Tokyo Tech
Research Units

Advanced Data Analysis and Modeling Unit

Overview

The accelerated increase in the level of information this century has seen the generation of a greater amount of big data on human behavior than ever before. The Advanced Data Analysis and Modeling Unit utilizes big data owned by public and private entities in an integrated manner to clarify phenomena in human society from a scientific viewpoint. The unit attempts to express changes in society through equations applying both mathematics and physics. Expansion in this field of research will make possible the prediction of future conditions in economic and social systems in much the same way we now forecast weather utilizing airflow equations.

Research Unit Leader **Misako Takayasu**

Profile

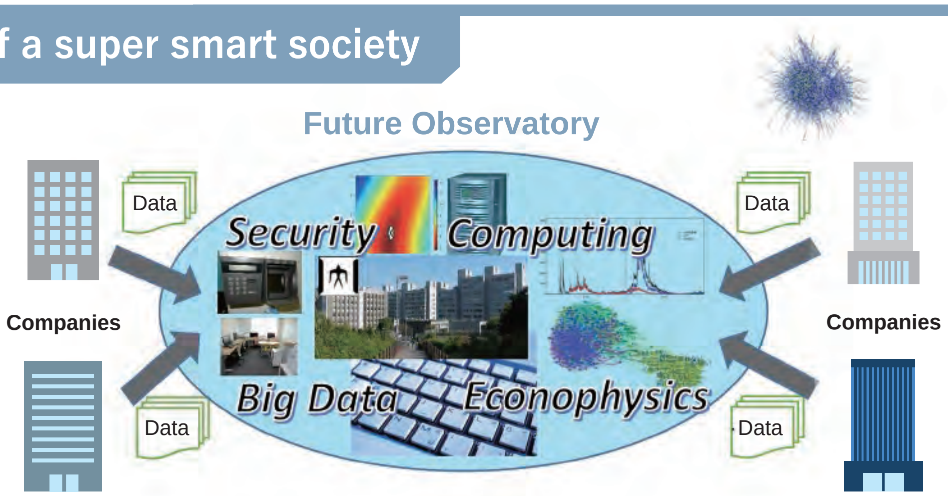
2017	Professor, Institute of Innovative Research, Tokyo Institute of Technology
2016	Associate Professor, Institute of Innovative Research, Tokyo Institute of Technology
2015	Associate member, Science Council of Japan (Committee on Physics and Informatics)
2007	Associate Professor, Department of Computational Intelligence and Systems Science, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
2000	Assistant Professor, Department of Complex and Intelligent Systems, Future University Hakodate
1997	Assistant Professor, Faculty of Science and Technology, Keio University
1993	JSPS Research Fellow, Tohoku University
1993	Doctor of Science, Department of Material Science, Graduate School of Science and Technology, Kobe University
1987	Bachelor of Science, Department of Physics, School of Science, Nagoya University

