by Electromagnetic Articulography (EMA) and real-time magnetic resonance imaging (rtMRI) in this study. We constructed a model to synthesize speech sounds from EMA through the International Phonetic Alphabet (IPA) and a model to synthesize speech sounds from rtMRI through the Mel-spectrogram and confirmed that the models generated speech sounds with good sound quality.

Nobuko Miyamoto

"A study on construction and optimality of spanning bipartite block designs"

We proposed a block design called Spanning Bipartite Block Design (SBBD), in which the edge set of a complete bipartite graph is a treatment set and a spanning subgraph is a block, and studied its construction method and optimality. SBBD is a combinatorial structure applicable to the drop-connect method to improve generalization performance in deep learning.

Kazuyuki Kuchitsu

"Elucidation of the mechanism of action of a putative plant defense activator based on large-scale analysis of gene expression patterns"

In order to better understand the mechanism of action of a putative plant defense activator we discovered recently, we conducted a comprehensive large-scale transcriptomic analysis of temporal changes in gene expression patterns associated with the activator treatment. Our results indicate that the activator can activate both the jasmonic acid pathway and the salicylic acid pathway, which are typically considered to act antagonistically, as well as stimulate specialized metabolism. These findings provide new insights into the molecular mechanisms underlying plant defense activation by this novel compound.

Aya Ishigaki

"Design and implementation of human-centric production and logistics system"

In the field of production and logistics, there is a need to design automation systems with high intelligence and autonomy that make the best use of people, machines, and technology. In this research project, we have focused on the development of human-centric production and logistics systems based on the following three principles: (1) modeling of psychologically and physically friendly behavior for workers and optimal environment design, (2) design of human-robot collaboration that facilitates human work, and (3) fusion of data-driven systems from the IT perspective and model-based systems from the field perspective.

Hiroyuki Nishiyama

"Summary information generation technique for newborn calves using a high-speed logic-based machine learning system"

Through the utilization of a high-speed logic-based machine learning algorithm, we have successfully developed a system that applies logical rules based on the shipping weight of calves as a reference to generate summary information explaining the growth status of new calves from various data obtained through mammal robots. This study verifies the efficacy of the system by applying it to data collected from multiple dairy farms.

Seiichi Yasui

"Design of learning for data-driven problem solving"

We research educational methods to improve statistical problem-solving skills using golf as a subject. We capture and analyze data on putting behavior and analyze the factors that affect the ball rolling distance. Using the obtained findings, we aim to develop practical learning materials that enable students to acquire statistical thinking through putting golf using an educational engineering approach. By integrating behavior analysis and data-driven instructional design, we propose a new form of experiential learning that excels in comprehension and retention.

Hidefumi Ohmura

"Research on digital representation and manipulation in music and communication"

We developed a system detecting errors in musical performance based on digital sound data of musical instruments. We also developed a communication system using mixed reality combining virtual reality and reality, which solves the discord in remote communication.

Tomofumi Matsuzawa

"Study of ad hoc network routing between mobile devices"

With the development of IoT, automobiles and home appliances are now connected to the Internet, and it is estimated that the number of IoT devices will exceed about 29 billion by 2030. Current communications in mobile devices communicate with other devices via fixed devices such as base stations, but there is demand for communications that do not (cannot) use base stations, such as during disasters or congestion. We are engaged in research on routing methods that use multiple paths with maximum flow problems and fewer nodes as specific bottlenecks.

Aki Ishii

"Study on statistical inference for high-dimensional data with huge noise"

It is well known that high-dimensional data such as genome data contain huge noise, which causes the eigenvalues of high-dimensional covariance matrices to be extraordinarily large. In this study, we systematically summarize statistical inference for high-dimensional data with huge noise following the strongly spiked eigenvalue model and give theoretical accuracy guarantees for each statistical inference method. In particular, for high-dimensional quadratic discriminant analysis, we gave a classifier based on high-dimensional data transformation and geometric representation of high-dimensional data, which guarantees high accuracy.

Shuji Ando

"Study on models and measures in square contingency tables"

We proposed some new models having the structure of symmetry or asymmetry, revealed the relation between the proposed and existing models. Additionally, we proposed some measures for analyzing the degree of departure from the model. We showed that the utility of the proposed methods through real data analyses and numerical experiments.

Ryo Hatano

"Constructive study of dynamic epistemic logic for information flow analysis"

In this study, from the perspective that "modal logic is the logic that handles the content of information", we reconsider dynamic epistemic logic, which captures changes in the agent's epistemic state, as an extension of modal logic, which handles the flow of information. We then attempt to prove directly the completeness of the well-known Hilbert-style axiomatization and construct a new cut-free sequent calculus by providing an alternative semantics of DEL.

Kengo Morohashi

"Development of a new parallel distributed method that mimics biological systems"

To elucidate the parallel distributed processing in living organisms, I focused on the intracellular networks of living organisms. Particularly, I compared the combinations of transcription factors, and the target gene sets between the primitive land plant, Marchantia polymorpha, and the higher plant, Arabidopsis thaliana, to investigate the relationship between land plant evolution and transcription factor complex networks. I also investigated the dynamics of small molecules that interact with transcription factors.

Mitsuo Gen

"Development of a hybrid algorithm by multiobjective evolutionary algorithm with reinforcement learning for real-time scheduling problems"

With the development of economic globalization, the distributed hybrid flow-shop scheduling problem (DHFSP) is receiving more and more attention due to its wide application in the manufacturing industry. However, most of the existing DHFSPs assume that there are identical shops, and there is a lack of consideration of heterogeneous shops. Our study mainly concentrates on the energy-efficient distributed heterogeneous hybrid flow-shop scheduling problem (DHHFSP). Due to the complexity of the DHHFSP model, the efficacy of existing algorithms cannot meet the production requirements. Therefore, a multiobjective evolutionary algorithm (MoEA) with particle swarm optimization (PSO) and Q-learning-based local search (MoEA.PSO-QLS) is proposed to solve the energy-efficient DHHFSP with minimizing makespan and total energy consumption simultaneously.

Yasushi Kambayashi

"A study of flying robot control for structure inspection using mobile agents"

We have developed an autonomous unmanned aerial vehicle (UAV) system that inspects the integrity of structures with complex geometries, such as bridges, from the outside. We fabricated a UAV that maintains a certain distance from the structure while maintaining formation and developed a control algorithm. In order to verify the effectiveness of the system, we implemented real UAVs that are controlled by generating control information from digital information received from sensors, converting it to analog signals, and transmitting it to the UAVs for flight control.

Yukio Uematsu

"Toward digital transformation on mobile network"

In recent years, mobile networks, represented by 5G, have been undergoing digital transformation in term of cloudification, openness, etc. We are engaged in research and development of AI technologies (such as anomaly detection) that contribute to data management, data quality, and operations of these mobile networks."

Tsutomu Kumazawa

"Lightweight model checking based on swarm intelligence with multiple swarms"

Model checking is one of the formal verification techniques of software systems. We aim to develop a novel check method based on multi-swarm Particle Swarm Optimization in order to improve the performance of model checking and comprehensibility of check results. In order to adapt multi-swarm to model checking, we decompose the whole search space of model checking into small subspaces for each swarm. We also utilize effective heuristic techniques that make model checking more lightweight and comprehensible. We finally conduct the performance evaluation by applying it to benchmark problems.

Statistical Science Research Division

Statistical Science Research Division

1. Overview

In this research division, the researchers interested in the underlying common theory gather to improve the level of study on essential theories and methods. Additionally, we aim to create new theories in the age of data science and develop new fields.

This division is composed of two research groups, "the Mathematical Statistics Basis Group" and "the Applied Statistics Research Group", and will promote research in collaboration with the Data Science Center.

2. Organization and Facilities

This research department is roughly divided into two groups that conducts research in the following fields.

(1) Mathematical Statistics Basis Group
(Leader: Hiroki Hashiguchi (Department of Applied Mathematics, Faculty of Science Division I))

The "multivariate analysis group" comprises faculty members from Kagurazaka, Katsushika, and Noda Campuses and visiting associate professors. Focusing on the existing research themes of each faculty member, "multidimensional missing data analysis," "high-dimensional data analysis," "random matrix theory," and "dimension reduction method," we will conduct research with a view to developing the Applied Statistics Research Group. The "statistical model group" comprises faculty members from Kagurazaka and Noda Campuses and conducts research on topics such as "statistical modeling and model selection," "nonparametric methods," and "contingency table analysis." The method, handled by the Mathematical Statistics Basis Group, has a clear theoretical background and acts as a white box. However, the method of solving a "real-world problem" has a black-box aspect, such as in heuristics and deep learning. In constructing the theory of AI and data science, how to clarify the black-box-like solution of the latter using the methodologies of the former, as well as other methodologies, will be asked.

(2) Applied Statistics Research Group
(Leader: Takashi Sozu (Department of Information and Computer Technology, Faculty of Engineering))

In the field of "medical statistics (biostatistics)," the faculty members of Katsushika Campus and Noda Campus will conduct research activities related to the methodology of research design and data analysis, focusing on medical research. Research on the development of educational methods and systems via quantitative analysis in "educational engineering" will be conducted mainly by the faculty members of Kagurazaka Campus. The faculty members with visiting associate professors will conduct research activities of "sports statistics". Regarding the "statistical machine learning and mathematical optimization field," the faculty members of Kagurazaka Campus will conduct research on "natural-language processing that integrates statistical machine learning and symbolic modeling,", "large-scale nonlinear optimization problems," and "machine scheduling problems".

3. Activity Reports

Each group conducted the following activities.

3. 1. The Mathematical Statistics Basis Group

Through the 20th, 22th, 24th, and 25th statistical science seminars, research introductions of laboratories belonging to the group, presentations of the latest research topics, and research introductions by external lecturers were conducted. At the 20th seminar, Dr. T. Nakagawa (Meisei University) introduced research on robust Bayes estimation using density power divergence. At the 22th seminar, Mr. A. Kaneko, a first-year doctoral student at the Graduate School of Science, Tokyo University of Science, presented his research results on the network clustering methods. At the 24th seminar, Prof. Seong Keon Lee, Sungshin Women's University, introduced the decision tree and its related recent topics. At the 25th seminar, Dr. T. Momozaki introduced his research on semiparametric Bayes estimation for mixed discrete and continuous data. We also refer to "Major Research Achievements" for individual research achievements.

3. 2. the Applied Statistics Research Group

The biostatistics team (Takashi Sozu and Tomohiro Shinozaki (Department of Information and Information and Computer Technology, Faculty of Engineering) and Shuji Ando (Department of Information Sciences, Faculty of Science and Technology)) conducted research on the study design and data analysis of medical research.

(1) Design of medical research
  • Effectiveness of Specific Health Checkups in Japan for the primary prevention of obesity-related diseases: a protocol for a target trial emulation. (BMJ Open 2023)

(2) Data analysis of medical research
  • Efficacy of azilsartan on left ventricular diastolic dysfunction compared with candesartan: J-TASTE randomized controlled trial (Scientific Reports 2023)
  • Use of clinical variables for preoperative prediction of lymph node metastasis in endometrial cancer (Japanese Journal of Clinical Oncology 2024)
  • Associations of age-adjusted coefficient of variation of R-R intervals with autonomic and peripheral nerve function in non-elderly persons with diabetes (Journal of Diabetes Investigation 2024)
  • The inter-laboratory validation study of EpiSensA for predicting skin sensitization potential, (Journal of Applied Toxicology, Online ahead of print)
  • Comparative effectiveness of tocilizumab vs standard care in patients with severe COVID-19–related pneumonia: a retrospective cohort study utilizing registry data as a synthetic control. (BMC Infectious Diseases 2023)
  • Clinicopathological characteristics and prognosis of mucinous gastric cancer. (Anticancer Research 2023)
  • Intramuscular and abdominal fat measured by computed tomography and mortality of hemodialysis patients. (Nephrology Dialysis Transplantation, 2024)
  • Association of postexercise vagal dysfunction with protein-energy wasting and noncardiovascular outcomes in patients receiving hemodialysis: a retrospective cohort study. (Journal of Renal Nutrition, Online ahead of print)

- Comparison of intradialytic continuous and interval training on hemodynamics and dialysis adequacy: A crossover randomized controlled trial. (Nephrology, Online ahead of print)

4. Challenges and Perspectives

We will continue to conduct statistical science seminars that include graduate students and post-graduate students across campuses and departments to promote publicity activities (enhancement of the website) and a deeper understanding of each other's theoretical research. Furthermore, we are considering building an environment in which students from laboratories in other fields can also participate in seminars and other activities across campuses, leading to joint research. In addition, we will promote collaboration with the Medical Data Sciences Research Division of the Research Institute for Science & Technology, Research center for multi-hazard urban disaster prevention and continue to strengthen ties with the Data Science Center at the Tokyo University of Science.

5. Conclusion

Six statistical science seminars were held jointly with the Data Science Center at the Tokyo University of Science. We plan to continue to strengthen our collaboration and conduct educational activities and joint research with external organizations such as companies that consult with us via the Data Science Center at the Tokyo University of Science. In the coming year, we will continue to aim to raise the level of research on essential theories and methods, create new theories for the data science era, and explore new fields.

Major Research Achievements (FY2023)

Academic Papers

1. Simultaneous tests for mean vectors and covariance matrices with three-step monotone missing data, Sakai, R., <u>Yagi, A.</u>, <u>Seo, T.</u>, Journal of Statistical Theory and Practice, 18, 3, 2024 (Peer-reviewed)

2. Parameter estimation and forecasts for an integrated Lee-Carter model, Kanazawa, R. and <u>Kurosawa, T.</u> SUT Journal of Mathematics, 59 (2), 91-116, 2023 (Peer-reviewed)

3. Chi-Square approximation for the distribution of individual eigenvalues of a Singular Wishart Matrix, <u>Shimizu, K.</u>, <u>Hashiguchi, H.</u>, Mathematics, 12(6), 921, 2024 (Peer-reviewed)

4. Greedy separation algorithm finding community for a stochastic block model, Kaneko, A., <u>Hashiguchi, H.</u>, Communications in Statistics - Simulation and Computation(online: 02 Aug 2023) (Peer-reviewed)

5. 声質を制御可能な音声合成, 松永隆太郎, <u>松崎拓也</u>, 第 38 回信号処理シンポジウム予稿集, 2023 (in Japanese)

6. 最低ビットレートの MP3 に対する深層学習を用いた音声超解像, 中谷俊介, <u>松崎拓也</u>, 第 38 回信号処理シンポジウム予稿集, 2023 (in Japanese)

7. Absolute position embedding learns sinusoid-like waves for attention based on relative position, Yamamoto, Y., <u>Matsuzaki, T.</u>, Proceedings of the 2023 Conference on Empirical Methods in Natural Language Processing, 15-28, 2023 (Peer-reviewed)

8. 自己注意機構のアテンション重みが特定の種類のトークンに集中する現象と外れ値次元の関係, 丸田 佳, <u>松崎拓也</u>, 言語処理学会第 30 回年次大会論文集, 2023 (in Japanese)

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10. Effectiveness of multi-task training for prediction of helpfulness of online movie reviews, Che WANG, <u>Matsuzaki, T.</u>, 言語処理学会第30回年次大会論文集, 2023

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72. CINV 対策充実を目指した電子患者日誌-薬学的管理システムの開発と実装研究，木村沙織，大畑紘一，飯原大稔，西岡佐和子，尾関理恵，齊藤光江，<u>中川智之</u>，小茂田昌代，医薬品情報学会学術誌, 25 (3), 131-142, 2023 (Peer-reviewed) (in Japanese)

Book
1. Python で学ぶ統計学入門，<u>橋口 博樹</u>(著)，東京書籍, 264 頁, 2023
2. データ解析のための線形回帰〔原著第 4 版〕,Sanford Weisberg(著)，<u>宮岡悦良</u> (監訳)，下川 朝有，黒澤匠雅 (訳)，共立出版, A5 版, 380 頁, 2024
3. 臨床試験の事典(15 章 96.イベント発生に関する割合・率の指標と推定 p.288-289,97.治療効果の指標 p.290-292,17 章 101.割合の二群比較解析.302-303,102.割合の多群比較解析と傾向性検定 p.304-305,104.表の解析 p.308-311,105.率の二群比較解析 p.312-314 分担執筆)，丹後 俊郎，松井茂之編集，朝倉書店, 2023
4. 生物統計学の道標，坂巻 顕太郎,<u>篠崎 智大</u>(監修)，厚生労働統計協会, 2023
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Invited Lectures
1. 村おこし構想立案のための AI システムズアプローチ実験，舩橋誠壽，<u>椿美智子</u>，板倉宏昭，第 14 回横幹連合コンファレンス, D-2-1, 東京, 2023
2. ベイジアンネットワークを用いた檜原村の幸福感や地域力への影響の要因モデリング，<u>椿美智子</u>，瀬川優太郎，今井友貴，平林里桜，第 14 回横幹連合コンファレンス, D-2-3, 東京, 2023

3. ビジネスデータの統計モデリングとデータサイエンス, 照井伸彦, 2023 年度統計関連学会連合大会(日本統計学会会長就任記念講演), 京都, 2023.

4. 動物実験代替法に関わる方に知ってほしい統計学の正しい使い方, 寒水孝司, 日本動物実験代替法学会第 36 回大会, 千葉大学 西千葉キャンパス, 千葉県千葉市, 2023

5. Ordinal quasi-symmetry and its properties for multi-way contingency tables, Tahata,K., IMS-APRM 2024, The University of Melbourne's Parkville Campus, 2024

6. 連続最適化とその周辺－雑感－, 矢部 博, 最適化の理論とアルゴリズム：未来を担う若手研究者の集い 2023, 筑波大学, 2023

7. Quadratic classifiers for high-dimensional noisy data, Ishii, A., Kazuyoshi, Y., Aoshima, M., The 6th International Conference on Econometrics and Statistics, Tokyo, 2023

8. Shinozaki, T. (October 2023). "Recent development in causal mediation analysis." At: The Asia Cohort Consortium 2023 General Membership Meeting, Nagoya, Japan

9. 治療への反応にもとづく治療方針による介入の個別化, 篠崎 智大, 2023 年度統計関連学会連合大会(企画セッション：個別化医療に向けたヘルスデータサイエンスの実践 臨床予測モデルの最前線), 京都, 2023

10. 二者関係データ(dyadic data)の相互影響関係の統計モデル, 篠崎 智大, 第 30 回日本家族看護学会学術集会(研究促進委員会企画：二者関係データを用いて家族ユニットを捉える研究をするための分析方法), 大阪, 2023

11. 時間依存性交絡とその調整, 篠崎 智大, 第 28 回日本薬剤疫学会学術総会 チュートリアル 2：薬剤疫学研究における因果推論, 京都, 2023

12. 臨床試験を読み解くための統計学の基本, 篠崎智大, 第 73 回日本消化器病学会甲信越支部例会／第 95 回日本消化器内視鏡学会甲信越支部例会合同支部例会 合同シンポジウム 1 特別講演, 新潟, 2023

13. 標的学習の考え方と実装：因果推論×機械学習という異なる手法による観察研究データ解析, 篠崎智大, ヘルスデータサイエンス学会第 2 回学術集会 シンポジウム 3：多様なデータにもとづく標的(ターゲット)を定めた統計的推論の最前線, 京都大学, 2023

14. 標的試験エミュレーション：RCT デザインをベンチマークとした観察研究データ解析, 篠崎智大, 第 34 回日本疫学会学術総会 シンポジウム 1 因果効果の探求：ランダム化比較試験と観察研究の架け橋, 大津, 2024

15. Asymptotic properties of kernel k-means under high dimensional settings, Egashira, K., Yata, K. and Aoshima, M., The Institute for Mathematical Statistics – Asia-Pacific Rim Meeting 2024, The University of Melbourne, Melbourne, 2024

16. Asymptotic properties of kernel k-means for high dimensional data, Egashira, K., Yata, K. and Aoshima, M., International Symposium on Recent Advances in Theories and Methodologies for Large Complex Data, Tsukuba International Congress Center, Tsukuba, Japan, 2023

17. Asymptotic behaviors of k-means under high dimensional settings, Egashira, K., Yata, K. and Aoshima, M., The 6th International Conference on Econometrics and Statistics, Waseda University, Tokyo, Japan, 2023

18. 0n Robustness against outliers Bayesian estimation via γ-divergence, Nakagawa, T., IMS-APRM 2024, The University of Melbourne, Australia, 2024.

19. ダイバージェンスを用いたロバストな一般化ベイズ法とその応用, 中川智之, 日本数学会 2024 年度年会, 大阪, 2024

Award

1. 清水康希, 橋口博樹, 論文賞, 日本計算機統計学会, 2023

2. Hongo, W., Ando, S., Tsuchida, J., Sozu, T. Performance evaluation of augmented inverse propensity weighted estimators with penalized regression methods. The 12th conference of the Asian Regional Section of the International Association for Statistical Computing (IASC-ARS). NSW, Australia, December, 6-8, 2023. IASC-ARS 2023 Outstanding Young Researcher/Student Award

3. 奥田 守, 寒水孝司, 2023 年度スポーツデータサイエンスコンペティション最優秀賞, 日本統計学会スポーツデータサイエンス分科会, 2023

4. 福田遥也, 小泉和之, 2023 年度スポーツデータサイエンスコンペティション優秀賞, 日本統計学会スポーツデータサイエンス分科会, 2024

Individual Research Topics

Takashi Seo
"Studies of tests for mean vectors and covariance matrices and a test for adequacy in growth curve model with monotone missing data"

This study is concerned with tests of mean vectors and covariance matrices with monotone missing data. In particular, we studied test of a mean vector with three-step monotone missing data, a test of covariance matrix when the covariance matrix has sphericity structure, tests of some types of partial mean vectors, and a test for adequacy in growth curve model with two-step monotone missing data.

"A study of multivariate normality test problem"

This study is concerned test statistics and its approximate null distribution using multivariate kurtosis and multivariate skewness for the multivariate normality testing problem. A modified normalizing transformation statistic under complete data and a new test statistic under three-step monotone missing data were proposed. A numerical evaluation for normal approximation was given through Monte Carlo simulations.

Takeshi Kurosawa
"Study on EIV model and robustification methods"

We considered error in variables (EIV) model and robustification methods. As for the EIV, we focus on problems in regression models and assume the situation that explanatory variables have errors. As for the robustification problems, we assume the situation that a response variable has an error, and then we estimate the regression parameters in the model correctly. Finally, we considered a robust coefficient of determination using the estimated regression parameters.

Hiroki Hashiguchi
"Study on the distribution of the singular random matrices"

In this study, we gave some results on the exact distribution theory of the eigenvalues of the singular Wishart matrix, which is a constant multiple of the sample covariance matrix when the dimension of the variate is larger than the sample size. First, we introduced heterogeneous hypergeometric function and showed that the joint density function of the eigenvalues can be expressed using this function. We also showed that the distribution function of the largest eigenvalue can be unify expressed for both of singular and nonsingular Wishart matrices. We obtained the density function of the ratio of the singular Wishart matrix and the independent non-singular Wishart matrix, the joint density function of the eigenvalues, and the larges eigenvalue distribution.

Takuya Matsuzaki
"Study on the mechanism of neural language models"

Neural language models, such as BERT, have become indispensable basic technology for numerous language processing applications. It is however not easy to understand the process of their learning and how they work in the applications. We analyzed the mechanism of the position-dependent inference in the self-attention architecture, which is the basis of many neural language models. We also investigated the relation between the concentration of attention on special tokens and so-called outlier dimensions.

Hidetoshi Murakami

"Study on the two-sample nonparametric test statistic"

Two-sample comparison is widely used in many scientific fields. However, the assumption of normality can often not be ascertained due to limited sample sizes. Then, nonparametric procedure is preferable to analyze data in many scientific fields. We proposed two-sample nonparametric test statistics with theoretical properties and derived the distributions of proposed test statistics. Simulations were used to investigate the power of proposed tests. We include illustrations of the proposed tests using real data.

Etsuo Miyaoka

"Study on a framework of new statistical inference"

Today, in data science with big data and machine learning, we need new framework of statistical inference. We hope that this department will be lending the field.

Michiko Tsubaki

"Study on the creation of UX and evolution of management based on the understanding of customer well-being trends"

The purpose of this study is to develop a service informatics methodology that can create customer experience value that increases Consumer Well-being by enabling companies and customers to co-create value and encourage the development of customer well-being, 1) the development of method to extract emotional customer behavior from large-scale data on customer behavior to understand superior customer experiences, and 2) Capturing the various levels of well-being behind customer emotions and extracting the conditions under which changes in customer social attributes lead to a balance between the well-being of others and one's own well-being.

