Tokyo University of Science

RIST TUS

Research Institute for Science & Technology

2023 / 2024

The Edge of Cross Disciplines

RIST TUS
Research Institute for Science & Technology

Bio and Pharmacy

- Research Center for Drug Discovery and Applied Sciences
- Division of Nucleic Acid Drug Development
- Division of Synthetic Biology
- Division of Biological Environment Innovation
- Development of superior cell and DDS for regenerative medicine

Information and Societal

- Center for Fire Science and Technology
- Research Center for Fire Safety Science
- Research Center for Space System
- Research Center for Multi-Hazard Urban
- Research Division for Advanced Disaster
- Statistical Science Research Division
- Parallel Brain Interaction Sensing division
- Division of Digital Transformation
- Medical Data Science
- Division of Smart Healthcare Engineering
- Research ＆ Development Platform of

Structural Materials

- Division of Composite Materials Engineering
- Division of Implementation of sustainable technology in society

Fundamentals

- Research Alliance for Mathematical
- Division of Nano-quantum Information
- Modern Algebra and Cooperation

Functional Materials

- Water Frontier Research Center
- Carbon Value Research Center
- Division of Nanocarbon Research
- Division of Colloid and Interface Science
- Renewable Energy Science & Technology Research Division
- Research Group for Advanced Energy Conversion
- The Kao "Kirei" Future Open Innovation Project

Research Centers

These are research organizations that obtain the research funding needed for their activities from the national government, from local governments, and from industry and other sources, and that carry out initiatives that are strategically important for their research.

Joint Usage / Research Center

A nationally selected organization for joint use / joint research open to public and funded partially by MEXT.

Research Divisions

These are core research organizations comprised of researchers selected from within TUS and from outside the TUS in order to provide a synergistic effect. They develop interdisciplinary and cross-disciplinary"Only at TUS"research activities.

The Open Innovation Projects

These are research organizations that promote the co-creation of new value with the aim of contributing to society through both TUS and corporations.

Building a better future with

Innovation [SSI]

Disaster Prevention

Prevention on cities

Functional Green Building Materials

analysis

Science and Technology

with Engineering

Message from the Director

The Research Institute for Science and Technology (RIST) is a cross-disciplinary research organization within the Organization for Research Advancement that was established in 2015 as a general research institution. Its forerunner, the Institute for General Research, was established in 1981. Education, research, and social contributions, the three pillars of Tokyo University of Science (TUS), are synergistically related, and the many cutting-edge integrated research projects conducted at RIST play a major role in training students to take a broad perspective and create social value.

As of September 2023, one Laboratory, three Research Centers, one Joint Usage/Research Center, two Research Hubs, 19 Research Divisions, and two Open Innovation Projects are active at RIST. In all our activities, in addition to actively pursuing basic science in various academic fields, we promote close cooperation between disciplines and conduct innovative research by removing bureaucratic barriers both inside and outside the university. We began promoting research focused on environmental and energy issues even before the United Nations established its SDGs (Sustainable Development Goals) in 2015.

Since 2021, we have launched three Research Centers, two Research Hubs, and two Open Innovation Projects. More information is available below.

The Water Frontier Research Center is the successor to the Water Frontier Science & Technology Research Center (WFST), which was established under a Ministry of Education, Culture, Sports, Science and Technology branding project in 2016 and launched in 2021. It was established as a research center to promote cutting-edge research related to “water interfaces,” the behavior of water on material surfaces, and to provide comprehensive services for cooperatively finding solutions to problems faced by industry.

The Space System Creation Research Center was established in 2021 from a reorganization of the Photocatalyst International Research Center (established in 2013) and the Space Colony Research Center (established in 2017). It has been building and expanding a human resource base consisting of next-generation space scientists and engineers capable of operating at the international level, and it has been developing technologies required for space habitation involving water, air, food, energy, and so on to create a virtuous cycle between earth and space with a focus on photocatalysis. It also conducts research and development on technologies necessary for humans to stay in extreme enclosed environments for prolonged periods, and it has been developing integrated systems that encompass the science and technologies necessary for creating future space planes as well as the legislation that governs commercial space transportation. In 2022, the Research Center for Near-Future City Function by Terrestrial-Space Dual Development was selected by the Japan Science and Technology Agency (JST) as an educational project (in the field of co-creation) under the Program on Open Innovation Platforms for Industry-Academia Co-creation (COI-NEXT).

The Research Center for Drug Discovery and Applied Sciences was established in 2023 to carry on the Chemical Biology Division Supported by Practical Organic Synthesis, which had been active until 2022, through collaboration with researchers in the field of molecular biology. The goal of this Center is to create drugs by carrying out drug discovery research on new substances developed by TUS using our proprietary organic synthesis technology.

One of the research hubs, the Carbon Value Research Center was developed in January 2022 with the aim of utilizing the science and technology of the university’s faculty to develop essential chemical science and technology, such as artificial photosynthesis, that will contribute to carbon neutrality, through collaboration and joint research with external organizations. The Center is developing carbon value science and technology by pursuing the science and technology of green hydrogen production and the synthesis of useful materials utilizing carbon dioxide as a source of carbon.

The other research hub, the Research Center for Multi-Hazard Urban Disaster Prevention was launched in August 2023. The Center will create and implement a new science of urban disaster management that addresses multi-hazards in which hazard chains occur across time and space causing an increase in damage, through strong collaboration of disaster management researchers on various hazards and data science researchers. Through this Center, we aim to build a safe and security society in which no one is left behind in a sustainable and diversity-conscious manner.

With our Open Innovation Projects, we aim to contribute to the creation of new value by disseminating, both inside and outside the university, the results and findings of joint research involving both university faculty and companies. These research activities, which could be described as “knowledge co-creation”, are expected to produce solid research results in line with the medium-term R&D strategies of corporations and other participants. Through the Kao ‘Kirei’ Future Open Innovation Project, which we launched in 2021, we continue to recognize the roles of the respective social missions of companies and the university while we promote the development of innovative technologies in order to enrich people’s lives. In 2022, we launched our second Open Innovation Project, the Research & Development Platform of Functional Green Building Materials, in collaboration with Shimizu Corporation. This project promotes research and development aimed at the social implementation of environmentally friendly architecture.

Through collaboration on research across Research Centers, Research Hubs, and Research Divisions, RIST aims to enhance the fluidity and mobility of faculty personnel. By taking advantage of appealing research environments that are rich in vitality and unity, we aim to foster highly creative, diverse human resources who will lead the next generation of society, and to become an international hub for interdisciplinary research. We will also create new academic trends and produce transparent research results in a way that is unique to TUS.

Dr.Hiroshi Nishihara

Director

Research Institute for Science and Technology

Tokyo University of Science

Science

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RIST Organization Chart

FOCUS①

Research Center for Drug Discovery and Applied Sciences

Structure-Activity Relationship (SAR) and Mode of Action (MOA) Studies Using New Compounds Developed at the Tokyo University of Science

Artificial synthesis of FE399, a natural substance derived from a fungus of the Japanese yew (a tree in the yew family): First successful synthesis of a natural substance through MNBA macrolactamization

~ Prospects for the development of cancer drugs that inhibit the growth of colorectal cancer and other forms of cancer caused by mutations of gene p53 ~

Cancer is the leading cause of death in modern society. It is said that one in two men and one in three women will develop some form of cancer during their lives. This makes the development of new treatment techniques and new drugs an important social issue.

FE399 is a novel natural compound (Fig. 1) that has been isolated from cultures of Ascochyta sp., which is a type of fungus. It has an inhibitory effect on the growth of various tumor cells, including human colorectal cancer cells. In particular, it is understood that some cells, including those of colorectal cancer, esophageal cancer, and breast cancer, come about due to a mutation of the p53 gene, which is a cancer suppressor gene. Thus, FE399 suppresses the growth of cancer cells formed by the p53 mutation by promoting apoptosis in them.

In order to synthesize compounds with bioactivity that is similar to that of natural compounds, it is essential to clarify not only the molecular formula but also its structure and stereochemical properties. However, until now, the exact molecular structure of FE399 was unknown, even though the precise molecular formula was known. For that reason, the precise structure of FE399 and the establishment of a method for synthesizing it were long-awaited.

The Synthetic and Pharmacological Activity Evaluation Groups at the Research Center for Drug Discovery and Applied Sciences, RIST, TUS have determined the structure of FE399 using a synthetic chemistry approach and has established a highly efficient route for the total synthesis of FE399 by using MNBA (2-methyl-6-nitrobenzoic anhydride), a rapid dehydration condensation agent that the university had previously developed, utilizing a three-stage key reaction (Fig. 2).

We have clarified the molecular structure of FE399 and established a pathway for synthesis. This is expected to improve quality of life (QOL) in the treatment and prognosis of colorectal cancer and other forms of cancer.

At present, the Research Center for Drug Discovery and Applied Sciences is evaluating bioactive compounds that were seen during the synthesis of FE399. We are also testing artificial analogs of other natural substances to determine their therapeutic efficacy for treating colorectal cancer, lung cancer, and blood-related cancers. We expect the results of this research to make significant contributions to the development of novel future cancer drugs based on natural substances as lead compounds.

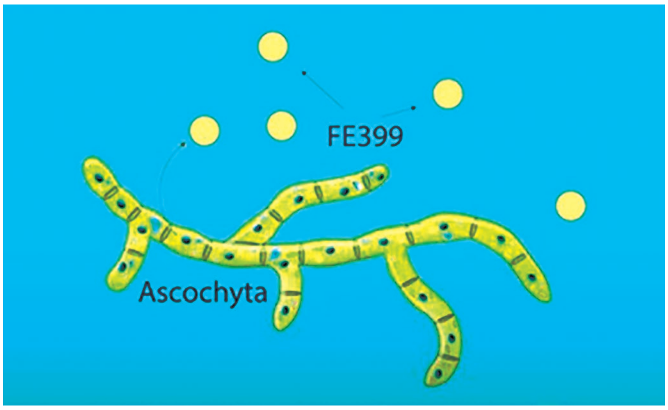


Fig. 1. FE399, a natural substance obtained from Ascochyta, a type of mold

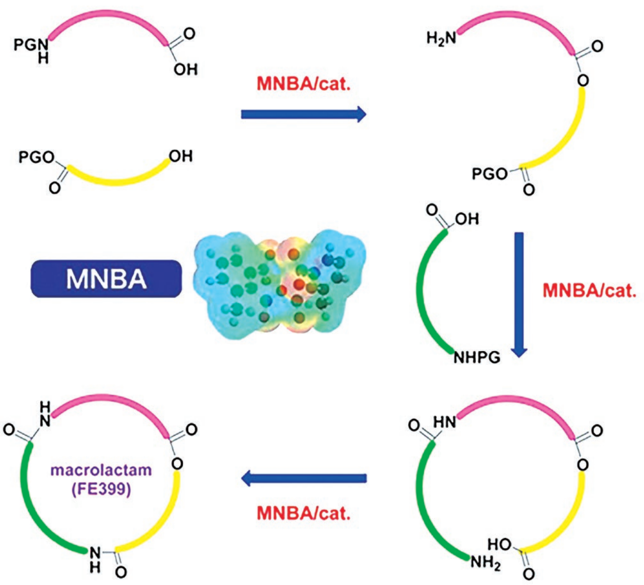


Fig. 2. Overview of an artificial synthesis method for FE399 using MNBA

FOCUS②

Research & Development Platform of Functional Green Building Materials

Achieving Environmentally Friendly Construction Through Research and Development of High-Functionality Materials and Construction Methods That Help to Reduce CO_2 Emissions

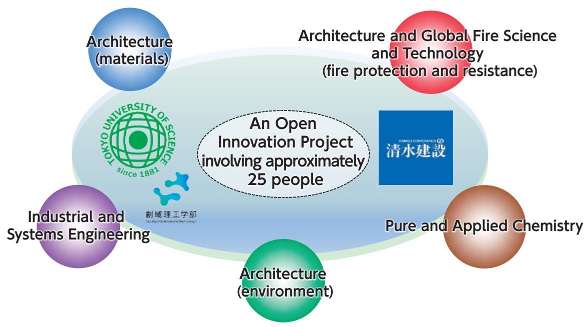
In this project, we will construct a system for evaluating and visualizing CO_2 emissions related to non-structural components—an area in which no research and development progress has been made so far—taking life stages into consideration, in order to create a society oriented toward environmentally friendly construction. We will also promote research and development of high-functionality materials, including exterior materials, interior materials, entrance components, and foundation materials, as well as construction methods that help to reduce CO_2 emissions during manufacturing and construction.

In order to reduce the burden of buildings on the environment at a time when efforts to eliminate carbon are increasing throughout society, it is crucial to establish an academic foundation for achieving environmentally friendly construction at a high level and to develop a comprehensive platform for encouraging the implementation of those goals in society. In particular, non-structural components for approximately 20% of the CO_2 emitted as embodied carbon during the construction. However, despite individual studies and societal attempts from an environmental conservation perspective, there has been little holistic attempt to optimize the overall environmental impact of buildings.

In order to reduce the environmental impact of non-structural components, we need to consider whole life carbon—the total amount of CO_2 emissions produced during a building's life cycle, including embodied carbon as well as operational carbon, which is the amount of CO_2 emitted during the operational stage of a building. However, at present, there is no established method for assessing whole life carbon. Another issue is that in the case of non-structural materials, unlike structural materials, there has not been adequate preparation of the basic information that would be indispensable for making precise calculations of embodied carbon, taking into account the effect of differences in material processing treatments on environmental impact, the effects of reducing environmental impact through the use of recycled materials, and other such factors.

In this project, we will develop a system for evaluating and visualizing the CO_2 emissions of non-structural components for each life stage, and we will promote research and development of materials and construction methods that achieve a high degree of compatibility between environmental performance and functionality with regard to exterior materials, interior materials, entrance components, and foundation materials—items that have a high level of impact on whole life carbon. We will also contribute to nature-positivity, encouraging research and development directed toward high-functionality and high-performance interior and exterior building materials that also promotes resource conservation and recycling.

By promoting this industry-academia collaboration project as a comprehensive initiative based on open innovation, the project's members intend to create pioneering examples in a wide range of boundary regions and lead the way in environmental conservation efforts within the construction industry.



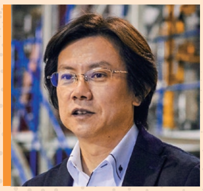
This project is an Open Innovation Project conducted by Tokyo University of Science and Shimizu Corporation.

Examples of efforts aimed at achieving environmentally friendly construction

Joint Usage/Research Center

Established: July, 2009 kasaianzen-ml@tusml.tus.ac.jp

Research Center for Fire Safety Science



Director
Professor,
Graduate School of Science and Technology, Department of Global Fire Science and Technology
Ken Matsuyama
Dr.Eng.

Research Center for Fire Safety Science is currently promoting formation of research and education center, and produced two major outcomes, one is the development of "theory" pertaining to performance-based fire safety design, and the other is the development in "practice" through experimental research utilizing the full-scale experimental facilities. Upon these two pillars, the Center will further research and deepen our knowledge of how to control the potential fire risks that are increasing along with the emergence of new spatial configurations (high-rise or underground) and use of new materials (e.g. aluminum and plastics). These are inevitable changes brought about by modernization, industrialization and increased need of energy conservation.

Open Call Schedule

The Center invites and accepts research plans from public basically once a year research activities of the selected plans start at the beginning of each academic year. However, research of urgency may be accepted at any point of an academic year as needed.

The rough schedule of the application is as follows:

- Announcement of the theme : early February
- Application period : February to mid-March
- Notification of acceptance : March to April
- Conducting collaborative research : April to next March
- Briefing report of achievement : by next April

Reference Research Theme

[General Category, A～F]

A. Fundamental research on building fire safety

(Examples from the past)

- An experimental study on measurement method and estimation algorithm of radiant heat flux from large scale facade fire

B. Fundamental research on material combustion science

- Measures for controlling fire propagation at the surface of wooden linings
- An investigation of the measurement methods of lateral flame spread rate over wall lining materials
- FT-IR/Thermal Decomposition Analysis of Surface Combustion Characteristics in Flame Retardant Cross-Laminated Timber with Intumescent Nano-Clay Composites

C. Fundamental research on fire safety and disaster prevention

- An Experimental Study on Fire Prevention Effect with High Viscosity Liquid on A Wood Board

D. Fundamental research on large-scale fire

E. Research on technology and measures pertaining to fire safety

F. R & D issues that can be expected for technological innovation to reduce fire risk

[Emphasis Category, G] (※)

G. Experimental Research on Building Structural Fire Resistance

(※) Large-scale experimental challenge to use Structural Fire Resistance Furnace, or Multiple Full-scale Furnace

Management Structure and Assessment Procedure

The Research Center for Fire Safety Science Committee "(the Committee"), playing the central role in the Center, consists of a chairperson and 10 members (5 from inside and 5 from outside of TUS).

The Committee is the supreme decision-making body of the Center that develops a research and operation policy, formulates a management policy (including budget drafting), and plans research projects such as deciding a theme to call for entries.

Aiming to support smooth operation of the Center, the Research Theme Selection Committee and two special committees (called Working Groups or WG) are placed under the Committee. The Research Theme Selection Committee and two special committees function as follows respectively:

The Research Theme Selection Committee

This committee makes judgment on acceptance or rejection of applications received. Judgment will be made considering whether the research objective is defined clearly, the plan and the methodology are appropriate, proposed budget is reasonable, and whether the research outcome has potential for further development.

Facilities and Equipment Control Committee (WG)

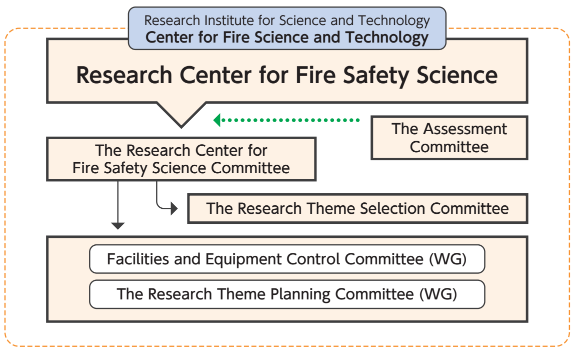
This committee (WG) is primarily involved in the operation planning of the full-scale experimental facilities. It is also responsible for the maintenance of facilities and equipment installed in the institution. In addition, it gives users instruction on how to use these facilities and equipment and on safety control.

The Research Theme Planning Committee (WG)

This committee (WG) draws out research themes and projects that are appropriate for the collaborative use or research and that serve the purpose of the Center and fulfill a social need.

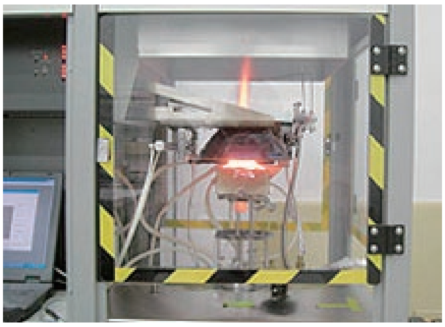
The Assessment Committee

This committee functions as an assessing body of the Center by providing interim and ex-post evaluation on the progress and outcome of research projects.



(Management Structure)

Example of Available Facilities/Equipment

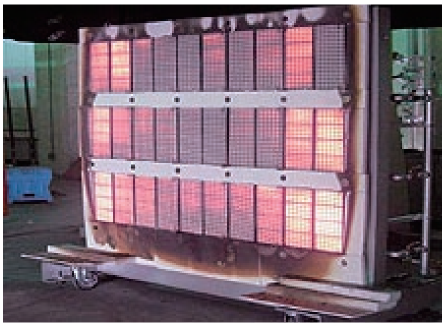


Cone Calorimeter Testing Device (ISO 5660)

This device is used to examine ignitability and the exothermal properties of construction materials using thermal radiation. A test object is placed under the conical-shape electric heater, which controls the thermal radiation to the object, and a pilot flame, is applied to the object 10mm from its surface. The ignition time and the heat release rate can be measured per thermal radiation that can be set in the range of 0 to 50 kW//m^2.