WEB www.adam.iir.titech.ac.jp

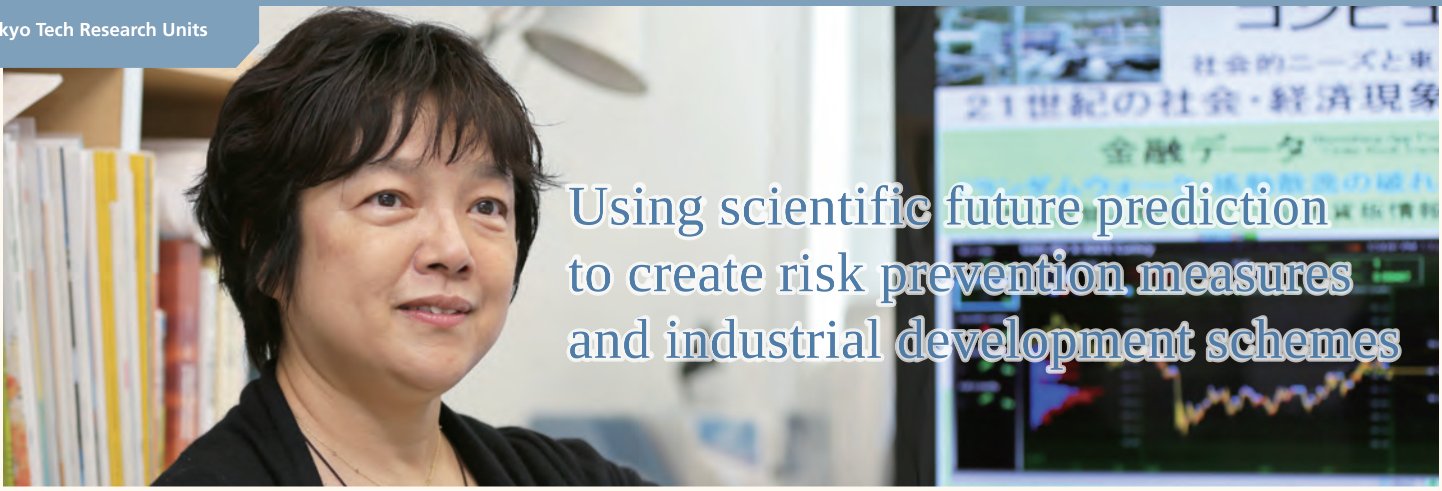
Research goals

Transactions in financial markets are made in milliseconds, and the amount of data collected in real time is now one million times greater than it was 20 years ago. It is now also possible to scientifically formularize how violent fluctuations in prices occur and how these affect other markets, which we do in much the same way as we write molecular formulas based on detailed observation. The Advanced Data Analysis and Modeling Unit attempts to analyze big data in a wide range of fields, including financial markets, to create descriptive mathematical models. This makes it possible to understand individual research conducted in different fields in an integrated manner. Through the Future Observatory, which will be established to store big data and serve as a base for scientific research, the unit attempts to precisely simulate future conditions to solve a wide range of problems encountered in society to gain a multilateral understanding of phenomena in economics and human society.

Needs of a super smart society



Creating added value in society through cutting-edge integration of big data



Using scientific future prediction to create risk prevention measures and industrial development schemes

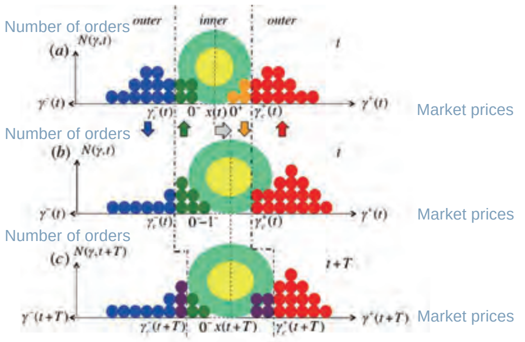
Q Why was this research unit established?

Current social phenomena are multi-layered and complex. Significant breakthroughs are possible, however, if we carefully and quantitatively observe correlations among them, and clarify the relationship between individual activities and social phenomena through an integration of mathematics, physics, and computational sciences. The Advanced Data Analysis and Modeling Unit aims to develop models capable of identifying how certain changes, occurring at various scales, cause specific shifts in society. This would in turn enable us to consider more specific applications. Researchers specializing in a wide range of fields such as econophysics, machine learning, system sciences, optimization, and security participate in the unit, which forms a major research organization for big data at Tokyo Tech and facilitates the efficient achievement of results. An example of the systems developed by this research unit are PUCK-tools, financial market data risk analysis tools included in standard applications used in the financial industry. Estimation algorithms and transactions among Japanese companies are used by RESAS, a regional economy analysis system provided by the Cabinet Office. The unit conducts joint research with other groups in the United Kingdom, Switzerland, Israel, and the United States to form a base that serves as an international hub in the field.

Q What are the strengths of this research unit?