Shin Ando

"Study on out of distribution detection"

This study addressed the task of Out-of-distribution (OOD) detection which aims to detect sample from classes unseen during the training phase of a deep model. The focus of the study was on understanding the requirements for detecting near and far OODs differentiated by semantic and textual similarities from in-distribution samples. We proposed an ensemble model for sufficiently detecting both types of OODs and a self-supervised contrastive loss for training such models. The numerical experiments using image benchmarks were conducted to show the advantage of the proposed models.

Nobuhiko Terui

"Study on business data science for marketing decisions"

We considered data science study on large-scale and unstructured business data for the optimal marketing decisions.

Takashi Sozu

"Bayesian methods to accelerate drug development process"

It is necessary to develop a clinical trial design that can accelerate the drug development process. This study evaluates and develops new Bayesian methods for study design and data analysis to utilize historical data, assuming the following three situations:

Situation 1: Phase I dose-finding study of a combination of two anticancer drugs

Situation 2: Clinical trials with multiple primary endpoints

Situation 3: Clinical trials utilizing historical data from multiple studies.

Kouji Tahata

"Study of modeling on square contingency tables"

A contingency table is one of the essential tools for analyzing categorical data. Especially for the analysis of the square contingency table, which has the same row and column classifications, we are interested in considering the symmetry structure than the independence structure. This research aims to assess the modeling of symmetry and asymmetry. Additionally, we reveal the interpretation of the model concerning information theory and properties of goodness-of-fit test statistics. Moreover, we apply the proposed models to a real data set.

Sadao Tomizawa

"Models of symmetry for contingency tables"

We showed some models to analyze the structure of symmetry for contingency tables in my several works. We showed the models of symmetry, the decompositions for models of symmetry, and the measures for representing the degree of departure from symmetry.

Yuki Watanabe

"Impact of others' note-taking visualization on classroom interaction"

The purpose of this study was to investigate whether visualization of others' note-taking promotes interaction in the classroom and improves note-taking and instruction. We developed a tablet-based note-taking support system and conducted two studies. The results showed that high school students improved their sense of classroom community and note-taking through visualization. Therefore, we found that interaction among students was facilitated. Furthermore, the visualization of class comprehension by the system allowed the teacher to change the instruction in class, which could improve the students' understanding of the content. Thus, we suggested that the visualization promotes interaction between the teacher and the students.

Toshiya Iwashita

"Study on uniformity test over the hypersphere"

Testing for elliptical symmetry can be replaced by one for uniformity over the Stiefel manifold. Furthermore, we are able to equate uniformity test over the Stiefel manifold with one on the hypersphere. Hence, we try to construct new test procedures for elliptical symmtery by making use of uniformity test on hyperspher based on some methods, for example, equality test for the eigenvalues of the sample covariance matrix or goodness-of-fit test by using the empirical characteristic function.

Hiroshi Yabe

"Study on numerical methods for nonlinear optimization"

We considered numerical methods for solving nonlinear optimization problems. We proposed a proximal structured quasi-Newton method based on the Broyden family for unconstrained minimization of a composite function whose Hessian matrix has a special structure, which includes LASSO, and we showed its global convergence. Furthermore, we dealt with a trust-region sequential quadratic programming method with a nonsmooth merit function, and we analyzed the convergence to a second-order critical point.

Asanao Shimokawa

"Construction of a survival tree based on restricted mean survival time"

We considered the restricted mean survival time (RMST) that is paid attention as an evaluation index of clinical trials with time-to-event outcome in recent years. We proposed a new splitting criterion that minimizes the prediction error of the RMST for the tree. That criterion consists of the test statistics for RMST estimators between child nodes. The performance of the method was investigated through simulations.

Tomohiro Shinozaki

"Statistical causal inference using epidemiologic and clinical data"

In this research project, we are conducting theoretical studies on the identification of statistical models based on the counterfactual potential outcome model to uniformly handle not only clinical trial data but also observational study data without experimental interventions. Specifically, we are interested in statistical inference theory for the optimal treatment regimes, which involves selecting treatment policies tailored to individual patients, particularly adaptive treatment selection based on clinical progression.

Wanwan Zheng

"Study on two-machine job-shop scheduling problem with one joint job"

We considered a two-machine job-shop scheduling problem with one joint job where a joint job is defined as a job whose operations are to be processed by different machines. We show that the corresponding problem is strongly NP-hard. We then propose heuristic algorithms and polynomial-time exact algorithms based on dynamic programming when the number of jobs is given as a fixed number. We further improve time complexity using various techniques, including the two-pointer method.

Shuji Ando

"Study on models and measures in square contingency tables"

We proposed some new models having the structure of symmetry or asymmetry, revealed the relation between the proposed and existing models. Additionally, we proposed some measures for analyzing the degree of departure from the model. We showed that the utility of the proposed methods through the real data analyses and numerical experiments.

Aki Ishii

"Study on statistical inference for high-dimensional data with huge noise"

It is well known that high-dimensional data such as genome data contain huge noise, which causes the eigenvalues of high-dimensional covariance matrices to be extraordinarily large. In this study, we systematically summarize statistical inference for high-dimensional data with huge noise following the strongly spiked eigenvalue model, and give theoretical accuracy guarantees for each statistical inference method. In particular, for high-dimensional quadratic discriminant analysis, we gave a classifier based on high-dimensional data transformation and geometric representation of high-dimensional data, which guarantees high accuracy.

Ayaka Yagi

"Study on simultaneous tests of the mean vectors and the covariance matrices with monotone missing data"

We considered simultaneous tests of the mean vectors and the covariance matrices under three-step monotone missing data for a one-sample and a multi-sample problem.

We provided the likelihood ratio test statistic and proposed statistics for improving the accuracy of the chi-squared approximation and approximate upper percentiles. Finally, we investigated the asymptotic behavior of the upper percentiles of these test statistics and the accuracy of approximate upper percentiles via Monte Carlo simulation.

Masato Kitani

"Study on asymptotic properties of goodness-of-fit tests"

In quantitative risk analysis, it is important to assess the quality of fit between the data and the selected distribution. Therefore, we propose new one-sample goodness-of-fit test statistics. We show that the proposed tests are more powerful than existing tests via simulation studies. Moreover, we derive the limiting distribution and the asymptotic power of the proposed tests. Furthermore, we discuss approximations to the test statistics, and we investigate the accuracy of the approximation.

Kouki Simizu

"Study on the distribution theory of eigenvalues of singular random matrix"

This study is concerned with the distribution theory of eigenvalues of a random matrix when the number of variables exceeds the sample size. In particular, we derived the approximate distribution of eigenvalues of a singular Wishart matrix, which is important in multivariate analysis. we applied the Laplace approximation to the hyper geometric functions in the joint density of eigenvalues. Furthermore, we showed that a chi-square approximation of the eigenvalue distribution can be obtained when the population covariance matrix has spiked eigenvalues.

Kento Egashira

"Study on hierarchical clustering for high dimensional data"

We investigated the hierarchical clustering theoretically in the high-dimension, low-sample size context as dimension goes to infinity while sample size is fixed. We defined the behaviors of dendrograms created by hierarchical clustering and derived the conditions under which this behavior occurs for high-dimensional data. Especially, we derived the differences in asymptotic properties and in their sufficient conditions for each linkage function.

Hikaru Yamaguchi

"Study on linear rank statistics in the presence of ties"

In nonparametric rank tests, some theoretical properties are discussed under the assumption of continuity of the population distribution. However, ties may frequently occur in the discretized continuous data because measurement instruments are not arbitrarily precise. In this study, we derived the moment-generating function of a vector of tie-adjusted linear rank statistics and provided a moment-based approximate distribution of a proposed test based on tie-adjusted linear rank statistics. Furthermore, we showed the usefulness of this approximation method through numerical experiments.

Takayuki Shiohama

"Study on statistical analysis on geometric manifold"

We considered statistical analysis of the data that took values on a specific geometric manifold. Such geometric manifolds include a circle, a torus, a cylinder, and a space of their joint probability distributions. In the 2023 academic year, we studied statistical inference for cylindrical distributions and their parameter estimation. We also studied the statistical analysis of stationary time series models whose spectral density has a skew-circular distribution on a circle.

Takahiro Nishiyama

"Study on statistical hypothesis testing procedures in diverse situations"

With the advancement of information technology in recent years, the importance of developing new statistical analysis methods that can handle realistically diverse situations that may arise has increased.

In this study, we aimed to develop theories and methodologies for statistical hypothesis testing problems, especially in situations where conventional statistical theories cannot be applied.

Tamae Kawasaki

"A two-sample test for profile analysis with unequal covariance matrices"

We discussed the flatness hypothesis of profile analysis in the two-sample problem. An asymptotic expansion of the test statistic was derived and an approximate upper percentile point was obtained. The accuracy of the approximation is evaluated by Monte Carlo simulation.

Kazuyuki Koizumi

"Research on data science theory and applications"

Recently, due to the ease of acquiring and accumulating data, it is necessary to obtain new knowledge based on data that could not be handled in the past.In this situation, the data science industry needs to develop both theoretically and practically, and this research will carry out theoretical development of data science and applied research in several fields (sports, marketing, and law).

Tomoyuki Nakagawa

"Study on Bayesian Inference by using divergence"

In recent years, there has been an increase in handling large-scale data, and issues such as model misidentification and outliers are becoming more common. As a solution to such problems, robust methods using divergence have garnered attention. In this study, we explored Bayesian inference using divergence, implemented MCMC, and derived its theoretical properties. We also considered its application to data on manifolds, such as directional data.

Division of Nanocarbon Research

Division of Nanocarbon Research

1. Overview

Carbon nanotubes and graphene are low dimensional materials (with linear and flat shapes, respectively) composed of networks of 6-members rings (honeycomb structure). Owing to strong covalent bonds of carbon atoms, they have excellent mechanical strength and chemical stability enough to sustain the monolayered structure in a free space. Furthermore, they exhibit properties peculiar to the geometrical configuration and low dimensionality, which cannot be expected for three-dimensional crystals. As you can see from the fact that the Nobel Prize in Physics 2010 relates to graphene, nanocarbons such as carbon nanotubes and graphene are extensively studied in basic science. In the future, nanocarbons are expected to play a main role in an industrial revolution as iron and silicon did in the Industrial Revolution and the information technology revolution, respectively. The Division of Nanocarbon Research covers topics of nanocarbons from fundamental to applied research by collaboration of experts in theoretical and experimental condensed matter physics, electrical engineering, thermal engineering, and biophysics. We expect synergy effects by enhancing mutual discussion and exchange of ideas in the division.

2. Organization and Facilities

Within the wide range of fields related to nanocarbon, we aim to develop distinctive research mainly in the following areas (Fig. 1).

2. 1. Materials Sciences in Nanospace

We use an individual single-walled carbon nanotube as a well-defined nanospace, and study the interactions between nanotubes and molecules such as water and alcohol by optical spectroscopy, electron microscopy and molecular dynamics simulations. Thereby, we elucidate the structure and phase of the molecules in the nanospace. We also study the interaction between nanotubes and polymers, aiming at application of polymer-nanotube composites.

We regard systems composed of nanotubes with adsobates or defects as extended composites, and study the basic properties by first-principles electronic state calculations and model calculations.

Fig. 1. Configuration of the division.

2. 2. Nanotube-Hybrid Materials

We study structural properties of composites composed of nanotubes and biomolecules (DNA, protein). Specifically, we fabricate biodevices with nanotubes functionalized by DNA, and examine whether the structural properties of the biomolecules are retained, and whether the molecular recognition function is retained.

We theoretically investigate the host-guest interactions of the nanotube/biomolecule composites, and clarify the effect on the properties of the composites.

2. 3. Growth Control of Nanocarbons

We develop techniques for precise structural control of nanocarbons based on the various nanotube synthesis techniques such as vertically-aligned growth on silicon and silica substrates and horizontally-aligned growth on quartz substrate.

We study novel synthesis methods of nanocarbons utilizing arc discharge by changing the discharge ambience, electrode materials, etc. We also study novel methods for graphene synthesis.

2. 4. Properties and Functions

We develop the physics of energy conversion based on nanocarbons and its application. We establish the basic science for nanocarbon-based paper electronics.

3. Activity Reports

3. 1. Measurement Group

Thermal properties of SWCNT

We analyzed the one-dimensional (steady-state) heat conduction equation based on experimental temperature distributions of single-walled carbon nanotubes (SWCNTs). We found an improvement in the handing of differential equations proposed in the previous study and implemented a new calculation method incorporating it. We are currently working on writing a paper. (M. Irita, Y. Homma)

Research and development of optical isolator using SWCNT and nanofiber

Chirality-separated (10,3) and (9,7) SWCNTs have different absorption wavelengths depending on their chirality. We attached these SWCNTs to an optical nanofiber and measured the propagating light in the nanofiber. In each absorption wavelength band, we found that transmission varied depending on the direction of light propagation. We filed a patent application regarding the SWCNT optical isolator. (M. Irita Y. Homma)

Hot spring - bathtub temperature automatic control

As part of research on SWCNT thin films, we have researched and developed a device for automatic temperature control of bathtubs in Kannada Onsen, Oita prefecture, and have achieved a bath temperature of 42°C at all times. We filed a patent application regarding these research activities. (M. Irita)

The photoluminescence response of (6, 5) SWCNTs on microsilica beads with the addition of biomolecules has been quantitatively detected by near-infrared microscopy. This study is currently being submitted for publication. Analysis of the enhancement of luminescence intensity by electron doping of inorganic polymers is also in progress. (Ito)

Thermoelectric measurement of carbon nanotubes

This year, we encountered issues with sample destruction due to static electricity, prompting us to reconstruct our measurement system. Simultaneously, we prepared wiring for measuring temperature characteristics in a vacuum. For temperature measurements, we utilized nitrogen-vacancy (NV) centers in nanodiamonds to measure thermal performance. Investigating the effect of nanodiamond coatings on temperature measurement directly on the device, we verified the effect of thin film stress caused by the coating. Although there was a slight decrease in accuracy, we found that measurements could be conducted without any issues. (Shimizu)

3. 2. Materials Science Group

In our laboratory, we have succeeded in synthesizing size-selective platinum (Pt) nanoclusters under atmospheric conditions and easily by reducing Pt using polyol reduction and then adding ligands. By

adsorbing them onto carbon nanotubes (CNTs), which have excellent durability and conductivity, we have prepared oxygen reduction reaction (ORR) catalysts that are more active and durable than commercially available ones. We also succeeded in preparing an even higher-performance ORR catalyst by doping CNTs with different atoms to prevent aggregation of Pt nanoclusters. (Kawawaki)

Research has shown that highly active Pt/C oxygen reduction reaction (ORR) catalysts can be produced by creating carbon defects in a carbon substrate through argon plasma etching, followed by platinum sputtering in the same batch (without exposure to air). The activity of these catalysts was 3-4 times higher than that of 'standard catalysts' (TEC10E50E and TKK) when single-walled carbon nanotubes and graphitized Ketjen black was used as carbon supports. (S. Iwasaki and Y. Tanaka)

We perfoemed irradiation experiments using the Kyoto University infrared free electron laser and investigated the parameters of surface modification. Furthermore, FT-IR and other measurement equipment were set up from FEL-TUS. We plan to further refine these experiments in the future. (Fujioka)

Evaluation of ionic liquid penetration mechanism into nanoporous metal-organic frameworks (MOFs): The mechanism of solvent penetration into MOF nanopores is proposed to be molecular diffusion due to capillary action or concentration gradient, but the detailed penetration mechanism has not been elucidated. After dropping the IL droplet on one of the representative MOF of $Cu_3(btc)_2$, we observed the permeation behavior into the nanopore. Immediately after dropping the droplet, the IL did not permeate into the nanopore for a long time of more than 100 seconds, and furthermore, the permeation distance, z, and the time after starting the permeation, t. It was confirmed that the relationship that $z \propto t$ holds true. Penetration by capillarity or surface diffusion gives the relationship $z \propto \sqrt{t}$, so this result cannot be explained by them. Elucidation of the physics behind the extremely long wetting time for IL to start permeation into the pore and the relationship that $z \propto t$ is urgently needed. (Kinoshita)

3. 3. Engineering Group

The cantilever of a scanning probe microscope was brought into contact with CNTs, and images of the current density distribution induced by the electric field and temperature gradient were obtained. By analyzing the obtained images, the physical properties of electrical conductivity, thermoelectric conductivity, and Seebeck coefficient of CNTs were successfully obtained on a nanoscale. We believe that this method is useful for understanding the inhomogeneity and hierarchy of thermoelectric properties obtained macroscopically. (Nakajima)

We investigated the stabilization control of charge carriers in electric double layer transistor (EDLT)-type thermoelectric device with CNTs as the channel layer. We succeeded in fabricating an ionic liquid in a semi-permanently polarized solid state as an electret, and fabricated an EDLT-type thermoelectric device utilizing the electret. We confirmed the change of pn-type by controlling the gate voltage in the thermoelectric device. We succeeded in stably holding n-type CNTs in the thermoelectric device with no gate voltage bias. (Anno)

We developed an infrared high-temperature furnace in a reactive gas atmosphere and investigated the synthesis of multilayer graphene by vapor-solid phase growth with a solid template. Here, a single crystal of hexagonal boron nitride (h-BN) flakes was used as a solid template. In this year, we succeeded in forming monolayer graphene islands with diameters as large as 2-3 μm on h-BN flake by optimizing the growth conditions. Furthermore, conductivity was confirmed by connecting electrodes to the grown graphene islands, and graphene layers were also found out to be grown via layer-by layer mode from a cross-sectional TEM observation. (Negishi)

We investigated the possibility of creating new electronic devices using polymer materials with host-guest effects. Specifically, we stacked polymer material A, which has a host-guest effect, and material B, which is

a polymer material with carbon nanotubes added to it, to form a layered material (pictured on the right) with different properties, and evaluated its electrical characteristics. reached the pre-stage. The material created by pouring it into a cylindrical mold with a height of approximately 2 mm has a two-layer structure: additive-free (transparent) polymer material A (bottom) and black material B containing carbon nanotubes (top). I understand that. (Yasuo KATO, Nagase & Co., Ltd.)

3. 4. Theory Group

We explored how the carrier density and temperature affect the exciton valley polarization relaxation and exciton valley phase relaxation in transition metal dichalcogenides, materials consisting of atomic layers. We found that both the valley polarization and phase relaxation times significantly increase with an increase in carrier density. (S. Konabe)

Electronic structure calculations based on the KKR-CPA method and transport coefficient calculations using the Kubo-Greenwood equation were performed for systems containing multiple impurities and native defects. As a result, the calculated Seebeck coefficients for pure and *n*-type Mg_2Si systems reproduced the experimental values. Furthermore, the dependences of the electrical conductivity on temperature were qualitatively consistent with the experimental trend in the range of 300 K to 600 K. (Hirayama)

The fabrication of devices using new materials such as carbon nanotubes is currently conducted by the members of this project. We have been analyzing the signal data obtained by such devices. In this year, we proposed a method that uses the multi-fractal dimension of recurrence time to reflect the phase information of the signal, which could not be reflected by the previously proposed KL divergence method. (Hashizume)

We have investigated the cause of the high thermoelectric performance of FeSe thin films, and succeeded in explaining the experimental results using a simple two-band model. The result obtained in this study that multiband contributes to improved thermoelectric performance is useful for the development of thermoelectric materials. (Matsubara)

4. Challenges and Prospects

A problem for the platinum nanocluster-supported catalysts with CNTs prepared in this study is the increase in particle size of Pt nanoclusters compared to the catalysts using carbon black. Therefore, the adsorption method and calcination temperature in catalyst preparation should be investigated. In the future, we will develop a new catalyst preparation method and aim to further improve the activity and durability of the catalysts. (Kawawaki)

Quantitative evaluation of defect formation at the interface between the carbon support and Pt particles has not been achieved in our gas-phase preparation of Pt/C oxygen reduction reaction (ORR) catalysts.

To elucidate the effect of Pt atoms adsorbed on C defects (referred to as 'V-site Pt') on the properties and catalytic activity of Pt particles, it is necessary to quantitatively evaluate 'V-site Pt' using synchrotron radiation in the future. (S. Iwasaki and Y. Tanaka)

Analysis of the increase in luminescence intensity due to electron doping with inorganic polymers is ongoing. We will also evaluate the relationship between the polymer and the chirality of SWCNTs. (ITO)

In the creation of hybrids of inorganic nanoparticles and nanocarbons, we will continue to investigate the interaction between layered sulfide nanosheets and nanocarbons and its effect on thermoelectric properties by calculations based on density functional theory utilizing the nonequilibrium Green's function method. On the other hand, we will also explore nanoparticles of inorganic thermoelectric materials other than layered sulfide to investigate the processes of nanosizing, dispersion, and hybridization of inorganic thermoelectric

materials, and experimentally investigate the thermoelectric properties of their hybrids. We will also investigate the optimization of thermoelectric properties of an EDLT-type thermoelectric device that uses CNTs as the channel layer and utilizes an electret with the polarization of an ionic liquid immobilized in it. (Anno)

In this study, we found that highly crystalline graphene layers grow on h-BN via van der Waals epitaxy. In 2024, we will fabricate field-effect transistors using a grown single island as a channel and verify carrier conduction reflecting the linearly dispersive electronic structure from gate characteristics, which will be a stepping stone to THz-band electronic device applications utilizing linearly dispersive electronic structure. (Negishi)

The results using a data obtained preArch's experiment showed that the new method using the multifractal dimension works well to identify state transition of an object; however, the principle of this analysis method was not sufficiently clarified. Because this is related to the limits of application and the selection of sensing methods/targets that are easy to apply, it is necessary to demonstrate the method using a wider range of sensor information in the future and to analytically advance the proof of principle. (Hashizume)

This year, laser processing of carbon composite materials will be continued using the Kyoto University Infrared Free Electron Laser (KU-FEL), and the reaction mechanism will be investigated by chemical analysis of the gas produced. Furthermore, we plan to conduct similar experiments using an Nd: YAG laser and compare the results. (Fujioka)

We establish a physical model that explains the relation that $z \propto t$, confirmed in the evaluation of ionic liquid penetration into MOF nanopores. In addition, we will clarify the confinement effect of ionic liquids in MOF nanopores through thermal analysis and impedance measurement, and develop design guidelines for creating composite materials of MOF and IL. (Kinoshita)

To measure the thermoelectric properties of semiconducting carbon nanotubes, we have not been able to overcome the problems of the difficulty of measuring the voltage generated in a material with high resistance and the unstable hysteresis, resulting in a large noise level. Reduce the contact resistance of the sample itself as much as possible, and consider heat treatment and passivation to reduce hysteresis.(Shimizu)

Using the KKR-CPA method and linear response theory, we performed thermoelectric calculations for impurity doped semiconductors with light doping levels, considering the native defects. However, the electrical conductivity was underestimated by this method. To improve the accuracy of the calculation, it is necessary to adjust calculation conditions such as the muffin tin radius. It is also important to verify the validity of the carrier localization effect due to impurities obtained by this method.(Hirayama)

In fiscal 2013, we spent time conducting experiments to find combinations of multiple base materials that could be stably processed into gel-like materials. In FY2014, we plan to move on to electrical characteristic evaluation. (Yasuo KATO, Nagase & Co., Ltd.)

5. Conclusion

Researchers from different fields belonging our university, including physics, chemistry, materials, mechanics, data science, and architecture, collaborated to investigate the thermoelectric, catalytic, and filtering effects of nanocarbon materials, and actively engaged in research from basic science to social implementation. In particular, a new form of industry-academia collaboration with ZEON Corporation was started this year and has produced many important results. It is worth mentioning that many of these results have led to patent applications.