FTIR Gas Analyzer

This unit is designed to be connected to the combustion and smoke generation tester and enables high-speed and continuous analysis of combustion gas. A measured value can be updated at short intervals (five to ten seconds). This unit specializes in measuring certain types of gas that is result from combustion in fire.



ICAL Testing Unit (Heat Radiation Panel)

This unit is designed to elucidate the burning behavior of combustible materials under the condition where a certain heat flux was given through radiative heat transfer. The unit can also be used to investigate the behavior of members exposed to radiative heat. The panel heater has a heating area of 1.75 m (W) × 1.38 m (H). Members can be exposed experimentally to surface temperatures up to 950 and a heat flux of 50 kW/m2.

Calorimetry Hoods (5 m × 5 m)

This unit is used to analyze the burning characteristics of furniture and equipment in a room by burning them and collecting the burning gas. The duct is equipped with devices for flow measurement and sampling. The design heat release rate is 2 MW at maximum, and the smoke suction power is 600 m^3/min at maximum. A movable unit (4 m × 4 m) is also available.

Full-Scale Compartment for Fire Experiment (with Water Pump)

This fire compartment is 6 m (W) × 6 m (D) × 2.7 m (H) in actual size, and the sprinkler system can be attached to the ceiling. The compartment is mainly used to evaluate the fire extinguishing performance of sprinkler systems and also has used for experiments on smoke movement during sprinkler system activation.

Room Corner Testing Unit (ISO 9705)

This unit is comprised of a space of 2.4 m (W) × 3.6 m (D) × 2.4 m (H) (approximately, the size of a 6-tatamimat room) and an opening 0.8 m (W) × 2 m (H). It can be used to recreate a fire in a room with furniture and dry walls, which can be developed into a fully developed fire.

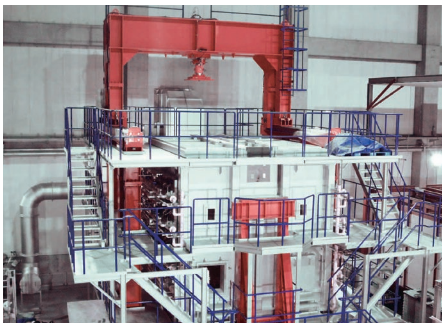
In addition, flashover experiments can be performed with this unit by recreating fires that spread to entire rooms in a short time period, and then combustible gas concentration and temperature distribution data can be collected. The development of the fire can be captured by video camera.

Structural Fire Testing Furnace (Medium scale)

This unit is used to evaluate the fire-resistive performance of various structural members such as columns, beams, floors and walls. The unit can control the heat to the standard heating temperature and furnace pressure set by ISO 834.The heating furnace, with dimensions of 1.5 m (W) × 1.5 m (D) × 1.5 m (H), can also provide immediate heating.

Structural Fire Testing Furnace (Large scale, for Walls)

This unit is used to evaluate the fire-resistive performance of an exterior wall under fire and can control the heat to the standard heating temperature and furnace pressure set by ISO 834. There are 20 burners on the lateral side, and this can heat up to a 3.5 m × 3.5 m area. The unit is also suitable for performing heat tests.



Multiple Full-scale Furnace

This device is used to measure the fire-resistive duration of horizontal materials of buildings including beams, floors and roofs by using the standard heating test (ISO834). Fire-resistive performance of any kind of horizontal materials can be evaluated by the heating test using this device. Put a full-scale model of 3 m (W) × 4 m (D) on the top the heater like covering it and then turn on the burner to heat the model from beneath.

Functional Materials
Established: April, 2021

watus@rs.tus.ac.jp

Water Frontier Research Center (WaTUS)

Director
Professor,
Department of Mechanical Engineering,
Faculty of Engineering
Masahiro Motosuke
Ph.D

Objectives	To discover principles and mechanisms of interaction between water and materials surface including how to control them by interdisciplinary research collaboration.
Future Development Goals	To promote advanced researches on water interface by collaboration, and to form a research organization offering one-stop service for water science and technology.

Water is one of the most familiar substances but there are many unexplained issues, especially around the interface with materials surface. We, WaTUS, tackle these researches relating to “water interface” by interdisciplinary approaches and aim to provide practical solutions to industries as well.

Core of excellence for research and development of “Water Interface”

Background

“Water” is one of the most essential substances which supports our basis of lives in various forms, and we, not only the human being but also all the life cannot survive without the benefit of water. It plays crucial roles to transfer oxygen, nutrition and waste, and to assist structuring and fulfilling cells, tissues and organs. Additionally, in industrial fields, it is of importance in drinking, cleaning, immersion, coating and so on. So, it is no exaggeration to say that water is the longest and most frequently used substance in our history. However, there are still plenty of unexplained issues in its properties, performance and function; especially, interaction between water and materials’ surface, namely “water interface”, is generally very complicated and particularly difficult to be fully understood (Fig. 1).

To tackle these issues, a former research center, Water Frontier Science and Technology Research Center (W-FST) was launched on November 2016. Through research activities of W-FST, it is found that the topic of “water interface” is crucial and is highly needed both for academics and industries. Then we concluded to keep our continuous challenges and progresses to these issues by expanding and deepening the fields. Then, the successive research center “Water Frontier Research Center (WaTUS)” has been established after the reorganization on April 2021 to highly promote our research activities. The logotype of our center (Fig. 2) represents “water” encompassing its molecule, nature of continuum, and interfacial behavior.

Our mission

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 (Fig. 3);

(i) Pursuit of state-of-the-art science and technologies of water interface by collaboration and technical excellence
(ii) Establishment of international research core of excellence
(iii) Provision of “one-stop service” of water researches for industries
(iv) 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.

Research organization of WaTUS

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 x 3 matrix-based research unit (Fig. 4), 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.

In addition, events such as the Water Frontier Symposium and evening seminars are held to promote the output of research activities and enhance mutual exchange among related researchers.

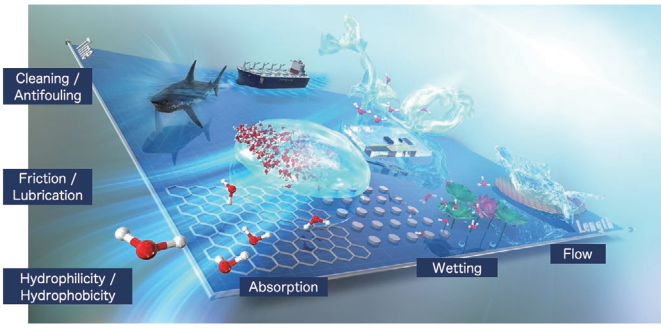


Fig. 1 Various phenomena and applications of “Water Interface” from atomic/molecular scale to macroscale

Fig. 2 Logo of Water Frontier Research Center (WaTUS)

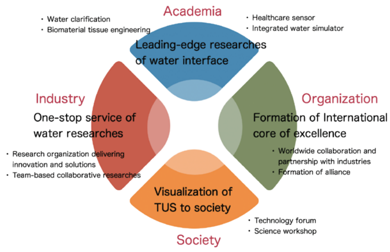


Fig. 3 Strategies of WaTUS

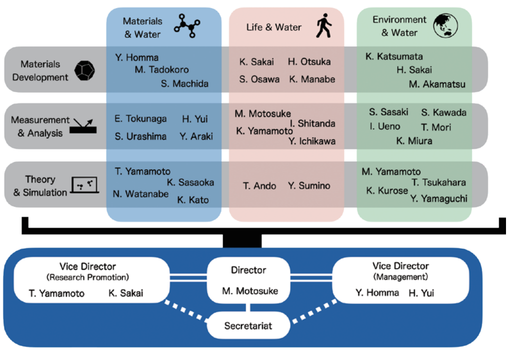


Fig. 4 Matrix-based research units in WaTUS

Established: January, 2022

a-kudo@rs.tus.ac.jp

Carbon Value Research Center

Objectives	We aim at developing technologies based on basic researches for green H_2 production and CO_2 utilization by converting it into valuable products.
Future Development Goals	We will contribute to achievement of carbon neutral and solution of resource, energy and environmental issues we are globally facing.

Director
Professor,
Department of Applied Chemistry, Faculty of Science Division I
Akihiko Kudo
Ph.D. (Science)

For a carbon neutral society, it is indispensable to develop technologies utilizing CO_2 as a carbon source for production of valuable compounds. Our CV center study science and technology using photocatalysts and batteries that are our strong research fields for the CARBON VALUE that contributes to the solution of resource, energy, and environmental issues.

Carbon value beyond carbon neutral ~ Green H_2 production and CO_2 utilization ~

Background of the establishment

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 discussion done here, "University Coalition for Carbon Neutrality" was established.

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.

Aims of our CV center

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.

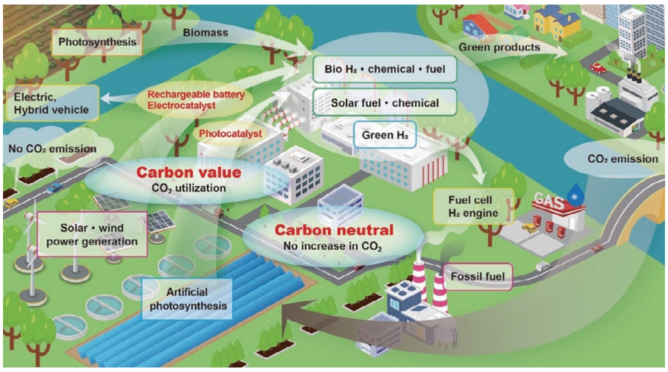


Fig. 1 Future vision that our CV center aims

Research system of CV center

About 10 researchers from Tokyo University of Science 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, life cycle assessment (LCA) simulation, CO_2 storage and adsorption, biological process, and measurement technology are also studied. The collaboration will be expanded to accelerate the research in the future.

Main research topics in our center

- **Manufacturing of highly-valuable products by CO_2 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.

- **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 are still remaining. To achieve carbon neutral, technological development of green hydrogen production from water with renewable energy is desired. Our 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.

- **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. Our 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 view point of stable supply of the alkaline metal resource. The secondary battery contributes to carbon neutral in an electric vehicle.

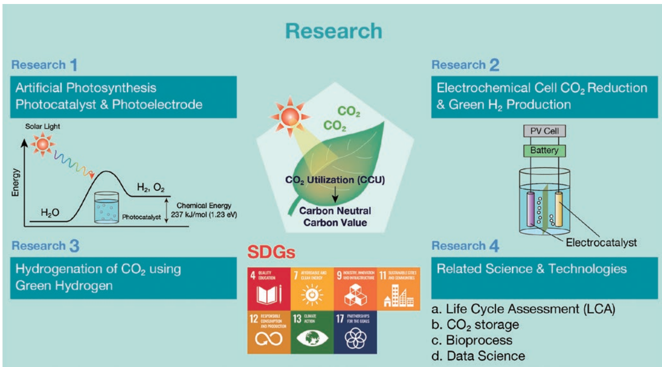


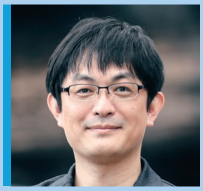
Fig. 2 Research topics in our center

Functional Materials
Established: October, 2012

takahiro@rs.tus.ac.jp

Division of Nanocarbon Research

Objectives	To investigate novel properties relating to carbon nanotubes and graphene, and to develop material sciences utilizing the nanospace of nanotubes and the interaction between nanotubes and various molecules.
Future Development Goals	To promote advanced researches on nanocarbons based on tight and highly active collaborations of division members.



Director
Professor,
Department of Physics,
Faculty of Science Division I

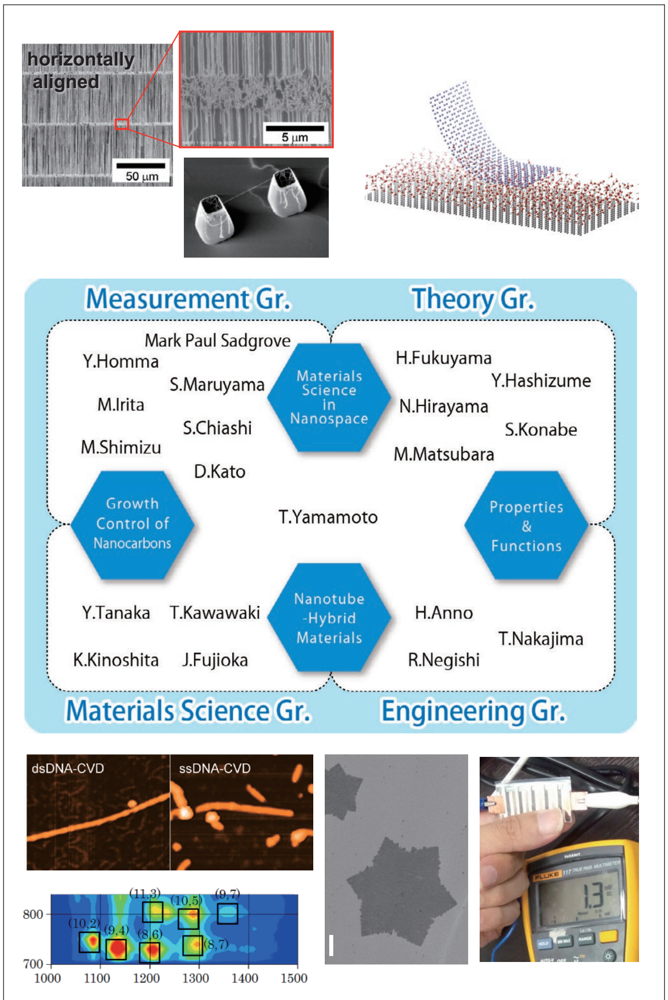
Takahiro Yamamoto
Ph.D.

Nanocarbon is an active research field with increasing publications. Our research division is unique in that advanced researchers of nanocarbons are getting together and perform researches with wide scopes. In particular, tight collaborations between theorists and experimentalists are our strength. We are aiming at creating new fields and technologies based on our researches.

Research and development on carbon nanotubes and graphene.

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 researches 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.



Research topics

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.

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.

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 substarte.
- 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.

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.

Functional Materials

Established: January, 1981

mhashizu@ci.tus.ac.jp

Division of Colloid and Interface Science

Objectives	To play a leading role in colloid and interface science both in Japan and the world.
Future Development Goals	Promoting researches on "experimental and theoretical elucidation of the dynamic behavior of interfaces" and "construction of new functional interfaces" in collaboration with different fields such as chemistry, physics, biology, and mechanical engineering.

Director
Professor,
Department of Industrial Chemistry,
Faculty of Engineering
Mineo Hashizume
Dr. Eng.

It may be said that knowledge in the field of surface and interface science is necessary to understand all tangible "things". We aim to utilize the strengths of the group of experts in various fields related to interface science, not only to connect the results obtained to the development of next-generation materials, but also to pioneer new academic fields.

Basic and applied researches on phenomena at various interfaces

Interface science is a field of study that deals points, lines, surfaces, and volumes (spaces), and uses geometry such as dimensions, sizes, shapes, boundaries, front and back, and connectivity as elements, and comprehensively systematizes these phenomena. In particular, 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), making it a unique academic field that deals with a wide range of research topics. 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.

Tokyo University of Science has traditionally had laboratories specializing in "interface science" on each campus. The Division of Colloid and Interface Science was established in 1981 by the researchers specializing in this fields, and has been active as a cross-campus and cross-departmental research center, and its activities are widely recognized in Japan and around the world. The first Director, Professor Kenjiro Meguro (Faculty of Science Division I) was succeeded by Professor Tamotsu Kondo (Faculty of Pharmaceutical Sciences), Professor Minoru Ueno (Faculty of Science Division I), Professor Kijiro Konno (Faculty of Engineering), Hiroyuki Ohshima (Faculty of Pharmaceutical Sciences), Professor Takeshi Kawai (Faculty of Engineering). Since 2018, Professor Hideki Sakai (Faculty of Science and Technology) has led the division as the director. In the meantime, the division had been shifted to the Center for Colloid and Interface Science during FY 2008-2012, because a project application was accepted as the MEXT Program for the Development of Strategic Research Bases.

We would like to introduce our recent activities. In FY 2013-2017 (Director: Prof. Kawai), we divided the research subjects of interface science into two major areas, soft and hard interfaces, and worked to deepen our understanding of dynamic interface phenomena. The soft and hard interfaces here are different from the general definition that distinguishes between then by the substances that make up the interface. A "soft interface" is a dynamic interface in which the molecules (atoms) forming the interface are constantly replaced during normal observation time, such as micelles (molecular assemblies) of surfactants. On the other hand, a "hard interface" is a rigid interface in which there is (almost) no replacement of surface constituent molecules (atoms), such as metal nanoparticles. The division members were divided into groups dealing with "soft interfaces" and "hard interfaces", and each interface was further classified into one-dimensional, two-dimensional, and three-dimensional interfaces. We promoted accurate understanding of the phenomena at the interface and "manufacturing" research using interface science (Fig. 1). The distinctive feature of this division is that researchers who conduct research on the theme of interface science from the aspects of chemistry, physics, bioscience, theoretical chemistry, etc., to carry out research from basic to application on interface phenomena through mutual information exchange and collaboration, while being conscious of "dynamics of interfaces" and "dimensionality of objects". Through the collaboration of the members, we were able to achieve synergistic results, especially with regard to "stimulus-responsive interfaces that respond to external stimuli such as light, temperature, and electricity".

In FY 2018-2022 (Director: Prof. Sakai), the researchers who specialize in physics, mechanics, pharmacology, theoretical science, and measurement science joined the membership, which was previously mainly consisted of chemists. With the support of advanced measurement science and theoretical science, we have set a new goal of conducting "accurate understanding of the interface dynamics/reaction mechanism at the interface" regarding "manufacturing using interface science". Especially in the fields of "advanced interface measurements", "stimulus-responsive materials", and "biofunctional interfaces", we were able to achieve many results, including collaborations among members with different specialties. We also strengthened our ties with industry by actively holding seminars by corporate researchers. In addition, we contributed to public outreach, such as by cooperating with open colleges.

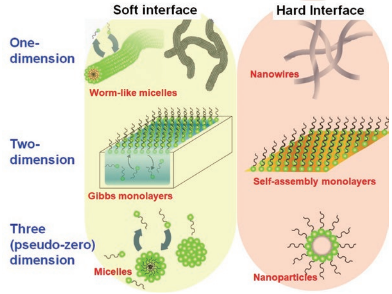


Figure 1

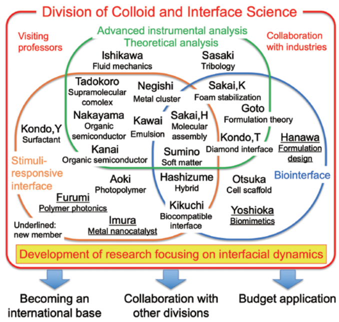


Figure 2

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.

Regarding the operation of the division, we have set "advanced interface measurements/theoretical analyses", "stimuli-responsive interfaces", and "biointerfaces" as priority themes, and promote research development with an awareness of collaboration between members while utilizing their specialties (Fig. 2). In particular, we will promote further collaboration between experts in both materials fabrication and theory in order to understand and utilize dynamics at interfaces as described above. In addition, we will work on creating a system that feeds back the results obtained in one material system to other systems and utilizes them. We will develop the results of "only at TUS", and integrate collaborations within the group, and in the future, we will open up new research areas by the entire division and lead to the acquisition of external research funds. We will also continue the cooperation with industry that we have cultivated so far, and promote activities such as seminars. As for international activities, we aim to effectively coordinate the efforts of individual members so far and develop the division into an international base.

Functional Materials

Established: April, 2020

solar@rs.tus.ac.jp

Renewable Energy Science & Technology Research Division

Objectives	To propose a foundation for stable and low-cost power supply/management, and to activate and promote research, development and education of renewable energy utilization technology at TUS.
Future Development Goals	Through active interaction among the Division members from different backgrounds, we will promote both internal and external joint research to create novel concepts for renewable energy technology.