Along with a system that enables the use of highly confidential data owned by companies for academic research, the Advanced Data Analysis and Modeling Unit will also establish the Future Observatory, enabling joint industry-government-university research utilizing this data. When analyzing valuable big data owned by different companies in an integrated manner, data sharing is often difficult due to the confidentiality requirements of individual companies. However, a university can serve as a neutral core for a consortium, making it easier to share data beyond the boundaries of companies. This is also a great advantage for industry. The Advanced Data Analysis and Modeling Unit is equipped with a high-quality computational environment and cutting-edge security management system that contribute to advanced mathematical analysis and safe management of data, making possible the protection of healthcare data, positional information from mobile phones, and other highly confidential data. The Future Observatory will also be highly valuable as a historical archive of Japanese industry and culture as time goes by.

Analogy between dynamics of financial market order information and colloidal particle motion in water molecules



Based on the assumption that there is a virtual colloidal particle between buying and selling orders, and regarding orders as water molecules, market price fluctuations share similarities with the motion of the colloidal particle.

● ● Buying orders
● ● Selling orders

Sources：Physical Review Letters 112, 098703 (2014), Physical Review E 92, 042811 (2015)

Q What is the path to achieving the unit's goals?

In the first year, the research unit will enhance the environment of the Future Observatory by implementing an entry management system using biometric authentication and a network security system. Progress in big data collection, integration, and analysis, and the establishment of models will continue. In the second year, the unit aims to set up a consortium for industry-government-university collaboration to accumulate a broader range of data, verify and review predictions to improve established models, and construct an environment where the use of these models in society can be simulated. Through scientific future prediction, the unit hopes to create risk prevention measures and industrial development schemes that significantly contribute to society.

Contact us

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Tokyo Tech
Research Units

Atomhybrid Materials Unit

Overview

Nanoparticles, measured in units of one billionth of a meter, are extensively applied in engineering. However, we have yet to fully clarify the properties of sub-nanoparticles, particles that are even smaller than nanoparticles. This has hindered the development of synthesis methods. It is expected that if we can freely structure sub-nanoparticles by programming the number of atoms in them and the compounding ratio of constituent elements, then we can create substances with properties that are completely different from what we have now. Specifically, there is no known method for integration and combination of atoms of different metallic elements. Considering the more than 90 metallic elements in the periodic table of elements, the potential combinations are infinite. The Hybrid Materials Unit aims to create new materials using a highly precise hybrid method of blending metallic elements utilizing uniquely developed dendritic polymers (dendrimers) with the goal of opening the door to a new field that will serve as the base for next-generation functional materials.