Major Research Achievements (FY 2023)

Academic Papers

1. Clarifying the Electronic Structure of Anion-templated Silver Nanoclusters by Optical Absorption Spectroscopy and Theoretical Calculation, Y. Horita, S. Hossain, M. Ishimi, P. Zhao, M. Sera, T. Kawawaki, S. Takano, Y. Niihori, T. Nakamura, T. Tsukuda, M. Ehara, Y. Negishi, Journal of the American Chemical Society, 145, pp 23533-23540, 2023 (Peer-reviewed)

2. Metal Single-Atom Cocatalyst on Carbon Nitride for the Photocatalytic Hydrogen Evolution Reaction: Effects of Metal Species, Y. Akinaga, T. Kawawaki, H. Kameko, Y. Yamazaki, K. Yamazaki, Y. Nakayasu, K. Kato, Y. Tanaka, A. T. Hanindriyo, M. Takagi, T. Shimazaki, M. Tachikawa, A. Yamakata, Y. Negishi, Advanced Functional Materials, 33, 2303321, 2023 (Peer-reviewed)

3. Towards comprehensive understanding of piezoelectricity and its relaxation in VDF-based ferroelectric polymers, T. Furukawa, H. Kodama, H. Ishii, S. Kojima, T. Nakajima et. al., Polymer, 283, pp 126235, 2023 (Peer-reviewed)

4. High Performance Composition-Tailored PVDF Triboelectric Nanogenerator Enabled by Low Temperature-Induced Phase Transition, D. T. K. Ong, J. S. C. Koay, M. T. Sim, K. C. Aw, T. Nakajima et. al., Nano Energy, 113, pp 108555, 2023 (Peer-reviewed)

5. Coexistence of slow and fast dynamics in interfacial water around a carbon nanotube, Yusei Kioka, Takemi Hara, Yuki Maekawa, Kenji Sasaoka, Yoshikazu Homma, and Takahiro Yamamoto, Jpn. J. Appl. Phys. 62, 085003, 2023 (Peer-reviewed)

6. Anomalous thermal radiation due to the chiral magnetic effect in Weyl semimetals, S. Konabe, Physical Review B, 109, 085145, 2024 (Peer-reviewed)

7. Optical Filters with Asymmetric Transmittance Depending on the Incident Angle, Produced Using Liquid Crystalline Ink (Louver LC Filters), Kohki Takatoh, Mika Kobayashi, Masahiro Ito, Materials, 16, 16, 5584, 2023 (Peer-reviewed)

8. Angular Dependence of Guest–Host Liquid Crystal Devices with High Pretilt Angle Using Mixture of Vertical and Horizontal Alignment Materials, Masahiro Ito, Eriko Fukuda, Mitsuhiro Akimoto, Hikaru Hoketsu, Yukitaka Nakazono, Haruki Tohriyama, Kohki Takatoh, crystals, 13, 4, 696, 2023 (Peer-reviewed)

9. Promotion of the structural repair of graphene oxide thin films by thermal annealing in water-ethanol vapor, Ryota Negishi (#: Corresponding author), Takuya Nakagiri, Masashi Akabori, Yoshihiro Kobayashi Thin Solid Films Vol. 775 (2023) 139841Doi: 10.1016/j.tsf.2023.139841

10. Non-fibril form but not fibril form of human islet amyloid polypeptide 8–20 changes brain functions in mice, Ryuji Owada, Akiko Katano-Toki, Ayaka Mori, Jun Fujioka, Kazuhiro Nakamura, PLOS ONE 2024, https://doi.org/10.1371/journal.pone.0296750 January 5, 2024 (Peer-reviewed)

11. 密度汎関数理論による Ga-P 同時ドープ $Ba_8Cu_6Ge_{40}$ クラスレートの電子構造の研究, 阿武宏明, 橋國克明, 山陽小野田市立山口東京理科大学紀要, 7 号, pp 21-26, 2024 (in Japanese) (Peer-reviewed)

12. A time-delayed physical reservoir with various time constants, Yutaro Yamazaki and Kentao Kinoshita, Applied Physics Express, 17, 027001-1, 2024 (Peer-reviewed)

13. Photonic Physical Reservoir Computing with Tunable Relaxation Time Constant, Yutaro Yamazaki and Kentao Kinoshita, Advanced Science, 2304804, 2023 (Peer-reviewed)

14. Effect of pore size on heat release from CO_2 adsorption in MIL-101, MOF-177, and UiO-66, G. Auti, Y. Kametani, H. Kimura, S. Paul, W.-L. Hsu, S. Kusaka, R. Matsuda, T. Uemura, S. Chiashi, H. Daiguji†, J. Mater. Chem. A, 11, 20043-20054 (2023) (Peer-reviewed)

15. Two-band Model with High Thermoelectric Power Factor and Its Application to FeSe Thin Film
M. Matsubara, T. Yamamoto, and H. Fukuyama, J. Phys. Soc. Jpn. Volume92, Number10, page 104704 (Peer-reviewed)

Books

1. 原子精度にて制御された白金ナノクラスターを用いた高活性な酸素還元反応触媒の創製, 川脇徳久, 根岸雄一, 燃料電池誌, 23 巻, p31-35, 2023 (in Japanese)

2. スルフォネート保護銀ナノクラスターの合成と発光特性評価, 秋山 葵, Sakiat Hossain, 新堀佳紀, 川脇徳久, 緒方大二, Pei Zhao, 湯浅順平, 江原正博, 根岸雄一, ナノ学会会報, 22 巻, p11-15, 2023 (in Japanese)

3. 遷移金属ダイカルコゲナイドの基礎と最新動向, 小鍋 哲, シーエムシー出版, 第 1 編, 第 1 章 (11 ページ), 2023 年 12 月 27 日 (in Japanese)

Invited Lectures

1. 精密設計に基づく配位子保護金属微粒子の創製と光電気化学的な応用, 川脇徳久, 日本化学会第 104 春季年会,日本大学理工学部船橋キャンパス, 2024 年 3 月 (in Japanese)

2. Synthesis and catalytic properties of ligands-protected metal clusters, Tokuhisa Kawawaki, JSPS exchange program Mini-symposium on Advanced Nanomaterials, IPCMS, Strasbourg, France, November, 2023.

3. 配位子保護金属微粒子の電気/光電気化学的な応用,川脇徳久,第 168 回 東京工業大学フロンティア材料研究所学術講演会,東京工業大学すずかけ台キャンパス,2023 年 11 月 (in Japanese)

4. 金属ナノクラスター連結体による次世代電子材料の創製,川脇徳久,第 1 回セイコーインスツル新世代研究財団（ATF）コンファレンス,ロイヤルホテル八ヶ岳,2023 年 7 月 (in Japanese)

5. Synthesis of Pt17 Nanoclusters and Their Oxygen Reduction Reactivity, Tokuhisa Kawawaki, The 8th International Workshop on Advanced Nanoscienceand Nanomaterials 2023, Hankyong National University, Anseong, Korea, October, 2023

6. 光触媒における粒径約 1 nm 微細助触媒の精密制御：高活性な水分解光触媒の創製にむけて, 川脇徳久, 第 42 回光がかかわる触媒化学シンポジウム,岡山大学創立五十周年記念館, 2023 年 7 月 (in Japanese)

7. 原子精度で制御された貴金属クラスターを用いた高機能触媒の創製, 川脇徳久, 令和 4 年花王科学奨励賞研究発表交流会, 花王すみだ事業場, 2023 年 6 月 (in Japanese)

8. 単層カーボンナノチューブのカイラリティー分布計測のための研究開発, 入田 賢, 基礎科学セミナー 862nd ASRC Seminar (原子力研究開発機構, 茨城県), 2024 年 2 月 (in Japanese)

9. Kubo-Luttinger linear response theory of thermoelectric transport in disordered system, Takahiro Yamamoto, ISSP Regular Workshop: How high can we raise thermoelectric performance? The Institute for Solid State Physics, the University of Tokyo, December, 2023

10. Theoretical analysis of thermoelectric effect in FeSe thin films based on two-band model, Manaho Matsubara ISSP Regular Workshop: How high can we raise thermoelectric performance? The Institute for Solid State Physics, the University of Tokyo, December, 2023

11. Prediction of Optimal Thermoelectric Properties of Low-dimensional Carbon Nanomaterials, Manaho Matsubara, 13th A3 Symposium on Emerging Materials: Nanomaterials for Electronics, Energy and Environment Korea University (Seoul, Korea) November 2023.

12. バッテリーレス・バッテリー混載型 EH 異常診断システム, 中嶋宇史, 佐藤智浩, 第 7 1 回応用物理学会春季学術講演会, 東京都市大学, 2023 (in Japanese)

13. 高分子圧電材料を用いた振動発電と故障診断デバイスへの応用展開, <u>中嶋宇史</u>, 近畿化学協会エレクトロニクス部会 2023 年度第 2 回研究会, 大阪科学技術センター, 2023 (in Japanese)

14. 圧電性高分子の機能物性と新展開, <u>中嶋宇史</u>, 精密工学会　次世代センサ・アクチュエータ委員会, 東京・日本特殊陶業株式会社, 2023 (in Japanese)

15. 圧電性高分子材料の機能物性とその応用, <u>中嶋宇史</u>, 電気学会　基礎・材料・共通部門大会, 愛知工業大学, 2023 (in Japanese)

16. 圧電性高分子の振動発電能と応用展開, <u>中嶋宇史</u>, 高分子学会有機エレクトロニクス研究会, 東京工業大学, 2023 (in Japanese)

17. 第 2 回研究会「準周期電子状態とマルチフラクタリティ・ハイパーユニフォーミティ」, <u>橋爪洋一郎</u>, 1/18 盛岡, 2024 (in Japanese)

18. イオン液体の高分子デザイン性によるリザバー特性制御の試み, <u>木下健太郎</u>, 第 87 回半導体・集積回路技術シンポジウム, 東京理科大学　森戸記念館, 2023 (in Japanese)

19. イオン液体リザバー -イオン液体による時系列データの学習-, <u>木下健太郎</u>, イオン液体研究会, 金沢商工会議所, 2023 (in Japanese)

20. Thermoelectric Transport Calculation of Impurity-Doped Mg2Si Considering Finite Temperature Effects, <u>N. Hirayama</u> and H. Akai, International Workshop on Recent Advances in Thermoelectric Materials & Device Development, NIMS (WPI-MANA), 2023.

21. 希薄不純物を含む Mg2Si の電子状態および熱電物性の理論解析, <u>平山尚美</u>, 第４２回シリサイド系半導体研究会, オンライン, 2024 (in Japanese)

Patents
1. 根岸雄一, <u>川脇徳久</u>, S. Biswas, 田中智也, 特願 2024-006028(2024)「銅クラスター,二酸化炭素還元用電極,二酸化炭素還元装置及びメタノールの製造方法」, (in Japanese)
2. 根岸雄一, <u>川脇徳久</u>, 新行内大和, 尾上雅季, 特願 2024-1785(2024)「イリジウムクラスター, イリジウムクラスターの製造方法, 酸素発生電極, 水電解装置及び電気分解方法」, (in Japanese)
3. <u>入田　賢</u>, 山本貴博, 特願 2024-11248 (2024.1.29)「情報処理装置、情報処理システム, 情報処理方法, 及び情報処理プログラム」(in Japanese)
4. <u>入田　賢</u>, 本間芳和, マークサッドグローブ, 特願 2023-112654 (2023.7.7)「光伝送路, 光アイソレーター, フォトニックデバイス, 及び光伝送路の製造方法」 (in Japanese)
5. 内田秀樹, <u>中嶋宇史</u>, <u>山本貴博</u>, <u>橋爪洋一郎</u>, 洲崎崇, 特願 2023-187102 (2023.10.31)「薄膜, 振動センサ, 振動計測装置, 及び振動計測システム」 (in Japanese)
6. 伊藤拓海, <u>中嶋宇史</u>, 特願 2023-068796 (2023.4.19)「危険判定システム及びプログラム」 (in Japanese)

Public Relations
1. <u>田中研究室</u>, 研究室探訪問(研究室紹介), 東京理科大学こうよう会報「浩洋」 No. 76, 2023 (in Japanese)

Awards
1. <u>川脇徳久</u>, 第 16 回分子科学会奨励賞, 分子化学会, 2023
2. <u>川脇徳久</u>, 第 73 回日本化学会進歩賞, 日本化学会, 2023
3. <u>T. Sugano</u>(中嶋研究室, M2), The Dilip Das-Gupta Memorial Award, International Symposium on Electrets 2023 (Linz, Austria), 2023.9.20
4. <u>宮下裕之介</u>(東洋大学　根岸研 B4), 電気学会東京支部　埼玉支所研究論文賞, 2023

Individual Research Topics

Takahiro Yamamoto
"Quantum transport in nanocarbon"
We investigate theoretically and numerically quantum transport in nanocarbons and related materials as well as interaction between nanocarbon and water molecules.

Hidetoshi Fukuyama
"Theory of thermoelectrics of nanocarbon materials"
We investigate theoretically thermoelectric property of nanocarbons using Kubo-Luttinger formula.

Yoshikazu Homma
"Research on physical properties and structural evaluation of nanocarbon materials"
Using scanning electron microscopy (SEM) and spectroscopy, we investigate the structure and physical properties of novel nanocarbon materials. By combining these with the results of molecular dynamics simulations, we will elucidate the interactions between nanocarbon materials and other substances and molecules.

Yumi Tanaka
"Study on the effect of carbon suppots on activity of Pt/carbon-based oxygen reduction catalyst"
Two kinds of Pt/carbon ORR catalysts were prepared by Pt sputtering on g-KB and dg-KB, the former is ketjen black in which a graphite structure had been developed by calcination at 2400°C under He and the latter is the "g-KB" in which the defects were introduced by argon plasma etching treatment, and the ORR activities were compared to investigate the effect of differences in crystallinity of carbon supports on the ORR activity of Pt. As a result, Pt/dg-KB showed higher activity than Pt/g-KB, indicating that the defect introduction into carbon supports with a well-developed graphite structure contributed to the improvement of ORR activity of Pt/C catalyst.

Takashi Nakajima
We develop a scanning thermoelectric response microscope based on current measurement method and clarify the functional properties of CNTs that encompass multilevel nature. We also fabricate thermoelectric power generation devices based on the flexible Kirigami structure and construct an anomaly detection system that can operate without batteries.

Mark Paul Sadgrove
"Study on chiral coupling between nano-optical fibers and SWCNTs"
At Sadgrove lab, single wall carbon nanotubes (SWCNTs) are combined with optical nanofibers of waist diameter ~500 nm. The optical nanofibers have the property of mode chirality – that is, left and right propagating modes in the nanofiber have opposite circular polarizations. Working together with Prof. Homma (TUS) and Prof. Shimizu (Saitama Univ.), the aim of the research is to interface the optical nanofiber mode chirality with the structural chirality of SWCNTs. By achieving this goal, the Sadgrove group plans to make new non-reciprocal optical devices, and new methods of isolating and analyzing single SWCNTs.

Yoichiro Hashizume

"Pioneering technology for processing information obtained from thermoelectric devices"

The fabrication of devices using new materials such as carbon nanotubes is currently conducted by the members of this project. We, therefore, investigate a more efficient analysis of the information obtained by such devices. In particular, it is necessary to develop two methods; the first is the imputation method of missing information caused by signal instability, and the second is security robustness. To meet these needs, we focus on an analysis method using information entropy, called Kullback-Leibler divergence (KL divergence).

Tokushisa Kawawaki

In polymer electrolyte fuel cells, which are attracting attention as a clean power generation system, the oxygen reduction reaction (ORR) occurs at the cathode electrode. This reaction is the rate-limiting step, and a large amount of platinum (Pt) catalysts are currently used. In this study, we aim to prepare a more active ORR catalyst and reduce the amount of Pt used by adsorbing fine Pt nanoclusters on highly conductive carbon nanotubes.

Manaho Matsubara

"Study on optimization of thermoelectric properties of low-dimensional materials"

Using Kubo-Luttinger theory, we will investigate the thermoelectric performance of low-dimensional thermoelectric materials, e.g., carbon nanotubes and graphene, furthermore, we will clarify the optimization conditions for their thermoelectric performance.

Masaru Irita

"Research on thermal properties of single-walled carbon nanotubes and their applications"

We aim to establish a nanoscale thermal control technology by measuring the thermal properties of single-walled carbon nanotubes (SWCNTs) using photoexcitation emission and Raman spectroscopy. In addition, we are working on research and development of optical isolators using SWCNTs and related devices.

Hiroaki Anno

"Research on creation of nanocarbon thermoelectric conversion device materials"

The objective of this study is to develop stable p- and n-type carbon nanotubes (CNTs) for application in thermoelectric conversion devices. Two approaches will be pursued: creation of hybrids consisting of inorganic nanoparticles, CNTs, and organic matrices, and creation of charge-injected CNT thermoelectric devices. The improvement of thermoelectric properties will be advanced by controlling and optimizing inorganic nanoparticles, organic matrix, hybrid structure, electric double-layer transistor structure, and the amount of carrier injection.

Shigeo Maruyama

"Synthesis and application of one-dimensional heterostructures"

One-dimensional heterostructures have been realized using single-walled carbon nanotubes (SWCNTs) as templates, with boron nitride nanotubes and transition metal dichalcogenide nanotubes formed on the outer layers. CVD synthesis of various 1D heterostructures and elucidation of their synthesis mechanism, electronic, optical, thermal, and mechanical properties, and various device applications will be discussed.

Satoshi Konabe

"Exciton valley dynamics in transition metal dichalcogenides"

In this study, we investigate the exciton valley dynamics in atomic layer materials to identify the conditions that extend both the valley polarization relaxation time and the valley phase relaxation time.

Shohei Chiashi

"Fabrication of novel structures of nanocarbon materials and evaluation of their physical properties"

I aim to develop novel nanomaterial construction techniques for single-walled carbon nanotubes (SWCNTs), graphene, and other nanocarbon materials, and to combine them with other nanomaterials such as boron hexagonal nitride (e.g., stacked or lateral structures), and to explore and clarify their physical properties. In the case of SWCNTs, I will develop a chirality-controlled synthesis method, and in the case of graphene and other nanomaterials, I will promote the development of large-area and high-quality nanomaterials. At the same time, I will develop optical analysis methods for these nanomaterials and nanostructures.

Ryota Negishi

"Study on sysnetsis and carrier transport property analysis of multilayer graphene"

We explore a scalable synthesis method of turbostratic multilayer graphene material. To achieve this goal, we develop an ultra-high temperature heating system using an infrared heating furnace. By introducing reactive gas using ethanol and hydrogen gases, we will synthesize highly crystalline of turbostratic multilayer graphene. We will reveal the structural and electrical properties of synthesized multilayer graphene using quantum Hall, angle-resolved photoemission spectroscopy and absorption spectrum.

Hiroki Kato (JEOL Ltd.)

"3D analysis of nanocarbon composite material"

Three-dimensional (3D) analysis using focused ion beam (FIB) – scanning electron microscope (SEM) will be performed on carbon nanotube composite.

Naomi Hirayama

"Thermoelectric transport calculation with high accuracy and low computational cost"

In order to calculate thermoelectric properties of semiconductors containing multiple impurities and defects, we have introduced a calculation code Akai KKR (Machikanayama), based on the Green's function method and the Kubo-Greenwood equation. Furthermore, we focus on finite temperature effects by evaluating the phonon scattering on the carrier transports. This method is expected to predict thermoelectric properties at finite temperaturas with high accuracy and low computational cost, even at light doping levels. Therefore, the present calculation will provide insight into carrier transport and guidelines toward the creation of new thermoelectric materials.

Maki Shimizu

"Thermoelectric measurement of carbon nanotubes"

We will perform thermoelectric measurement of a single carbon nanotube. We will search for a more accurate method to measure high resistivity range. We will construct a system to measure the temperature dependence and measure the physical properties of carbon nanotubes.

Masahiro Ito

"**Increased emission intensity from single-walled carbon nanotubes**"

The luminescence from single-walled carbon nanotubes (SWCNTs) with antioxidants will be characterized in liquid using a near-infrared photoluminescence measurement system and a near-infrared microscope. Furthermore, the devices will show high luminescence emission even in the dry state. We will also evaluate the relationship between the chirality of SWCNTs and the polymers to be added.

Jun Hujioka

"**Highly efficient processing of carbon composite materials**"

Carbon composite materials are composed of materials with several different coefficients of thermal expansion, and efficiently laser processing methods is not established. We have studied the optimum wavelength for difficult-to-process resins and their chemical reactions using the Kyoto University infrared free electron laser. Thus, based on the knowledge obtained from these studies, processing carbon composite materials will perform to highly efficient laser processing.

Kentaro Kinoshita

"**Elucidation of the interaction between metal-organic framework pores and ionic liquids**"

A composite material (IL-MOF) in which an ionic liquid (IL) is introduced into the nanopores of a metal-organic framework (MOF) exhibits interesting physical and chemical properties that cannot be achieved with either MOF or IL alone. In order to establish material design guidelines for IL-MOF, we have to clarify the interaction between MOF pores and IL.

Suguru Iwasaki

Non-stoichiometry in inorganic compounds is a crucial factor that determines their functionality. Thus far, in the development of functional materials, thermodynamically stable phases are focused on. If the non-stoichiometry is controlled in the thermodynamically metastable region, the development of functionality is expected to further advance. In this study, we aim to synthesize metastable materials via anisotropic ion diffusion control method.

Yasuo Kato (Nagase & Co., Ltd.)

"**Development of electronic devices using nanoscale materials**"

Continuing from the previous year, we will take on the challenge of developing new electronic devices using nanoscale materials including nanocarbon. We will evaluate the resistance value and rectification characteristics of the CNT 4-terminal pair circuit, which was made into an element last year, to determine its potential for evolution into electronic elements and systems.

Division of Nano-quantum Information Science and Technology

Division of Nano-quantum Information Science and Technology

1. Overview

In the field of quantum information, research toward the realization of quantum computers has been actively advancing around the world in recent years. In our division, we are conducting research in three research areas: superconducting quantum circuits, quantum optics, and quantum information theory. It is expected that the emergence of error-tolerant quantum computers by 2050, and the research division intends to contribute to its realization. Research on superconducting qubits with its good integration potential and operability is currently the most advanced physical system. Physical systems other than superconductivity, such as light, ions, cold atoms are also being actively studied. In our research division, we study quantum system not only with superconducting qubits, but also with optical qubits and spin qubits.

2. Organization and Facilities

The division mainly consists of a superconducting quantum circuit research group, a quantum optics research group, a quantum information research group, and a visiting group.

Since FY2020, the research group for superconducting quantum circuits has been conducting research on the theme of "research and development of bosonic codes using superconducting resonators" in the government funded Moonshot Project. The Superconducting Quantum Circuits Group (Tsai and Yoshihara Laboratory) possesses the following facilities:

Refrigerant-free dilution refrigerator LD250 (Bluefors)
Refrigerant-free dilution refrigerator LD400 (Bluefors)
Vector Network Analyzer 2 units N5231B (Keysight)
Two high-frequency arbitrary waveform generators and real-time observation devices,
M9010A, M9048B, M9023A, M3102A, M3202A (Keysight Technology)
High-speed, high-sampling arbitrary waveform generator, M8195A (Keysight)

The quantum optics research group aims to combine single rare earth atoms with nanofiber optic resonators, and carbon nanotubes to optical fibers. Joint research with the University of Tokyo is currently underway.

The Quantum Information Theory Research Group has traditionally conducted research on quantum information theory, starting from the late Professor Oya. 202 It also hosted an international conference in this field. On the other hand, we are also conducting research to cover the theoretical aspects of superconducting quantum circuits.

3. Research Activities

3. 1. Superconducting Quantum Circuits Research Group (Tsai, Yoshihara)

This group is studying quantum circuits based on superconducting qubits using Josephson junctions. Regarding the integration of qubits, we are conducting research on quantum chips that can be packaged planarly using a pseudo-two-dimensional qubit coupling network originally developed by us. In addition, as a research theme of the Moonshot Program, Bosonic qubits, we are conducting research on quantum

information processing using a superconducting Kerr parametric oscillator (KPO). By generating a cat state in a two-dimensional KPO circuit and evaluating the fidelity using a quantum tomography method, we succeeded in realizing a universal quantum gate that can operate 1-bit and 2-bit gates. We took advantage of the unique characteristics of the KPO to realize entangled cat states in two ways. In the first method, the entangled state (bell state) based on the Fock state is converted to the entangled cat state. In the second method, a $\sqrt{\text{iSWAP}}$ gate is added to two independent cat states to create an entangled cat state. These results show that this novel physical system could be a platform for a new scalable quantum computer. In the future, we will proceed with experiments of autonomous error correction of KPO qubit. In research on the initialization of superconducting qubits, we achieved a high-speed initialization of 200 ns with an accuracy of 99.5% with a novel circuit that involving a SINIS junction. In order to extend the coherence time of superconducting qubits, we studied surface treatment methods and significantly improved T1 and T2 time. Similar surface treatment also reduced the loss of the superconducting resonator by about one order of magnitude. Cross-resonance readout method, which is expected to be faster with higher-fidelity, was tried out for flux qubits readout. As a result, it showed a higher fidelity.