Director
Professor,
Department of Electrical Engineering,
Faculty of Science and Technology

Mutsumi Sugiyama
Ph.D.

In response to the trend of times, this division is created by reorganizing the Photovoltaic Sci & Tech Division established in 2010. We are composed of members from different fields of expertise in various renewable energy devices and systems. We will develop unique renewable energy and integrated systems/infrastructures such as solar-wind-biomass power generation.

Research and development on renewable energy and systems such as solar, wind, biomass etc.

To solve the global warming problem, the biggest issue for humankind in the 21st century, it is necessary to substantially shift the energy sources from fossil energy such as coal, oil and natural gas to renewable energy. With this background, the predecessor Solar Power Generation Technology Division had worked to promote research of the University on solar power generation by disseminating the research results in Japan and worldwide, tackling the global warming problem. Meanwhile, in today world, there is a wide variety of research and development ongoing on "renewable energy" beyond solar, such as wind power, biomass power generation and fuel cells. In addition, at the time of the establishment of the predecessor Division, the power supply was simply based on nuclear power to provide a stable base power and thermal power generation to supplement the fluctuation of demand. However, nowadays many types of renewable energy are connected to the grid and the operation of the system infrastructures for stable power supply has become highly difficult and critical. We have therefore reorganized the Division, which previously focused only on solar, to include the entire "renewable energy", and defined the purpose of the new Division as following:

(i) Development of power generation materials that reduce the installation and operation costs to the same level as power generation by fossil fuels.
(i i) Development of highly efficient management technology for electric power from various power generation methods.
(i i i) Development of new materials and new system technologies.
(i v) Collaborations between our research division and external research institutes.

Members of the Division

The Division consists of 19 members listed as follows, who all have different fields of expertise in physics, chemistry, electrical power, electronics, materials and management. We are gathered together to deepen the discussion on the development of renewable energy utilization technology and aim for major developments through synergistic effects.

Table Members of Renewable Energy Science & Technology Research Division

Name	Job title	Affiliation of key role	Main research field
Mutsumi Sugiyama	Professor/ Director	Faculty of Science and Engineering, Department of Electrical Engineering	Semiconductor material engineering / Thin film solar cell
Takashiro Akitsu	Professor	Faculty of Science Division II, Department of Chemistry	Coordination chemistry / Photofunctional fuel cells of organic/ inorganic hybrid materials
Zhao Xinwei	Professor	Faculty of Science Division II, Department of Physics	Semiconductor nano-material engineering / Thin film photovoltaic cell
Yuzuru Ueda	Professor	Faculty of Engineering, Department of Electrical Engineering	Electricity and energy engineering / Photovoltaic system
Morio Nagata	Associate Professor	Faculty of Engineering, Department of Industrial Chemistry	Organic photovoltaic cell / Artificial photosynthesis
Junji Kondoh	Associate Professor	Faculty of Science and Engineering, Department of Electrical Engineering	Photovoltaic power system / Wind power generation / Power conditioning system
Noboru Katayama	Associate Professor	Faculty of Science and Engineering, Department of Electrical Engineering	Fuel cells / Hydrogen storage / Diagnosis for energy devices
Takashi Ikuno	Associate Professor	Faculty of Faculty of Advanced Engineering, Department of Applied Electronics	Surface and interfaces / Photovoltaic devices / Nanogenerators
Tomoyuki Haraguchi	Junior Associate Professor	Faculty of Science Division II, Department of Chemistry	Coordination chemistry / Dye sensitized solar cell
Yuka Takagi	Junior Associate Professor	Faculty of Science and Engineering, Department of Electrical Engineering	Ferroelectric Materials, Energy Storage, Metamaterials
Daisuke Nakane	Assistant Professor	Faculty of Science Division II, Department of Chemistry	Coordination chemistry / Bioinorganic chemistry / Catalytic chemistry
Cui Jindan	Assistant Professor	Faculty of Engineering, Department of Electrical Engineering	Photovoltaic system / Energy management system
Kohei Terashima	Assistant Professor	Faculty of Engineering, Department of Architecture	Solar heat utilization / Photovoltaic system
Yoichi Hirata	Visiting Professor	Suwa University of Science, Faculty of Engineering	Photovoltaic power generation system / Wind-power generation / Micro grid
Yasuyuki Watanabe	Visiting Professor	Suwa University of Science, Faculty of Engineering	Molecular electronics & Bioelectronics / Photosynthetic engineering
Sho Shirakata	Visiting Professor	Ehime University	Semiconductor material engineering / Thin film photovoltaic cell, CIGS solar cell
Satoshi Ohnishi	Visiting Researcher	National Institute for Environmental Studies	Energy economics / Low carbon city management
Ayaka Kanai	Visiting Researcher	Nagaoka University of Technology	Thin film photovoltaic cell / Optical Properties of Semiconductor
Daisuke Kodaira	Visiting Researcher	University of Tsukuba	Smart grid / Energy storage system management / PV generation forecasting

Research Activities

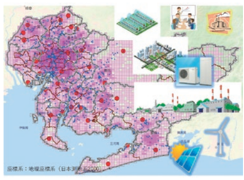
As a research and development hub for renewable energy technology, we will realize novel renewable energy materials and power generation systems through vertical integration of technologies, as well as educate the next generation of researchers and disseminate the technology to society. Specifically, the following activities will be carried out:

• Renewable energy materials group:

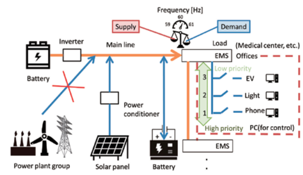
(i) Proposal of ultra-high efficiency power generation device by tandem configuration of thin film solar cells/thermoelectric generation elements.
(i i) Establishment of hydrogen production technology using solar cell thin films and charging technology such as supercapacitors.
(i i i) Development of ultra-low-cost solar and fuel cell materials and manufacturing methods, and examination of their common basic technology.

• Energy management group:

(i) Development of technologies of failure diagnosis, remote diagnosis, power generation prediction and AI utilization for energy loss control.
(i i) Integration of smoothing technology development for wind × solar power generation and power storage technology such as batteries and flywheels.
(i i i) Solar matching for agriculture and application of renewable energy technologies to smart houses.



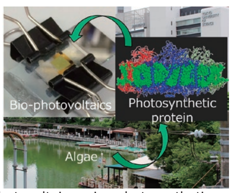
Design and evaluation on renewable energy system utilizing regional characteristics



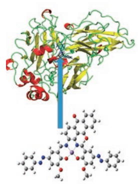
Renewable energy recovery system assuming a blackout due to a disaster

Monitoring of output power from multiple small wind turbines, and a prototype of a flywheel energy storage system

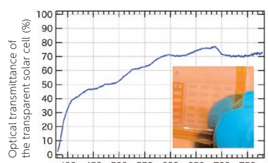
Polymer electrolyte membrane fuel cell and automatic humidity control system for supply air



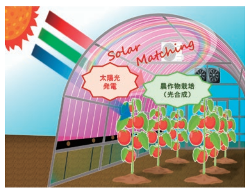
Bio-photovoltaics using photosynthetic proteins from algae



Photofunctional metal complex and catalytic enzyme for biofuel cell



Transparent solar cells fabricated on bio-derived transparent film substrates



Solar matching (Co-developing technology both photovoltaics and photosynthesis)

Figs. Research theme of Renewable Energy Science & Technology Research Division

Functional Materials

Established: April, 2021

gunji@rs.tus.ac.jp

Research Group for Advanced Energy Conversion

Objectives	This research aims at the development of novel “Only at TUS” energy systems based on SDGs by establishing elemental know-how of the systematic material-to-system research.
Future Development Goals	Practical use of secondary cells and fuel cell systems, building of efficient thermoelectric conversion systems, and the development of new light-reactive materials.

Director
Professor,
Department of Pure and Applied Chemistry,
Faculty of Science and Technology
Takahiro Gunji
Dr. Eng.

An efficient, new energy system based on Sustainable Development Goals (SDGs) is needed. In this group, specialists in chemistry, mechanical engineering, electronic engineering, and system engineering come together to develop and test a new, efficient system for the generation, storage, and utilization of clean energy by “Only at TUS”.

The development of a system for the generation, transformation, storage, and utilization of energy by “Only at TUS”

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 in order to achieve the goal of this research group early.

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.

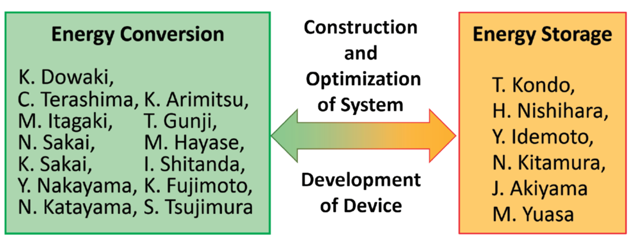
We will manufacture a printable wearable biofuel cell with paper and transfer sheet. For example, a fuel cell that uses organic material in urine as fuel can be used for urine detection (Elderly care, health maintenance). By using lactic acid in sweat as fuel, one can monitor the health of athletes. 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.



Structural Materials

Established: April 2023

rmatsuza@rs.tus.ac.jp

Division of Composite Materials Engineering

Objectives	Experts in various specialized fields, such as molding process, fracture mechanics, material science, and numerical simulation, collaborate to achieve rapid technological development, with a focus on composite materials.
Future Development Goals	The division aims to be a center of research and development where the results of basic research at the university are used as seeds to promote the development of applications in collaboration with industry.

Director
Professor
Department of Mechanical and Aerospace Engineering,
Faculty of Science and Technology

Ryosuke Matsuzaki

Doctor of Engineering

The division is equipped with an advanced experimental and analytical environment with faculty members who are capable of advancing research centered on composite materials in a cross-sectional manner. We also actively promote collaboration with industry, government, and academia outside the university. If you are interested in working with us, please feel free to contact the head of the division.

We conduct research on a wide range of lightweight and high-strength composite materials, such as CFRP, from the fundamentals to applications.

The Division of Composite Materials Engineering promotes research on composite materials with members who have extensive knowledge of materials and structures. Composite materials have been mainly used in the aerospace field, but their adoption in the automotive industry has been increasing in recent years, and their application to flying mobility is expected to expand in the future (Figure 1). In order to utilize composite materials in these new industrial fields, new design, evaluation, and molding methods specific to CFRP are required. In this division, research is being conducted with a particular focus on simulation technology and new forming methods.

Simulation technology ranges from material simulation at the atomic and molecular level to fracture analysis at the structural level, and is studied in parallel with experimental verification. With the recent improvements in computer performance, numerical analysis has become an important tool, and we are benefiting from it.

As a new forming method, we are focusing on 3D printing of composite materials (Figure 2). Conventional composite molding relies on the know-how of skilled craftsmen and molds, and as a result, it is difficult to produce a wide variety of products. On the other hand, general thermoplastic resin-laminated 3D printers have low mechanical properties of resin, making it difficult to fabricate aerospace and automotive product-level structures. However, recent progress in research on carbon fiber composite 3D printers has solved these problems, and high-strength 3D modeling for automotive and aerospace applications is now possible. In this division, research is being conducted on new optimal design methods applicable to carbon fiber composite 3D printers, understanding the mechanism of molding by 3D printing, and functionalization.

The division emphasizes industry-academia collaboration and serves as a partner for commissioned and joint research to meet the needs of industry. We also focus on training engineers in composite materials. Our goal is to create synergies between the university and industry by producing a large number of ready-to-work engineers who have acquired skills through research. Our research division is characterized by education and research activities based on strong collaboration between industry and academia.

Figure 1 We expect personal flight mobility to become commonplace with the development of composite materials engineering.

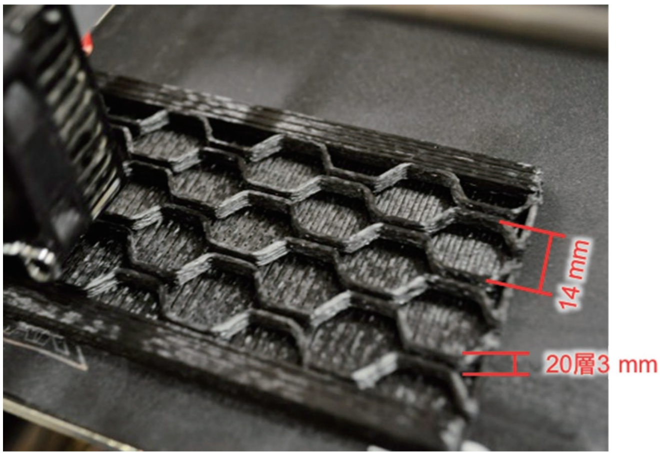


Figure 2 Honeycomb structure molded by composite 3D printer

hiroshi@kobalab.com

Division of Implementation of sustainable technology in society

Objectives	The objective is to provide concrete solutions to realize a sustainable society by creating new products which create new value.
Future Development Goals	To apply to NEDO and then obtain a large budget, to launch 1 new product/year, to establish 1 venture/year, and to apply for 3 patents/year.

Director
Professor
Department of Mechanical Engineering
Faculty of Engineering

Hiroshi Kobayashi
Ph.D

The true longing of engineering is to "make something useful." The social implementation of university-originated products mainly consists of publishing findings in papers and commenting on them as academics. Whereas, in engineering, I think that we should implement it as a real object and even see how it's used and useful. This division aims to be a role model for the social implementation.

Commercializing university-originated medical, welfare, and life support technologies and energy ones that will realize a sustainable society.

First goal is social implementation

With a strong awareness of practicality and realization, this division aims not only to produce papers but also to commercialize technologies that create new value and open up new markets.

Therefore, as shown in the table below, we will combine the elemental technologies possessed by the contributors, actively collaborate with external organizations (participants from external organizations are underlined), and conduct collaborative research and development with an awareness of specific applications as an exit. is performed.

At the moment, there are only a few external organizations, but we will ask them to participate as needed according to the progress and strengthen cooperation beyond formality.

In addition, we will commercialize products and start ventures, and actively promote social development of new technologies originating from universities.

Compared to IT and materials/devices that spread rapidly around the world, the creation of "products" as "things", especially as integrated systems of technologies that are directly related to our daily lives, has high risks and extremely poor cost performance.

For this reason, commercialization at universities tends to be generally avoided, but since universities are public institutions of society, we will propose new solutions to society in the form of "real things."

Members and R&D content

Table 1 shows the specialized classifications of the members and the specific items of applications that combine them.
This field is mainly classified into (1) motion analysis/sensing (images/measurement and analysis in the table), (2) motion assistance/creation devices (mechanisms/devices and control in the table), (3) vehicles, and (4) field verification/evaluation.

(1) are Kobayashi, Hashimoto, Takemura, Iida, Arai, Hobara, Hayakawa, Kasai, Ushijima, Huang, and Yoshida; (2) are Wada, Kobayashi, Hashimoto, Takemura, Iida, and Hobara; Matsumoto and Kasai each specialize.

For example, (1) A. Precise walking motion analysis device and B. Swallowing sensor, (2) C. Assist device and prosthetic arm/leg, and (3) D. Highly intuitive operation interface and omnidirectional mobile device. We will create various deliverables by consolidating each knowledge.
The details are described below.

Kobayashi, Takemura, and Hobara will lead the development of a sensor that extracts the three-dimensional displacement of the body during walking and the rotation angle around three axes with high accuracy.

Yoshida, Miyashita, Tabata, and Huang link the movement of the whole body with dynamic models and image analysis.

Accurate walking motion data of healthy and non-healthy subjects will be accumulated, tools will be prepared to quantitatively indicate changes after diagnosis and treatment, and practical application and commercialization will be examined.

Kurusu and Matsumoto will acquire data at the clinical site.

In B, Hashimoto will lead the development of a swallowing sensor to determine the presence or absence of aspiration in daily life and to encourage early rehabilitation intervention.

Currently, we are researching a unique sensing technology that can simultaneously measure body sounds, muscle activity, and laryngeal elevation during swallowing using a piezo film.

In addition, together with Kobayashi, we are developing a robot simulator to clarify the swallowing mechanism, and we can make use of the knowledge obtained.

In addition, Iida's world-leading soft robotics technology will be used to develop sensor devices with high biocompatibility and no discomfort when worn.

Kurusu and Matsumoto conduct evaluation experiments in clinical settings to evaluate the practicality of the medical and welfare equipment described above.

In addition, by providing feedback to each group, the development for practical use can be advanced efficiently.

Kobayashi, Takemura, and Hobara have already put C into practical use.

Wada, Hayashi, and Nagano are the main members of D, and conduct research and development on the design and control of mobile units and related systems that support the mobility of people with disabilities and the elderly.

It integrates elemental technologies such as electric motor control technology that realizes the movement of mobile objects, comfortable and intuitive control interface, self-position recognition and route planning technology for mobile objects, remote control, automatic driving/navigation technology, and so on.

Furthermore, by further expanding the application range of the original technology "Active Caster" developed for the omnidirectional movement system, we will consider practical application to wheelchairs and senior cars using practical mobile robot technology.

Table1 The specialized classifications of the members and the specific items of applications

Technology \ Application	Medical and Welfare	Livelihood Support	Agriculture	Infrastructure・Production・Industry	Resource・Energy
	·Rehabilitation ·Diagnosis ·Examination ·Welfare Vehicle ·Motion Assist	·Motion Assist ·Monitoring ·Automatic Driving ·Sports	·Motion Assist ·Automatic Cultivation/ Harvest ·Genetically Modified	·Motion Assist ·Digital Fabrication ·Laboratory Automation ·Recycle	·Binary Power Generation
Vehicle・Car	Wada, Kurusu	Hayashi, Wada	Kobayashi, Iida, Arai	Arai	
Mechanism・Device	Kobayashi, Hashimoto, Takemura, Iida, Wada, Kurusu, Matsumoto S.	Kobayashi, Hashimoto, Takemura, Iida, Matsumoto K., Wada, Nagano, Hobara, Kurusu, Matsumoto S.	Kobayashi, Takemura, Iida, Arai, Hobara	Kobayashi, Hashimoto, Arai	Kobayashi
Visual/Signal Processing・Measurement	Kobayashi, Hashimoto, Takemura, Iida, Arai, Hobara, Hayakawa	Hashimoto, Takemura, Hayashi, Arai, Matsumoto K., Hobara, Tabata, Miyashita	Takemura, Iida, Arai, Hobara	Takemura, Iida, Arai, Hobara	Arai
Analysis・Control	Kobayashi, Takemura, Ushijima, Iida, Wada	Kobayashi, Hashimoto, Takemura, Hayashi, Matsumoto K., Wada, Nagano	Iida, Arai	Hashimoto, Yoshida, Ushijima, Iida, Arai	Ushijima, Arai
Robotics・Humanoid	Yoshida, Iida, Arai	Hashimoto, Yoshida	Iida, Arai	Yoshida, Arai, Huang	

Target results

In accordance with the progress of research and development, we will periodically review specifications, prioritize them, roadmap for commercialization, and new developments. We will operate with the goals of 1 new product launch/year, 1 start-up venture/year, and 3 patent applications/year.

shiina@rs.tus.ac.jp

Research Center for Drug Discovery and Applied Sciences

Objectives	Our goals include the efficient production of pharmaceutical products from natural and/or artificial compounds. In our research center, our team will collaborate with researchers within the campus, as well as outside, who have made considerable achievements in the field of molecular biology, thereby completely exploiting synthetic organic technologies from which the representative research can derive its strength.
Future Development Goals	Recently, the discovery of new medicines originating from academia via industry-university collaboration from an industrial viewpoint has attracted a significant amount of attention. Results obtained from such research provide a methodology for solving various issues associated with the development of drugs derived from natural sources.