Research Unit Leader

Kimihisa Yamamoto

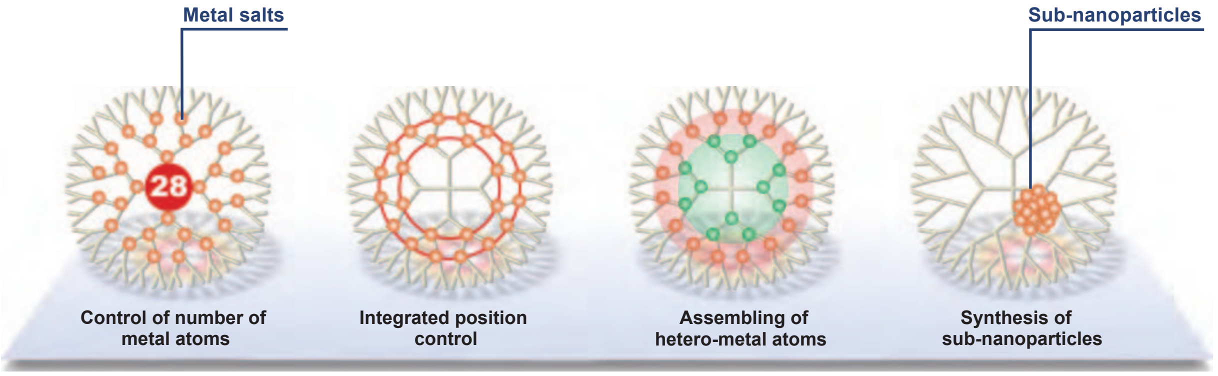
Profile

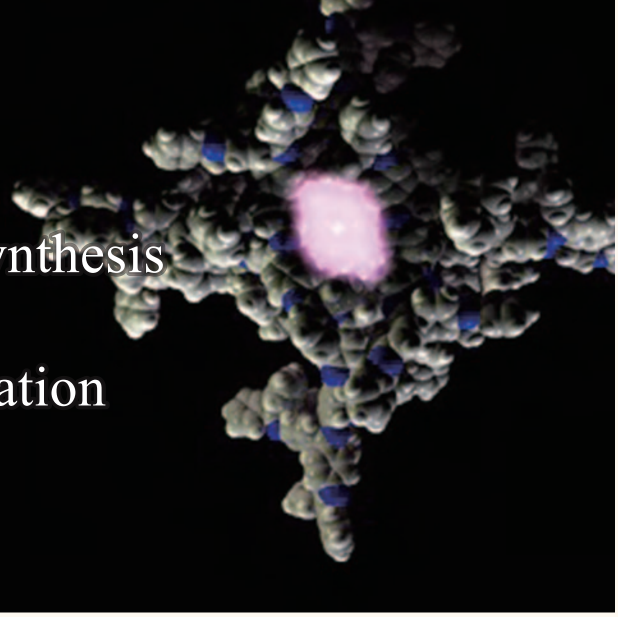
2016	Professor, Institute of Innovative Research, Tokyo Institute of Technology
2010	Professor, Chemical Resources Laboratory, Tokyo Institute of Technology
2002	Professor, Faculty of Science and Technology, Keio University
1997	Associate Professor, Faculty of Science and Technology, Keio University
1990	Doctor of Engineering, Graduate School of Science and Engineering, Waseda University
1989	Research Associate, School of Science and Engineering, Waseda University
1985	Bachelor of Engineering, Department of Applied Chemistry, School of Science and Engineering, Waseda University

Research goals

Dendrimers have a three-dimensional structure with internal voids like the spaces between the branches of a tree. They are high-molecule structures with regular geometrical shapes and potential gradient. In the past, metallic sub-nanoparticles were thought to have been randomly arranged. However, the Hybrid Materials Unit was the first to discover that dendrimers have a stepwise complexation that extends from their inner to outer layers. The unit also established a method of synthesis that allows flexible and accurate control of the number, arrangement, ratio, and order of similar and dissimilar elements. The unit calls this the atom hybrid method. By applying this method, the Hybrid Materials Unit aims to produce new materials that are beyond our imagination, clarify their properties, and discover the number of atoms and correlations with different types of elements. The unit also aims to systematize new materials and create a next-generation material library leading to the future design of materials.

Atom hybrid method





Progressing in sub-nanoparticle synthesis and discovering new materials with functions beyond our imagination

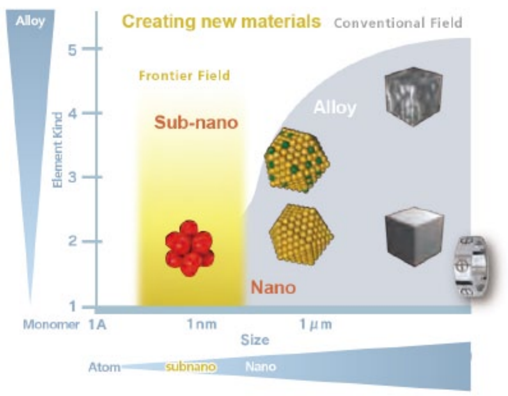
Q Why was this research unit established?

Providing a spacious and secure environment for researchers contributes to innovation and advancement. The Hybrid Materials Unit facilitates consistent research, synthesis, and measurement, and serves as a space for discussion and information sharing among scientists. The unit also considers ways of supporting young chemists and establishing new fields of chemistry.