3. 2. Quantum Optics Research Group (Sanaka, Sadgrove)

The Optical Quantum Information Group has realized a "single-photon light source," which is required in quantum cryptographic communications, a next-generation secure communication system, by using tapered rare earth-doped optical fiber. The application of single-photon light source technology to quantum cryptographic communication will overcome the vulnerabilities (e.g., eavesdropping) of conventional quantum cryptographic communication, which has been implemented in society to date. However, single-photon sources using crystalline materials such as semiconductors, which are currently under research and development, present technical and economic challenges in controlling the operating environment (temperature), as well as in manufacturing and mass production. In this study, a single-photon light source using optical fiber materials doped with rare-earth elements has been developed, which enables a stable single-photon source to be produced at room temperature. By changing the rare earth elements, it is possible to obtain single-photon sources corresponding to various wavelength bands, and at present single photon generation at near-infrared wavelengths has been achieved using the rare earth atoms Ytterbium and Neodymium.

3. 3. Quantum Information Theory Research Group (Watanabe, Iriyama, Hashizume)

In this group, we are conducting research on several of the following subjects:

(1) Research on the formulation of generalized quantum entropy

Basic research founded on quantum probability theory, quantum channel theory and quantum entropy theory, including quantum coherence determined based on the mathematics of entanglement.

(2) Research on the formulation of Quantum Dynamical Mutual Entropy

The channel coding theorem of commutative systems shows the limit of the average mutual entropy obtained from dynamic entropy from the transmission capacity and provides an important criterion for constructing error-free channels and coding.

(3) Basic theoretical research and implementation of cryptographic theory.

(3-1). Construction of authentication algorithm incorporating secure computation and information distribution structure.

(3-2). Construction and implementation of a mathematical framework for Strongly Asymmetric Public Key Agreement.

(3-3). Formulation of quantum algorithms using adaptive mechanics.

(4)   Application of "effective" algorithmic methods to quantum system analysis and quantum information theory.

(4-1). Determination of existence of decoherence-free subspace (DFS).

(5)   Evaluation of quantum annealing including finite temperature dissipation.

(6)   Development of imaginary-time quantum toolbox (JST PRESTO).

(7)   Indicators for large-scale quantum computers.

(8)   Artificial intelligence/machine learning and quantum computers.

4. Challenges and Prospects

Quantum information is a field that is currently being intensively invested in research around the world. It is one of the three basic technologies of the Japan Government Cabinet Office's "Integrated Innovation Strategy": AI, quantum information, and biotechnology, and is also one of the four pillars of the Department of Physics of the University of Science: space and elementary particles, earth and planets, quantum information, and condensed matter physics. In order to accelerate the progress of this important research field, our division was established in 2020 within the Institute of Research that brings together researchers in the university. Until now, the Tokyo University of Science has been conducting research on superconducting quantum computers under JST CREST (completed in FY2021, total of about 200 million yen) and Cabinet Office Moonshot (total of about 150 million yen until FY2025). In addition, NEDO Next Generation Computing and the Cabinet Office Q-Leap are also collaborating.

Regarding intergroup collaboration within the division, collaborative research is progressing especially between the Superconducting Quantum Circuits Group and the Quantum Information Theory Group. On the other hand, there is a large energy difference between the two physical qubits, superconductivity and light, and there is a limit to research activity that directly fuses them.

In addition, with regard to the expansion of membership of the division as pointed out by the Advisory Committee, that is, the incorporation of new researchers involving in the research of classical control circuits, which are important peripheral circuits of quantum computers, no such researchers are identified within the university.

5. Conclusion

Research in this division has progressed smoothly this fiscal year in general. Concerning the superconducting quantum circuits, where research towards the quantum computers is particularly advanced, the following outcomes were achieved: integration of qubits using a pseudo-two-dimensional qubit coupling network that can be planarly packaged; cat states generation with the superconducting Kerr parametric oscillator (KPO) and its fidelity evaluation using quantum tomography, as well as realization of 1-bit gate operation; measurement and reduction of low-frequency noise of KPO oscillation; high-speed initialization of superconducting qubits; extension of the coherence time of superconducting qubits, realization of novel quantum optical circuits using artificial atoms with ultra-strong coupling to resonators.

Although the development of field of quantum information is what the government is paying particular interest, there is a serious shortage of domestic research personnel. In particular, the shortage of researchers who can handle experiments is one of the major obstacles to the progress of quantum computer research in Japan. As a research organization within an educational institution, we also focus on human resource development in the division.

Major Research Achievements (for FY2023)

Academic Papers

1. Active initialization experiment of a superconducting qubit using a quantum circuit refrigerator, Teruaki Yoshioka, Hiroto Mukai, Akiyoshi Tomonaga, Shintaro Takada, Yuma Okazaki, Nobu-Hisa Kaneko, Shuji Nakamura, and Jaw-Shen Tsai, Phys. Rev. Applied 20, 044077, 2023 (Peer-reviewed)

2. Observation and manipulation of quantum interference in a superconducting Kerr parametric oscillator, Daisuke Iyama, Takahiko Kamiya, Shiori Fujii, Hiroto Mukai, Yu Zhou, Toshiaki Nagase, Akiyoshi Tomonaga, Rui Wang, Jiao-Jiao Xue, Shohei Watabe, Sangil Kwon & Jaw-Shen Tsai, Nature Communications (2024)1 5:86 (Peer-reviewed)

3. Tunable compact on-chip superconducting switch, Julia Zotova, Alexander Semenov, Rui Wang, Yu Zhou, Oleg Astafiev, Jaw-Shen Tsai, Physical Review Applied 21, 024059, 2024 (Peer-reviewed)

4. Control and readout of a transmon using a compact superconducting resonator, Julia Zotova, Shtefan Sanduleanu, Gleb Fedorov, Rui Wang, Jaw-Shen Tsai, Oleg Astafiev, Applied Physics Letters, 124, 102601, 2024 (Peer-reviewed)

5. Single-photon generation from a neodymium ion in optical fiber at room temperature, Kaito Shimizu, Kai Inoue, Kazutaka Katsumata, Ayumu Naruki, Mark Sadgrove, and Kaoru Sanaka, Appl. Phys. Lett. 124, 081106 (2024) (Peer-reviewed)

6. Numerical investigation of plasmon-enhanced emission from a nanofiber coupled single photon emitter, Yining Xuan, Rui Sun, Soyoung Baek, Mark Sadgrove, Keiichi Edamatsu, Applied Physics Express 17, 012003 (2024) (Peer-reviewed)

7. Room-temperature addressing of single rare-earth atoms in optical fiber, Mikio Takezawa, Ryota Suzuki, Junichi Takahashi, Kaito Shimizu, Ayumu Naruki, Kazutaka Katsumata, Kae Nemoto, Mark Sadgrove, and Kaoru Sanaka, Phys. Rev. Applied 20, 044038 (2023) (Peer-reviewed)

8. Position-controlled trapping of nanoparticles and quantum dots on a fiber taper, Ryusei Watanabe, Daiki Yamamoto, Mark Sadgrove Physical Review A 108, 043512 (2023) (Peer-reviewed)

9. Note on Complexity of Communication processes, Noboru Watanabe, Infinite Dimensional Analysis, Quantum Probability and Applications, Vol. 32, pp. 251-271, 2023, ISBN 978-981-12-7598-2 (Peer-reviewed)

10. On Transmitted Complexity Based on Modified Compound States, Noboru Watanabe, Entropy Vol. 25(3), 455, 2023 (Peer-reviewed)

11. A Study of Noise Effect in Feedback control with White Noise Analysis, Taihei Takahashi and Noboru Watanabe, submitted to Open Systems and Information Dynamics

12. Security Verification of an Authentication Algorithm Based on Verifiable Encryption, Kihara M, Iriyama S., Information. 2023; 14(2):126 (Peer-reviewed)

Invited Lectures

1. Superconducting Quantum Circuit, Jaw-Shen Tsai, Invited lecture at National Yang Ming Chiao Tung University, Taiwan, 2023/6/1

2. Superconducting qubit and quantum computer, Jaw-Shen Tsai, Invited seminar at Shanghai Institute of Microsystem and Incormation Technology, China, 2023/7/19

3. Superconducting qubit and quantum computer, Jaw-Shen Tsai, Invited seminar at European Center for Quantum Science (CESQ), France, 2023/11/3

4. Direct observation and manipulation of quantum interference in a superconducting Kerr parametric oscillator, Jaw-Shen Tsai, INQA 2023-International Network Quantum Annealing Conference, Austria, 2023/11/6-8

5. Direct observation and manipulation of quantum interference in a superconducting Kerr parametric oscillator, Jaw-Shen Tsai, Invited seminar at University of Innsbruck, Austria, 2023/11/8

6. Nanofiber photonics using electron beams, Mark Sadgrove, Optical Nanofiber Applications (ONNA) 2023

7. Quantum emitters coupled to optical nanofibers: an overview of some recent results, Mark Sadgrove, Dodd Walls Centre Seminar (Online Seminar, Auckland University, New Zealand, 2023/5/5

8. Note on Transmitted Complexity of Modified Compound States for Quantum Dynamical systems, Noboru Watanabe, The QBIC Workshop 2023 (Real and Online), Tokyo University of Science, Noda, Japan, 2023/10/11-10/13

9. Note on transmitted complexity for the modified compound states, Noboru Watanabe, International Workshop on Foundation of Quantum Physics and Its Mathematics, Suwa University of Science, Chino, NAGANO, Japan, 2023/3/2-3/3

10. On complexities for the quantumcompound systems, Noboru Watanabe, The International Workshop on Infinite Dimensional Analysis, Quantum Probability, Ohio State University, Ohio, U.S.A., 2023/6/1-6/3

11. Note on Transmitted Complexity for Quantum Dynamical Systems, Noboru Watanabe, Quantum Information and Probability from foundations to engineering (QIP23) conference, Linneaus University, Vaxjo, Sweden, 2023/6/13-6/16

12. Note on complexities for the quantum compound systems, Noboru Watanabe, 54 Symposium on Mathematical Physics, Nicolaus Copernicus University, 2023/6/8-6/11

13. Note on complexities for the quantum compound systems, Noboru Watanabe, ICIAM 2023 Tokyo, The 10th International Congress on Industrial and Applied Mathematics August 20-25, 2023, Waseda University, Tokyo, Japan, 2023/8/20-8/25

14. Study on Formulation of Mean Mutual Dynamical Entropy Based on Dynamical Entropy in Quantum Systems, Masayuki Miyashita and Noboru Watanabe, The QBIC Workshop 2023 (Real and Online), Tokyo University of Science, Noda, Japan, 2023/10/11-10/13

15. Digital Quantum Computation and Classical Teleportation Scheme, Satoshi Iriyama, QBIC Workshop 10/11-13, TUS, 2023

16. Violation of Bell's Inequality by Classical Correlation via Adaptive Dynamics,Satoshi Iriyama, ICIAM, 8/20-25, Waseda Univ. Tokyo, 2023

17. Classical Simulation of EPR Correlation Based on Adaptive Dynamics and Its Application, Satoshi Iriyama, QIP23, 6/13-/6/16, Sweden, 2023

18. Study on constructing an entropy-generating model and its multifractality, Yoichiro Hashizume, 2nd Meeting on Quasiperiodic Electronic States and Multifractality Hyperuniformity.1/16-1/18, Iwate, 2024

International Conferences Hosting

1. From October 11 to October 13, 2023, Tokyo University of Science and the Division of Nano Quantum Information held the "Hybrid QBIC International Workshop 2023" via on-site and Zoom. The conference was held as a Tokyo University of Science Session and an International Session, and the opening address of the international session was given by Prof. Hideaki Takayanagi. Fourteen researchers from overseas, six researchers from outside the university, seven researchers from the Nano Quantum Information Research Division and one researcher from the Tokyo University of Science gave invited lectures, and poster lectures were given by 10 researchers from this research division, 3 researchers from the Tokyo University of Science, and 2 researchers from outside the university. https://www.rs.noda.tus.ac.jp/qbic/VQBICworkshop2023new.html

2. QBIC small workshop on information security was held on Friday, March 22, 2024. Faculty members of the university, collaborators from outside the university, and researchers from overseas were invited to discuss and share information.

International Conferences Supporting

1. ANF Workshop on Commercialization, 2024.1.31

Seminars

1. Speaker：Professor Seth Lloyd (MIT)
   Title：Quantum machine learning
   Abstract：This talk presents an introduction to quantum machine learning, with an emphasis on quantum neural networks, quantum kernel methods, and quantum annealing.

Pattent

1. Refernece No. : T2020-038
   Patent No.　　：特許第 7301389 号
   Title　　　　 : Quantum Computing System and Use Method for Quantum Computing System

Public Relations

1. Jaw Shen Tsai, "New Technology of Fast Initialization of Quantum Computers, Accelerates Initialization of Superconducting Qubits Using Photon Absorption in Nanodevices", Press Release, 2023
2. Kaoru Sanaka,"Position-controlled trapping of nanoparticles and quantum dots on a fiber taper", Ryusei Watanabe, Daiki Yamamoto, Mark Sadgrove Physical Review A 108, 043512 (2023) https://doi.org/10.1103/PhysRevA.108.043512, Press release

Awards

1. Jaw Shen Tsai, Japan Academy Prize, "Pioneering Research on Superconducting Qubits and Their Quantum Control", 2023/6/12
2. Jaw Shen Tsai, 2023 (93rd) Hattori Hoko "Hogong Award", "Pioneering Research on Superconducting Qubit Circuits for the Realization of Quantum Computers", 2023/9/5
3. Jaw Shen Tsai, 2023 C&C Award, "Realization of Superconducting Qubits and Contributions to the Field of Quantum Information Technology, including Quantum Computers", 2023/10/10
4. Kaoru Sanaka, Student Presentation Award at the 48th Quantum Information Technology Workshop of the Institute of Electronics, Information and Communication Engineers, 2023/6/7

Others

1. August 24 and 25, 2023, selected for the University Trade Fair 2023 ~ Innovation Japan sponsored by the Japan Science and Technology Agency (JST) at Tokyo Big Sight, and participated in the following events and exhibited the equipment developed in our laboratory.
2. Infrastructure, Safety, and Social Infrastructure Exhibit No. S-06, "Optical Fiber Single Photon Light Source"

Individual Research Topics

Jaw-Shen Tsai

We have shown that it is possible to convert the Fock state to the cat state on a one-to-one basis with KPO, and that quantum coherence is preserved in this process. In addition to quantum coherence, the other element that makes quantum information powerful is entanglement. We showed that the entangled Bell-Fock state is converted one-to-one to the entangled cat state (Bell-Cat) using two KPOs.

Previous Wigner tomography cannot properly study entanglement of two cat states. To solve this problem, we newly implemented tried 2-mode Wigner tomography, which is an extension of 1-mode Wigner tomography. The interference pattern seen in the Im-Im plot indicates that the two cat states are entangled rather than simply correlated. Recently, research has been actively conducted to convert the Fock state into the cat state, and this achievement succeeded in conserving entanglement for the first time in the microwave regime.

In addition, without going through the Bell-Fock state, we entangled the two cat states that are independent of each other through gate operation. Taking advantage of the fact that the cat state generated by KPO can be gated in almost the same way as a general qubit, we succeeded in generating an entangled cat state in a very simple manner. This research is significant for it realizes a universal quantum gate set with two-dimensional KPO circuits, demonstrating it is a scalable platform of quantum computer.

Fumiki Yoshihara

While dispersive readout is commonly used among various readout method, cross-resonance readout method, which is expected to be faster with higher-fidelity, attracted more attention, recently. In most of the study on cross-resonance readout method, transmon is used. On the other hand, flux qubits are less common but have higher anharmonicity and expected to be readout faster and with high-fidelity. We study cross-resonance readout method for flux qubits. In this study, cross-resonance readout method showed a higher fidelity. As a future work, we will implement single-shot readout to compare fidelity of dispersive readout method and cross-resonance readout method.

Kaoru Sanaka

We succeeded in stably generating a single-photon source at room temperature by using a single-photon light source with rare-earth doped optical fiber. Single-photon generation at near-infrared wavelengths was achieved with two types of rare earth atoms, Ytterbium and Neodymium, and two academic papers were published on the characteristics of each single-photon light source. In the future, we try to demonstrate that single-photon generation is similarly possible at fiber-optic communication wavelengths using Erbium. We also try to manipulate single-photon generation time with pulsed laser pumped light sources, and enhancement of single-photon emission by resonator effects.

Mark Sadgrove

We published two papers relating to single photon generation. In the first paper, we demonstrated the simultaneous manipulation of quantum dots and gold nanoparticles using an optical nanofiber. In the second paper, we numerically investigated the relation between Purcell enhancement and photonic loss for a quantum dot coupled to a plasmonic cavity.

Noboru Watanabe

(1) Research on the formulation of generalized quantum entropy:

Quantum information communication theory is the extension of some information quantities such as entropy and mutual entropy formulated in classical systems by Shannon et al. It is a thing. In the formulation of information theory in quantum systems, based on quantum probability theory, quantum channel theory and quantum entropy theory, including quantum coherence determined based on the mathematics of entanglement, are extended, and a foundation is established that correlates them.

(2) Research on the formulation of Quantum Dynamical Mutual Entropy:

The commutative channel coding theorem shows the limit of the averaged mutual entropy (transmission rate) obtained from the dynamic entropy from the transmission capacity and provides an important criterion for constructing error-free channels and coding. Extending this theorem to quantum systems is an essential and important issue for rigorous research on communication processes including non-commutativity and coherence in terahertz and next-generation quantum optical communications. We conducted this basic research.

(3) A Study of Noise Effect in Feedback Control with White Noise Analysis:

In Proportional-Integral-Derivative (PID) control, it is well known that the selection of a method to deal with the noise is an important issue and various methods have been proposed.

However, methods to determine the response to noise in probability theory have not been studied. In this study, based on the White Noise Analysis, a probabilistic analysis of filtered derivatives is performed. As a result, a White Noise form on the filtered derivative. The method in this study is considered to be effective when feedback control is not employed.

Satoshi Iriyama

In this year, we focused into three topics, (1) mathematical and computational study on squeezed entangle state, (2) theoretical research on post quantum cryptography, (3) digital quantum computation. In (1) we improved the efficiency of information transmission using squeezed entangled state. In (2) we study on MTRU and one of its subclass Falcon from the view point of generalization. We found that there exists a larger class of MTRU in the mean of matrix expantion. In (3) we constructed a new classical probabilistc computation inspired by quantum algorithm where we replace the entangled particle by the EPR chamereon classical pair. We found that the classical computation can simulate quantum algorithm using limited resource, not exponential.

Yoichiro Hashizume

In this year, we investigated the "thermalization process of quantum current in a quantum model as a driven dissipative system" with the aim of making the readout of information from a qubit more efficient and precise. We constructed a model in which a spin system modeling a quantum probe is in contact with a qubit that serves as the current source and a thermal bath corresponding to the external noise. The model is expressed in terms of the extended Lindblad equation, and the time evolution of the current and entropy production was analyzed. We found a transition in the scaling law of the relaxation time, which depends on the coupling strength with the heat bath, owing to the lifetime of the current inflow from the qubits. We believe that this is a possible new nonequilibrium phase transition and will continue to investigate it.

Parallel Brain Interaction Sensing Division

Parallel Brain Interaction Sensing Division

1. Overview

Neuroscience (brain science) is a field of life science that is rapidly developing in the 21st century. The field is attracting attention from society and industry because the maintenance of brain health is expected to improve the quality of life in a super-aging society, and the application of information processing mechanisms in the brain leads to the creation of innovative technologies. In recent years, most things have been connected to the Internet (IoT: Internet of Things), and wearable devices such as smartwatches have made it possible for humans to connect to the Internet before they even realize it (IoB: Internet of Bodies). It is easy to imagine that the next era will happen when the human mind will be connected to the Internet (IoM: Internet of Minds). This is indeed the beginning of the era of the Internet of Brains. This division will establish a multidisciplinary and interdisciplinary research and development platform by concentrating the multidimensional and multiaxial expertise and information on the brain and neural information/systems with related researchers in/outside of the university. We aim to create an innovative academic field of brain science, "Parallel Brain," originating from Tokyo University of Science in preparation for the coming age of the Internet of the Brain.

2. Organization and Facilities

We propose technology for sensing and reproducing biological information based on the knowledge of brain research by synchronous (parallel) measurement of the brains of multiple individuals using brain research methods for mice and humans, which became our original interdisciplinary brain research field. By utilizing elucidation and support of the mechanisms of group formation and symbiosis in online space, as well as the common sensing technology in both mouse and human experiments, we aim to describe the interaction between multiple brains common to social animals using mathematical models and to build a theoretical background. This division consists of three groups and seeks to produce emergent results through synergistic effects among these groups.

Animal experiment group (Mouse / human)

This group conducts multidimensional research on brain health and diseases focusing on cognition (depression characterized by pessimistic cognition, senile dementia with impaired cognition and memory functions, autism with impaired social cognition and communication, etc.), from molecular and neural circuits to animal models, elucidates related mechanisms, and creates seeds for improvement drugs and diagnostic agents.

Sensing Group

The Sensing Group conducts multidimensional research on the analysis and evaluation of brain dysfunction concerning personality traits focusing on gaze behavior and physiological indicators in developmental disorders, etc., and aims to create related measurement technologies and assistive devices.

Mathematical Model Group

The Mathematical Modeling Group conducts multidimensional studies on functional brain imaging, cognitive psychology experiments, brain-type algorithms, etc., about brain information processing with a focus on human visual perception. We aim to elucidate brain information processing systems and to develop models and theories.

The division consists of 17 researchers in interdisciplinary neuroscience-related fields. The fifteen researchers belong to the Faculty of Science and Technology (Hiroshi Takemura, Takeo Ushijima, Takahiko Yamamoto, Akari Hagiwara, Takumi Asakura, and Masataka Yamamoto), the Faculty of Pharmaceutical Sciences (Akiyoshi Saitoh and Daisuke Yamada), the Research Institute for Biomedical Sciences (Takeshi Nakamura and Shingo Koinuma), the Faculty of Engineering (Osamu Sakata and Takuya Hashimoto), the Faculty of Advanced Engineering (Eri Segi-Nishida and Kanzo Suzuki), and the Institute of Arts and Sciences (Hiroko Ichikawa). The others are two visiting researchers: Ryohei Hasegawa (National Institute of Advanced Industrial Science and Technology (AIST)) and Asami Oguro-Ando (The University of Exeter Medical School)

We are mainly engaged in cooperative research using the unique talents and strengths of each member. The following is a list of collaborative research projects that transcend the boundaries of each specialized field, which are only possible in this division.

Fig. 1. What this division aims to achieve

3. Activity Reports

Since the establishment of the division, we have started various collaborative research that transcends the boundaries of each group, which was possible only in this division. The part of activities of the division in FY2023 is the following.

3. 1. Research Collaborations Beyond Groups

3. 1. 1. Elucidation of brain functions that regulate social behavior 'Evaluation of social behavior and brain developmental changes in a human chromosome deletion disease model of autism' (Segi-Nishida [TUS] / Oguro-Ando [Univ. of Exeter])

We focus on a human chromosome deletion disease, a three-gene deletion in the p26.3 region of chromosome 3. This disease is a *de novo* mutation that occurs after fertilization and its symptoms include

developmental delay, including intelligence and autism (Fernandez et al., 2008). Three genes involved in neural adhesion factors, CHL1, CNTN4, and CNTN6, are located in this region and have been reported as risk factors for autism. Oguro has generated triple knockout mice (3PKO) of these three genes. Although these mice were known to survive, it was completely unknown how they affected emotional behaviors such as social cognition, anxiety, and depression, as well as cognition such as memory, etc. In FY2022, we evaluated social behavior, motor coordination, and anxiety behavior in 3PKO mice. 3PKO mice showed decreases in both anxiety-like and social behaviors. Furthermore, histological analysis of the brain suggested a morphological defect in the hippocampus. To assess the specificity of emotional and social changes, we will measure stress adaptation, cognition, memory, and basic need motivation in these mice and examine changes in hippocampal neurodifferentiation and synaptic development. These studies are expected to advance our understanding of hippocampal function and the contribution to social and emotional behavior of three neighboring genes, CHL1, CNTN4, and CNTN6, which mimic human chromosomal deletion diseases that have not been previously elucidated.