Director
Professor
Department of Division of Applied Chemistry,
Faculty of Science Division I
Isamu Shiina
Ph.D

In this project, novel biological research will be conducted by completely exploiting organic synthesis technology, referred to as the "total synthesis of naturally occurring products," which has been scarcely used so far for the discovery of new drugs. Synthetic studies based on natural product-derived compounds lead to the production of novel drugs with a unique mechanistic MOA and pave the way for the treatment of intractable diseases that have not been treated thus far.

Structure-Activity Relationship (SAR) and Mode of Action (MOA) Studies Using New Compounds Developed at the Tokyo University of Science

Development of New Synthetic Methods for the Effective Transformations in Organic Chemistry

A majority of the products that are 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. Hence, in 2002, our team 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.

Dehydration condensation is a structural transformation where two hydrogen atoms and one oxygen atom are simultaneously removed from organic molecules, and two compounds are ligated using a reagent such as a dehydrating condensation agent. For decades, dehydration condensation has been employed to construct the basic skeleton of pharmaceuticals. However, as conventional methods require harsh reaction conditions, including the use of an acid catalyst or high temperatures, issues related to the destruction of reagents or compounds that serve as the raw materials were noted.

With the establishment of the Shiina laboratory in 1999, compounds and reaction conditions for the invention of the fastest dehydration condensation reaction in the world were thoroughly analyzed, which finally led to the development of MNBA.

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 (Please check YouTube using "YouTube MNBA Shiina" as the keyword, Fig. 1).

Fig. 1 Efficient Synthesis of Various Compounds Using MNBA (The Shiina Research Group)(https://www.youtube.com/watch?v=Dw1ajJchujw)

A New Method for the Inhibition of Cancer Cells (Total Synthesis of Vesicle Protein Transport Blocker, M-COPA)

In this center, research on the "Development of New Reactions" and "Total Synthesis of Natural Products" is interconnected as major research topics. Total synthesis involves the artificial synthesis of natural-derived chemical substances with complex molecular structures using a minimum amount of raw materials. For example, some rare chemical compounds extracted from soil-borne bacteria exhibit anticancer properties. If these compounds can be artificially synthesized, not only the stable production of medicines can be achieved but also the chemical structures that are optimum for pharmaceuticals, including the suppression of side effects, can be designed.

In the total synthesis research, MNBA is predominantly used for the synthesis of organic compounds exhibiting anticancer properties.

Our team completed the total synthesis of M-COPA, which limits the function of the Golgi apparatus that is responsible for the transport of intracellular proteins. Both domestic and international research groups have attempted to apply this compound to cancer cells activated by the Golgi apparatus to block transportation pathways and to suppress the growth of cancer (Fig. 2). At the Shiina laboratory, our team has worked toward the development of a large-scale method to prepare M-COPA for use in animal experiments.

Each reaction step was analyzed to ensure gram-scale production, or higher, of M-COPA with seven consecutive stereogenic carbons. Our team established largescale synthesis by effectively employing organic reactions, such as asymmetric aldol reaction, intramolecular Diels–Alder reaction, and MNBA dehydration condensation reaction. Experiments to verify the effect on cancer cells using M-COPA via total synthesis have been conducted, and even the inhibition of proliferation of cancer, which has been thought to not be cured using the current anticancer drugs, has been observed. In addition, other outstanding achievements have been consistently reported in articles. The design of a synthetic method in the anticipation of the development up to industrial use has played an important role in successfully achieving this objective.

In addition, these results have also been presented on YouTube.

These can be viewed on the YouTube handle "YouTube M-COPA Shiina" or "YouTube Shiina Laboratory TUS."

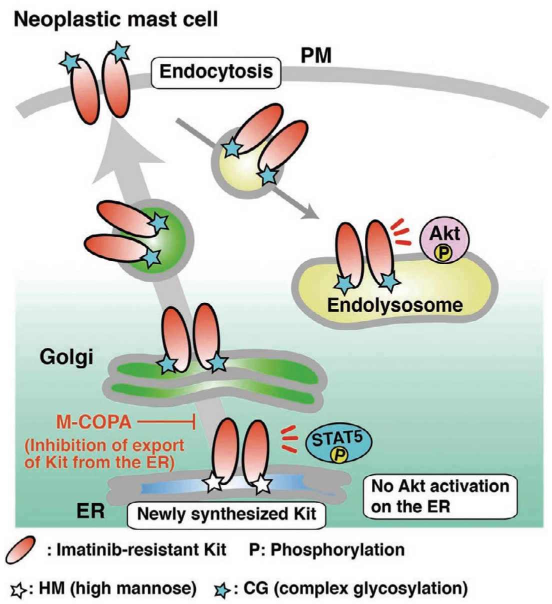


Fig. 2 Proliferation Suppression Mechanism of Cancer Cells using M-COPA (Fig. 2 was created by Dr. Yuuki Obata who collaborates with Prof. Shiina: *PLOS ONE*, 12(4), e0175514 (2017))

Bio and Pharmacy

Established: April, 2019

twada@rs.tus.ac.jp

Division of Nucleic Acid Drug Development

Objectives	We aim to create nucleic acid drugs to treat unprecedented target diseases through the synthesis of novel chemically-modified nucleic acids and the establishment of DDS and formulation methods.
Future Development Goals	Our goal is to make a breakthrough in the field of nucleic acid drugs through the collaboration of researchers within the university.

Director
Professor,
Department of Pharmaceutical Sciences
Takeshi Wada
Doctor of Science

This division was established by the cross-departmental team of in-house researchers working on the nucleic acid or other related research fields. By succession of networks and joint researches created through the activity of the TR center, we aim to develop innovative nucleic acid drugs from TUS.

Development of nucleic acid-based drugs that are expected to be a next-generation drug

History of This Division

The TR (Translational Research) center, which was the former organization of this division and lasted until 2018, got notable results in the field of nucleic acid drug. Also, nucleic acid-based drugs have recently attracted much attention as a next generation type drug. There are a plenty of researchers who work on nucleic acids at TUS, and the most of them took part the activity of TR center. Then, "round-table conference on nucleic acid drugs and DDS" was established in 2017 (representative: Prof. Makiya Nishikawa), and we have active discussions on nucleic acid drugs. Under these circumstances, the Division of Nucleic Acid Drug Development was established as a subsequent organization of TR center in April 2019.

Research Objectives

The development of nucleic acid drugs requires a knowledge from wide range of research field. There are many prominent researchers who work on nucleic acid or related research at TUS, thus innovative and unique results are highly anticipated through their collaborations. In this division, one of our mission is the development of novel nucleic acid derivatives which overwhelm conventional ones in the viewpoint of efficacy, stability and safety. Also, we aim at establishing the cationic molecules and formulation technology which stabilize and improve pharmacokinetics of nucleic acid drugs. We chose immune system, metabolic system related diseases and cancer as targets. As just described, the development of original nucleic acid drugs targeting unique diseases are highly expected by gathering of in-house competent researchers in this division.

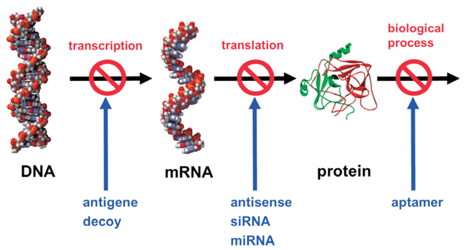


Figure 1 Oligonucleotides as therapeutic agents

Members

In-house Members

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)

Faculty of Science

Satoru Miyazaki (Bioinformatics)
Hidetaka Torigoe (Biophysical chemistry)
Hidenori Otsuka (Polymer chemistry)

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)

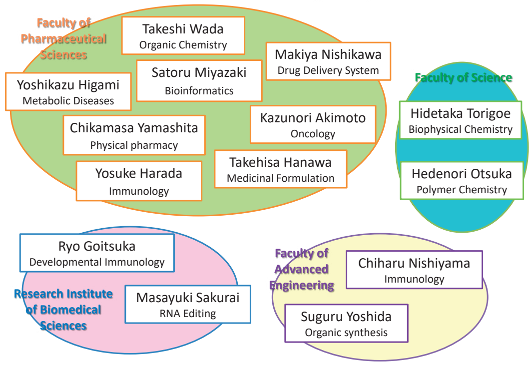


Figure 2

Current Situation of Nucleic Acid Drugs and Our Research Topics

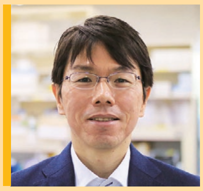
Nucleic acid-based drugs are anticipated to be an epoch-making remedy for the treatment of intractable hereditary diseases. The global market size of nucleic acid-based drugs is predicted to expand to 19 billion dollars in 2030 from 2 billion dollars in 2018, according to the estimation of Seed Planning Inc., a marketing research and consulting enterprise. Although much efforts have been devoted to the research of nucleic acid-based drugs, only 17 drugs have been approved so far. There are a lot of challenges to overcome for the development of potent nucleic acid drugs, and a break-through is required for the further progress of this area. To address this issue, we are dealing with following topics;

1. Development of an efficient method to synthesize boranophosphate oligonucleotides which is anticipated as an alternative candidate of phosphorothioate
2. Establishment of a scalable synthetic method of artificial cationic oligosaccharides and peptides that bind to and stabilize nucleic acids.
3. Construction of a highly target selective drug delivery system through the elucidation of interaction between nano-structured nucleic acid and cells
4. Development of antisense drugs that target such as wound and bladder cancer remedy
5. Development of a novel formulation method of nucleic acid drug
6. Research on the control of aging, aging related diseases and metabolic abnormalities by nucleic acid drugs
7. Development of nucleic acid drugs which regulate autoimmune response and rejection reaction during an organ transplantation
8. Development of effective breast cancer drugs using novel artificial cationic molecules and siRNAs
9. Establishment of investigation technology via bioinformatics and AI to determine the sequence of a mRNA that codes disease-related protein

ikawa@rs.tus.ac.jp

Division of Synthetic Biology

Objectives	Using informatics analysis and modern biotechnology such as DNA synthesis, cell fusion, microinjection and microscopic laser technology, we create genetically transplanted cells.
Future Development Goals	Emphasis on ethical, legal and social impacts, we aim to establish genome transplantation technology with sufficient safety measures.



Director
Professor,
Division of Immunology and Allergy
Tomokatsu Ikawa
Ph.D.

We will promote our synthetic biology projects that create cells with our frontier spirits. This research division can become a platform for joint research, information sharing and technology exchange with synthetic biology researchers.

We create genetically transplanted cells, which will contribute to useful substance production and medical technology.

Synthetic biology is the study to elucidate the biological principle through artificial cells with DNA synthesis. Pet animals such as dogs and cats, horticultural crops such as orchids, livestock such as mules and chickens, and multiple species of agricultural products such as wheat and fruits are hybrids by crosses of related species. Since ancient times, we have created and used such genomic hybrid organisms. Current technological innovations have also enabled crosses and transfer of genomes other than closely related species. In order to create a frontier area from the modern biotechnology, we will promote departmental research. Our research is conducted with strict awareness of ethical, legal and social issues. With a view to the development of useful substance production technology and medical technology in the future, we will promote the following three research subjects with the aim of establishing a genome transfer technology with sufficient safety measures.

Strategy 1: Plant genome transplantation

There are many modules in the plant genome that are not found in animal genome, such as photosynthetic modules, pigment modules, and metabolic pathway modules that produce medicine materials. By transplanting these plant modules into the animal genome, we aim to impart new functions to animal cells. We call artificially photosynthetic animal cells “planimal cells” (Figure 1).

Strategy 2: Genome transfer beyond the species barrier

Even close relatives, there is a “species barrier” in genome crossing between organisms. Therefore, we aim to create ascomycete hybrid cells that enable useful substance production by genome engineering and cell fusion.

Strategy 3: Cell creation leading to regenerative medicine

Methods to control cell proliferation and cell metabolism are needed to promote the production of spheroids and organoids. We aim to develop technologies that can be safely applied to medical technology by incorporating a regulatory system with epigenetic and optogenetic techniques.

Through this department, the fields of biology divided into microbiology, botany, zoology and medical science can be fused to make it possible to elucidate the basic principles of life.

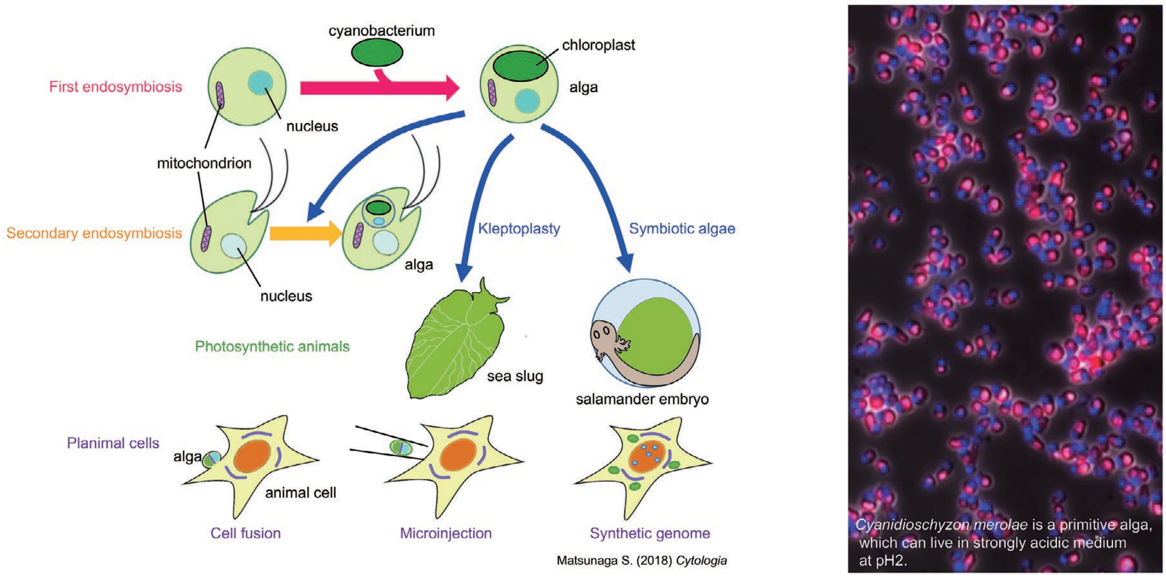


Figure 1 Creation of artificially photosynthetic animal cells “planimal cells”

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Division of Biological Environment Innovation

Director
Professor
Department of Biological Science and Technology,
Faculty of Advanced Engineering
Gen-ichiro Arimura
Ph.D.

Objectives	We 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.
Future Development Goals	We will create a new revolutionary academic field that has never existed by fusing individually developed research areas such as environmental biology and ecology.

With the theme of "environment," we will elucidate the environmental adaptability and molecular evolution mechanisms of various species, such as plants, mammals, reptiles, amphibians, fish, insects, and fungi species. We will explore applications of novel discoveries to aid the preservation of natural ecosystems and biological diversity.

Bioenvironmental research with the aim of creation of synergy between academic fields and technological seeds in an environmentally changing society.

Summary

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 produce new technological seeds that will contribute to protecting our lives in a global environment that is always changing.

<Section of Environmental Adaption>

We explore 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 biologial 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, Kenji Hashimoto, Takuya Sakamoto (Kanagawa Univ.), Sachihiro Matsunaga (Univ. of Tokyo)

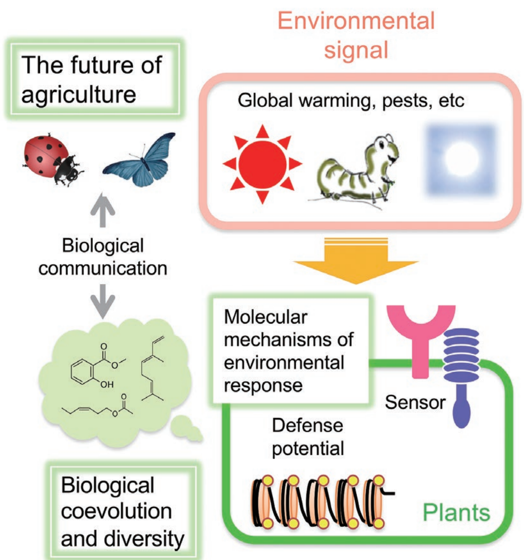


Figure 1

<Section of Molecular Evolution>

We analyze the mechanisms of genomic evolution and biology's central dogma that enable adaptation and diversification of life from the viewpoint of evolution, which has been overlooked in the past. We also aim 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

Members: Koji Tamura, Toshiki Furuya, Mitsunori Shiroishi, Masayuki Sakurai, Takashi Nakajima, Kazunori Okada (Univ. of Tokyo), Akiko Soma (Chiba Univ.)

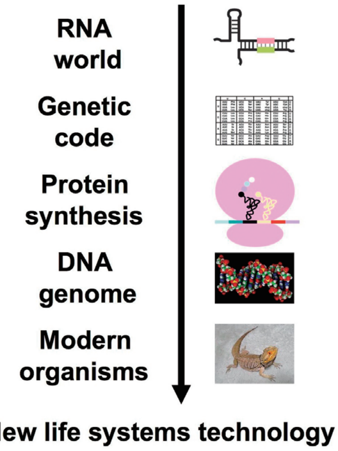


Figure 2

<Section of Nature Symbiosis>

We advance 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 (NIEFS)

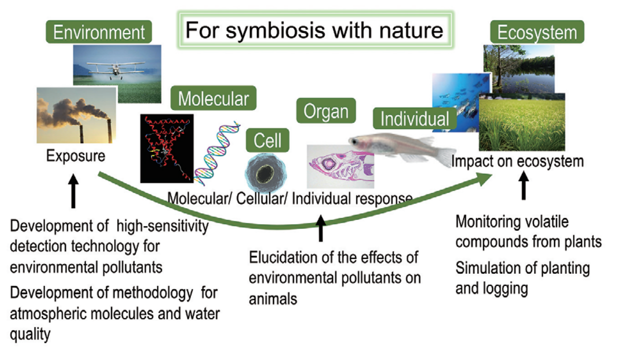


Figure 3

Established: April, 2021

makiya@rs.tus.ac.jp

Development of superior cell and DDS for regenerative medicine

Objectives	To develop "superior cells" and DDS that can precisely control the function and in vivo fate of the cells for accelerating regenerative medicine.
Future Development Goals	To create a novel and unique research field focusing on "superior cells" by collaboration of researchers with a variety of expertise.

Director
Professor
Department of Pharmacy
Faculty of Pharmaceutical Sciences

Makiya Nishikawa
Ph.D.

Cell-based therapy and regenerative medicine can be greatly accelerated by applying the concept of drug delivery system (DDS), i.e., drug delivery at the right time, at the right site of action, and in the right amount, to cells that are administered to patients for disease treatment. This division aims at developing "superior cells" whose functions are extremely upregulated and DDS that improves their functions.

Development of superior cells and DDS for accelerating regenerative medicine

History and Background of This Division

This division has a root in the DDS Research Division established in the Research Institutes for Science and Technology, Tokyo University of Science in 2003. In "Fusion of Regenerative Medicine with DDS Division" started from 2015, researchers headed by Professor Kimiko Makino have conducted collaborative researches focusing on regenerative medicine and the development of DDS for intractable diseases. To continue these activities, a predecessor round-table conference on Superior Cells and DDS Development for Regenerative Medicine was founded on 2020, which has been re-established as a division in April 2021.

Research Purposes and Goals of This Division

Under the overall goal of accelerating cell-based therapy and regenerative medicine, this division is focusing on (1) the development of "superior cells" by functionalizing the cells administered to patients for therapeutic purposes, and (2) the development of DDS that can precisely manipulate the in vivo distribution of cells and other functional molecules. The research purposes also include the development of therapeutic modalities against respiratory, brain, immune, cancer, and bone diseases.

Members and Their Roles in This Division

The four groups below cooperate with one another to accelerate the group research.

(1) Superior cell/DDS development group
This group designs and constructs superior cells, and develops DDS aiming at controlling the function and in vivo distribution of cells and other functional bioactive molecules. A goal is to develop "superior cells" that super-exceed the existing cells in terms of cellular functions through (1) the addition of novel functions, (2) the development of multicellular spheroids/organoids, and (3) the use of exosomes and other extracellular vesicles. In addition, various delivery systems are developed and applied to the superior cells and their usefulness is examined in animal models.