Q What are the strengths of this research unit?

While other researchers succeeded in synthesizing sub-nanoparticles, the Hybrid Materials Unit established a method that allows researchers to freely determine the number of atoms and handle them stably. Although global competition is fierce in the field of sub-nanoparticle research, the unit is still far ahead of others in the area of efficient synthesis. The unit continues to move forward in dendrimer synthesis to discover new materials with heretofore unimaginable functions.

Unexplored field: Sub-nanoparticles



The dendrimers we discovered and patented make it possible to easily form unified integrated structures by programming the number of atoms and the arrangement of a wide range of metals. Of the 112 elements, there are about 90 metallic elements. Among these 90 metallic elements, there are 65 metallic materials that Tokyo Tech can handle stably. In other words, the unit has the potential to create new materials through an infinite number of combinations of such metallic materials.

Q What is the path to achieving the unit's goals?

The Hybrid Materials Unit sets *synthesis*, *structure*, and *function* as the three major pillars as it sheds light on the unexplored field of sub-nanoparticles, aiming to systematize it as a new academic area. The unit confidently takes the lead toward mass synthesis processes as it considers practical implementation in society. The research structure was established in 2015. In 2016, the unit will promote research within the established structure, focusing on advancing the individual research topics of the group leaders.

Contact us

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Atomhybrid
Materials Unit

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March 2016

Tokyo Tech
Research Units

Biointerfaces Unit

Overview

The Biointerfaces Unit focuses on mechanisms by which information sent from our brain moves our body, and develops technology that enables brainwaves to control machines and devices. The unit also develops technology capable of assessing the condition of organs such as the liver, kidneys, and brain to promote health and enable the early detection of disease. Utilizing sensors that noninvasively assess the condition of the brain and other organs, the unit develops biointerfaces that control devices using collected biological signals. The goal of the unit is to utilize biointerfaces not only for the benefit of the elderly and disabled, but also for a wide range of purposes including the development of equipment designed to maintain health in daily life.

Research goals

The Biointerfaces Unit aims to clarify the mechanisms of hand and foot movements via signals from the brain utilizing brain waves and electromyograms, develop prosthetic arms and hands that can be moved by brain activity alone, and apply this technology to rehabilitation of individuals suffering from limb paralysis due to strokes and other diseases. The unit also plans to develop mobile devices that can noninvasively detect internal conditions from outside of the body. These include the condition of the liver and bladder, and other biological information such as blood and breathing to be used in the prevention of disease. By bringing together such technologies, the unit conducts research and development for wearable devices capable of monitoring health.