3. 1. 2. Examination of cross-species vocal communication: Relationship between ultrasonic vocalizations in mice and the effects of ultrasonic listening in humans (Ichikawa, Saitoh, Yamada, and Asakura)

We examined the relationship between ultrasonic vocalizations and emotional states in mice to clarify the relationship between vocal communication and emotion. Rodents are known to communicate with each other using sounds outside the human auditory range in response to pleasant or unpleasant stimuli or the approach of a predator. In a previous study, we found that the number of ultrasonic vocalizations decreased with anxiolytic treatment in mice under the condition that they vocalized ultrasonic sounds associated with unpleasant emotional states. The reduction in ultrasonic vocalizations was not observed with the administration of antidepressants or medications for schizophrenia. Furthermore, this test can be repeated, indicating its potential use as a novel screening system for anxiolytic drugs. The results have already been published in an international journal (Fig. 2, Yamauchi et al., Biol Pharm Bull. 2022; 45: 268.). In FY2022-FY2023, we recorded live gamelan music, which contains a large number of ultrasonic components, as an auditory stimulus to start ultrasonic listening experiments in human subjects. Additionally, the experimental paradigm of a previous study that evaluated physiological and psychological indices by listening to music was tested. It was confirmed that psychological changes by listening to music could be measured using existing psychological indices. In the future, we will use this paradigm to examine how music alters the psychological and physiological states of humans with and without ultrasonic components.

In the future, we will expose the collected ultrasonic sounds to animal models of depression, and proceed to elucidate the changes in emotional behavior and their mechanisms of action. At the same time, we will examine changes in brain activity, psychological state, and endocrine system when humans are exposed to ultrasound. The unique feature of this study is to examine the effects of ultrasound listening from the perspective of both experiments using model animals and human subjects. We will elucidate the detailed mechanisms in animal model studies and demonstrate their applicability in human studies.
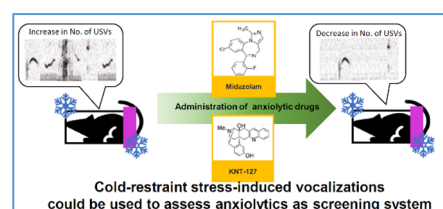
Fig. 2. P. Novel Screening Tool Model to Measure Anxiety in Mice.

3. 1. 3. Analysis of stress-induced depression-like state (Saitoh, Yamada, Takemura, and Yamamoto)

In recent years, it has been demonstrated that exposing the body surface to ultrasonic waves in the non-audible range can non-invasively alter brain activity, prompting applications for the treatment of mental

illnesses. However, the effects of ultrasonic exposure on depressive symptoms and the detailed mechanisms involved remain unclear. In FY2023, we explored the changes in emotional states induced by ultrasonic exposure at nonaudible frequencies using an animal model. We exposed olfactory bulbectomy (OB) rat models of depression to an ultrasonic source that exceeded the rat's audible range at 100 kHz. The results showed that exposure to 100 kHz artificial ultrasound improved depressive-like behaviors in OB rats and significantly reduced blood stress hormone levels. In particular, there was no change in neuronal activity in the auditory cortex of rats, suggesting that 100 kHz ultrasound exposure affects emotions without affecting the auditory system. These findings have been submitted to an international academic journal.

In the future study, to elucidate the neural mechanisms underlying the emotional and behavioral changes induced by exposure to ultrasonics, we plan to identify relevant brain regions, neural circuits, and neurotransmitters using OB rats.

3. 1. 4. Physiological changes due to pleasant emotional experiences and positive perception of other people's facial expressions (Ichikawa, Oguro-Ando)

Laughing has a positive impact on health (Martin, 2002, for a review). Laughter is believed to cause the same physiological changes that occur during exercise, including increased heart rate (Kop et al., 2011) and sweating (Guerra et al., 2012; Salimpoor et al., 2009), and facial muscle activity (Fiacconi & Owen, 2015). We focus our study on the changes that laughter causes in multi-person communication from the following two perspectives.

(1) Whether laughing makes us perceive other people's facial expressions as more positive: It has been reported that when we are in a positive emotional state in communication, we perceive other people's facial expressions as similar to our own emotional state, i.e., as positive. Therefore, we asked participants to watch a comedy video and examined whether they were more likely to perceive other people's facial expressions as more pleasant than when they watched a weather forecast. The results showed that the participants felt more pleasant emotions after watching the comedy video and perceived other people's facial expressions as pleasant. These results were presented at the BSN Annual Meeting 2023 and will be submitted to an international journal for further analysis. Currently, a project is underway to conduct the same experiment in the U.K. and to compare the results internationally.

(2) Are physiological changes associated with the subjective experience of "fun" when laughing: Participants in the study were asked to watch a comedy video and rate the video on a 5-point scale of subjective amusement at the point where they found the video amusing. In addition, the physiological indices of the participants (facial electromyography, electrical response of the skin produced by sweating of the palm, and heart rate) were measured during the viewing. The results showed that the electrical responses of the facial muscles and skin increased when the participants subjectively found the program interesting. These results will be presented at a domestic academic conference. In the future, we will further examine whether there is a quantitative correlation between the intensity of amusement and changes in physiological indices.

3. 1. 5. Biomechanical analysis of age-dependent gait deficiency in mice deficient in cerebellar neural transmission (Hagiwara, Takemura, and Yamamoto)

The cerebellum is important for balance control in locomotion, and plastic changes in neurotransmission have revealed the mechanism of motor learning. However, the involvement of the cerebellum in the decline in gait function due to aging and frailty and its neural mechanisms remain largely unknown. To establish the appropriate treatment and rehabilitation methods, we investigated newly developed conditional knockout

(cKO) mice, in which a specific deletion of LKB1, a phosphatase of the AMPK family involved in cell metabolism and morphogenesis, is observed in the cerebellar granule. Hagiwara et al. have found an age-dependent gait defect in this mouse.

The Rotarod test, which evaluates coordinated locomotion, measures the time the mouse stays on a rotating thin rod and thus does not provide any measure of stance and balance. Therefore, we measured the walking of freely behaved mice using machine learning technology developed by Takemura and Yamamoto et al. and analyzed the walking movements of mice lacking the LKB1 gene. The results showed that there were no significant differences in gait functions such as stride length, indicating that there is a disorder in coordinated locomotion involving the cerebellum. This research has been adopted as part of the Soikinome Project 2022-2023, and the promotion of interdisciplinary research has greatly contributed to the formation of practical skills of the students. Morphological analysis of weekly age-dependent changes in the cerebellum is currently underway, and the results of this study are being prepared for publication in an international journal.

3. 1. 6. Evaluation of the neural basis of stress sensitivity in synaptic protein-deficient mice (Hagiwara, Saitoh, Yamada, Takemura, and Yamamoto)

People are exposed to various physical and mental stresses from the environment, and the recent increase in the complexity of social structure is believed to be a factor that causes organic and functional changes in the brain, increasing the incidence of mental disorders. In other words, understanding the neural basis is essential to solve stress-related mental problems. At the site of neuronal transmission, called the synapse, information is transmitted through transmitters, and various proteins modify synaptic functions in a plastic way. In mice lacking the presynaptic protein CAST, Hagiwara has shown neglect-like maternal behavior, suggesting that stress sensitivity during pregnancy is involved (Hagiwara et al., Scientific Reports, 2020). Therefore, we will examine the sensitivity of CAST-deficient mice to various types of stress and elucidate the neural mechanisms associated with stress sensitivity.

CAST-deficient mice were subjected to physical restraint stress, and depression-like symptoms were assessed by the sugar preference test (SPT) and the tail suspension test (TST). The TST results showed that CAST-deficient mice showed an increase in immobility time, suggesting that stress sensitivity is enhanced. In the future, we will examine the pharmacological effects of antidepressants and other drugs to further elucidate the mechanism. In addition, there is concern that the current experimental method may result in a blurring of the judgment criteria by the experimenter. Therefore, we will develop a video analysis program to measure immobility time. This program is expected to unify the judgment criteria and significantly shorten the analysis time.

3. 1. 7. Analysis of Jakmip1-deficient mice, a mouse model for autism (Saitoh, Oguro-Ando, Hagiwara, and Yamada)

Autism spectrum disorder (ASD) is a highly heritable developmental disorder characterized by communication disorders and patterning of behavior. Oguro identified JAKMIP1 as a factor down-regulated in Fragile X syndrome and 15q duplication syndrome, the most common syndrome among ASD. Furthermore, the analysis of the RNA sequence of JAKMIP1-deficient mice suggests that JAKMIP1 is involved in the regulation of cytokine signaling, and a more detailed analysis will be performed. This research was selected for the Daiichi Sankyo TaNeDS program in 2022 and will continue as an industry-academia collaborative project over the next two years to develop a novel therapeutic agent for ASD. Oguro and Hagiwara will perform morphological analysis, such as the maturation of the dendritic spine of neurons. In addition, Yamada and Saitoh will evaluate the response to calcium signaling as a function of neurons, and a graduate student from the Oguro lab will join the Saitoh lab to conduct the analysis. In addition, Saitoh, Yamada, and Hagiwara will assess behavioral deficits in mice and the pharmacological effects of various drugs.

3. 1. 8. DNA methylation analysis in various mouse models (Oguro-Ando, Segi-Nishida, Saitoh, Hagiwara, and Yamada)

Neuronal circuits change in various ways depending on the environment, and neuronal activities undergo epigenetic changes that regulate gene expression. The development of transcriptome technology has been under intense competition in recent years, and the earliest introduction of novel technology is necessary for the effective development of research. The University of Exeter, where Oguro belongs, has a biomedical informatics center funded by the Wellcome Trust and equipped with the necessary facilities to carry out research at a high level. In this study, Segi, Hagiwara, Saitoh, and Yamada will collaborate with Oguro to conduct a comprehensive analysis of DNA methylation in order to clarify the interaction between neural activity and gene expression in various genetically engineered mice and disease model mice. In addition, Professor Jonathan Mill, a leader in epigenetic research, and his colleagues have mapped regulatory genomic variation in human psychiatric disorders (Washer SJ, et al., 2022). By comparing the results of the comprehensive analysis in humans with those of various mouse models, it is possible to explore new developments in the elucidation of the pathogenesis of psychiatric disorders for which the causes have not yet been clarified, as well as for clinical applications.

3. 1. 9. Unveiling emotional resonance in classical music through brainwave analysis (Asakura, and Hasegawa)

There are still many mysteries surrounding how music influences people's emotions. In this study, to unveil the effects of tonality (the distinction between major and minor keys), a crucial determinant of a song's atmosphere, we created an auditory stimulus set consisting of pairs of several well-known classical compositions and their sister pieces with altered tonality. Subsequently, we measured rhythmic brain waves from eight locations on the heads of 13 healthy volunteers while exposing them to this stimulus set. Upon analyzing the power in various frequency bands, it became evident that, overall, major key compositions exhibited stronger alpha-wave power compared to minor key compositions.

After the experiment, the participants were asked about their impressions of the music. The results revealed anticipated differences in evaluative criteria such as "bright", "dark", "lively", and "melancholic" between major and minor key compositions. However, for the descriptor "calm", believed to be closely related to alpha waves, there was little difference. In other words, the variation in alpha waves due to tonal differences could reflect emotional aspects other than just whether the music is calming.

These findings not only highlight the advantages of focusing on brain waves in understanding the impact of music on emotions, but also offer new insights into interpreting brainwave patterns. Furthermore, the emphasis on brain waves could potentially contribute to the early detection of emotional disorders, including conditions such as depression.

3. 1. 10. Research on causality analysis technology between various biological signals for visualization of brain-gut correlation phenomenon (Sakata)

When the mind becomes ill, the gastrointestinal tract becomes ill, and when the gastrointestinal tract deteriorates, the mind is adversely affected, and the vicious cycle continues. This is a phenomenon known as the brain-gut correlation, and we are well aware of its existence empirically, although the details have not been clarified. However, this is not the kind of symptom that suddenly and severely appears at one time, but rather a gradual deterioration of health. Early detection of the existence of this vicious cycle makes it possible to deal with it quickly and prevent it from becoming more serious. We will continue this research in the second and third years.

3. 2. Public Events

3. 2. 1. Third Public Symposium "Expanding parallel SDGw: Parallel-mind synergy for divers and generational well-being"

- **Saturday, December 9, 2023, 9:30-17:30**
- **Tokyo University of Science, Noda Campus Lecture Building K401**
- **Three invited lectures from academic researchers, two invited lectures from researchers in the companies, and 54 student posters.**
- **Participants: 130 (including 17 general participants)**

It was a great success with lectures and related information provided by researchers active in brain research fields from the basics to the latest hot topics, as well as an exchange of information on the latest research results in the laboratories of the division members and personal exchanges.

3. 2. 2. Parallel brain workshops and seminars

We held parallel brain workshops and seminars by inviting four great lecturers who are conducting cutting-edge research in their respective fields in FY2023. Since the members of this division have a wide range of specialties, the specialties of the speakers are also different. However, each talk was connected to brain research, and it was a very meaningful meeting that led not only to the studies but also to the opportunities for human exchange for the division members.

4. Challenges and Prospects

This division is composed of interdisciplinary researchers who specialize in multiple fields and different fields inside and outside the university to promote fusion-type collaboration and joint research. By bringing together the wisdom and technical capabilities of multiple fields and different fields, we will pioneer creative basic research and applied research that is unique to TUS with the brain at the core and integrate multiple fields and different fields. We will promote new joint research that started from the establishment of the division, gather the wisdom and power of science and engineering, expand the cutting-edge technology of the sensing team, and apply new analysis methods and measurement technologies to animal and human measurement experiments. We will conduct 'Parallel Brain' research unique to TUS. In addition, we will strengthen cooperation with researchers outside TUS through symposiums, workshops, and seminars, and we will actively carry out publicity and lobbying activities to acquire large-scale grants. Furthermore, through the above activities, we will convey the joy of interdisciplinary collaborative research not only to faculty members, but also to students, and strive to nurture young people who will support the field of brain science in the future.

5. Conclusion

To develop brain research unique to TUS, this division integrates the promotion of collaborative research and original individual research, and develops innovative academic fields originating from TUS, such as 'Connecting Brain' and 'Parallel Brain'. We will continue to work to build this by pursuing the interdisciplinary comprehensive strength and synergistic effects of science and engineering and collaborating with clinical institutions such as medical schools and hospitals. We will further enhance and develop the research base of brain science and neuroscience within TUS and develop the next generation of human resources. We also practice education for training. Despite being only two years old, the results of the division's activities are gradually taking shape, such as the publication of papers on the results of collaborative research and the acquisition of budgets for newly created collaborative research.

Major Research Achievements (FY 2023)

Academic papers

1. STP4: spatio-temporal path planning based on pedestrian trajectory prediction in dense crowds. Sato Y, Sasaki Y, Takemura H, PeerJ Computer Science 9:e1641, 2023 (Peer-reviewed)

2. Evaluating identification of the extent of gastric cancer by more than 1000-nm near-infrared hyperspectral imaging using surgical specimens. T. Mitsui, A. Mori, T. Takamatsu, T. Kadota, K. Sato, R. Fukushima, K. Okubo, M. Umezawa, H. Takemura, H. Yokota, T. Kuwata, T. Kinoshita, H. Ikematsu, T. Yano, S. Maeda and K. Soga, Journal of Biomedical Optics 28(8), 086001,2023 (Peer-reviewed)

3. Hagiwara A*, Mizutani A, Kawamura S, Abe M, Hida Y, Sakimura K, Ohtsuka T, Critical role of the peptide CAST in maintaining the photoreceptor ribbon synad. International Journal of Molecular Sciences, 24(8), 7251 (Peer-reviewed).

4. Bridging rapid and sustained antidepressant effects of ketamine. Kim, JW *, Suzuki, K *, Kavalali, ET, Monteggia, LM. Trends Mol. Med., 29(5):364-375, 2023. *Contributed equally (Peer-reviewed)

5. Kim, JW, Suzuki, K, Kavalali, ET, Monteggia, LM. Ketamine: Mechanisms and relevance to the treatment of depression. Annu. Rev. Med., 75:129-143, 2024 (Peer-reviewed).

6. Matsuura S, Nishimoto Y, Endo A, Shiraki H, Suzuki K, Segi-Nishida E. Hippocampal Inflammation and Gene Expression Changes in Peripheral Lipopolysaccharide Challenged Mice Showing Sickness and Anxiety-Like Behaviors. Biol. Pharm. Bull., 46:1176-1183, 2023 (Peer-reviewed).

7. Kasakura N, Murata Y, Shindo A, Kitaoka S, Furuyashiki T, Suzuki K, Segi-Nishida E. Overexpression of NT-3 in the hippocampus suppresses the early phase of the adult neurogenic process. Front. Neurosci., 17:1178555, 2023 (Peer-reviewed)

8. T. Asakura, "Psychological and Physiological Effects of Low-Level Meaningful Artificial Sounds on Intellectual Tasks," Acoust. Australia, 2023 (Peer-reviewed)

9. T. Asakura, 'Effects of face-to-face confrontation with another individual on the physiological response to sounds', Appl. Acoust., 109634, 2023 (Peer-reviewed)

10. T. Asakura, R. Ito, M. Hirabayashi, S. Kurihara, and Y. Kurashina, "Mechanical effect of reconstructed shapes of autologous ossicles on middle ear acoustic transmission", Front. Bioeng., Vol. 11, 2023 (Peer-reviewed)

11. Bridging rapid and sustained antidepressant effects of ketamine. Kim, JW *, Suzuki, K *, Kavalali, ET, Monteggia, LM. Trends Mol. Med., 29(5):364-375, 2023. *contributed equally (Peer-reviewed)

12. KNT-127, a selective delta opioid receptor agonist, shows beneficial effects in the hippocampal dentate gyrus of a chronic vicarious social defeat stress mouse model. Yoshioka T., Yamada D., Segi-Nishida E., Nagase H., Saitoh A. Neuropharmacol. 232, 109511, 2023 (Peer-reviewed)

13. Perturbation-Based Balance Exercise Using a Wearable Device to Improve Reactive Postural Control; M. Yamamoto, K. Shimatani, D. Yoshikawa, T. Washida, and H. Takemura, in IEEE Journal of Translational Engineering in Health and Medicine, vol. 11, pp. 515-522, 2023 (Peer-reviewed)

14. The delta opioid receptor agonist KNT-127 relieves innate anxiety-like behavior in mice by suppressing transmission from the prelimbic cortex to basolateral amygdala. Kawaminami A., Yamada D., Yoshioka T., Hatakeyama A., Nishida M., Kajino K., Saitoh T., Nagase H., Saitoh A.. Neuropsychopharmacology Reports, 44:256-261, 2023 (Peer-reviewed)

15. Oxytocinergic projection from the hypothalamus to supramammillary nucleus drives recognition memory in mice. Takahashi J., Yamada D., Nagano W., Sano Y., Furuichi T., Saitoh A. PLoS One, 18:e0294113, 2023 (Peer-reviewed)

Invited Lectures

1. TC10 on endosomes regulates the local balance between microtubule stability and dynamics and promotes axon outgrowth through PAK2-JNK pathway, Shingo Koinuma, Misa Miyaji, Suzuka Akiyama, Naoyuki Wada, Hiroshi Takemura, Michihiro Igarashi, Takeshi Nakamura, 96th Annual meeting of Japanese Biochemical Society, Fukuoka, 2023

2. Musculoskeletal Model for Analysis of Swallowing Function, Takuya Hashimoto, 5th International Bio/Medical Interface Symposium 2024 (IBMI 2024),March 9-10, 2024, Taipei Medical University, Taipei, Taiwan R.O.C.

3. Numerical simulation of vibroacoustic transmission characteristics via human middle ear, Takumi Asakura, 5th International Bio/Medical Interface Symposium 2024 (IBMI 2024), March 9-10, 2024, Taipei Medical University, Taipei, Taiwan R.O.C.

Public Relations

1. Takuya Hashimoto, Musculoskeletal Analysis toward Elucidating Neuromuscular Control of Swallowing, The 47th Annual Meeting of the Society of Swallowing and Dysphagia of Japan, Symposium 4, Niigata, 2023

Awards

1. Daima Kobayashi, Aoi Miyazaki, Shun Hamada, Akiyoshi Saitoh, Toshihisa Ohtsuka, Akari Hagiwara. Poster award for junior investigator, 46th Annual Meeting of the Japan Neuroscience Society, 2023

2. Saki Kawamura, Yamato Hida, Toshihisa Ohtsuka, Akari Hagiwara, Best poster award (student), The 79th Annual Meeting of the Japanese Society of Microscopy, 2023

3. Tsuruda, Y., Akita, S., Yamanaka, K., Yamamoto, M., Sano, Y., Furuichi, T. and Takemura, H., SICE International Young Authors Award, IEEE/SICE International Symposium on System Integrations, 2023

Individual Research Topics

Hiroshi Takemura
"Research on 3D gait measurement of mice"

In this research, the combined measurement method of RGB-D video shooting from below using Azure Kinect DK and body part tracking by deep learning using DeepLabCut is proposed for measuring three-dimensional limb movements with a single RGB-D camera. As a result, the proposed method can measure the 3D gait of a mouse with sufficient accuracy by improving the accuracy of existing limb tracking methods. In addition, a model was developed that predicts the position of the mouse after 1 second from the time-series data of the nose and front paws. In the future, we will construct a model that enables the prediction of more diverse mouse behaviors.

Takeshi Nakamura and Shingo Koinuma
"Analysis of Rab39, a risk factor for multiple psychiatric and neurological disorders"

Rab39B is a risk factor for mental retardation, autism, and juvenile Parkinson's disease. Time-lapse FRET imaging of homotypic lysosome fusion in Neuro2A cells expressing the Rab39B sensor showed that Rab39B activity increased significantly from 1 minute before fusion. This can be interpreted as evidence that Rab39B acts through lysosomal tethering to induce lysosome fusion. Analysis of Neuro2A cells lacking Rab39B suggests that Rab39B acts to improve lysosomal degradation by accumulation of lysosomes around the nuclei and lumenal acidification.

Eri Segi-Nishida and Kanzo Suzuki
"Research on emotional responses focusing on hippocampal functions"

This study focuses on changes in hippocampal function related to stress-induced depression and antidepressant effects and aims to clarify what molecules affect emotional function and what changes occur in the hippocampus during these changes. This year, we made progress in the following two areas: 1) We examined the relationship between changes in emotional behavior and neurogenesis in the hippocampus under chronic social frustration stress in a mouse model of depression and found a high correlation between the proliferative response of neurogenesis and anxiety-like behavior in the hippocampus. In the future, we will examine how changes in neurogenesis are involved in the induction of stress-induced anxiety-like behavior. 2) We examined changes in hippocampal function using electroconvulsive stimulation (ECS) as an antidepressant treatment model and found that the activity-dependent transcription factor SRF (serum response factor) is important in promoting ECS-induced gene expression and neurogenesis induced by ECS. We found that the activity-dependent transcription factor SRF is important in promoting ECS-induced gene expression and neurogenesis induced by ECS. In the future, we will examine whether SRF is necessary for the induction of antidepressant-like behavior.

Akiyoshi Saitoh
"Emotional behavior analysis in stress-induced ultrasonic vocalization"

In this study, we found that mice exposed to a specific stress exposure (cold + restraint stress) vocalize ultrasonic sounds in the 20 kHz band. This negative emotion-induced ultrasound was suppressed by anxiolytic drugs and was not altered by other antipsychotics or antidepressants, suggesting that it indicates a state of anxiety.

Daisuke Yamada

"Research on the mechanism of stress-induced alteration of the brain-gut axis"

Negative emotions such as depression, anxiety, and fear are known to be influenced not only by the brain but also by the intercommunication between the brain and peripheral organs, often referred to as the brain-gut axis. This study aims to elucidate how stress affects the autonomic nervous system and neural circuits of the brain, which are considered crucial on the brain-gut axis. In FY2023, we demonstrated that the diarrheal symptoms exhibited by animals subjected to vicarious social defeat stress were alleviated by the administration of an opioid delta receptor agonist.

Hiroko Ichikawa

"Psychological perspective on interaction between individual"

In collaboration with other researchers in this division, we will examine the mechanism of interactions between individuals based on psychological findings. Together with Takemura, Yamamoto, and colleagues, we will examine the relationship between the perception of approaching pedestrians and the physical reaction to avoid collisions, using university students with autistic characteristics as research subjects. With Saitoh, Yamada, Asakura, and colleagues, we will examine the effects on the organism of listening to music containing ultrasonic components that exceed the range of human hearing. Together with visiting researcher Oguro, we will examine the effects of experiencing pleasant emotions such as comedy on the perception of other people's facial expressions.

Takeo Ushijima

"Analytical research on various mathematical models"

This research aims to elucidate various properties of solutions of mathematical models described by differential equations for various phenomena. In FY2021, we studied the properties of special solutions called traveling wave solutions, which are necessary to investigate the properties of the explosion solutions of mathematical models for interfacial phenomena, and found that their properties change significantly depending on the parameters included in the model. The results show that the properties of the traveling wave solution vary significantly depending on the parameters included in the model.