(2) Cell function regulation system development group
This group creates novel compounds that regulate cellular functions, and functional materials that can be used in cell-based therapy and regenerative medicine. These compounds and materials are supplied to other groups for applications and analysis. The data obtained using them are used for the development of more functional compounds/materials.

(3) Physical property control/analysis group
This group evaluates the physical properties of the items developed by the superior cell/DDS development group and the cell function regulation system development group, including superior cells, delivery systems, and functional compounds/materials. This group supports the optimization of these items by data feedback to the corresponding groups.

(4) Cell/tissue regeneration group
This group investigates the mechanisms of the regeneration of the lung, bone and other tissues, and treat the diseases of these tissues/organs. The interaction of superior cells/DDS and the immune systems is also analyzed.

Figure 1 summarizes the members and roles of each group. This division develops superior cells and DDS regenerative medicine by constructing organic interrelationships among the members of the division in pursuit of a new-stage collaboration.

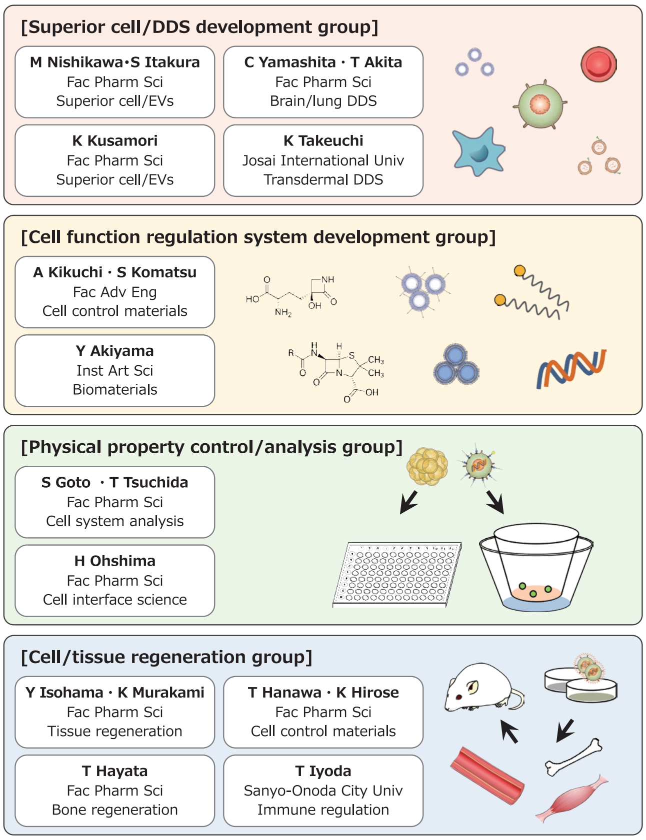


Figure 1 Members and roles of each group.

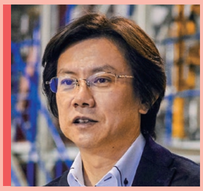
Information and Societal

Established: April, 2004

kmatsu@rs.tus.ac.jp

Center for Fire Science and Technology

Objectives	To promote the development of fire science and fire safety engineering, as well as the training of young researchers and specialist professionals.
Future Development Goals	To establish an education and research center at the highest level of the world, to meet various social demands concerning fire safety, and to contribute to society.



Director
Professor,
Department of Global Fire Science and Technology,Graduate School of Science and Technology
Ken Matsuyama
Dr. Eng.

Safety and security play pivotal roles in social development. TUS has, as a core of the fire safety engineering community both domestically and internationally, contributed to their advancement. In recent years, major cities in East Asia in particular have been undergoing marked development at a speed that no other Asian countries, including Japan, have ever experienced. We have a duty to mitigate this urgent situation sufficiently and, at the same time, to develop the innovative educational research system to prevent the occurrence of such fire accidents.

Research on the safety technology to protect human life and property from fires, and research on the fire science to support it.

Fire science at TUS

In 1981, Tokyo University of Science established Department of Fire Science and Technology in its Institute for Science and Technology. The aim was to set up a research center that would promote research on the safety technology to protect human life and property from fires, and research on the fire science that supports the technology. This development was initially started by the inauguration of a course on Architectural Fire Safety Engineering when the Department of Architecture, TUS was founded some 50 years ago. In this way, TUS laid the foundations of research and education on fire science ahead of the times, when such developments were unknown in other universities. These foundations have yielded a strong record of accomplishment of achievements since then, as amply illustrated in the fact that we have received two prestigious awards from the International Association for Fire Safety Science, the highest authority body of its kind in the world. The first of these was awarded for "Meritorious achievements in research contributing to the advancement of fire safety science", and the second was for "Meritorious achievements in education producing numerous researchers in fire science". In the past, Japan has suffered many fires in large buildings, which have claimed a large number of human lives. Members of the Department of Fire Science and Technology, TUS have been involved in appraising the majority of these serious building fires since 1968.

In recognition of this record of accomplishment, the Department was included in the 21st Century COE Program of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in fiscal 2003, as a "Center of Advanced Fire Safety Science and Technology for Buildings". It is currently engaged in activities aimed at establishing itself as a research and education center on fire science and fire safety engineering at the world's highest level. Other aims are to promote the advancement of fire safety engineering and the training of young researchers and specialist professionals. We will continue our efforts in offering innovative education and research to protect human lives and properties from fires. Following the 21st Century COE Program, which concluded in 2007, the Global COE Program 2008, which would conclude in 2012, further adopted the "Center for Education and Research on Advanced Fire Safety Science and Technology in East Asia". Now, the Center restarted as a five-year project after having been selected as a 2013 recipient of the Private University Strategic Research Formation Assistance Grant from the MEXT. "Fire Safety Information Center in Asia based on Sharing Expertise-New Fire Safety in Information Society" was started. Fire Safety Information in Asia as a research base that focuses on building a network of networks, and works together to reduce fire risk in Asian cities, we have realized the global development of science, which is an issue for the 21st century.

Since April 2018, it has been playing a role as permanent organization of "Fire Science Research Center", as a center for fire science and fire safety engineering that represents East Asia.

Fire Research and Test Laboratory

Taking the opportunity of being adopted as the 21st Century COE Program, this laboratory was built in March 2005. It is one of the largest and most functional laboratories in the world meant solely for fire science. Built at Noda campus, it has a building area of 1,500 m², and gross floor area of 1,900 m², and a height of 20 m (Photo1). Members of the Center constructed a basic plan and did the designing utilizing their wealth of experiences, so that the laboratory would enable us to promote world-leading researches on fire sciences.

In March 2006, a large-scale fire furnace was added. Other large-scale experimental facilities to be included in the laboratory are composite furnace, fire resistance assessment machines for exterior wall materials, and combustion performance testing facilities, which are needed internationally, to contribute to the advancement of innovative researches.

Graduate School of Global Fire Science and Technology

The Master's Course in Fire Science & Technology at the Tokyo University of Science's Graduate School of Global Fire Science & Technology was established in April 2010 is the first postgraduate fire science course in Asia, and is aimed at those employed in the area of fire science and safety (such as the construction, firefighting, and non-life insurance industries) as well as students from Japan and overseas who want to become fire safety technicians and fire officers.

The graduate school represents one aspect of the MEXTs Center of Excellence (COE) program, "Center for Education and Research on Advanced Fire Safety Science & Technology in East Asia", being promoted by the Center for Fire Science and Technology, and aims to establish Asia's first definitive fire science education facility. The school to familiarize students with basic theory in a practical setting uses the Fire Research Test Laboratory.

In addition to the Master's Course, students also have the opportunity to continue their studies, such as Doctoral Course in Fire Science & Technology established in April 2012. The Department of Global Fire Science and Technology is scheduled to be set up in April 2018 under the Graduate School of Science and Technology by reorganization of the Graduate School.

Designated Performance Evaluation

In order to improve fire safety technology and improve reliability at the Fire Science Research Center, the Building Standard Law has been applied to the construction method of buildings as a designated performance evaluation body designated by a designated performance evaluation body of the Ministry of Land, Infrastructure and Transport. Carry out performance evaluations required to obtain Minister of Land, Infrastructure, Transport and Tourism approval.

Performance evaluation is conducted by an evaluator who has expert knowledge of the field of performance evaluation based on the business method approved by the Minister of Land, Infrastructure, Transport and Tourism.

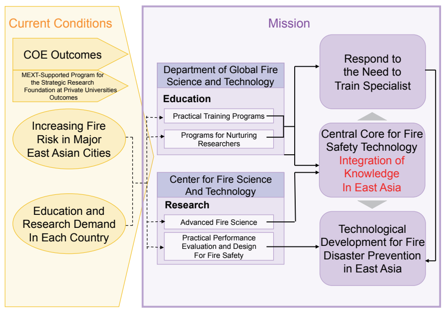


Fig. 1 Perspective of the Center for Fire Science and Technology

Photo 1 Fire Research and Test Laboratory

Fig. 2 Home Page
[Center for Fire Science and Technology]
https://gcoe.tus-fire.com/

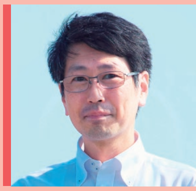
Information and Societal

Established: April, 2021

ssi@rs.tus.ac.jp

Research Center for Space System Innovation[SSI]

Objectives	To develop a virtuous cycle between earth and space research and solve various problems common to both.
Future Development Goals	Through technology transfer to collaborative private companies, SSI aims to enhance state-of-the-art technologies that can improve life on earth and are usable in space.



Director
Professor,
Department of Electrical Engineering,
Faculty of Science and Technology

Shinichi Kimura

Ph.D.

The goal of the center is to become an innovation-driven hub for outer space and earth research through collaboration with various entities. These collaborations will allow innovation by fostering excellent human resources. Researchers, businesspersons, and students can explore the frontiers of space.

Living in space, bringing benefits to earth!
−Trial for Space-Terrestrial Dual Development on Space Living and Spacecraft−

Background of SSI Establishment

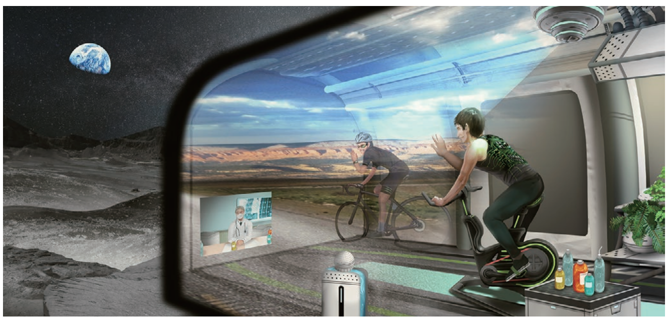
In recent years, space research has gained considerable attention. Space systems are multidisciplinary, and in addition to aerospace engineering, require expertise of various domains. As exemplified by recycling-based living in the closed environment of space, technologies required for humanity to reach into space are closely related to solving various earth-related problems, such as sustainable development and a recycling society.

About the Center

By pooling research and education activities related to space development and space environment utilization at Tokyo University of Science, the research center can be used for comprehensive analyses of various technological challenges, including research related to space travel.

The aim is to develop a creation hub in which cross-disciplinary technologies and human resources can be pooled to form a virtuous cycle to solve problems common to both space and earth.

- By utilizing photocatalytic technology, which is the specialty of our university, we aim to develop life-support technologies in space and realize a safe and comfortable living environment on earth.
- We will demonstrate suborbital spaceplanes under development, and develop a new "space" market in partnership with the 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 strategic development.
- We will provide a place for education based on space research opportunities, secure and foster PhD students and young researchers, and develop an environment where they can experience "real" research.



Research Organization of SSI

▪ **Education Unit**
−Education based on "real" technology and experience that can be used in space−

Utilizing Tokyo University of Science research, such as flight missions, rocket launches, theoretical research in astrophysics, and astronomical observations, for the purpose of education can be an incentive for both researchers and students. In addition to participating in numerous missions, we will cooperate with domestic and international space development organizations, space venture companies, and space development companies and actively use the results for education.

▪ **Photocatalysis International Unit**
−Solving resource and environmental problems by using photocatalysis−

Photocatalysts, such as titanium dioxide, can effectively decompose organic pollutants and exhibit antibacterial and disinfecting properties because of their strong oxidative decomposition. Considerable research is being conducted on artificial photosynthesis using photocatalysts (hydrogen production by water decomposition and generation of valuable substances by carbon dioxide reduction). By advancing these studies, we can address existing issues, such as environmental purification and energy production, on earth and implement solutions in space.

▪ **Space Colony Unit**
−Advancement of space-stay technologies and promotion of their use, with a focus on space habituation−

We will conduct cross-disciplinary research on various technologies related to clothing, food, and housing that have not been directly related to space so far, as well as infrastructure construction technologies, such as electric power and telecommunications, in closed environments. In addition, we will collaborate with companies and research institutes for the development of space-stay technology to allow humans to stay in an extreme closed environment for a long time. The results can be applied in case of common problems such as disasters or food scarcity on earth.

▪ **Spaceplane Unit**
−Development of spaceplanes that can facilitate easy space travel−

The Spaceplane Unit is focused on the integration of technologies including system optimization technology, fault-tolerant systems, LOX/LNG engine operation, autonomous navigation technology, composite airframes and propellant tanks, and legalization of commercial space transportation. This integration is necessary to allow travel to and from space using spaceplanes in a manner similar to airplanes under the motto "Space is for everyone."

Information and Societal
Established: August, 2023

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Research Center for Multi-Hazard Urban Disaster Prevention

Objectives	Our mission is to develop and apply innovative urban disaster prevention studies that target multi-hazards, with the ultimate goal of fostering a safe, sustainable society that values diversity and ensures no one is left behind.
Future Development Goals	We are dedicated to stimulating research exchanges both within and beyond the university, focusing particularly on multi-hazard urban disaster prevention. Notably, we aim to foster the expansion of connections among young researchers and students.

Director
Professor
Department of Civil Engineering
Faculty of Science and Technology
Yasuo Nihei
Ph.D.

Even a single hazard - be it a natural disaster, a large fire, or a novel infectious disease - can spell disaster. However, when multiple hazards coincide, the situation escalates into a crisis threatening the survival of the nation. In response to this challenging problem, we collaborate with researchers from various hazard-related and data science fields. Would you consider joining our quest to save as many lives as possible?

Research center for multi-hazard urban disaster prevention

What is multi-hazard?

Cities, the epicenters of population density and valuable assets, represent unique societal structures and living spaces teeming with skyscrapers and bustling with a vast network of transportation and information. The blend of order and intensity has peaked within these urban landscapes. However, these complex systems are vulnerable to chain reactions of devastation in the face of natural disasters, large fires, and the emergence of new infectious diseases. Should an element of the system fail, it can trigger a cascading collapse of others, leading to widespread social unrest, medical emergencies, and life-threatening situations.

Located in a region prone to frequent natural calamities, Japan presents significant urban risks from a global perspective. Particularly, earthquakes, tsunamis, floods, storm surges, strong winds, volcanic eruptions, and fires, as exemplified by historical events, such as the Great Kanto Earthquake of 1923, Great Hanshin-Awaji Earthquake of 1995, and Great East Japan Earthquake of 2011, pose significant threats. The nation's future anticipates further calamities such as the Tokyo Inland Earthquake, Nankai Trough Earthquake, and super typhoons. The impact becomes even more severe when multiple hazards occur simultaneously within the same region, a scenario known as spatially chained multi-hazard. In such cases, the survival of the nation is at stake. Therefore, we must leverage previous research on each type of hazard, elevating it into an academic system that addresses these time-space chained multi-hazards. Our goal is to develop a comprehensive approach that transcends various disciplines, including science, engineering, life science, humanities, and social sciences. The advancement of urban disaster prevention science is essential in this endeavor.

Direction

At our center, our objective is to develop and apply innovative studies on time-space-linked multi-hazard urban disaster prevention. Our goal is to contribute towards building a safe, sustainable society that values diversity and ensures no one is left behind (Fig. 1). Our university houses numerous researchers specializing in disaster prevention across various hazards, including earthquakes, fires, and floods, as well as experts in data science. We intend to forge a new path in urban disaster prevention studies through two collaborative cross-sections: the synergy between disaster prevention researchers and the combined efforts of these researchers and data science professionals.

Research system

This center is composed of approximately 10 faculty members hailing from diverse faculties and graduate schools within the university. The research units include: (1) the Multi-Hazard Unit, led by Professor Ken Matsuyama from the Department of Global Fire Science and Technology, Graduate School of Science and Engineering; (2) the Disaster Prevention Informatics Unit, led by Professor Takahiro Yamamoto from the Department of Physics, Faculty of Science; and (3) the Regional Co-Creation Unit, led by Professor Takumi Ito from the Department of Architecture, Faculty of Engineering. Moving forward, the center will collaborate with external academic institutions (such as universities and scholarly societies), administrative bodies (including national and local governments, medical institutions), national research institutes (specializing in various areas including civil engineering, architecture, disaster prevention, and materials and information systems), and private sector entities (including sectors such as communication, electricity/gas, automotive, construction, IT, and media).

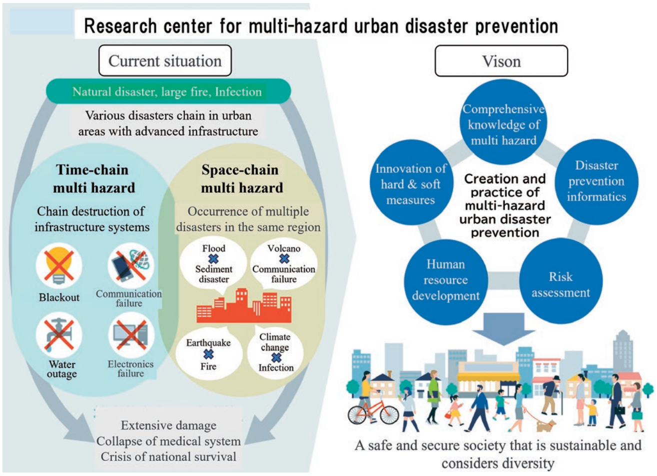


Fig. 1 Direction of this research center

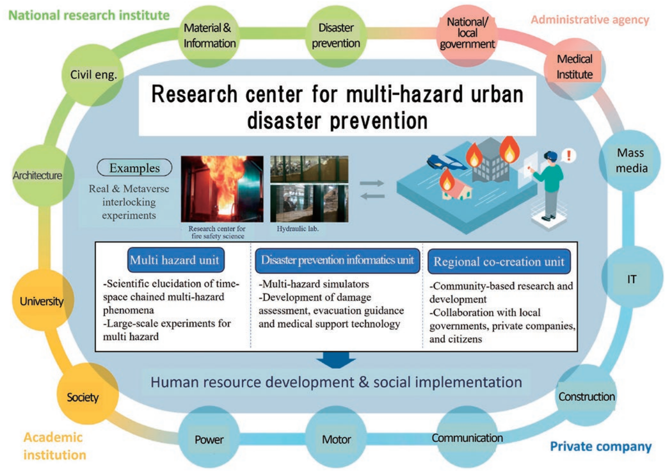


Fig. 2 Research system

Established: April, 2014

o.taka@rs.tus.ac.jp

Research Division for Advanced Disaster Prevention on Cities

Objectives	Respond to the city's complex environment and lives caused by the significant development of technology, by bringing together wisdom for various fields of architecture. Explore the Visions for Tokyo as a metropolis in the 21st century from the Kagurazaka and Sotobori (outer moat) areas, where Tokyo University of Science locates. How to prepare modern cities should against incoming unprecedented disasters
Future Development Goals	Building up theories for city planning with the sustainability and resilience against disasters.Renewal of infrastructures in cities by merging various perspectives and knowledge of the architectural fields: materials, structures, planning, design, and history, into the primal purpose, disaster prevention.