Research Unit Leader **Yasuharu Koike**

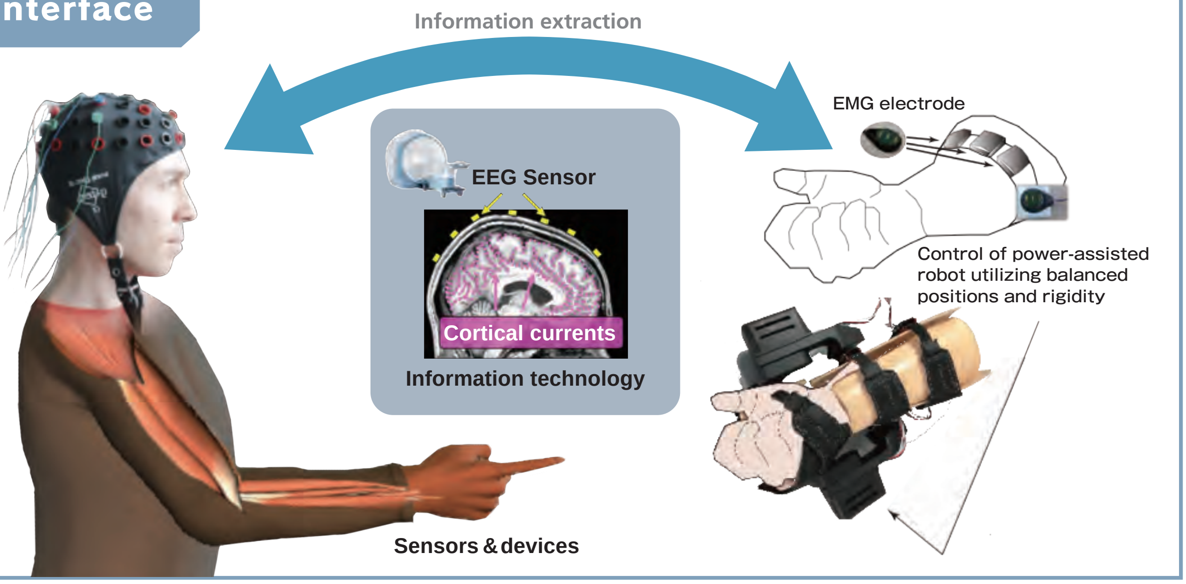
Profile

2016	Professor, Institute of Innovative Research, Tokyo Institute of Technology
2009	Professor, Precision and Intelligence Laboratory, Tokyo Institute of Technology
1998	Associate Professor, Tokyo Institute of Technology
1995	Toyota Motor Corporation
1992	Researcher, Advanced Telecommunications Research Institute International
1989	Toyota Motor Corporation
1989	Master of Engineering, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
1987	Bachelor of Engineering, School of Engineering, Tokyo Institute of Technology

Unit members

- Associate Professor Hirohiko Kaneko
- Associate Professor Natsue Yoshimura
- Professor Kentaro Nakamura
- Associate Professor Kotaro Tadano
- Professor Yoshitaka Kitamoto
- Professor Scott Makeig, University of California San Diego
- Associate Professor Nicolas Schweighofer, University of Southern California
- Associate Professor Marie Tahara
- Professor Susumu Kajiwara

Biointerface



Creating a global base for biointerface research through cooperation with companies and faculties of medicine at other universities

Q Why was this research unit established?

The Biointerfaces Unit consists of a wide range of groups, including one that carries out research on brain-machine interfaces via brain signals and another that studies biological signals to the liver and other internal organs. The unit enables the gathering of component technology from the various groups, promotes information sharing, and conducts research and development for overall systems for the healthcare industry. Centering on Tokyo Tech, the unit also promotes cooperation with companies and faculties of medicine at other universities with the aim of creating a global base for biointerface research.

Q What are the strengths of this research unit?

Tokyo Tech has 150 faculty members engaged in research in the life sciences, medical care, and health. Their research is expanding to a wide range of fields, including chemical biology and regenerative medicine. Tokyo Tech researchers have achieved excellent results, particularly in the area of sensors and devices capable of monitoring the condition of the brain and internal organs noninvasively. The Institute also has information technology that allows us to analyze tremendous amounts of data collected from these sensors as big data. We are proud of our elemental technology and comprehensive capabilities.

Comprehensive development of health and medical care prototypes

- **Brain-type information technology development**
- **Biointerface and device development**

↓

Development as international research base

Collaboration with

Faculties of medicine, universities, companies

Q What is the path to achieving the unit's goals?

The Biointerfaces Unit will promote its five-year plan for the development of elemental technology in the life sciences. We will advance research on algorithms used to move the human body utilizing brain sensors that are under development, and will swiftly move toward commercialization. The unit will also work on new diagnostic methods by effectively utilize the resources available at Tokyo Tech, which include functional magnetic resonance imaging to visualize brain activities. The Biointerfaces Unit also continues to promote research and development of wearable devices capable of understanding health conditions, aiming also for their rapid commercialization.