Takahiko Yamamoto

"Investigation of the effects of AC magnetic fields on the human body"

Although electromagnetic waves are used in all aspects of modern life, the effects of electromagnetic waves on the human body are still largely unknown. In this study, we investigate the effects of AC magnetic fields of several hundred kHz, which are used for noncontact power transmission, on the behavior of small laboratory animals. As a result, a significant difference in locomotion was observed between the groups exposed to the magnetic field and those not exposed to the magnetic field, indicating that exposure to the magnetic field has some effects on the organisms.

Takumi Asakura

"Relationship between subjective and biological responses to pleasant and unpleasant sounds"

This study examined the relationship between subjective and biological responses to two contrasting acoustic stimuli: a murmuring river and white noise. Compared to the murmuring sound, the EEG energy in the alpha region and the change in SD2/SD1, a heart rate-related index, was significantly lower when white noise was presented, suggesting the influence of the pleasantness/unpleasantness of the presented sound. On the other hand, a detailed clustering analysis revealed that EEG energy in the alpha region decreased in the case of subjects who perceived the murmuring of a river as "powerful" rather than "beautiful", even though it was presented as a pleasant sound, suggesting that biological responses to exposure to sound may be influenced by the impression of different sounds depending on the individual. This suggests the possibility that biological responses to exposure to sound may be affected by the impression of sound that differs from one individual to another.

Masataka Yamamoto

"Human enhancement through rehabilitation"

This study proposes a wrist orthosis stiffness magnitude selection support system for stroke-indicated individuals and clinicians using the markerless motion capture system. A single RGB camera was used as the markerless motion capture system, and this system accurately measures the primary gait parameters. We measure post-stroke gait with various ankle-foot orthosis stiffnesses in the hospitals. The results of this measurement suggest that small changes in the magnitude of ankle-foot orthosis stiffness have a significant effect on the symmetry of the angle of the lower limb joint and the duration of stance during gait in stroke-sick individuals.

Osamu Sakata

"Causal analysis of heterogeneous biological signals"

The human body generates various types of biological signals and information, many of which can be measured. For each biological signal, technologies for deciphering, analyzing, and processing them have been developed mainly for medical use, and their utilization in non-medical fields has also been progressing. However, the use of each biosignal alone or in combination with multiple biosignals has been limited, and the technology to objectively analyze the relationship between different biosignals has not yet been developed, even though the signals and information are obtained from a single human body. In this study, we will focus on the causality between different biological signals and information obtained from a single human body, and we will work on the development of technology for quantitative analysis and visualization of this causality.

Takuya Hashimoto

"Robot simulator"

This project aims to reproduce gestures and behaviors that are difficult to control in humans by using robots that closely resemble humans (android robots) and to evaluate the impressions and influences that these behaviors have on others. Currently, we are developing a simulated patient robot (SP robot) for medical interview training to reproduce patient-like behaviors. In the future, we will investigate methods to quantify the physician's non-verbal behavior and speech information during a simulated medical interview using the SP robot and develop a method to quantify the physician's interviewing skills.

Akari Hagiwara

"Analysis of neural networks and brain functions based on synaptic transmission"

Morphological analysis of neural circuits for various information processing in the brain. In particular, the sites of information transmission, called synapses, would be essential to reveal the neural mechanisms of brain functions and psychiatric and neurological disorders. The recently developed mouse has the potential to serve as a model mouse for analyzing the decline in gait function and will be integrated with biomechanics research to develop the mechanism of gait disorders and appropriate rehabilitation methods.

Ryohei Hasegawa

"Brain training system using EEG for competitive competitions"

We are developing a hands-free brain training system that utilizes "EEG switches" by immediately detecting event-related potentials, which are supratentorial EEG components that reflect momentary increases in attendance. We are aiming for further advancement of this system by confirming that a competitive game (b-sport) can be conducted between subjects of different generations, in which multiple people try this system simultaneously to see how quickly and accurately they can select robotic movements.

Division of Composite Materials Engineering

Division of Composite Materials Engineering

1. Overview

The Division of Composite Materials Engineering researches lightweight and high-strength composite materials used in aerospace equipment from material to structure. Our goal is to promote rapid technological development through cooperation among experts in specialized fields such as materials science, processing, fracture mechanics, and numerical simulation. Specific themes include new methods for predicting composite degradation, 3D printing of composite materials, and composite ropes, among others. In addition, we regularly hold research meetings on composite materials engineering to create opportunities for collaboration among the division members and to foster young researchers. In the future, the division aims to form a research and development center that will utilize the results of basic research at the university, deepen cooperation with industry, and promote the development of applications.
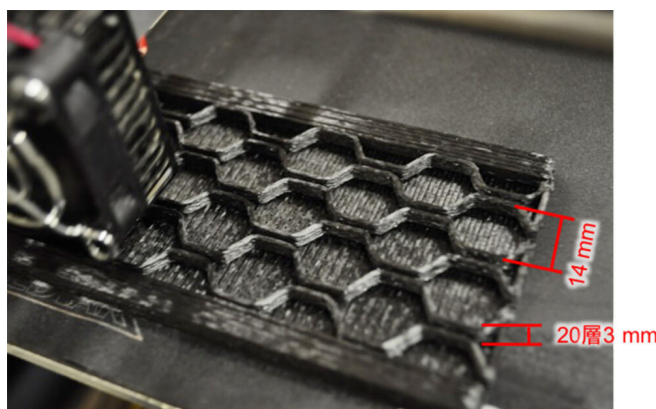
Fig. 1. Composite 3D printing for automated processing.

2. Organization and Facilities

This division consists of 12 faculty members in the following three fields: chemistry, materials, and mechanics (Table 1). The unique feature of this division is that the faculty members in these three fields cooperate with each other to conduct research on composite materials from materials to structures in an integrated manner. In addition, the division uses shared laboratories in Building No. 10 on the Noda campus.

Table 1. Division member list.

Name	Job Title	Affiliation
Ryosuke MATSUZAKI	Director / Professor	Department of Mechanical and Aerospace Engineering, Faculty of Science and Technology
Shinji OGIHARA	Vice Director / Professor	Department of Mechanical and Aerospace Engineering, Faculty of Science and Technology
Jun KOYANAGI	Professor	Department of Materials Science and Technology,Faculty of Advanced Engineering
Koji ARIMITSU	Professor	Department of Pure and Applied Chemistry,Faculty of Science and Technology
Hiroshi OKADA	Professor	Department of Mechanical and Aerospace Engineering, Faculty of Science and Technology
Akiyuki TAKAHASHI	Professor	Department of Mechanical and Aerospace Engineering, Faculty of Science and Technology
Yasuo KOGO	Professor	Department of Materials Science and Technology,Faculty of Advanced Engineering
Ryo INOUE	Associate Professor	Department of Mechanical Engineering, Faculty of Engineering
Yutaro ARAI	Junior Associate Professor	Department of Materials Science and Technology,Faculty of Advanced Engineering
Fikry MOHAMMAD	Assistant Professor	Department of Mechanical and Aerospace Engineering, Faculty of Science and Technology
Yutaka OYA	Assistant Professor	Department of Materials Science and Technology,Faculty of Advanced Engineering
Huachao DENG	Assistant Professor	Research Institute for Science and Technology,Organization for Research Advancement
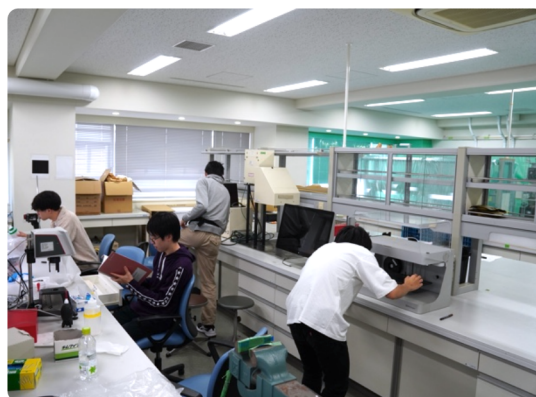
Fig. 2. Shared laboratory of the division (Noda Bldg. No. 10).

3. Activity Reports

The steady research and education activities to date have been successful in obtaining large-scale funds since FY2010. Tokyo University of Science will obtain 138 million yen in direct costs for FY2022-FY2026 as a full-fledged research subcontractor of JST-Mirai Program. The project title is "Elucidation of fatigue deterioration mechanism and establishment of evaluation method to estimate the remaining life of CFRP laminates" and the principal investigator is Professor Arai from Nagoya University. Tokyo University of Science, led by Professor Koyanagi, is the first group to receive a large portion of the grant. In addition, the division is conducting joint research on strength estimation of CFRP ropes and 3D printing of composite materials.

In addition, the division regularly holds "Composite Materials Engineering Seminars" featuring lectures and tours by researchers who are active in the forefront of related fields. In 2023, this division hosted the

Japan-U.S. Joint Symposium on Composite Materials. Many Japanese and U.S. researchers exchanged opinions with each other. The department also aims to attract the interest of students and foster young researchers by organizing tours and conferences.

Composite Materials Engineering Seminar

21st Session (October 31, 2023)

　　Field Trip: SUBARU Corporation Aerospace Company Utsunomiya Plant

　　5 faculty members, 31 students attended

22nd Session (November 8, 2023)

　　Lecturer: Dr. Shuhua Peng (UNSW, Sydney)

　　Topic: Conductive Nanocomposites for Wearable Strain Sensors

23rd Session (February 29, 2024)

　　Lecturer: Professor Takenobu Sakai (Saitama University)

　　Topic: Fundamental Course on AE and Introduction to Composite Material Applications

24th Session (March 14, 2024)

　　Lecturer: Dr. Mohammad Hajikazemi (Ghent University, Belgium)

　　Topic: Physics-Based Multi-Scale Modeling of Composite Laminates and Short Fiber Composites

International Conferences Hosted by the Division

2023 US-Japan Joint Symposium for Composite Materials (June 14-16, 2023)

4. Challenges and Prospects

Continuous support for young researchers, such as producing and supporting doctoral students and introducing master's students to careers in related fields, is an important current issue. In the future, we would like to foster young researchers by supporting post-doctoral and doctoral students by utilizing large project budgets. Through these efforts, we hope to contribute to developing the research capabilities and knowledge of the division, training next-generation researchers, and developing the field of composite materials engineering.

5. Conclusion

The Division of Composite Materials Engineering has established a forum for research exchange and held regular research meetings to share the latest topics and results, strengthen collaboration within the division, and foster young researchers. We promote exchanges with external researchers and industries by holding academic conferences and workshops, and we are also working on social implementation by strengthening industry-academia collaboration on specific themes. Through these efforts, we will realize the development of the field of composite materials engineering and sustainable contributions to society.

Major Research Achievements (FY2023)

Academic Papers

1. 3D visualization of morphological evolution of large defects during spark plasma sintering, G. Okuma, M. Endo, H. Minagawa, R. Inoue, H. Kakisawa, T. Kohata, T. Osada, T. Yamamoto, M. Azuma, A. Takeuchi, M. Uesugi, O. Guillon, F. Wakai, Adv. Eng. Mater., 25 (2023) 2201534. Open Access, https://doi.org/10.1002/adem.202201534 (Peer-reviewed)

2. Macroscopic tensile properties of AlxCoCrCuFeNi (x=0.3 and 1) before and after heat treatment, K. Kiyomiya, Y. Arai, R. Inoue, Mater. Res. Express, 10 (2023) 056504. Open Access, https://doi.org/10.1088/2053-1591/acd1d541 (Peer-reviewed)

3. Static and Fatigue Tensile Properties of Cross-Ply Carbon-Fiber-Reinforced Epoxy-Matrix-Composite Laminates with Thin Plies, K. Naito, Y. Seki, R. Inoue, J. Compos. Sci., 7 (2023) 146. https://doi.org/10.3390/jcs7040146 Open Access (Peer-reviewed)

4. Heterogeneous evolution of pore distribution during sintering of a submicron alumina powder visualized by using synchrotron X-ray CT, G. Okuma, T. Osada, H. Minagawa, Y. Arai, R. Inoue, H. Kakisawa, K. Shimoda, A. Takeuchi, M. Uesugi, S. Tanaka, F. Wakai, J. Euro. Ceram. Soc., 42, 2 (2023) 486-492. https://doi.org/10.1016/j.jeurceramsoc.2022.10.020 Open Access (Peer-reviewed)

5. Evaluation of true bonding strength for adhesive bonded carbon fiber reinforced plastics, M Takamura, M Isozaki, S Takeda, Y Oya, Jun Koyanagi, Materials, Vol. 17 (2024), pp. 2 (Peer-reviewed)

6. Enhanced estimation of axial compressive strength for CFRP based on microscale numerical simulation and the response surface method, H Yoshida, D Huachao, Jun Koyanagi, Materials, Vol. 17 (2024), pp. 478 (Peer-reviewed)

7. Durability analysis of CFRP adhesive joints: A study based on entropy damage modeling using FEM, Yutong Li, Huachao Deng, Maruri Takamura, Jun Koyanagi, Materials, Vol. 16 (2023), pp. 6821 (Peer-reviewed)

8. Improved XFEM for 3D interfacial crack modeling, Mechanics of Materials, H. Deng, B. Yan, Jun Koyanagi, Vol. 186 (2023), pp. 104811 (Peer-reviewed).

9. Micro-scale numerical simulation of fatigue failure for CFRP subjected to multiple-amplitude cyclic loadings based on entropy damage criterion, H. Deng, K. Toda, M. Sato, Jun Koyanagi, Materials, Vol 16 (2023), pp. 6120 (Peer-reviewed)

10. New crack front enrichment for XFEM modeling, Huachao Deng, Bo Yan, Xiaomin Zhang, Yongqiang Zhu, Jun Koyanagi, International Journal of Solids and Structures, Vol. 274 (2023), pp. 112280 (Peer-reviewed)

11. Identification of invisible fatigue damage of thermosetting epoxy resin by non-destructive thermal measurement using entropy generation, N. Kudo, R. Fujita, Y. Oya, T. Sakai, H. Nagano, Jun Koyanagi, Advanced Composite Materials, Vol. 33 (2024), pp. 233-249 (Peer-reviewed)

12. Effect of overlap joint position on strength of composite interlaminar reinforcement for fused filament fabrication 3D printer, Aiko Fujii, Jumpei Kajimoto, Jun Koyanagi, Yusuke Maruyama, Hideyuki Kajita, Ryosuke Matsuzaki, Composites Part C, Vol. 11 (2023), pp. 100363 (Peer-reviewed)

13. A molecular dynamics simulation for thermal activation process in covalent bond dissociation of a crosslinked thermosetting polymer, N. Yamada, Y. Oya, N. Kato, K. Mori, Jun Koyanagi, Molecules, Vol. 28 (2023), pp. 2736 (Peer-reviewed)

14. Numerical and experimental studies for fatigue damage accumulation of CFRP cross-ply laminates based on entropy failure criterion, Huachao Deng, Asa Mochizuki, Mohammad Fikry, Shun Abe, Shinji Ogihara, Jun Koyanagi, Materials, Vol. 16 (2023), pp. 388 (Peer-reviewed)

15. Numerical simulation for the tensile failure of randomly oriented short fiber reinforced plastics based on a viscoelastic entropy damage criterion, Hikaru Kagawa, Yuta Umezu, Kenichi Sakaue, Jun Koyanagi, Composites Part C, Vol. 10 (2023), pp. 100342 (Peer-reviewed)

16. Evaluation of viscoelastic non-isochoric plastic behavior of PBT and PA6, Sato Y, Masumizu S, Sakaue K, Koyanagi Jun, Ohtani A, Sakai T, Mechanics of Time-Dependent Materials, Vol. 27 (2023), pp. 829-841 (Peer-reviewed)

17. Mechanical properties and damage behavior of tapered unidirectional CFRP laminates, M. J. Mohammad Fikry, Vladimir Vinogradov, Shinji Ogihara, Mechanical Engineering Journal, Vol. 10 (2023) No. 4, p. 23-00079 (Peer-reviewed)

18. Ply Refinement Technique を用いた負荷方向に材料特性が異なる領域を有する積層板の変分応力解析の拡張, M. J. Mohammad Fikry, Vladimir Vinogradov, 荻原慎二, 日本複合材料学会誌, Vol. 50 (2024) No. 2, pp. 42-54 (in Japanese) (Peer-reviewed)

19. Prediction of the Binding Energy of Self Interstitial Atoms in Alpha Iron by a Graph Neural Network, T. Kumagai, K. Suzuki, A. Nomoto, S. Hara, A. Takahashi, Materialia, Vol. 33, (2024), p. 101977 (Peer-reviewed)

20. Stress field and interaction forces between dislocations and precipitate distributions, A. Takahashi, T. Kasuya, N.M. Ghoniem, International Journal for Numerical Methods in Engineering, (2024), p. e7468 (Peer-reviewed)

21. Application of redefined J-integral range ΔJ for ultra-low cycle fatigue problems with large magnitude of elastic-plastic deformation, Keigo Shoda, Koichiro Arai, Sora Nakamura, Hiroshi Okada, Theoretical and Applied Fracture Mechanics, Volume 126, 2023, 103938, https://doi.org/10.1016/j.tafmec.2023.103938 (Peer-reviewed)

22. Redefined three-dimensional J-integral as finite strain elastic-plastic crack parameter (Energy release rate and contribution of weakly singular terms), Hiroshi Okada, Takahiko Gouda, Koichiro Arai, Theoretical and Applied Fracture Mechanics, Volume 130, 2024, 104310 (Peer-reviewed)

23. Toughening Ionic Polymer Using Bulky Alkylammonium Counterions and Comb Architecture, Daisuke Aoki, Kento Yasuda, Koji Arimitsu, ACS Macro Lett., 2023, 12, 462-467 (Peer-reviewed)

24. Fabrication of an Organic−Inorganic Hybrid Hard Coat with a Gradient Structure Controlled by Photoirradiation, Yoshiki Shirai, Ayano Sasaki, Sayako Sato, Daisuke Aoki, Koji Arimitsu, ACS Appl. Mater. Interfaces, 2023, 15, 28563-28569 (Peer-reviewed)

25. Room Temperature Anionic UV-curable Adhesive of Episulfide Resin by a Thiol Initiator and Photobase Generator, Daisuke Aoki, Chen Gu, Mayu Suzuki, Yoshinori Kawamura, Koji Arimitsu, Chem. Lett., 2023, 52, 775-778 (Peer-reviewed)

26. 光および熱潜在性硬化剤の最近の進歩, 有光晃二, 青木大亮, 塗装工学, 2023, Vol.58, No.2, 47-60 (in Japanese) (Peer-reviewed)

27. 撚り構造を有する CFRP 単線の曲げ変形挙動, 新井優太郎, 阿部正和, 宮腰千代子, 井艸 遼, 向後保雄, 山下弘展, 日本複合材料学会誌, vol.49(5), pp. 143-148. (in Japanese) (Peer-reviewed)

28. Material design using calculation phase diagram for refractory high-entropy ceramic matrix composites, Y. Arai, M. Saito, A. Samizo, R. Inoue, K. Nishio, Y. Kogo, International Journal of Applied Ceramic Technology (accepted) (Peer-reviewed)

29. Thermomechanical performance of continuous carbon fibre composite materials produced by a modified 3D printer, Antoine Le Duigou, Monia Grabow, Mickael Castro, Roxane Toumi, Masahito Ueda, Ryosuke Matsuzaki, Yoshiyasu Hirano, Justin Dirrenberger, Fabrizio Scarpa, Raffaele D'elia, Karine Labastié, Ugo Lafont, Heliyon, 9-3 (2023), e13581 (Peer-reviewed).

30. Effect of temperature conditions of a heated plate on the crystallization of CFRTP, Yasuhiro Tasaka, Ryosuke Matsuzaki, Mechanical Engineering Journal, 10-4 (2023), 23-00049 (Peer-reviewed)

31. Optimization of fiber orientation and layer thickness in thin carbon fiber-reinforced plastic curved structures, Haruya Tanaka, Yuto Mori, Naoya Kumekawa, Ryosuke Matsuzaki, Composites Part C, 12 (2023), 100381 (Peer-reviewed)

32. High accuracy 3D printing of composite materials using CNT yarns, Junro Sano, Ryosuke Matsuzaki, Composite Structures, 325 (2023), 117577 (Peer-reviewed)

33. Formability of curved multilayer laminates via 3D printing using twisted continuous fiber composites, Keigo Nakajima, Ryosuke Matsuzaki, Heliyon, 9-10 (2023), e20986 (Peer-reviewed)

Book
1. 多元素セラミックスの設計とその性能の可能性, 新井優太郎, 井上 遼, 月刊機能材料, 2024 年 3 月号(in Japanese)
2. 井上 遼, 新井優太郎, 垣澤英樹, 下田一哉, 溶射 (日本溶射学会誌), 60, 4 (2023) 222-28 (Invited) (in Japanese)
3. 極超音速機向け炭素繊維強化超高温セラミックス複合材料の開発動向, 井上 遼, 新井優太郎, FC Report, 41, 4, 134-137 (Invited) (in Japanese)
4. 垣澤英樹, 井上 遼, 新井優太郎: 溶射 (日本溶射学会誌), 60, 2 (2023) 111-117 (Invited) (in Japanese)
5. 第 1 章 第 2 節 エポキシ樹脂の光硬化 〜基礎と影部の光硬化〜, 有光晃二, エポキシ樹脂の配合設計と高機能化, 技術情報協会, 2023, 16-26. (in Japanese)
6. 有光晃二, 「第 3 編 第 2 章 第 3 節 光開始ラジカル重合・光硬化」, 新訂三版ラジカル重合ハンドブック, エヌ・ティー・エス, 2023, 473-483. (in Japanese)

Invited Lectures
1. エポキシ樹脂の低温硬化, 有光晃二, エポキシ樹脂技術協会 第 46 回公開講座, 関西大学東京センター ハイブリッド形式, 2023 年 8 月 3 日(in Japanese)
2. トピックス 光クリックケミストリー 〜2022 年ノーベル化学賞「クリックケミストリー」の展開〜, 有光晃二, 第 33 回フォトポリマー講習会, オンライン開催, 2023 年, 8 月 25 日(in Japanese)
3. カスケード式化学で構築する高感度フォトポリマー, 有光晃二, 令和 5 年度高分子学会九州支部フォーラム（主題：光・電気を利用する高分子材料）, 熊本大学産業ナノマテリアル研究所, 2023 年 12 月 19 日(in Japanese)

Patents
1. application pending.

Individual Research Topics

Jun Koyanagi
"Various numerical simulations related to the mechanical properties of composite materials"

Research primarily focuses on the mechanical properties of composite materials, with a particular emphasis on carbon fiber reinforced plastics (CFRP). We utilize finite element analysis and molecular dynamics simulations to pursue research in strengthening, extending lifespan, and developing new materials. Recently, we established a comprehensive durability evaluation method focusing on entropy, aiming to create sustainable products. This method is beneficial for detecting damage and degradation, as well as predicting residual strength and service life for composite materials.

Shinji Ogihara
"Research on microscopic damage behavior of fiber reinforced composites"

We experimentally studied the microscopic damage generation and propagation process within the material due to various forms of load, mainly in laminated fiber-reinforced composite materials. Furthermore, we experimentally evaluated the effect of damage on the mechanical properties of the material. We compared the obtained results with the predictions by the finite element method and the damage mechanics model and examined their validity. We laid the foundation for application to material systems with more complicated internal structures. This is expected to contribute to the structural integrity evaluation of materials in operation.

Ryosuke Matsuzaki
"Research on 3D Printing of Composite Materials"

We develop 3D printing technology to produce high-strength and high-rigidity products applicable to automotive and aerospace structural components using resin-based composite materials reinforced with continuous carbon fibers. Particularly, this year, we conducted verification tests such as the improvement of curved formability using twisted fibers and the printing of microstructures using carbon nanotube fibers, aiming to enhance the precision of composite material 3D printing.

Ryo Inoue
"Development and characterization of heat-resistant composite materials"

We engage in the development of new composite materials for use in environments exceeding 1000°C, including jet engines. We develop new manufacturing methods for heat-resistant composite materials using heat-resistant fibers and ceramics as base materials (e.g., 3D printing), simulate manufacturing processes, develop measurement techniques for high temperatures, and evaluate techniques in simulated environments resembling actual usage conditions.