Director
Professor
Department of architecture,
Faculty of engineering

Osamu Takahashi

Dr.Eng.

This research division is composed of experts of architecture, city planning and civil engineering. Stuffs belong to Faculty of Engineering and to Faculty of Science and Engineering, and School of International Fire Science. For many years, researchers in this division continue to develop regional researches, contributions to local communities, and regional exchanges with thick accumulation of their researches.
We aim to create results to contribute the areal development of Kagurazaka and Sotobori area where is the home of Tokyo University of Science.

Based on the theme of "Disaster Prevention in Cities Built on Advanced Systems", building cities which enable recovery, maintenance and sustain their whole cultures and functions on themselves, by interconnecting the research results of the three fields: city culture, city performances and city planning.

Academics or Social Characteristics for the Division

The researchers and specialists belonging to this division consist of faculty members from four faculties: the Faculty of Engineering, the Former Faculty of Engineering II, the Faculty of Science and Technology for Innovation, and the International Graduate School of Fire Science and Technology.

They are conducting front-line research in their respective fields of expertise. In addition, they are certificated by major domestic academic societies such as AIJ (Architectural Institute of Japan), CPIJ (The City Planning Institute of Japan), and SAHJ (Society of Architectural Historians of Japan).

Our division collaborates for advanced research in various fields related to city planning, including architecture and disaster prevention.

The Kagurazaka and its surrounding areas are unique in terms of chronological context and city structure in the world's city's history, and research on these areas is likely to attract international attention.

In addition, there are high expectations from both sectors public (governmental organizations) and private (private commercial and non-profit organizations) for proposing, reflecting, and presenting the results of our research.

This is one of the unique characteristics of contribution to society by the university and the division.

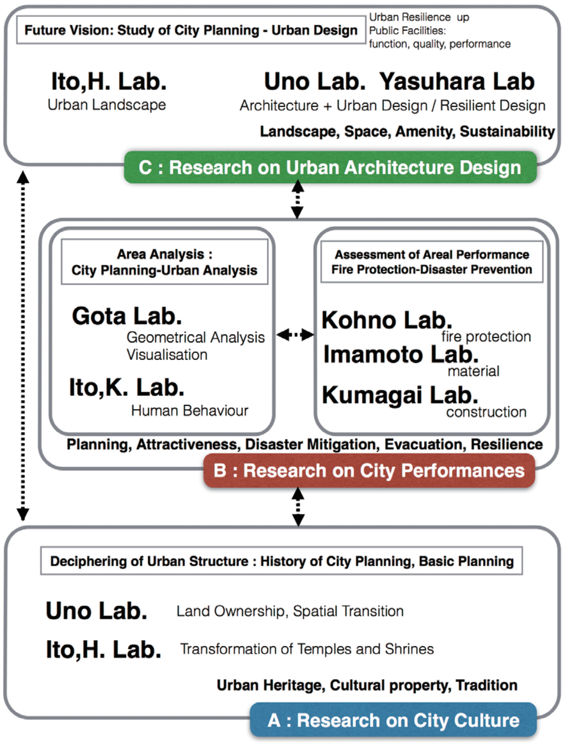
Areas Researching

Our principal research areas are Kagurazaka and its surrounding areas including Sotobori (outer moat), which should be called the home of Tokyo University of Science.

Researchers and specialists belonging for the division have long been engaged in regional research, contribution, and exchange activities in these areas, and have accumulated sufficient research experience.

We have created disaster prevention plan models and city plan models based on the results obtained in the areas.

We will develop urban disaster prevention research by applying and extending these results to urban areas throughout Japan.



Tbl. 1 Historical Changes of Kagurazaka "Outside of Sotobori", Lecture of Professor Akihisa ITO, April 2014

Fig. 1 Research field and partners

Fig. 2 "Sotobori-Kagurazaka 7 images", CKARD_TUS, April 2014

Fig. 3 "Brought Close between Town and Sotobori" Proposal to connect town and Sotobori with a barrier-free deck, Sotobori Reconstruction Plan Symposium, CKARD_TUS, May 2014

Information and Societal

Established: April, 2020

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Statistical Science Research Division

Objectives	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.
Future Development Goals	This research division contributes to the study of mathematical data science with the aim of working closely with the Data Science Center, conducting joint research with companies, and becoming a base for the international research on statistical science.

Director
Professor,
Department of Applied Mathematics,
Faculty of Science

Takashi Seo

D.Sc.

Many professors involved in statistics are enrolled in our university, across campuses and undergraduate departments. In this research division, these professors from the field of statistical science come together and actively interact with each other to conduct a research which is unique to Tokyo University of Science. In the future, we would like to establish a “Statistical Science Research Center” and “AI and Data Science Theory Research Center”.

Development of mathematical and applied statistics and their fusion

Background and Purpose of the Research Department

“Statistical science” is a field of study that uses the concept of probability to provide optimality theory and statistical methods to estimate the characteristics of the population behind the data obtained. In the recent years, “data science”, which is associated with big data, as well as artificial intelligence (AI), has attracted significant attention. Furthermore, the core of these theories is “statistical science (statistical theory)”, which has gained considerable prominence.

Accordingly, our university must build a research system that will lead not only Japan but also the rest of the world in the domain of AI and data science research. However, research in AI and data science is significantly extensive. Tokyo University of Science has been planning to conduct research in this field, intending to make the world proud. The university has many faculty members who specialize in “statistics”, and these members are present across all its campuses. In particular, it is no exaggeration to say that our university is the only one in Japan with a huge number of researchers that specialize in mathematical statistics, which handles statistical inference logic mathematically. Tokyo University of Science also has the distinction of being strong in medical statistics, as it used to host a medical statistics program for the working members of society. Therefore, we aim to create a research stronghold where the researchers in these fields can come together and actively interact with members from across all campuses and departments to conduct research “unique to Tokyo University of Science”. Furthermore, establishing this department will bring together researchers with specialties in different research topics but with a shared interest in a common theory. Our goal is to increase the level of research on essential theories and methods, and to create new theories and introduce new fields in the era of data science.

Members of Statistical Science Research Division

Name	Job title
ANDO Shin	Professor, School of Management, Department of Business Economics
HASHIGUCHI Hiroki	Professor, Faculty of Science Division I, Department of Applied Mathematics
IWASHITA Toshiya	Professor, Institute of Arts and Sciences, Noda Division, Institute of Arts and Sciences
KUROSAWA Takeshi	Professor, Faculty of Science Division I, Department of Applied Mathematics
MATSUZAKI Takuya	Professor, Faculty of Science Division I, Department of Applied Mathematics
MIYAOKA Etsuo	Professor, Faculty of Science Division II, Department of Mathematics
MURAKAMI Hidetoshi	Professor, Faculty of Science Division I, Department of Applied Mathematics
NISHIYAMA Takahiro **	Professor, Senshu University, Department of Business Administration
SEO Takashi *	Professor, Faculty of Science Division I, Department of Applied Mathematics
SHIOHAMA Takayuki **	Professor, Nanzan University, Department of Data Science
SOZU Takashi	Professor, Faculty of Engineering, Department of Information and Computer Technology
TAHATA Kouji	Professor, Faculty of Science and Technology, Department of Information Sciences
TERUI Nobuhiko	Professor, School of Management, Department of Business Economics
TOMIZAWA Sadao	Professor, Faculty of Science and Technology, Department of Information Sciences
TSUBAKI Michiko	Professor, School of Management, Department of Management
WATANABE Yuki	Professor, Organization for Education Advancement, Center for Teacher Education
YABE Hiroshi	Professor, Center for Data Science
KAWASAKI Tamae ***	Associate Professor, Aoyama Gakuin University, College of Economics
KOIZUMI Kazuyuki ***	Associate Professor, Juntendo University, Faculty of Health Data Science
NAKAGAWA Tomoyuki ***	Associate Professor, Meisei University, School of Data Science
SHIMOKAWA Asanao	Associate Professor, Faculty of Science Division II, Department of Mathematics
SHINOZAKI Tomohiro	Associate Professor, Faculty of Engineering, Department of Information and Computer Technology
ANDO Shuji	Junior Associate Professor, Faculty of Science and Technology, Department of Information Sciences
HU Yannan	Junior Associate Professor, Faculty of Science Division I, Department of Applied Mathematics
ISHII Aki	Junior Associate Professor, Faculty of Science and Technology, Department of Information Sciences
YAGI Ayaka	Junior Associate Professor, Faculty of Science Division I, Department of Applied Mathematics
EGASHIRA Kento	Assistant Professor, Faculty of Science and Technology, Department of Information Sciences
KITANI Masato	Assistant Professor, Faculty of Science Division I, Department of Applied Mathematics
SHIMIZU Koki	Assistant Professor, Faculty of Science Division I, Department of Applied Mathematics
YAMAGUCHI Hikaru	Assistant Professor, Faculty of Science and Technology, Department of Information Sciences

*Director, **Visiting Professor, ***Visiting Associate Professor

Research Group

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 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 from Kagurazaka Campus. Additionally, in recent years, the field of “sports statistics” has been gaining attention, and the faculty members from Noda Campus, visiting professors, and visiting associate professors are actively conducting research in this field. Moreover, we plan to conduct joint research involving student exchange programs.

Regarding the “statistical machine learning/mathematical optimization field”, research on “natural-language processing that integrates statistical/machine learning and symbolic modeling”, “large-scale nonlinear optimization problems related to big-data analysis and machine learning”, and “statistical methods for computer-based data mining and pattern recognition” will be conducted mainly by the faculty members from Kagurazaka Campus.

Moreover, regarding one of the objectives of this research department, “collaboration with external institutions, such as companies, through a Data Science Center”, a “data analysis team”, which comprises research coordinators appropriate for each research content, will be formed, and joint research will be conducted.

Information and Societal

Established: April, 2021

takemura@rs.tus.ac.jp

Parallel Brain Interaction Sensing Division

Objectives	Our goal is to proceed from the conventional brain research and technology development focused on a single individual, creating a new brain research area analyzing the multiple brain interaction.
Future Development Goals	We will have several open seminars and workshops to find a common language for researchers in multidisciplinary fields, educate the young investigator and students, increasing the integration of researchers.

Director
Professor,
Department of Mechanical and Aerospace Engineering,
Faculty of Science and Technology
Hiroshi Takemura
Doctor of Engineering

This division brings together researchers from both inside and outside the university in the field of the brain science and neural information and systems to create an innovative academic field, “Parallel Brain,” originating from the Tokyo University of Science. We aim to reveal how the brain activity of multiple individuals interacts with each other.

Toward Next-generation Brain Project: Knocking new era of IoB (Internet of Brains)

Background and purpose of the division

Neuroscience (brain science) is a field of life science that is dramatically developing in the 21st century. People expect that, the maintenance of brain health will improve the quality of life in an aging society, and the application of information processing mechanisms in the brain lead to the creation of innovative technologies. In recent years, most thing 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 without even realizing it (IoB: Internet of Bodies). It is easy to imagine that the next era will happen the human mind is connected to the Internet (IoM: Internet of Minds). This is indeed the arrival 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, and by collaborating with related researchers outside of the university. We aim to create an innovative academic field of brain science, “Parallel Brain,” which will be developed at the Tokyo University of Science in preparation for the coming era of the Internet of the Brain.

Research Organization and Members

We will 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 will become our original interdisciplinary brain research field. This division aims to elucidate and support the mechanisms of group formation and symbiosis in online space, and to build a theoretical background to describe the interaction between multiple brains common to social animals by using the common sensing technology in both mouse and human experiments through mathematical models. 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, to elucidate related mechanisms, and to create seeds for improvement drugs and diagnostic agents. We aim to create the seeds for new drugs and diagnostics.

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.

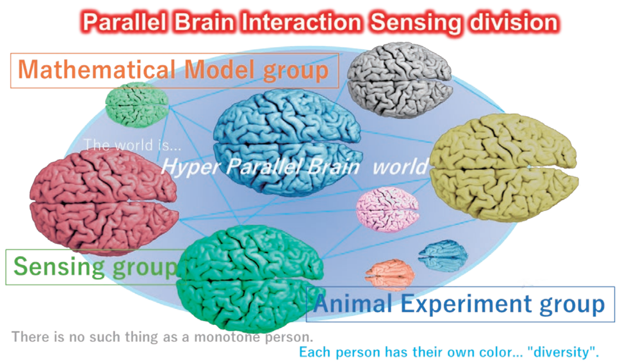
Mathematical Model Group

The Mathematical Modeling Group aims to develop models and theories of brain information processing systems based on the results of multidimensional studies of functional brain imaging, cognitive psychology experiments, brain-type algorithms, etc., with a focus on human visual perception.

The division consists of 17 researchers in interdisciplinary neuroscience-related fields, including the Faculty of Science and Technology (Hiroshi Takemura, Takeo Ushijima, Takahiko Yamamoto, Akari Hagiwara, Takumi Asakura, Masataka Yamamoto), the Faculty of Pharmaceutical Sciences (Akiyoshi Saito, Daisuke Yamada), the Research Institute for Biomedical Sciences (Takeshi Nakamura, Shingo Koinuma), the Faculty of Engineering (Osamu Sakata, Takuya Hashimoto), the Faculty of Advanced Engineering (Eri Segi (Nishida), Kanzo Suzuki), the Institute of Arts and Sciences (Hiroko Ichikawa), and two visiting researchers: Ryohei Hasegawa from the National Institute of Advanced Industrial Science and Technology (AIST) and Asami Oguro-Ando from the University of Exeter Medical School.

We are mainly engaged in collaborative and cooperative research use of the unique talents and strengths of each member. The following is a list of ongoing collaborative research projects that transcend the boundaries of each specialized field, which are possible only in this division. For details, please see the division’s website.

- Elucidation of brain functions controlling social behavior
  (Prof. Segi and Prof. Oguro-Ando [University of Exeter])
- Investigation of cross-species vocal communication
  (Prof. Ichikawa, Prof. Saito, and Prof. Yamada)
- Examination of cross-species vocal communication: Relationship between ultrasonic vocalizations in mice and the effects of ultrasonic listening in humans
  (Prof. Ichikawa, Prof. Saito, Prof. Yamada, and Prof. Asakura)
- Analysis of Stress-Induced Depression-like State
  (Prof. Saito, Prof. Yamada, Prof. Takemura, and Prof. Yamamoto)
- Study on the Relationship between Human Gait Behavior and Personality Traits: Extraction and Evaluation of Gait Characteristics Derived from Human Internal State
  (Prof. Ichikawa, Prof. Takemura, and Prof. Yamamoto)
- Biomechanical Analysis of Age-Dependent Gait Deficiency in Cerebellar Neural Transmission Deficient Mice
  (Prof. Hagiwara, Prof. Takemura, and Prof. Yamamoto)
- Evaluation of the neural basis of stress sensitivity in synaptic protein-deficient mice
  (Prof. Hagiwara, Prof. Saito, Prof. Yamada, Prof. Takemura, and Prof. Yamamoto)
- Analysis of Jakmip1-deficient mice, a mouse model for autism
  (Prof. Saito, Prof. Oguro-Ando, Prof. Hagiwara, Prof. Yamada)
- DNA methylation analysis in various mouse models
  (Prof. Oguro-Ando, Prof. Segi, Prof. Saito, Prof. Hagiwara, Prof. Yamada)



It is not enough to have good brains.
The main thing is to connect them well.

mune@rs.tus.ac.jp

Division of Digital Transformation

Objectives	Development of new integrated big data processing manners through breakthrough on mathematical theories in theory level, modeling methods in fundamental level, and statistical analyses of results in application level.
Future Development Goals	Development of big data processing manners that give accurate predictions for practical missions through mutually and spirally reflecting feedbacks between machine learning systems and statistical analyses of their results.

Director
Professor,
Department of Information Sciences,
Faculty of Science and Technology
Munehiro Takimoto
Ph.D.

This research division aims to give high-performance and more accurate big data processing manners with mutual feedbacks between machine learning systems and statistical analyses of their results, based on mathematical foundations in various levels. The processing manners include redesign from theory and implementation of systems and analyses. We believe that the challenges of this division will open new horizons for big data processing.

R&D on integrated big data processing manners based on new theory and implementation. They include mathematically redesigning machine learning systems and implementing high accurate and safe A.I. In addition, they achieve high confidential big data processing, through statistically analyzing the results generated by the systems.

Introduction and Background

In most science areas, which include DNA & molecule designs in micron level and earth environment sciences in macro level, it is so important to extract meaningful information from big data, which is superficially useless data with huge size. The extraction techniques are called data mining. Data mining is so costly that it is difficult to process it in traditional ways. To achieve much more efficient and accurate data mining and result in innovative science technologies, we have to propose new approaches based on mathematical theorems in algorithms and execution styles.

Division of Super Distributed Intelligent Systems, which is the previous division, especially focuses attention to medical and bio-systems, and has developed next generation data mining softwares together with researchers in artificial intelligence and statistics areas. In the process of that, we have found that we have to not only enhance parallelization/distribution and propose new approaches based on mathematical theorems to achieve new innovative technologies. In Division of Digital Transformation, we will improve the results of the previous division, and develop new big data processing manners based on performance and accuracy issues that the results have exposed. For example, we will continuingly enhance execution efficiency in the low level that is related with programming languages, parallel/distributed algorithms, and network protocols. In addition, we will design new deep learning manners based on adjusting their super-parameters based on combinatory theorem. Eventually, we will apply these techniques and models to several areas such as image processing, power systems, machine learning, robot systems, software engineering tools and so on, including data mining.

Research Hierarchy

We address the issues of big data processing in three hierarchical levels, “applications”, “fundamentals, and “theories” as follows:

1.Applications

In this level, members who are specialists of each applications investigate issues of the applications based on their expertise, propose approaches to solve the issues, and check validity of results given by the solution. In the process, they give new models based on characteristics of the applications, and develop systems implementing the models. The results given by the systems are validated in mathematical methods.

2.Fundamentals

In this level, members directly improve performance of fundamental techniques such as A.I. and machine learning, and propose new approaches of them. The improvement of performance includes network performance in distributed systems and sensor networks, and learning performance of A.I. 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 model based on biological systems. The fundamental techniques and systems developed in the level are validated in mathematical methods.

3.Theories

In 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.

Research Topics

We currently have two main projects as follows:

① Genomix Data Science Medical Care of Cancer

It is a project that is advanced with National Cancer Center Exploratory Oncology Research & Clinical Trial Center (NCC-EPOC) as a cooperative research (Fig. 1). In this project, the purposes in the applicative level are cancer prevention, lengthening the time of a healthy life, improvement of quality of life and rehabilitation. Also, we are developing methods special to each applicative level purpose through fusing data sciences such as mathematical statistics, machine learning, information processing and statistical analysis, and cancer biological experiments.

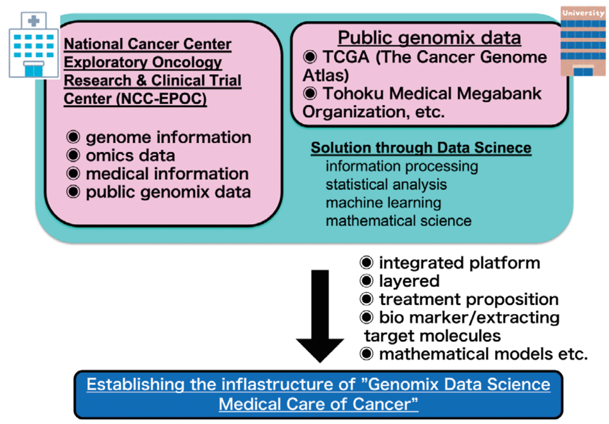


Fig. 1 Genomix Data Science Medical Care of Cancer.

② Implementation and Practical Realization of Cerebral Apoplexy Prevention by AI

We are developing the system that enables AI to support a doctor medically examining or treating patients of cerebral apoplexy using medical big data and engineering big data. This project was conducted as one of NEDO projects, implementing two kinds of A.I.s, which were A.I. α based on just medical information and A.I. β based on both of medical information and engineering information.