Contact us

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Biointerfaces Unit

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March 2016

Tokyo Tech
Research Units

Nanospace Catalysis Unit

Overview

In order to realize a low-carbon society, it is essential to reduce dependency on fossil fuels, utilize fossil resources more effectively, and reduce CO_2 emissions. The Nanospace Catalysis Unit aims to establish innovative production processes for nanospace catalysts and chemical substances utilizing diverse carbon resources. Nanospace catalysts have a number of super-fine pores (nanospaces) at the nanometer level in crystals. This unit focuses on the catalytic properties of zeolite,* one of the porous crystalline materials that controls the catalytic active site at the atomic level, and works to develop breakthrough catalysts that contribute to the realization of a low-carbon society.

*Zeolites are aluminosilicates with molecular-size pores in their crystal structures

Research Unit Leader **Toshiyuki Yokoi**

Profile

2018	Associate Professor, Institute of Innovative Research, Tokyo Institute of Technology
2016	Assistant Professor, Institute of Innovative Research, Tokyo Institute of Technology
2006	Assistant Professor, Chemical Resources Laboratory, Tokyo Institute of Technology
2004	Assistant Professor, Department of Chemical System Engineering, School of Engineering, University of Tokyo
2004	Doctor of Engineering, Department of Materials Science and Engineering, Yokohama National University

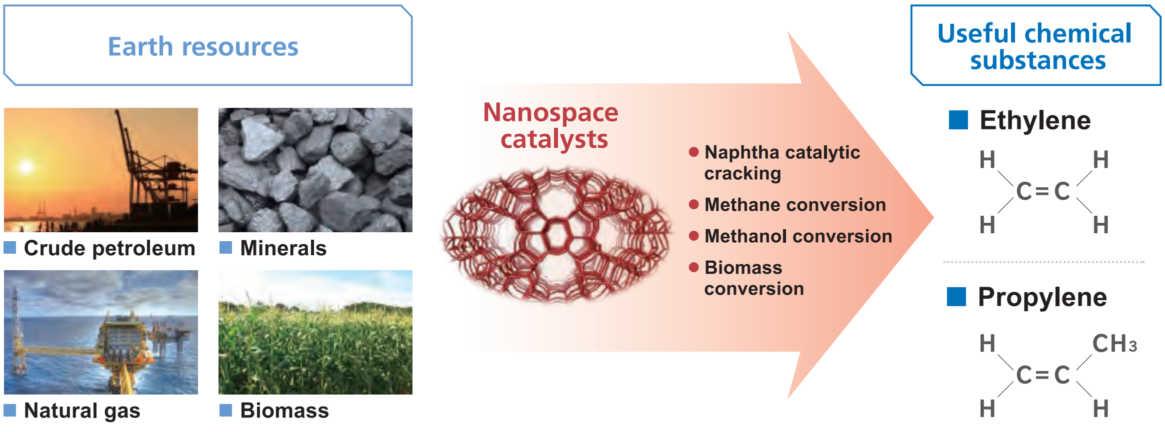
Unit members

- Adjunct Assistant Professor Yong Wang
- Adjunct Assistant Professor Yunan Wang
- Adjunct Assistant Professor Sungsik Park

Research goals

The diameter of zeolite pores is one nanometer or less. Larger molecules cannot pass into these pores. Therefore, zeolite can select smaller molecules such as methane and methanol, and promote their chemical reactions. Utilizing the characteristics of zeolite, this unit places catalytic active sites in optimal positions in pores at the atomic level with the goal of establishing catalytic reaction processes designed to synthesize useful chemical substances such as methanol and ethylene from methane, which until now has only been used as a fuel, and to synthesize basic chemical substances such as ethylene and propylene from methanol obtained from CO_2 and water.

Innovative nanospace catalysts that produce useful chemical substances utilizing diverse carbon resources



Earth resources

- Crude petroleum
- Minerals
- Natural gas
- Biomass

Nanospace catalysts

- Naphtha catalytic cracking
- Methane conversion
- Methanol conversion
- Biomass conversion

Useful chemical substances

- **Ethylene**
- **Propylene**

Realizing a low-carbon society with nanospace catalysts and effective use of diverse carbon resources

Why was this research unit established?