Hiroshi Okada

"Research on linear and nonlinear fracture mechanics analysis of heterogeneous materials"

The weld metal and heat-affected zone of weld joints are inhomogeneous because the thermal history and solidification process during welding affect the mechanical properties of the materials. A functionally graded material regarded as a kind of composite material creates a spatial distribution of the intended mechanical and thermal properties of the material. In general, the mechanical and thermal properties change continuously within the material. I have researched stress intensity factor calculation methods using the J-integral and cross-integral methods for rigorously evaluating the fracture mechanics of materials with non-uniform mechanical properties. In this fiscal year, various mutual integral method formulations were formulated, and their accuracy was evaluated to advance linear fracture mechanics analysis of welded joints and functionally graded materials. In addition, we have advanced the analysis method of the cycle jump method to shorten the analysis time of fracture phenomena progressing under cyclic loading.

Akitoshi Takahashi

"Microscopic structure of materials and dislocation dynamics analysis of mechanical properties"

We developed an analysis method based on dislocation dynamics to derive mechanical properties from the microscopic structure of alloys. We assumed various shapes of precipitates in the microscopic structure of alloys, such as spherical and platelike and applied the polymer mesh method as a modeling technique for internal stresses created by the microscopic structure. By implementing the internal stresses obtained by the polymer mesh method into the dislocation dynamics method, we successfully simulated dislocation motion under the influence of internal stresses to investigate the relationship between microscopic structure and mechanical properties.

Yasuo Kogo

"Preparation of ZrO_2 particle dispersed porous carbon composites and evaluation of their mechanical properties"

We established a material process for ZrO_2 particle dispersed porous carbon composites with 3D networked structures (ZCM). Uniform dispersion of particles up to ~9 vol% was observed and 3D networked structures without containing particles were maintained. The compressive strength of composites decreased compared to those without particles. However, the compressive strength of composites is similar to that of conventional porous carbon materials. The ablation behavior of ZCM as a component of the thermal protection system for re-entry vehicles will be evaluated.

Yutaro Arai

"Preparation and ablation behavior of refractory multi-elemental ceramic matrix composites by refractory high-entropy alloy melt-infiltration"

The composition for high-entropy alloys with a melting point of ~1700°C was designed by using calculation thermodynamics. The alloys were melted and infiltrated into carbon fiber reinforced carbon composites (C/C) with porous structures. Refractory multi-elemental ceramic matrix composites (RMECMC) were prepared by the reaction of C/C and infiltrated alloys. The heat exposure at 2000°C in an oxidizing atmosphere revealed that the thickness recession is ~5% compared to a C/C exposed to the same condition.

Koji Arimitsu

"Fabrication of organic-inorganic hybrid films having gradient structure by radical-anionic UV curing"

To have a gradient structure, radical polymerization and sol-gel reactions of temporarily miscible organic-inorganic single-layered films are performed by using both a radical photoinitiator and a photobase generator. Unprecedented organic-inorganic hybrid films that have gradient structure, transparency, good hardness, flexibility, and good adhesive properties, have been successfully obtained.

Mohammad Fikry

"Research on Interlaminar Toughening of CFRP Composite Laminates by Interlaminar Reinforcement Layers"

Carbon Fiber Reinforced Plastic (CFRP) laminates generally exhibit superior in-plane properties, but their out-of-plane properties (such as interlaminar toughness) are considered problematic. Therefore, the research objective was to improve interlaminar fracture toughness and suppress the occurrence of interlaminar damage by inserting interlaminar reinforcement layers, such as carbon fiber nonwoven, cellulose nanofiber reinforced resin, and polyamide mesh, between the layers of CFRP. The study focused on complex laminate structures with resin pockets at the discontinuities of fibers, conducting localized placement of interlaminar reinforcement layers, where damage suppression was confirmed.

The Kao "Kirei" Future Open Innovation Project

The Kao "Kirei" Future Open Innovation Project

1. Overview

Based on the educational philosophy of TUS, "Innovation in Science and Technology for Sustainable Development", TUS aims to solve various problems in society through education and research. In addition, Kao Group Mid-term Plan 2027 (K27) outlines the company's direction to "Become a company that saves future lives" and Kao conducts research and development to contribute to a sustainable society and the realization of a rich lifestyle culture. Thus, Kao and TUS expect significant synergy effects from the collaboration for Kirei—Making Life Beautiful.

Therefore, we have established "The Kao "Kirei" Future Open Innovation Project" and started joint research. We are promoting the development of innovative technologies to enrich people's lives on our respective social missions and roles.

The following four initial joint research themes are in progress. We will contribute to the areas of "Ecology", "Life" and "Everyday lives" through the research and development of each research theme.

Theme 1: Research on biofuel cells and biosensors
Theme 2: Research on foaming control and functionalization
Theme 3: Research on neural and molecular mechanisms of pain
Theme 4: Research on application of cellulose nanofiber reinforced resin composites to structural materials

2. Organization and Facilities

Associate Professor, Isao Shitanda, Department of Pure and Applied Chemistry, Faculty of Science and Technology (Project leader)
Professor Hiroharu Yui, Department of Chemistry, Faculty of Science Division I
Professor Eri Segi, Department of Biological Science and Technology, Faculty of Advanced Engineering
Professor Shinji Ogihara, Department of Mechanical Engineering, Faculty of Science and Technology

3. Activity Reports

Theme 1: Research on biofuel cells and biosensors

In this study, we developed a biofuel cell with controlled orientation of bilirubin oxidase (BOD) modification to the electrode to improve the performance of a self-driven paper substrate bio-cathode. The orientation of bilirubin was improved by modification, and the performance of the cathode was enhanced. The size of the biofuel cell could be reduced by this modification. In an implementation evaluation test, the frequency of wireless transmission was different depending on the lactate concentration, and the lactate concentration in human sweat was successfully monitored.

Theme 2: Research on foaming control and functionalization

The scope of Theme 2 is understanding and controlling foam for the efficient use of surfactant to keep our enriched and hygienic life. Particularly, we aim to reduce surfactant usage for foaming while maintaining their cleaning ability and pleasant touch. To achieve this purpose, we clarify the role of the additive polymers in the foam films from the viewpoint of physical chemistry using newly developed measurement techniques.

In the 2023 fiscal year, we succeeded in measuring the full time course of dynamic light scattering signals from foam films from their formation to collapse by originally developed heterodyne light scattering microscope. Based on these measurements, we established a new method to estimate the mechanical properties of the foam films. The method clarifies the following three mechanical properties that contribute the stability and touch of form films; (1) resistance to thinning, (2) structural rigidity, and (3) dynamic viscosity.

Theme 3: Research on neural and molecular mechanisms of pain

The goal of this theme is to elucidate the pathological mechanisms in chronic low back pain at the neural circuit and molecular level. First, we attempted to develop a novel animal model of low back pain, and constructed a reproducible model in which symptoms similar to low back pain, such as loss of gait balance and hypersensitivity, are chronically elicited. In the animal model of low back pain, we confirmed that gene expression of inflammatory factors in the dorsal root ganglia and spinal cord, which are the pathways of pain, was elevated. Furthermore, we found that chronic alterations in specific signals and suppression of neurogenesis occurred in the hippocampus, an area important for emotion and memory. The changes in the hippocampus were further exacerbated when combined with chronic social stress, indicating that stress-induced negative memories are retained longer by low back pain induction. The results of this study demonstrated the utility of a novel model of low back pain and characterized the molecular mechanisms in vivo from the peripheral to the central regions during low back pain.

Theme 4: Research on application of cellulose nanofiber reinforced resin composites to structural materials

In this theme, we explored the applicability of cellulose nanofiber (CNF) reinforced resin composite materials as new structural materials such as interlaminar toughening materials or adhesives for carbon fiber reinforced plastic (CFRP) laminates. Currently, Kao Corporation has undertaken the development and composite formation with resin for CNF intended for CFRP, and TUS (Ogihara group) have conducted localization technologies of CNF reinforced resin composite materials within CFRP laminates, as well as evaluations of mechanical properties and damage behaviors. We assessed the interlaminar fracture toughness of CFRP laminates and the fracture toughness and strength of CNF reinforced resin composite materials as adhesives, targeting unidirectional and woven CFRP laminates formed by autoclave and Vacuum-assisted Resin Transfer Molding (VaRTM) methods. The application of CNF-added epoxy resin between CFRP layers has confirmed improvements in interlaminar fracture toughness values of CFRP and damage suppression within CFRP laminates with complex structures. Furthermore, we have conducted searches for optimal conditions to improve the interlaminar fracture toughness with the addition of CNF reinforced resin composite materials to CFRP, clarifying the optimal conditions for the application amount of CNF reinforced resin composite materials between CFRP layers. Additionally, various challenges were identified when applying CNF-added epoxy resin, such as changes in viscosity (wettability) and fiber volume fraction of the entire CFRP when applied using the VaRTM method.

Major Research Achievements (FY2023)

Conference Presentations

1. Heterodyne-detection dynamic light scattering microscope for probing real-time changes in the structure and properties of a foam film (1) Instrumental development, Hiroharu Yui, Shu-hei Urashima, Koutaro Ichimaru, Shunsuke Urabe, Atsushi Miyazaki, Takaya Sakai, The 74th Divisional Meeting of Division of Colloid and Surface Chemistry, Nagano, 2023

2. Mechanism of improvement of mechanical stability of foam film by polymer, Shunsuke Urabe, Shuhei Urashima, Kotaro Ichimaru, Atsushi Miyazaki, Takaya Sakai, Hiroharu Yui, The 74th Divisional Meeting of Division of Colloid and Surface Chemistry, Nagano, 2023

3. Development of a microscope that enables interferometric imaging/simultaneous multicolor fluorescent measurement for real-time measurement of soap film dynamics, Risa Saito, Shu-hei Urashima, Naoya Nagase, Shunsuke Urabe, Atsushi Miyazaki, Takaya Sakai, Hiroharu Yui, The 74th Divisional Meeting of Division of Colloid and Surface Chemistry, Nagano, 2023

4. Fusion between supported lipid bilayer domains of double chain cationic surfactants: Measurement of their fluidic nature and lateral diffusion constants, Atsushi Miyazaki, Haruna Shibasaki, Shu-hei Urashima, Takaya Sakai, Hiroharu Yui, The 74th Divisional Meeting of Division of Colloid and Surface Chemistry, Nagano, 2023

5. Controlling Bilirubin Oxidase Orientation to Improve Performance of Paper-based Biocathodes,Chika Miura, Mitsuyoshi Okuda, Yuto Yasuda, Noya Loew, Hikari Watanabe, Isao Shitanda, Masayuki Itagaki, 4th Annual Meeting of ISE, 2023

6. Kazunari Mori, Yasuhito Yamaji, Hiroaki Motohashi, Sena Washizu, Oki Hoshino, Seishi Kanazawa, Yoshihiko Minegishi, Noriyasu Ota, Takuya Mori, Eri Segi-Nishida, Establishment of an Inflammatory Chronic Low Back Pain Model in Mice., 149th Kanto Meeting of the Japanese Pharmacological Society, Tokyo, 2023

7. Sena Washizu, Yasuhito Yamaji, Hiroaki Motohashi, Kazunari Mori, Oki Hoshino, Seishi Kanazawa, Yoshihiko Minegishi, Noriyasu Ota, Takuya Mori, Eri Segi-Nishida, Exploration of Hippocampal Functional Changes and Stress Susceptibility in a Low Back Pain Model Mouse., 149th Kanto Meeting of the Japanese Pharmacological Society, Tokyo, 2023

8. Yasuhito Yamaji, Hiroaki Motohashi, Sena Washizu, Kazunari Mori, Oki Hoshino, Seishi Kanazawa, Yoshihiko Minegishi, Noriyasu Ota, Takuya Mori, Eri Segi-Nishida, Establishment of a Chronic Low Back Pain Model Mouse and Identification of Microglial Changes in the Central Nervous System, 3rd Public Symposium of the Parallel Brain Sensing Research Division, Chiba, 2023

9. Kazunari Mori, Yasuhito Yamaji, Hiroaki Motohashi, Sena Washizu, Oki Hoshino, Seishi Kanazawa, Yoshihiko Minegishi, Noriyasu Ota, Takuya Mori, Eri Segi -Nishida, Gene Expression Analysis in the Peripheral Nervous System and Spinal Cord Using Chronic Low Back Pain Model Mice, 3rd Public Symposium of the Parallel Brain Sensing Research Division, Chiba, 2023

10. Sena Washizu, Seishi Kanazawa, Yasuhito Yamaji, Kazunari Mori, Hiroaki Motohashi, Yoshihiko Minegishi, Noriyasu Ota, Takuya Mori, Eri Segi-Nishida, Establishment of a Low Back Pain Model Mouse and Exploration of Central Pain Signaling, 3rd Public Symposium of the Parallel Brain Sensing Research Division, Chiba, 2023

11. Yasuhito Yamaji, Hiroaki Motohashi, Sena Washizu, Kazunari Mori, Oki Hoshino, Seishi Kanazawa, Yoshihiko Minegishi, Noriyasu Ota, Takuya Mori, Eri Segi-Nishida, Exploration of Stress Susceptibility Using Low Back Pain Model Mice, 97th Annual Meeting of the Japanese Pharmacological Society, Hyogo, 2023

12. Delamination suppression in CFRP laminate with ply discontinuity using cellulose nano fiber reinforced resin, M. J. Mohammad Fikry, Issei Hori, Tooru Hatano, Rinako Hano, Yuki Yoshikawa, Yutaka Yoshida, Yoshiaki Kumamoto, Akira Takenaka, Masashi Nojima, Shinji Ogihara, The 72nd Academic Conference of the Japan Society of Materials Science, Ibaraki, 2023

13. Interlaminar toughening of CFRP composite laminates using cellulose nanofiber (CNF) reinforced resin, Issei Hori, M. J. Mohammad Fikry, Tooru Hatano, Rinako Hano, Yuki Yoshikawa, Yoshiaki Kumamoto, Akira Takenaka, Masashi Nojima, Shinji Ogihara, The 30th Conference on Mechanical Materials and Material Processing by the Japan Society of Mechanical Engineers, Ibaraki, 2023

Research & Development Platform of Functional Green Building Materials

Research & Development Platform of Functional Green Building Materials

1. Overview

This project focuses on the research and development of high-functional materials and construction methods that contribute to CO_2 emission reduction for non-structural building components, such as exterior materials, interior materials, entrance components, and foundation materials. We aim to achieve environmentally conscious buildings with zero greenhouse gas emissions by 2050. Within this project, we will develop a system to evaluate CO_2 emissions across the entire life cycle of these components.

As decarbonization efforts become more active throughout society, reducing the environmental impact of buildings has become essential. Non-structural components are estimated to contribute over 20% of "Embodied Carbon," which includes CO_2 emissions from the production, processing, transportation, installation, and disposal phases of construction materials. Additionally, these components play a crucial role in the building's functionality and contribute significantly to "Operational Carbon," the CO_2 emissions during the building's operational phase. Therefore, finding the optimal balance between CO_2 reduction and functional enhancement in "Whole Life Carbon" (WLC) is vital.

Therefore, this project will advance the research and development of materials and construction methods that highly balance environmental performance and functionality for exterior materials, interior materials, openings, and substrates, significantly impacting Whole Life Carbon. Additionally, the research and development aimed at enhancing the functionality and performance of interior and exterior materials will contribute to resource conservation and recycling, thereby fostering a nature-positive approach.

2. Organization and Facilities

In implementing this project, Tokyo University of Science will establish a collaborative research framework primarily involving the Department of Architecture within the Faculty of Science and Technology, in conjunction with faculty members from the Department of Advanced Chemistry, the Department of Management Systems Engineering, and the Graduate School's International Fire Science program. This interdisciplinary approach will drive the university-industry collaboration as a comprehensive open innovation project,

Xenon arc Weathering Testing Machine

Cone calorimeter Testing Machine

creating pioneering examples in various interdisciplinary fields and leading efforts for environmental sustainability in the construction industry. For the fiscal year 2023, in addition to existing facilities, we have introduced a cone calorimeter test and a Xenon arc Weathering Testing Machine to enhance the performance evaluation system for building materials.

Faculty of Science and Technology
 Department of Architecture   Professor Manabu KANEMATSU
 Department of Pure and Applied Chemistry Professor Takahiro GUNJI
 Department of Industrial and Systems Engineering Associate Professor Seiichi YASUI
 Department of Architecture   Associate Professor Kozo TAKSE
Graduate School of Science and Technology
 Department of Global Fire Science and Technology Professor Yoshifumi OMIYA

3. Activity Reports

3. 1. CO$_2$ Reduction Strategies Working Group (WG0) M. Kanematsu, S. Yasui

In WG0, we aim to contribute to formulating CO_2 reduction strategies by establishing various performance evaluation methods, including environmental performance, for interior and exterior materials in environmentally conscious buildings and by identifying the priorities and improvement effects of challenges in material development. In the fiscal year 2023, we focused on the following items:
- ✓ Calculation of LCCO$_2$ for standard office buildings
- ✓ Examination of the priority of evaluation items for environmentally conscious buildings
- ✓ Examination of multi-objective optimization for environmentally conscious building

3. 2. Exterior Materials Working Group (WG1) M. Kanematsu

WG1 aims to develop new exterior materials for concrete substrates. We are advancing technologies for directly printing coating films onto concrete substrates and finishing the concrete surface with a glass layer. To ensure these materials are suitable for exterior use, we investigate substrate treatment methods to achieve adequate weather resistance. Furthermore, we are conducting performance evaluations based on exposure tests and UV-accelerated degradation tests and investigating the degradation mechanisms.

3. 3. Interior Materials Working Group WG2 (WG2) T. Gunji

Promoting the use of wood in buildings is encouraged as it can fix carbon dioxide (CO_2). While fire-retardant treatment is often required for wooden interior materials, and the leaching of chemicals under certain environmental conditions is a major problem. Additionally, fire-retardant-treated wood is produced by infusing large amounts of chemicals into the wood using significant energy, but the environmental impact is still unknown. WG2 will calculate the LCCO$_2$ of existing fire-retardant-treated wood to clarify its environmental impact. Moreover, to reduce CO_2 emissions, we are developing new fire-retardant treatment technologies that prevent chemical leaching, contributing to developing environmentally friendly buildings. Specifically, we are working on new fire-retardant treatment techniques that combine impregnation and coating methods.

3. 3. Openings Working Group (WG3) K. Takase

In WG3, we focus on openings to realize new openings that significantly contribute to environmentally conscious buildings. This involves evaluating openings' WLC (Whole Life Carbon), considering CO_2 emissions during material production, transportation, and installation phases (upfront carbon), and their performance during use. Generally, office buildings have high energy consumption for air conditioning. Therefore, we focused on office buildings with curtain walls, which are expected to be affected by differences in the thermal performance of the building envelope, and conducted studies to estimate the LCCO$_2$.

3. 4. Substrate Working Group (WG3) Y. Omiya

WG4 is advancing surveys on the current status of $LCCO_2$ and LCA evaluations related to fireproof coating work, aiming to achieve substrate materials that contribute to environmentally conscious construction. Efforts include understanding initiatives such as decarbonization, CO_2 reduction, and achieving carbon neutrality in fireproof coating operations, as well as grasping examples of initiatives such as research on $LCCO_2$ and LCA evaluations.

Major Research Achievements

Patents

1. Shunsuke KIYOMURA, Masato TSUJINO, Manabu KANEMATSU, Ang YANG, Hardened cement with printed layer and method for producing hardened cement with printed layer, (International application number)：2023067693, 2023

Public Relations

1. Decarbonizing nonstructural components, The Nikkan Kensetsu Kogyo Shinbun, 2023
2. Towards the realization of "green functional building materials," Kensetsunews.com, 2023
3. Koyama, Wataru, Reducing CO_2 emissions from nonstructural components, research and development by Shimizu Corporation and Tokyo University of Science, Nikkei XTECH, 2023

Research Achievements by Researcher

Masaru Irita ---

Invited Lectures
1. 単層カーボンナノチューブのカイラリティー分布計測のための研究開発, 基礎科学セミナー 862nd ASRC Seminar (原子力研究開発機構, 茨城県), (2024 年 2 月) (in Japanese)

Patents
1. 入田 賢, 山本貴博, 特願 2024-11248 (2024.1.29)「情報処理装置, 情報処理システム, 情報処理方法, 及び情報処理プログラム」 (in Japanese)
2. 入田 賢, 本間芳和, マークサッドグローブ, 特願 2023-112654 (2023.7.7)「光伝送路, 光アイソレーター, フォトニックデバイス, 及び光伝送路の製造方法」(in Japanese)

GUAN Sujun ---

Academic Papers
1. Annealing Temperature-Dependent Luminescence Color Coordination in Eu-Doped AlN Thin Films, Yingda Qian, Mariko Murayama, Sujun Guan*, Xinwei Zhao, Journal of Materials Science and Chemical Engineering, Vol. 12, pp 20-28, 2024 (Peer-reviewed)
2. g-C3N4/In2O3 heterojunction films and their excellent photocatalytic performance in fruit preservation and organic dye degradation, Liang Hao, Chunyang Wang, Qian Zhao, Te Hu, Zizhen Wang, Sujun Guan, Yun Lu, Journal of Environmental Chemical Engineering, Vol. 12, pp 112522, 2024 (Peer-reviewed)
3. Oxygen vacancies induced band gap narrowing for efficient visible-light response in carbon-doped TiO2, Sujun Guan, Yanling Cheng, Liang Hao, Hiroyuki Yoshida, Chiaki Tarashima, Tianzhuo Zhan, Takaomi Itoi, Tangbin Qiu, Yun Lu, Scientific reports, Vol. 13, pp 1412522, 2023 (Peer-reviewed)
4. A method to make the performance of photocatalytic films rivals that of photocatalytic nanoparticles through water flow, Enlong Zhu, Rong Jia, Liang Hao, Te Hu, Yiqiang He, Sujun Guan, Yun Lu, Journal of Materials Science: Materials in Electronics, Vol. 34, pp 1347, 2023 (Peer-reviewed)

Invited Lectures
1. Fabrication and characterization of visible-light-driven core-shell TiC-TiO$_2$ nanoparticles, GUAN Sujun, QIAN Yingda, 8th International Conference on Catalysis and Chemical Engineering, Boston, Feb.26-28, 2024

Shouren Huang ---

Academic Papers
1. Human-Robot Interaction and Collaboration Utilizing Voluntary Bimanual Coordination, Shouren Huang, Yongpeng Cao, Kenichi Murakami, Masatoshi Ishikawa, Yuji Yamakawa, The 2023 IEEE International Conference on Systems, Man, and Cybernetics (SMC2023) (Oahu, Hawaii, USA, 2023.10.02) Proceedings, pp.1044-1051, 2023 （Peer-reviewed）
2. 2D/3D 視線制御に基づく肢体不自由者向けの生活支援ロボットの実現, 黄 守仁, Sørensen Sune Lundø, Cao Yongpeng, Mikkel Kjærgaard, 石川正俊, 山川雄司, 第 24 回計測自動制御学会システムインテグレーション部門講演会 (SI2023) (新潟, 2023.12.14) 講演会論文集, pp.130-132, 2023 (in Japanese)
3. Robotic Assistance for Extended Sensing, Locomotion and Manipulation by Gaze Control, Shouren Huang, Sune Lundø Sørensen, Yongpeng Cao, Masatoshi Ishikawa, Kjærgaard Mikkel, Yuji Yamakawa, 2023 32nd IEEE International Conference on Robot and Human Interactive Communication (RO-MAN) (Busan, South Korea, 2023.08.29), pp.1-4, 2023 （Peer-reviewed）

Invited Lectures
1. 高速ビジョンに基づく知能ロボットおよび人間拡張を目指した人間機械協調の実現, 黄 守仁, 第 10 回日本医科大学・東京理科大学合同シンポジウム, 東京, 2023 (in Japanese)

Satoshi Tabata --

Academic Papers
1. 小型高速三次元スキャナの開発, 田畑智志, 渡辺義浩, 石川正俊, 日本ロボット学会誌, Vol.42, No.1, pp.82-85, 2024 (in Japanese) (Peer-reviewed)
2. 高速画像処理を用いた３次元計測とその応用, 宮下令央, 田畑智志, 石川正俊, レーザー学会誌 レーザー研究, Vol.51, No.4, pp.215-219, 2023 (in Japanese) (Peer-reviewed)

Awards
1. 田畑智志, 末石智大, 宮下令央, 石川正俊, システムインテグレーション部門 SI2023 優秀講演賞, 計測自動制御学会, 2023 (In Japanese)