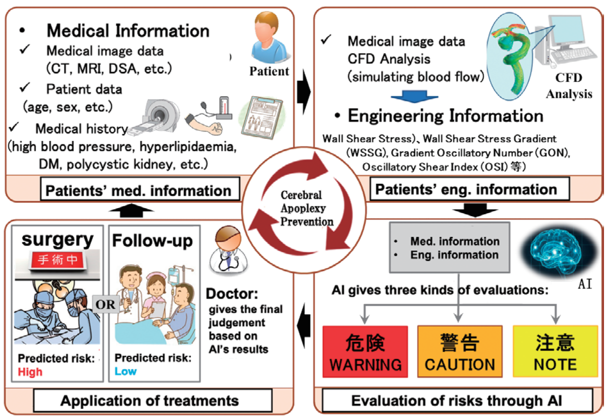


Fig. 2 Cerebral Apoplexy Prevention by AI.

Established: April, 2022

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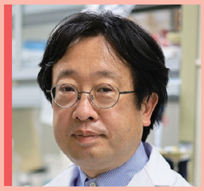
Medical Data Sciences



Director
Professor,
Department of Pharmaceutical Sciences

Kazunori Akimoto

Ph.D.

Objectives	Toward the realization of “Medical Data Sciences” based on digital medical data, we aim to solve the needs of clinical sites using data science methods and identify novel biomarkers for stratification.
Future Development Goals	In addition to the multifaceted analyses of global public medical data, it is expected that the unique “Medical Data Sciences” will be established by promoting cooperation with the National Cancer Center.

This division has been launched by a group of researchers specializing in data sciences and cancer biology, crossing the boundaries of the faculties and campuses of TUS. We aim to construct “Medical Data Sciences” at TUS by forming a network both inside and outside TUS, such as in collaboration with the National Cancer Center.

Construction of “Medical Data Sciences” establishing novel preventive and therapeutic methods for diseases at TUS

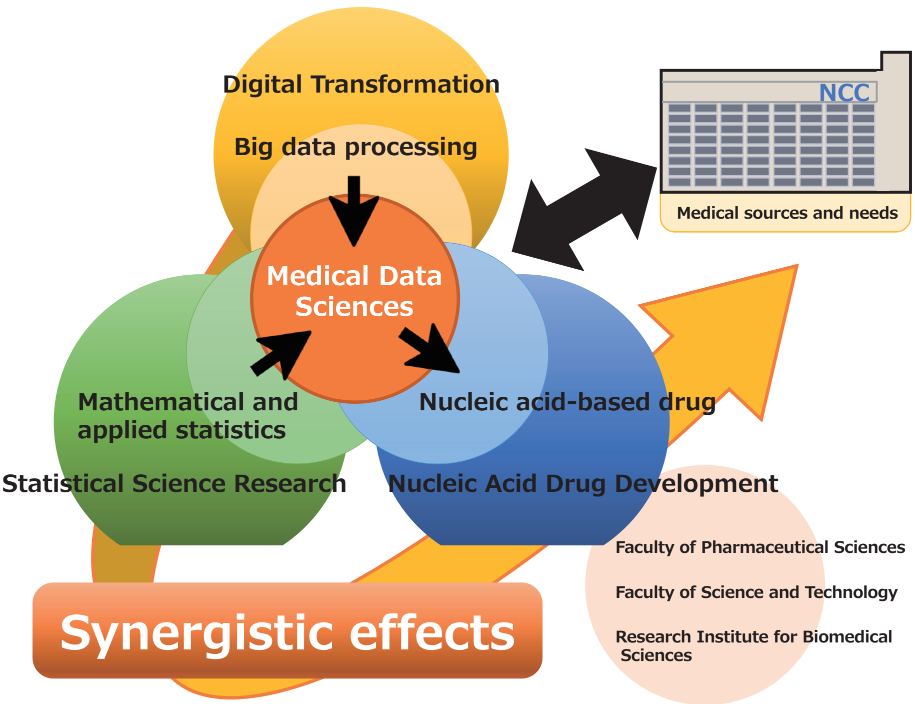
Objectives

The realization of “Medical Data Sciences” is becoming indispensable for establishing preventive and therapeutic methods for the cure of diseases. In medical care, Precision Medicine is being established: patients are stratified into specific groups by analyzing various medical big data, and the appropriate treatment is precisely selected for each patient group. However, at present, there are various problems pose barriers and is a limit to the provision of precise medical care. The purpose of launching this division is combined with data science methods and cancer biological methods to solve the medical problems by the collaboration between NCC-EPOC and TUS. The outcomes are expected to prevent cancer progression, extend healthy life expectancy, and realize high QOL and rehabilitation of cancer patients.

This division will promote new patient stratification and proposals for treatment methods by using data science research on medical big data as a starting point. There are various challenges to be overcome in the realization of “Medical Data Sciences”. Therefore, we will make full use of data science methods accumulated in TUS to solve the problem and develop the theoretical foundation for proposing new therapeutic agents and treatments. A series of research will enable the creation of new academic fields and the establishment for the theoretical foundation of “Medical Data Sciences”. Furthermore, we will promote next-generation education and the development of researchers who will adapt and develop “Medical Data Sciences” based on medical big data.

Current Situation of “Medical Data Sciences”

Attempts to solve medical problems with data science methods have become a global trend. Such efforts are also being actively carried out in Japan. This division uses NCC and global medical databases as medical sources and needs, but is characterized by using the data science methods accumulated at TUS. This is made possible by gathering specialists highly specialized data science and cancer biology of TUS. Although the network scale of researchers is smaller than the global networks by other groups, it secures the diversity of researchers’ specialties and enables them to cooperate closely and flexibly carry out research activities.



Established: April, 2022

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Division of Smart Healthcare Engineering

Objectives	This division aims to conduct interdisciplinary research that contributes to the creation of a smart, healthy, and longevity society by researchers in a wide range of fields, including physiology, materials engineering, metabolism, integrated circuit engineering, radio frequency systems, and wireless communication engineering.
Future Development Goals	We are promoting active interactions among division members covering a wide range of specific fields, to emphasize joint research within and outside TUS, and to encourage young researchers.

Director
Associate Professor,
Department of Electrical Engineering,
Faculty of Science and Technology
Takahiko Yamamoto
Ph.D.

This division conducts basic and interdisciplinary research on basic technologies and cross-disciplinary related to biometric sensing for health diagnosis to telemedicine, and high-quality, secure wireless communication, with the aim of supporting a smart, healthy, and longevity society in which people can lead healthy and high quality of life.

Creation of a Smart, Healthy, and Long-Lived Society that Supports People's Daily Life with High Quality of Life

The stresses that people may experience in their daily lives in society, even if they seem small and insignificant, increase the risk of various diseases. Research is needed to create a society in which people can live healthy daily lives with a high quality of life, even when their physiological functions are impaired or lost due to disease. This division advocates the value of smart healthcare systems that support to realize such a society and conducts research on the development of elemental technologies and their effective integrations.

Research Structure and Members of this Division

This division is divided into four major groups, and some of their research activities are presented below.

○ Sensing Group

・Elucidation of the mechanisms of health promotion and longevity through physical activity

Based on exercise physiology, behavioral physiology, material science, and metabolism, this group uses non-contact methods to quantify the amount of physical activity using animal models and explore the optimal amount of physical activity for physical and mental health in order to elucidate the mechanisms of health promotion and longevity from daily physical activity.

・Analysis of nanoscale materials derived from skeletal muscle/fat tissue on physical function and mental health

Quantitative visualization of various mental and physical functions in humans is being attempted. In particular, Yanagita, Umezawa, and Kobayashi in our members have collaborated on a health promotion/longevity mechanism through exercise that is opened up by brain-organ communication, and are currently working on a research project to reveal the mechanism of brain-peripheral organ communication associated with changes in the amount of physical activity. The physicochemical and biological properties of nanoscale structures produced and released by muscle and fat cells in response to environmental stimuli are also being studied to visualize brain-organ communication.

○ Device Operation and Control Group

・Transcutaneous energy transmission for body-implanted electronic devices

Transcutaneous energy transmission and information transmission systems for medical electronic devices implanted inside the body are studied. This system completely reduces the risk of infection when supplying the driving energy essential for device operation. and achieves miniaturization and weight reduction through battery-free operation (Figure 1).

・Development of an electromagnetic phantom

When conducting wireless power or information transmission between inside and outside living organisms, it is essential to investigate the effects of the presence of living bodies on the operation of the equipment and the electromagnetic radiation from the equipment to ensure stable operation of the equipment. By using materials that mimic the electromagnetic properties of living bodies, these studies can be performed without animal experiments. In this research, we are developing various types of simulated living organisms.

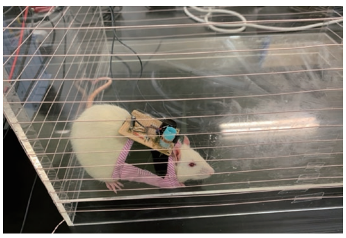


Figure 1 Wireless power transmission to an implantable momentum meter

○ Integrated Circuits and Signal Processing Group

The Transmission Group and the Information and Communication Group conduct research on high-frequency and high-speed signal processing circuits, low-voltage and low-power circuits, and their miniaturization, which are essential for hardware implementation. We develop high-performance amplifiers (low noise, high input impedance), analog-to-digital conversion circuits (ADC), and digital-to-analog conversion circuits (DAC) with high resolution and low power consumption, which are essential for measuring minute bioelectric potentials. In addition, as sensing devices become increasingly popular, we are analyzing device variation and studying variation-resistant circuits to realize robust circuits that are low-cost and highly resistant to variation.

○ Information and Communication Group

・Small antennas installed near living bodies

We are researching and developing compact, high-gain biometric antennas that can be used near living bodies and are not easily affected by them.

・Low power, high quality and secure wireless communication

This group is researching communication methods that achieve high speed, large capacity, high quality/low latency, multiple simultaneous connections, and low power consumption without degrading transmission quality. These are envisioned for transmitting biometric and other information measured by the sensing group to medical facilities using wireless communications. In addition, research will be conducted to promote the safe and secure use of radio waves by protecting information and communications from unauthorized access and malicious attacks.

Table 1 Member and Main Research Field

Affiliation	Job title	Name	Main research field	Group
Department of Electrical Engineering, Faculty of Science and Engineering	Associate Professor, Director	Takahiko Yamamoto	Medical Electronic Systems	Device Operation and Control
Department of Electrical Engineering, Faculty of Science and Engineering	Professor	Kenichi Higuchi	Wireless Communica-tions	Information and Communication
Department of Electrical Engineering, Faculty of Science and Engineering	Professor	Akira Hyogo	Electronic Circuits and Integrated Circuits	Integrated Circuits and Signal Processing
Department of Information Science, Faculty of Science and Engineering	Professor	Shigeo Akashi	Information Theory	Information and Communication
Department of Pharmacy, Faculty of Pharmaceutical Sciences	Professor	Akiyoshi Saito	Pharmacology	Sensing
Noda Division, Institute of Arts and Sciences, Institute of Arts and Sciences	Professor	Shinya Yanagita	Neurology and Exercise Physiology	Sensing
Department of Medical and Robotic Engineering Design, Faculty of Advanced Engineering	Associate Professor	Masakazu Umezawa	Pharmaceutical Science and Materials Engineering	Sensing
Department of Electrical Engineering, Faculty of Science and Engineering	Assistant Professor	Takanori Hara	Wireless Communications	Information and Communication
Department of Electrical Engineering, Faculty of Science and Engineering	Assistant Professor	Ryoichi Miyauchi	Integrated circuits, biological signal measurement systems.	Integrated Circuits and Signal Processing
Department of Pharmacy, Faculty of Pharmaceutical Sciences	Assistant Professor	Daisuke Yamada	Neurochemistry	Sensing
Department of Medicinal and Life Sciences, Faculty of Pharmaceutical Sciences	Assistant Professor	Yuka Nozaki	Functional biochemistry	Sensing
Department of Electrical Engineering, Faculty of Science and Engineering	Visiting Professor	Kohji Koshiji	Radio systems and medical electronics	Device Operation and Control
Tokyo City University	Visiting Professor	Tatsuji Matsuura	Integrated Circuits and Signal Processing	Integrated Circuits and Signal Processing
Tokyo Polytechnic University	Visiting Professor	Fukuro Koshiji	Bio-Communication	Information and Communication
Nippon Medical School	Visiting Professor	Shoji Yokobori	Emergency Medicine	Clinical engineering and medicine
Nippon Institute of Technology	Visiting Researcher	Kenko Ohta	Emotion Analysis	Sensing
Tokyo International University	Visiting Researcher	Natsuko Kubota	Physiology	Sensing
Tokyo Institute of Technology	Visiting Researcher	Hiroki Sato	Integrated circuits and software engineering	Integrated Circuits and Signal Processing
Ochanomizu University	Visiting Researcher	Masaki Kobayashi	Metabolism	Sensing
Toyama Prefectural University	Visiting Researcher	Ryo Kishida	Integrated Systems and Reliability	Integrated Circuits and Signal Processing
ZENKIGEN	Visiting Researcher	Issei Hashimoto	Sensitivity Engineering	Sensing
Jichi Medical University Saitama Medical Center	Visiting Researcher	Chinori Umeda	Clinical engineering	Clinical engineering and medicine

Fundamentals

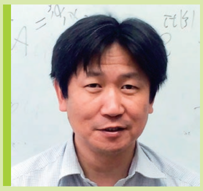
Established: April, 2020

kato@rs.tus.ac.jp

Research Alliance for Mathematical analysis

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Objectives	To make interdisciplinary researches with researchers of mathematical analysis, numerical analysis, physics, chemistry, biology and engineering
Future Development Goals	We make research alliance with other divisions in our research institute and institutes outside the university



Director
Professor,
Department of Mathematics,
Faculty of Science

Keiichi Kato

Mathematical Sciences

This division has been established on the April of 2020, as the succession of Division of Mathematical modeling and mathematical analysis. Our aim is to make interdisciplinary researches between mathematical analysis, numerical analysis, physics, chemistry, biology and technology. The members of our division are willing to cooperate to those who need to techniques of mathematical analysis, numerical analysis or theoretical physics.

Interdisciplinary researches between mathematical analysis, science and engineering

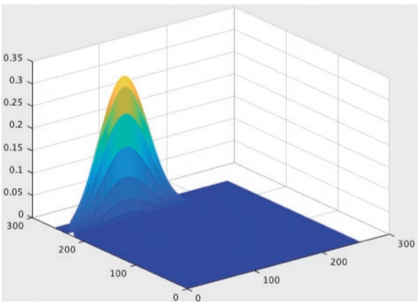
This division has been established on the April of 2020, as the succession of Division of Mathematical modeling and mathematical analysis. The aim of our division is to make alliance research over mathematical analysis, numerical analysis, physics, chemistry, biology and engineering.

Alliance inside the division

We make research alliance based on Three groups(Group of mathematical physics, Group of mathematical biology and Group of mathematical engineering).

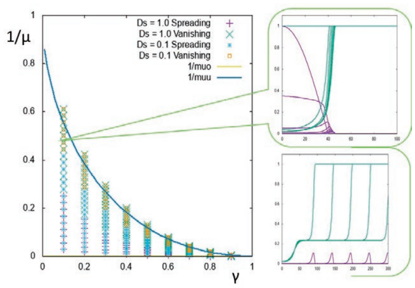
• Group of mathematical physics

The aim of the group is to establish original numerical method for Schrödinger equations based on representation of solutions via wave packet transform due to K. Kato et al. and apply it to condensed matter physics. We have succeeded to establish original numerical method and are applying it to compute numerical solutions of Schrödinger equations.



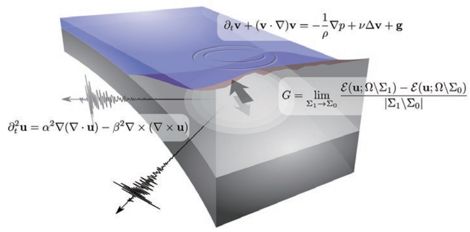
• Group of mathematical biology

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.



• 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.



Alliance with other divisions in RIST

From the beginning of the 21^{st} century, the importance of mathematics has been known more and more even in our country. In the research institute for Science and technology(RIST), we have two mathematical division: this division and the division of modern algebra and cooperation of engineering(DMACE). We will make research alliance with other divisions such as divisions of condensed matter physics, divisions of chemistry, divisions of biology and divisions of engineering with cooperation of DMACE.

Alliance with other institutes

On the January of 2020, we have concluded the agreement for research alliance between RIST and Research Alliance Center for Mathematical Sciences(RACMaS) in Tohoku University. We will promote research alliance between this division and RACMaS based on the agreement. We also try to make research alliance with other institutes.

Established: April, 2020

tsai@rs.tus.ac.jp

Division of Nano-quantum Information Science and Technology

Objectives	Our research division aims at optimization of the operation condition for superconducting, optical and spin qubits.
Future Development Goals	This division will contribute to the practical realization of the quantum computer thirty years later.

Director
Professor,
Research Institute for Science and Technology

Tsai Jaw-Shen
Ph.D.

The research of quantum computer has been very active during the recent years. One of the reasons of the rapid progress is the improvement in coherence time of the qubit due to the advancement of nanotechnology. However, the current status of the quantum circuit is still far from the real implementation. We must accelerate the pace of research and development toward the truly fault-tolerant quantum computer.

Nanotechnology and its applications to quantum information and electronics

Background

In recent years, demonstrations of quantum supremacy by Google and later the University of Science and Technology of China, the establishment of IBM's commercial quantum computer, and the D-Wave System's 4,000-bit quantum annealing machines, quantum information processing has made remarkable progress. All of the above systems are based on superconducting qubits, but quantum computing systems based on other systems such as light, semiconductors, and ions are also being actively researched around the world.

Our targets

Our division mainly investigate the superconducting qubit. Qubit cause errors like ordinary classical semiconductor circuits. Malfunction of the qubit also would come from the breakdown of the quantum superposition state. Such phenomenon is called decoherence. The fault-tolerant quantum computer would be realized by employing a quantum error correction procedure, and it would deliver truly practical applications. The division plans to carry out research of several kinds of fault-tolerant quantum circuits with superconducting qubits. It is expected that the fault-tolerant quantum computer would appear by 2050, and we would try to contribute to its realization.

Superconducting qubit is considered as the most suitable platform for the quantum computers. However, it also has its problems. The coherence time of superconducting qubit is still short, for example. Beside the superconducting qubit, qubits based on other physical systems, like photon, ion, atom and electron spin in quantum dot have been investigated earlier. In our division, spin qubit and optical qubit will also be investigated, along with the superconducting qubit.

Moonshot Research & Development Program

The research subject "Developing bosonic code using superconducting resonator" was adopted to the government moonshot research & development program in 2020. The program leader is Dr. Tsai and Drs. Yoshihara, Takayanagi, Watabe and Hashizume join this program.

This program continues until 2025 (https://ms-iscqc.jp).

Collaboration with the University of Tokyo

Other research activity of the division is the collaborated one with the University of Tokyo. The partner organizations are the Institute for Nano Quantum Information Electronics (http://www.nanoquine.iis.u-tokyo.ac.jp/) and Quantum Innovation Co-creation Center. The research subject is quantum optics utilizing single photon. Drs. Sanaka, Sadgrove, and Tkachenko join this activity.

Members

Affiliation	Name
Tokyo University of Science	Jaw-Shen Tsai
Tokyo University of Science	Kaoru Sanaka
Tokyo University of Science	Mark Paul Sadgrove
Tokyo University of Science	Fumiki Yoshihara (June, 2022 -)
Tokyo University of Science	Noboru Watanabe
Tokyo University of Science	Satoshi Iriyama
Tokyo University of Science	Takeo Kamizawa
Tokyo University of Science	Yoichiro Hashizume
Tokyo University of Science	Georgiy Tkachenko (July, 2022 -)
The University of Tokyo	Hideaki Takayanagi
Shibaura Institute of Technology	Shohei Watabe
The University of Tokyo	Yasuhiko Arakawa
Riken	Seigo Tarucha
NEC	Tsuyoshi Yamamoto
NTT	Shiro Saito

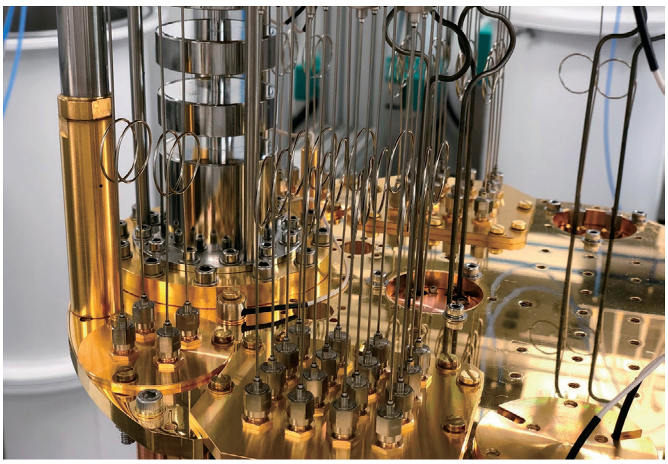


Fig. 1 Heart of the dilution refrigerator for superconducting qubits' evaluation. Multiple wideband signal lines can be seen.

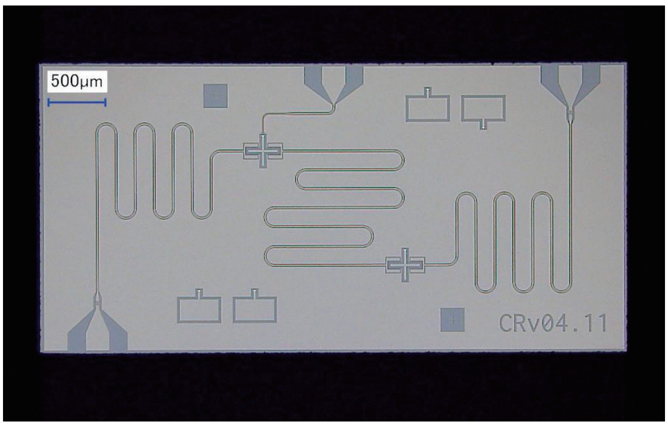


Fig. 2 2-bit quantum logic gate. Two transmon-type qubits (cross-shaped structures) are connected by a superconducting resonator.

(Tokyo University of Science, Tsai Laboratory)

Fundamentals
Established: April, 2021

ito_hiroyuki@rs.tus.ac.jp

Modern Algebra and Cooperation with Engineering

Objectives	To research and develop algebra itself and algebra based engineering, also to make cooperative research on algebra and engineering, thereby to make a contribution to mathematics and engineering.
Future Development Goals	To make contribution to mathematics and engineering, and to continue to be the center of research on algebra and its applications to engineering.

Director
Professor,
Department of Mathematics,
Faculty of Science and Technology

Hiroyuki Ito

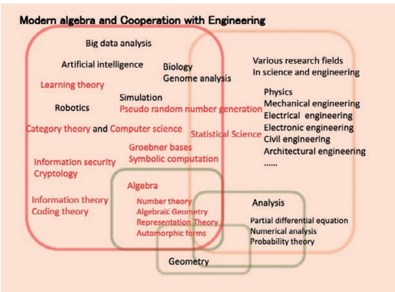
Doctor of Science

This division do research from purely theoretical mathematics to experimental engineering, and make cooperative environment between mathematicians and researchers in algebra based engineering. Furthermore, the division will contribute to make cooperative research between algebra and engineering which induces mathematical innovation. The division continue to play an important role as the international hub for research on algebras.

Theoretical research on algebra and its applications on engineering

Background and purpose of the division

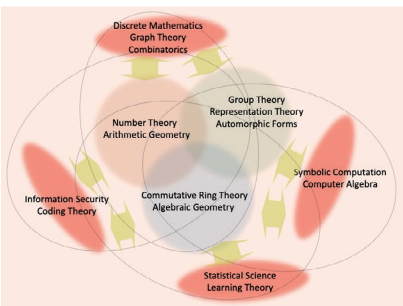
It is important for mathematics, which has more than 2000 years history for research, to interact with other research fields outside mathematics. Research area of pure mathematics is roughly divided into three parts, algebra, geometry and analysis. One can think that algebra and analysis are two wheels of a cart, via geometry and geometric objects. In its long history, analysis, which treat mainly continuous objects, has been developed in interaction with various engineering technology. On the other hand, algebra, which treat mainly discrete objects, has been started to make interaction with information science, information technology, electrical and mechanical engineering, etc., after 20th century, and produce many useful results and effects which are indispensable for modern human life. Our division based on algebra are going to cooperate with another division "Research Alliance for Mathematical Analysis", and are going to be a basis of science and technology to cooperate with various research areas. And finally, to be a center of research on algebra and algebra based engineering.



Research on Modern Algebra and Cooperation with Engineering

The division consists of various researchers inside 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 relationship not only inside the division, but also outside the division, and we are going to produce many cooperative research between pure mathematics and engineering.

More precisely, the division consists of three groups for purely mathematical research and four groups for applied research. Pure mathematics groups are managed by holding seminars, workshops and symposiums on algebra, algebraic geometry, number theory, and so on. Engineering groups are also managed by making a place for engagement of researchers of pure mathematics and engineering, and by proposing and developing many research plans for both sides, mathematics and engineering. Furthermore, the division do cooperative research under continuously pursuing the deep cooperation with Research Alliance Center for Mathematical Sciences, Tohoku University.



There are three special features of this division. 1) The generations of researchers are widely distributed. 2) They have enough experiences of joint research not only for domestic but also for international. 3) The researchers have been managed continuously various seminars and symposiums inside Tokyo University of Science.

About the Future of Modern Algebra and Cooperation with Engineering

Since making relationship between person and person in various research fields has already done, the next step is expanding the relationship between person and person to the cooperative relationship between person and group, group and group. Furthermore, develop a new cooperative research fields based on algebra. Also keep to play an role as an international research hub cooperate with Research Alliance Center for Mathematical Sciences, Tohoku University.

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
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
Yuya Matsumoto	Junior associate professor	Department of Mathematics Faculty of Science and Technology	Number Theory Algebraic Geometry
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
Takeda Wataru	Assistant professor	Department of Mathematical Information Science Faculty of Science Division I	Number Theory Combinatorics
Yoshinosuke Hirakara	Assistant professor	Department of Mathematics Faculty of Science and Technology	Number Theory

Open Innovation Project

Established: April, 2022

koho@admin.tus.ac.jp

The Kao "Kirei" Future Open Innovation Project

Objectives	Kao will promote the development of innovative technologies to enrich people's lives by collaborating with Kao's technologies and the TUS's knowledges in biochemical science, interface science, and brain science.
Future Development Goals	We will work not only on research and development, but also on contributions to the SDGs and human resource development. Details of these efforts can be found in the movie※ at TUS Forum 2021 (Japanese only). ※ URL: https://www.tus.ac.jp/tusforum/2021/archive.html#point03

Director
Associate Professor,
Department of Pure and Applied Chemistry,
Faculty of Science and Technology
Isao Shitanda

This open innovation project is a joint research project between Kao Corporation ("Kao") and the Tokyo University of Science (TUS). This is the first project designated under the "Open Innovation Projects" system of the RIST. Kao and TUS are both working to solve social problems through science and technology, and we expect significant synergy effects through collaborative research and development.

Develop innovative technologies to enrich people's lives

Based on 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 2025 (K25) outlines the company's direction to "Become a company that protects future lives" and Kao conducts research and development to contribute to sustainable society and 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 "The Kao "Kirei" Future Open Innovation Project" and started joint research. While recognizing their respective social missions and roles, both parties are promoting the development of innovative technologies to enrich people's lives.

The following four joint research themes are in progress. We aim to 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

Theme 1
Research on Biofuel Cells and Biosensors

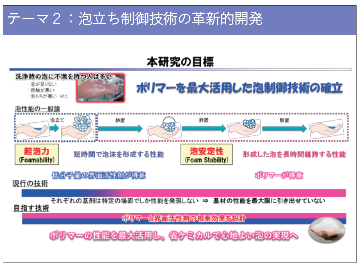
Innovative development of bio-devices

1) Investigation of the practical application of health monitoring devices that generate power from the human body
2) We will study the realization of an ultimate health care device that allows anyone to manage health information at any time by incorporating biofuel cells, which provide clean and safe power supply regardless of location, into wearable devices.

Theme 2
Research on foaming control and functionalization

Innovative development of foaming control technology

1) Maximize surfactant performance using small amounts of polymers to achieve comfortable and rich foam with a minimum of materials
2) Understand the synergistic effects of mixing surfactants and polymers to create technologies that can control various foam performances

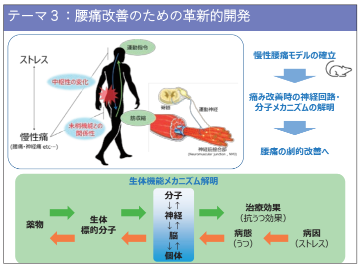


Theme 3
Research on Neural and Molecular Mechanisms of Pain

Innovative development for improvement of low back pain

1) Elucidation of neural and molecular mechanisms of chronic low back pain
2) Elucidation of the mechanism of stress-induced aggravation of low back pain and search for treatment methods by modulating brain functions

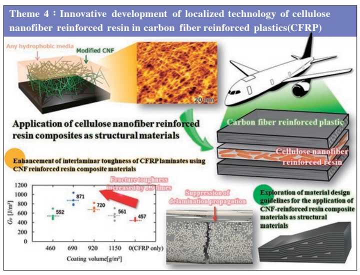
Through the above, we aim to clarify the relationship between the onset of low back pain and stress, and to improve low back pain by regulating brain functions.



Theme 4
Research on Application of Cellulose Nanofiber Reinforced Resin Composites to Structural Materials

Research on innovative development of CNF reinforced resin composites for internal localization in carbon fiber reinforced Plastics (CFRP)

1) Explore the application of CNF-reinforced resin composites for high interlaminar toughness of CFRP composite laminates.
2) Explore material design guidelines for the application of CNF-reinforced resin composites as structural materials.



In addition to research and development on the above existing themes, discussions are held on the establishment of new themes. In order to discuss new themes, we will hold a new technology presentation to introduce the TUS's technological seeds. Brainstorming sessions are also planned to discuss the expansion and development of research and development into new areas. In addition, we also offer special lectures for undergraduate and graduate students and other human resource development programs to expand organization-to-organization collaboration.

Established: June, 2022

manabu@rs.tus.ac.jp

Research & Development Platform of Functional Green Building Materials

Objectives	Our goal is to achieve the societal implementation of environmentally conscious architecture by developing a system to assess and visualize the life cycle CO_2 emissions of non-structural components, considering their lifespan. Additionally, we promote research and development of high-performance materials and construction methods that reduce CO_2 emissions during manufacturing and construction.
Future Development Goals	We will achieve the design and construction methods with innovative functional building materials based on new concepts while taking advantage of the industry-academia collaboration and science-engineering partnership, toward the ultimate goal of environmentally conscious architecture.

Director
Professor
Department of Architecture
Faculty of Science and Technology

Manabu KANEMATSU

Ph.D

What is Environmentally conscious architecture, and how should it be designed and constructed? What materials and construction methods contribute to that realization? Our goal is to create and enhance the academic research field that bridges cutting-edge and fundamental research areas with practical application areas, bringing together Tokyo University of Science's scientific and engineering expertise and Shimizu Corporation's practical and operational capabilities towards achieving the design and construction methods required to realize truly environmentally conscious buildings.

Toward the realization of environmentally conscious architecture through research and development of high-performance materials and design-construction methods contributing to CO_2 emission reduction

Background and Purpose of the Project

As efforts towards decarbonization spread throughout society, the role served by the construction sector, which forms the foundation of people's activities and lives, is immensely significant. It is essential to conduct a comprehensive examination that combines the academic foundation required for achieving highly advanced environmentally friendly architecture with the practical capability to implement these concepts in the real world. Given the significant advancements in energy conservation, renewable energy, and CO_2 reduction during the operational phase of buildings, the proportion of environmental impact generated during material procurement, production, and construction processes is relatively increasing throughout the entire building lifecycle. In particular, nonstructural components, which produce about 20% of the "Embodied Carbon" emissions during the construction phase, play an important role in controlling the diverse performance and functionality of spaces. On the other hand, while there are a vast number of combinations of materials and construction methods, and there have been many individual studies on it and social implementations from the perspective of environmental considerations, efforts to optimize the environmental impact, performance, and functionality of entire buildings have not been sufficient.

This project aims to establish practical design and construction methods that minimize environmental impacts throughout the entire lifecycle, by developing the evaluation methods for environmentally friendly architecture. Our fusion research project will serve as a platform for the development of new functional building materials that bridge advanced foundational research and practical applications, with the goal of creating new research fields.

Towards Achieving Environmentally Friendly Architecture through Reduction of Environmental Impact in Non-Structural Components

In the pursuit of reducing environmental impacts associated with non-structural components, a comprehensive assessment considering both Embodied Carbon and operational carbon emissions during the operational phase is necessary to evaluate the entire lifecycle CO_2 emissions of buildings, known as "Whole Life Carbon." However, the evaluation methodology for Whole Life Carbon has not been definitively established. Moreover, it's essential to take into account the impacts of variations in material production processes, the use of recycled materials, and other practical initiatives. However, when compared to structural materials, the inadequate progress in establishing a comprehensive database for non-structural materials, which is crucial for accurately calculating Embodied Carbon, is also a noteworthy concern.

Therefore, this project will advance research and development through the establishment of the following working groups for "Investigation of Environmentally Friendly Architecture Strategies," which aims to construct evaluation and optimization methodologies for the design and construction of environmentally friendly architecture, as well as "Research and Development of Environmentally Friendly Construction Methods," which involves the implementation of specific material and construction method developments.

i)Investigation of Environmentally Friendly Architecture Strategies
WG0: CO_2 Reduction Strategy
ii)Research and Development of Environmentally Friendly Construction Methods
WG1: Exterior Materials / WG2: Interior Materials /
WG3: Opening Components / WG4: Substrate Materials

In the WG0, we aim to construct a system that assesses and visualizes CO_2emissions of non-structural materials at each life stage. Additionally, we will promote research and development of materials and methods that achieve a high level of environmental performance and functionality for exterior materials (WG1), interior materials (WG2), opening components (WG3), and substrate materials (WG4), which have a significant impact on Whole Life Carbon.

Contribution of this Project

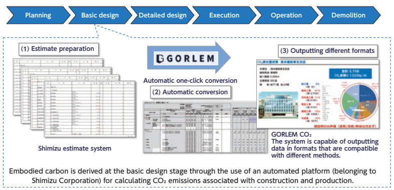
By promoting this industry-academia collaboration project as a comprehensive project based on open innovation, the project's two collaborators intend to create pioneering examples in a wide range of boundary regions and lead the way in environmental conservation efforts within the construction industry. The realization of this initiatives is expected to result in the following contributions to the societal issue:

Establishment of an ecologically congruous society via the formulation of methodologies underpinning design and construction facets of environmentally mindful architecture.

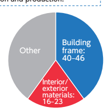
Pioneering the development and real-world assimilation of novel material technologies and construction methodologies that underpin environmentally conscious architectural endeavors.

The crystallization of an integrated framework that fosters both foundational research and societal deployment, culminating in the creation and implementation of pioneering environmentally conscious technological paradigms.

Nurturing a cadre of adept professionals pivotal to the realization of environmentally conscious architectural endeavors.



Items	A	B	C	D	E	F
Total floor area (m²)	3,700	4,100	6,500	7,500	16,000	19,000
CO_2 emissions (kg-CO_2 / m²)	1,300	1,300	1,200	1,200	1,100	1,400
Building frame (%)	40	40	42	43	46	42
Exterior materials (%)	8	9	7	6	4	12
Interior materials (%)	12	11	12	10	12	11



Examples of life cycle CO_2 calculation results (six office building examples) are based on the "LCA Guidelines for Buildings" published by the Architectural Institute of Japan Interior and exterior materials (non-structural components) play a functional role in determining the direct performance of buildings, and their share of CO_2 emissions cannot be ignored.

Examples of efforts aimed at achieving environmentally friendly construction

RIST Organization Chart

Chairman of the Board of Governors

President

Organization for Research Advancement

Research Institute for Science & Technology

Research Institute for Science & Technology Steering Committee

Research Institute for Science & Technology

Research Centers

- Center for Fire Science and Technology
- Water Frontier Research Center
- Research Center for Space System Innovation [SSI]
- Research Center for Drug Discovery and Applied Sciences

Joint Usage / Research Center

- Research Center for Fire Safety Science

Research Divisions

- ★Carbon Value Research Center
- ★Research Center for Multi-Hazard Urban Disaster Prevention
- Development of superior cell and DDS for regenerative medicine
- Division of Biological Environment Innovation
- Division of Colloid and Interface Science
- Division of Composite Materials Engineering
- Division of Digital Transformation
- Division of Implementation of sustainable technology in society
- Division of Nanocarbon Research
- Division of Nano-quantum Information Science and Technology
- Division of Nucleic Acid Drug Development
- Division of Smart Healthcare Engineering
- Division of Synthetic Biology
- Medical Data Sciences
- Modern Algebra and Cooperation with Engineering
- Parallel Brain Interaction Sensing Division
- Renewable Energy Science & Technology Research Division
- Research Alliance for Mathematical analysis
- Research Division for Advanced Disaster Prevention on cities
- Research Group for Advanced Energy Conversion
- Statistical Science Research Division

The Open Innovation Projects

- The Kao “Kirei” Future Open Innovation Project
- Research & Development Platform of Functional Green Building Materials

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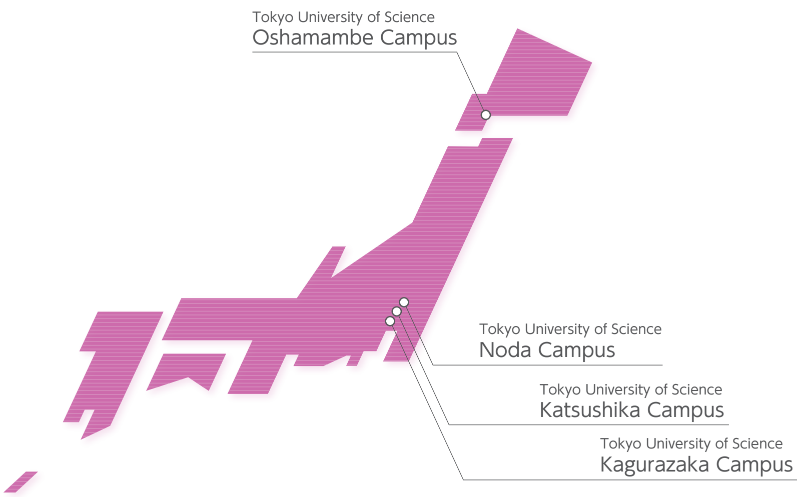
Campus Map



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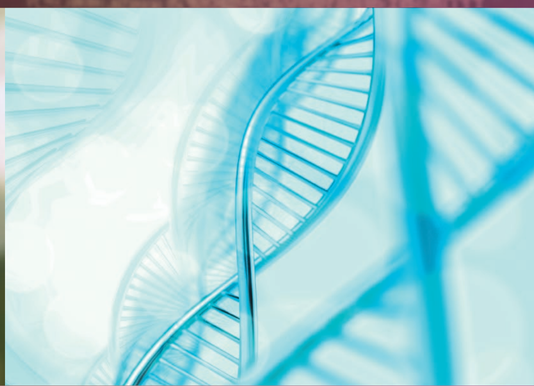


Tokyo University of Science
2023/2024

RIST creates new directions in science and technology achievable"Only at TUS".