Koji Tsuchiya --

Academic Papers
1. Anti-adsorption Mechanism of Photoresist by Pluronic Surfactants: An Insight into Their Adsorbed Structure, Masaki Hanzawa, Taku Ogura, Koji Tsuchiya, Masaaki Akamatsu, Kenichi Sakai, Hideki Sakai, Langmuir, Vol. 39, No. 22, pp. 7876-7883, 2023 (Peer-reviewed)
2. Novel O/W emulsions by utilizing a vesicle/disc transformation of polyether modified silicone, Kei Watanabe, Hidehito Munakata, Kento Ueno, Haruhiko Inoue, Makoto Uyama, Yohei Takahashi, Koji Tsuchiya, Kenichi Sakai, Hideki Sakai, Journal of Oleo Science, Vol. 72, No. 7, pp. 693-708, 2023 (Peer-reviewed)
3. Effect of polyol type on the structure and properties of lecithin liposomes prepared using the polyol dilution method, Kaoru Ohishi, Koji Tsuchiya, Taku Ogura, Aya Ebisawa, Aika Sekine, Yuji Masubuchi, Masaaki Akamatsu, Kenichi Sakai, Masahiko Abe, Hideki Sakai, Colloids and Surfaces, A: Physicochemical and Engineering Aspects, Vol. 656, pp. 130509, 2023 (Peer-reviewed)

Kosuke Nakamoto --

Patents
1. 駒場慎一, 多々良涼一, 保坂知宙, 中本康介, 星 悠樹, 国内優先出願, 金属錯体粒子, 電極, 電池, 及び金属錯体粒子の製造方法, 特願 2024- 29099, 2023.2.28. (in Japanese)

Hiroshi Nishihara --

Academic Papers
1. Chemical bottom-up approach for inorganic single-atomic layers aiming beyond graphene. T. Kambe, H. Nishihara, K. Yamamoto, *Dalton Trans.* 2023, *52*, 15297-15302 (Frontier) (Peer-reviewed)
2. Development and Prospect of 2D Metalladithiolene Nanosheets. H. Maeda, K. Takada, N. Fukui, S. Nagashima, H. Nishihara, *Acc. Mater. Surf. Res.* 2023, *8*, 116-124. (in Japanese) (Peer-reviewed)
3. Manipulation of Chemical and Crystal Structures of Multilayered Copper-Hexaaminobenzene Coordination Nanosheets to Modulate Conductivity with Precise Control of Liquid-Liquid Interfacial Synthesis. H. Maeda, K. Takada, Naoya Fukui, Junzo Ukai, Nobutaka Honma, Sono Sasaki, Hiroyasu Masunaga, Kenichi Kato, H. Nishihara, *J. Inorg. Organomet. Polym. Mater.* 2023, in press. https://doi.org/10.1007/s10904-023-02920-5 (Peer-reviewed)
4. A Bis(terpyridine)nickel(II)-Based Coordination Nanosheet: A Redox-Active Material with Flexibility and Transparency. K. Takada, H. Maeda, H. Nishihara, *J. Inorg. Organomet. Polym. Mater.* 2023, in press. https://doi.org/10.1007/s10904-023-02921-4 (Peer-reviewed)
5. Manipulating the Morphology and Electronic State of a Two-Dimensional Coordination Polymer as a Hydrogen Evolution Cocatalyst Enhances Photocatalytic Overall Water-Splitting. J. Guan, K. Koizumi, N. Fukui, H. Suzuki, K. Murayama, R. Toyoda, H. Maeda, K. Kamiya, K. Ohashi, S. Takaishi, O. Tomita, A. Saeki, H. Nishihara, H. Kageyama, R. Abe, R. Sakamoto, *ACS Catal.* 2024, *14*, 1146-1156 (Peer-reviewed)

6. Lateral Heterometal Junction Rectifier Fabricated by Sequential Transmetallation of Coordination Nanosheet. C. M. Tan, N. Fukui, K. Takada, H. Maeda, E. Selezneva, C. Bourgès, H. Masunaga, S. Sasaki, K. Tsukagoshi, T. Mori, H. Sirringhaus, H. Nishihara, *Angew. Chem. Int. Ed.*, 2024, *63*, e202318181. (Peer-reviewed)
7. Face-on-oriented formation of bis(diimino)metal coordination nanosheets on gold electrodes by electrochemical oxidation. H. Maeda, K. Takada, N. Fukui, H. Masunaga, S. Sasaki, K. Tsukagoshi, H. Nishihara, *New J. Chem.* 2024, *48*, 6081-6087. (Peer-reviewed)

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1. 金属錯体の二次元物質　配位ナノシート，前田啓明. 福居直哉. 髙田健司, 西原　寛, 化学の要点シリーズ 44, 日本化学会編, 共立出版, 2023．ISBN: 9784320044852 (Peer-reviewed) (in Japanese)

Invited Lectures
1. 科学用語に関する諸問題, 西原　寛, 第 27 回 CSERS シンポジウム, オンライン, 2023/5/14 (in Japanese)
2. 界面配位プログラミング, 西原　寛, さきがけ「自在配列」領域会議, 大阪, 2023/10/14 (in Japanese)
3. 金属錯体二次元物質「配位ナノシート」の創製と機能応用, 西原　寛, Fujita Laboratory Symposium, 三井リンクラボ柏の葉, FS CREATION, 2023/10/25 (in Japanese)
4. Overview of coordination nanosheets, H. Nishihara, JSPS-EPSRC Workshop on 2D conjugated MOFs and coordination nanosheets, Dresden, Germany, 2023/12/11
5. 二次元物質「配位ナノシート」の創製と特性・機能, 西原　寛, 界面科学研究部門 2023 年度成果報告会, 森戸記念館, 東京, 2024/3/13 (in Japanese)
6. 化学用語検討小委員会の活動－発足から現在まで－, 西原　寛, 第 30 回化学教育フォーラム, 日大船橋キャンパス, 千葉, 2024/3/20 (in Japanese)

Patents
1. 西原　寛, 福居直哉, 高田健司, 伊藤実祐, 二次元配位高分子の製造方法, 及び, 二次元配位高分子, 特願 2023-149526, 2023/9/14 (in Japanese)

Public Relations
1. 西原　寛，整流特性を示す新たな面内ヘテロ接合素子の簡便合成に成功〜電力変換装置や超大規模集積回路の開発・高性能化に寄与〜, 東京理科大学プレスリリース, 2024/2/9 (in Japanese)
   H. Nishihara, A New "Metal Swap" Method for Creating Lateral Heterostructures of 2D Materials, Tokyo University of Science Media Relations, 2024/2/8

Masashi Nojima --

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2. Delamination suppression in CFRP laminate with ply discontinuity using cellulose nano fiber reinforced resin, M. J. Mohammad FIKRY, Issei HORI, Shun ABE, Masashi NOJIMA, Vladimir VINOGRADOV, Shinji OGIHARA, Abstracts M&P2023 MPB303 (2023)
3. Mass-selected ion beam generation using two rotating electric-field mass separation technique, Masashi Nojima, AIP Advances, 13, 105205 (2023) p.1-7 (Peer-reviewed)
4. The generations of primary ion beam using two rotating electric-field mass (REF-MS) separation technique, Journal of Surface Analysis, 30, 2 (2023) p.89-97 (Peer-reviewed)

Awards
1. Masashi Nojima, Foundation of new material information for Promotion of Science, 2023, "Dynamics from the generations of matrix cracks to the stress fractures within carbon fiber materials"
2. Masashi Nojima, ISSN International Research Awards 2023, World Research Council, Times of Research & Z24 News

Ichiro Hagiwara --

Academic Papers

4. 萩原一郎，消防活動支援に関する基準の検討，日本火災学会研究発表会概要集, pp201-202, 2023 (in Japanese)

5. 曹文峰，萩原一郎，消防隊進入口の配置による消防活動支援性能分析，日本火災学会研究発表会概要集, pp203-204, 2023 (in Japanese)

6. 萩原一郎，消防活動支援における進入口の基準の検討，日本建築学会学術講演梗概集（防火），pp127-128, 2023 (in Japanese)

7. 曹文峰，萩原一郎，消防隊進入口の配置による消防活動支援性能分析，日本建築学会学術講演梗概集（防火），pp129-130, 2023 (in Japanese)

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1. 萩原一郎，大阪北新地放火火災から 2 年ビル改修支援に関するコメント，産経新聞, 2023.12.16 (In Japanese)

2. 萩原一郎，大牟田市の飲食店街火災についてコメント，西日本新聞, 2024.1.27 (In Japanese)

Tomohiko Hayakawa --

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1. Thick crack width calculating method using chalk-marks in low-contrast 2D images acquired during high-speed traveling, Conf. on NDE 4.0, Predictive Maintenance, Yushi Moko, Tomohiko Hayakawa, Yuka Hiruma, Yushan Ke, Yuriko Ezaki, Yoshimasa Onishi, Masatoshi Ishikawa, Communication, and Energy Systems: The Digital Transformation of NDE II / Proc. SPIE, Vol.12952, pp.12952-4:1--12952-4:3, 2024 (Peer-reviewed)

2. Active thermal marker using thermal images of heated areas with visible semiconductor laser, Tomohiko Hayakawa, Yuka Hiruma, Yushan Ke, Masatoshi Ishikawa, the 10th edition of the International Conference on Optical and Photonic Engineering (icOPEN 2023), 15617, 2023 (Peer-reviewed)

3. High-Speed Localization Estimation Method Using Lighting Recognition in Tunnels, Yushi Moko, Yuka Hiruma, Tomohiko Hayakawa, Yoshimasa Onishi, Masatoshi Ishikawa, 2023 7th International Conference on Intelligent Traffic and Transportation (ICITT 2023), ML755:1-ML755:12, 2023(Peer-reviewed)

4. トンネル内における照明認識による自己位置推定手法，望戸雄史，早川智彦，大西偉允，石川正俊，令和 5 年度土木学会全国大会第 78 回学術講演会, CS9-24:1-CS-24:2, 2023 (in Japanese)

5. Foveated Noise Reduction: Visual Search Tasks under Spatio-Temporal Control Synchronized with Eye Movements , Yuki Kubota, Tomohiko Hayakawa, and Masatoshi Ishikawa, In Proceedings of the 2023 Symposium on Eye Tracking Research and Applications (ETRA '23), Article 43, pp.1-2, 2023 (Peer-reviewed)

6. 宮下令央，末石智大，田畑智志，早川智彦，石川正俊: 高速ビジョンが拓くダイナミックプロジェクションマッピング技術，電子情報通信学会 通信ソサイエティマガジン B-plus, 解説論文, No.64, pp.275-284, 2023 (in Japanese)

Invited Lectures

1. Optical axis control methods for infrastructure inspection, Tomohiko Hayakawa, 2nd Intl. Conference Advances in 3OM, OPT23-42, 2023

2. User Performance based on the Effects of Low Video Latency between Visual and Haptic Information in Immersive Environments, Tomohiko Hayakawa, The 6th International Conference on Intelligent Robotics and Control Engineering, 2023

Hiroaki Maeda --

Academic Papers

1. Face-on-oriented formation of bis(diimino)metal coordination nanosheets on gold electrodes by electrochemical oxidation, <u>Hiroaki Maeda</u>, Kenji Takada, Naoya Fukui, Hiroyasu Masunaga, Sono Sasaki, Kazuhito Tsukagoshi, Hiroshi Nishihara, New J. Chem., Vol. 48, No.14, pp6081-6087, 2024 (Peer-reviewed)

2. Lateral Heterometal Junction Rectifier Fabricated by Sequential Transmetallation of Coordination Nanosheet, Choon Meng Tan, Naoya Fukui, Kenji Takada, <u>Hiroaki Maeda</u>, Ekaterina Selezneva, Cédric Bourgès, Hiroyasu Masunaga, Sono Sasaki, Kazuhito Tsukagoshi, Takao Mori, Henning Sirringhaus, Hiroshi Nishihara, Angew. Chem. Int. Ed., Vol.63, No.9, e202318181, 2024 (Peer-reviewed)

3. Manipulating the Morphology and Electronic State of a Two-Dimensional Coordination Polymer as a Hydrogen Evolution Cocatalyst Enhances Photocatalytic Overall Water-Splitting, Jingyan Guan, Kazuma Koizumi, Naoya Fukui, Hajime Suzuki, Kantaro Murayama, Ryojun Toyoda, <u>Hiroaki Maeda</u>, Kazuhide Kamiya, Keitaro Ohashi, Shinya Takaishi, Osamu Tomita, Akinori Saeki, Hiroshi Nishihara, Hiroshi Kageyama, Ryu Abe, Ryota Sakamoto, ACS Catal., Vol.14, No.2, pp1146-1156, 2024 (Peer-reviewed)

4. A Bis(terpyridine)nickel(II)-Based Coordination Nanosheet: A Redox-Active Material with Flexibility and Transparency, Kenji Takada, <u>Hiroaki Maeda</u>, Hiroshi Nishihara, J. Inorg. Organomet. Polym. Mater., Vol. 34, pp2990-2997, 2024, DOI: 10.1007/s10904-023-02921-4 (Peer-reviewed)

5. Manipulation of Chemical and Crystal Structures of Multilayered Copper-Hexaaminobenzene Coordination Nanosheets to Modulate Conductivity with Precise Control of Liquid-Liquid Interfacial Synthesis, <u>Hiroaki Maeda</u>, Kenji Takada, Naoya Fukui, Junzo Ukai, Nobutaka Honma, Sono Sasaki, Hiroyasu Masunaga, Kenichi Kato, Hiroshi Nishihara, J. Inorg. Organomet. Polym. Mater., Vol. 34, pp2948-2956, 2024, DOI: 10.1007/s10904-023-02920-5 (Peer-reviewed)

6. 二次元メタラジチオレンナノシートの発展と将来展望, <u>前田啓明</u>, 髙田健司, 福居直哉, 長島佐代子, 西原 寛, 材料表面, Vol.8, No.3, pp116-124, 2023 (Peer-reviewed, in Japanese)

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1. 化学の要点シリーズ 44　金属錯体の二次元物質 配位ナノシート, <u>前田啓明</u>, 福居直哉, 髙田健司, 西原 寛, 共立出版株式会社, 2023 (in Japanese)

2. Comprehensive Inorganic Chemistry III Third Edition, <u>Hiroaki Maeda</u>, Michihiro Nishikawa, Ryota Sakamoto, Hiroshi Nishihara, Elsevier, pp356-416, 2023

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1. Tan Choon Meng, Naoya Fukui, Kenji Takada, <u>Hiroaki Maeda</u>, Hiroshi Nishihara, A New "Metal Swap" Method for Creating Lateral Heterostructures of 2D Materials, TUS Press Release, 2024

Yuichi Matsuo --

Academic Papers

1. Application of Open Data in Building Scenes of the Autonomous Driving Simulation, Kiddo Mokutani, Tatsuya Ichikawa, Kengo Asada, <u>Yuichi Matsuo,</u> 2023 JSAE Annual Congress (Autumn) in NAGOYA CONGRESS CENTER (in Japanese)

2. Development of Production Digital Twin in Manufacturing Using Fischertetchnik Factory Model, <u>Yuichi Matsuo</u>, Kengo Asada, Kozo Fujii, Proceedings of the 2023 Winter Simulation Conference, IEEE, 2023

3. Development and Application of the One-Stop Flow Analysis Framework Enabling Rapid Digital Engineering, Kengo Asada, <u>Yuichi Matsuo</u>, Kozo Fujii, Proceedings of the 2023 Winter Simulation Conference, IEEE, 2023

Invited Lectures

1. Digital Twin – From the Basics to Application, <u>Yuichi Matsuo</u>, ICSCP 54th Seminar, Tokyo, February 2024 (in Japanese)
2. Research and Future Plan in University, <u>Yuichi Matsuo</u>, JSME Technical Section on Data Assimilation for Engineering Design and Operation, February 2024 (in Japanese)
3. Overview of the Digital Twin and Contribution to the Manufacturing DX, <u>Yuichi Matsuo</u>, JSME 101th Regular General Meeting Special Lecture, April 2024 (in Japanese)

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1. The largest in Tohoku! Celebration of robots and aerospace industry, NHK Fukushima WEB Special Article, https://www.nhk.or.jp/fukushima/lreport/article/002/75/, 2023 (in Japanese)

Leo Miyashita --

Academic Papers

1. 高速画像処理を用いた３次元計測とその応用, <u>宮下令央</u>, 田畑智志, 石川正俊, レーザー学会誌 レーザー研究, Vol.51, No.4, pp.215-219, 2023 (in Japanese) (Peer-reviewed)
2. Individual identification using black spots pattern on Humboldt penguins' (Spheniscus humboldti) chest, Akane Ogata, Chika Shirakata, <u>Leo Miyashita</u>, 11th International Penguin Congress, Poster, No.58, 2023 (Peer-reviewed)
3. Differential Frequency Heterodyne Time-of-Flight Imaging for Instantaneous Depth and Velocity Estimation, Yunpu Hu, <u>Leo Miyashita</u>, Masatoshi Ishikawa, SIGGRAPH 2023, Technical Papers (ACM Transactions on Graphics Vol.42, No.1), 2023 (Peer-reviewed)
4. High-speed optical sensing of pose, position, and surface normal for dynamic projection mapping, <u>Leo Miyashita</u>, Masatoshi Ishikawa, SPIE Optical Metrology 2023, Automated Visual Inspection and Machine Vision V, Oral 12623-16, 2023 (Peer-reviewed)

Invited Lectures

1. Virtual Material Creation by High-speed Projection, <u>Leo Miyashita</u>, International Display Workshops (IDW 2023), PRJ7-1, pp.829-831, Niigata, Japan, 2023
2. Differential Frequency Heterodyne Time-of-Flight Imaging for Instantaneous Depth and Velocity Estimation, 胡云普, <u>宮下令央</u>, 石川正俊, Visual Computing 2023 (VC2023), 芝浦工業大学 豊洲キャンパス, 東京, 2023 (in Japanese)

Awards

1. <u>宮下令央</u>, センシングフォーラム 2022 センシングフォーラム研究奨励賞, 計測自動制御学会, 2023 (in Japanese)
2. 田畑智志, 末石智大, <u>宮下令央</u>, 石川正俊, 第 24 回計測自動制御学会システムインテグレーション部門講演会 (SI2023), 優秀講演賞, 2023 (in Japanese)

Takahiro Yamazaki ---

Journal Papers

1. Soft Magnetostrictive Materials: Enhanced Magnetostriction of Fe-Based Nanocrystalline Alloys via Ga Doping, K. Sano, <u>T. Yamazaki</u>, C. Oka, J. Sakurai, S. Hata, Scripta Materialia, Vol.242, No.15, 11595 (Peer-reviewed)
2. Visualization of the Magnetostriction Mechanism in Fe-Ga alloy Single Crystal Using Dimensionality Reduction Techniques, A. L. Foggiatto, Y. Mizutori, <u>T. Yamazaki</u>, S. Sato, K. Masuzawa, R. Nagaoka, M. Taniwaki, S. Fujieda, S. Suzuki, K. Ishiyama, T. Fukuda, Y. Igarashi, C. Mitsumata, M. Kotsugi, IEEE Transactions on Magnetics, Vol.59, No.11, 2501604, 2023 (Peer-reviewed)

3. Origin of negative anisotropic magnetoresistance effect in $Fe_{0.75}Co_{0.25}$ single-crystal thin films upon Ir addition, R. Toyama, S. Kokado, K. Masuda, Z. Li, V. K. Kushwaha, T.T. Sasaki, L. S. R. Kumara, T. Koganezawa, H. Tajiri, <u>T. Yamazaki</u>, M. Kotsugi, Y. Iwasaki, Y. Sakuraba, Physical Review Materials, Vol.7, No.8, 084401, 2023 (Peer-reviewed)

4. Stress measurement based on magnetic Barkhausen noise for thin films, K. Omae, <u>T. Yamazaki</u>, C. Oka, J. Sakurai, S. Hata, Microelectronic Engineering, Vol.279, No.15, 112057, 2023.

5. Novel measurement method of internal stress in thin films using micro spring structure, S. Takase, <u>T. Yamazaki</u>, C. Oka, J. Sakurai, S. Hata, Mechanical Engineering Journal, Vol.10, No.4, 23-00074, 2023 (Peer-reviewed)

6. Tuning the Temperature Range of Superelastic Ni-Ti Alloys for Elastocaloric Cooling via Thermal Processing, <u>T. Yamazaki</u>, A. L. Montagnoli, M. L. Young, and I. Takeuchi, Journal of Physics: Energy Vol.5, No.2, 024020, 2023 (Peer-reviewed)

7. メリーランド滞在記，<u>山崎貴大</u>，日本セラミックス協会「セラミックス」，第 58 巻，第 9 号，2023 年（Peer-reviewed, in Japanese）

8. 高耐食性ナノ結晶合金のコンビナトリアル合成，<u>山崎貴大</u>，日本金属学会「まてりあ」，第 62 巻，第 9 号, pp 600-605, 2023 年.（Peer-reviewed, in Japanese）

Press Rerelese

1. 秦 誠一, 佐野光哉, <u>山崎貴大</u>, 環境振動発電応用に向けた新奇磁歪材料の開発指針を提示～磁気的に軟らかい「ナノ組織」と大きくひずむ「ナノ結晶」の組み合わせ～, 日本の研究.com, 2024.

Report of Research Institute for Science and Technology Forum

Report of "Research Institute for Science and Technology Forum 2023" (12/25)

On December 25 (Mon), 2023, Research Institute for Science and Technology Forum 2023 － Aiming Only at TUS was held in a hybrid type of face-to-face and online. The event was held in a great success with 154 participants (62 participants in the venue and 92 participants online).

In the forum, research centers and research divisions in the areas of "Fundamentals," "Functional Materials," "Bio and Pharmacy," and "Information and Societal," gave oral presentations on the most recent research trend or topic for each research group. A poster session by research divisions was also held.

During the Q&A session, many researchers engaged in lively discussions, making it a meaningful forum in which we can look forward to the future development of our university's unique research activities that go beyond the framework of Research Centers and Research Divisions.

[Program]

1. **Opening Remarks.** Yasuo Kogo (Director, Organization of Research Promotion)
2. **Overview of the Research Institute for Science and Technology (RIST).**
   Hiroshi Nishihara (Director, Research Institute for Science and Technology)

Oral Presentations of Research Centers and Research Divisions

[Bio and Pharmacy]
3. **Development of the Dehydration Condensation Reaction in the Presence of Trace Amounts of Water for the Ultra-high Sensitive Detection of Drugs**.
   Isamu Shiina (Director, Research Center for Drug Discovery and Applied Sciences)
4. **Drug discovery for the innovative next generation of oligonucleotide therapeutics.**
   Takeshi Wada (Director, Division of Nucleic Acid Drug Development)
5. **Opening the way for creation of novel cells by Synthetic biology.**
   Tomokatsu Ikawa (Director, Division of Synthetic Biology)

[Information and Societal]
6. **Advanced research and activities of the Center for Fire Science and Technology.**
   Ken Matukawa (Center for Fire Science and Technology), Base for Fire-Safety Science
7. **Research Center for Space System Innovation Approach for Space-Ground Dual Development and Terrestrial Utilization**.
   Shinichi Kimura (Director, Research Center for Space System Innovation)
8. **Advanced Technologies in Urban Disaster Prevention.**
   Osamu Takahashi (Director, Research Division for Advanced Disaster Prevention on cities)
9. **Lecture.** Masashi Nojima (Research Institute for Science and Technology)
10. **Fundamental Research and Future Developments in the Division of Digital Transformation.**
    Munehiro Takimoto (Director, Division of Digital Transformation)
11. **Striving for an innovative academic field of brain science, "Parallel Brain".**
    Hiroshi Takemura (Director, Parallel Brain Interaction Sensing division)
12. **Activity of Research Center for Multi-Hazard Urban Disaster Prevention.**
    Yasuo Nihei (Director, Development of Superior Cell and DDS for Regenerative Medicine)

[Functional Materials]

    13. **Tackling water research for sustainable future society.**

        Masahiro Motosuke (Director, Water Frontier Research Center (WaTUS))

    14. **Based on Only at TUS.**

        Takahiro Gunji (Director, Research Group for Advanced Energy Conversion)

    15. **Development of artificial photosynthetic technology aiming at carbon neutral.**

        Akihiko Kudo (Director, Carbon Value Research Center)

Poster Session

    16. **Poster presentations of 14 Research Divisions**

Panel Discussion

    17. **Expectations and Recommendations for Research Institute for Science and Technology**

        [Moderator]   Hiroshi Nishihara (Director, Research Institute for Science and Technology)

        [Panelists]   Yasuo Kogo (Director, Organization of Research Promotion)

                        Akihiko Kudo (Director, Carbon Value Research Center)

                        Yasuo Nihei (Director, Research Center for Multi-hazard Urban Disaster Prevention)

    18. **Closing Remarks.**   Hiroshi Nishihara (Director, Research Institute for Science and Technology)