A sustainable low-carbon and recycle-oriented society requires that we reduce the use of conventional fossil fuels such as crude petroleum and find more effective ways to use these resources. It is also necessary to develop production processes that synthesize fine chemicals such as plastics, fibers, coatings, pharmaceuticals, and agrichemicals utilizing shale gas, biomass, and other unconventional resources. To address these challenges, it is essential to develop innovative catalysts. Therefore, we focus on the establishment of the world's first optimal production processes for nanospace catalysts. In addition to zeolites, we are expanding our research targets to include other nanospace catalysts to achieve our goals.

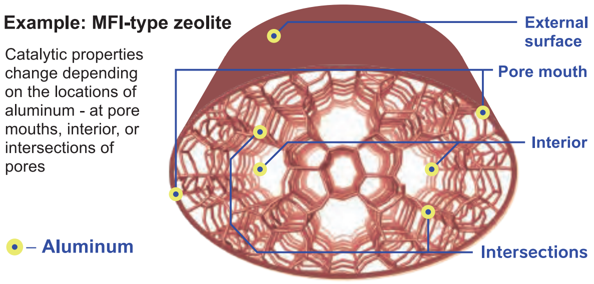
What are the strengths of this research unit?

Zeolite is a porous crystalline material composed of silicon, aluminum, and oxygen. The aluminum in the framework of zeolite crystal directly influences catalytic properties. Zeolite has been used as a catalyst to produce gasoline from crude petroleum. However, changing the molecular structure, strictly controlling the position of the aluminum, or changing the size of pores can produce new catalytic reactions. Chemists were particularly interested in the strict control of the position of aluminum, which we achieved for the first time in the world in 2015. The unique method of control is one of the strengths of our research.

Selective production of chemical substances by controlling the position of aluminum at the atomic level

Example: MFI-type zeolite

Catalytic properties change depending on the locations of aluminum - at pore mouths, interior, or intersections of pores



What is the path to achieving the unit's goals?

While over 200 zeolites have already been synthesized, we will develop a new zeolite catalyst that is superior to existing ones due to the nanospace structure and control of the position of catalytic active sites. Next, we will develop catalytic reaction processes that allow the synthesis of basic chemical substances with a high selectivity to contribute to the effective use of a wide range of carbon resources. We will also establish methods of structural analysis and evaluation of nanospace catalysts, including zeolite, by utilizing advanced NMR and electron microscopy techniques. In addition, we will participate in national projects organized by the New Energy and Industrial Technology Development Organization, Japan Science and Technology Agency, etc. to further the development of a broad range of innovative catalysts.

Contact us

Tokyo Institute of Technology
Nanospace Catalysis Unit

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Tokyo Tech
Research Units

Quantum Computing Unit

Overview

After decades of continued efforts in basic research, a prototype quantum computer was announced and commercialized in 2011 under the protocol of quantum annealing proposed by the group led by Professor Hidetoshi Nishimori in 1998. The machine has since been upgraded to its current fourth generation, and has spurred a flurry of R&D activities in industry as well as in academia toward real-life applications. Quantum computers are expected to process some of the very complicated tasks that are out of reach of supercomputers. The list of such tasks considered within reach of near-future hardware includes traffic optimization, portfolio optimization, large-scale code debugging, solutions to fluid equations, air traffic control, and medical diagnosis. Research activities of the Unit will cover a broad range of areas of quantum annealing from basic theory to software and applications.

Research goals

Quantum annealing, a term taken from the metallurgy technique “annealing”, is a metaheuristic (generic approximate algorithm) for optimization problems. Basic theories are still to be established on the mechanisms of enhancement of its performance. The Unit thus focuses on the following topics:

(1) Possible enhancement of the performance by the introduction of new mechanisms.

(2) Error correction in quantum annealing.

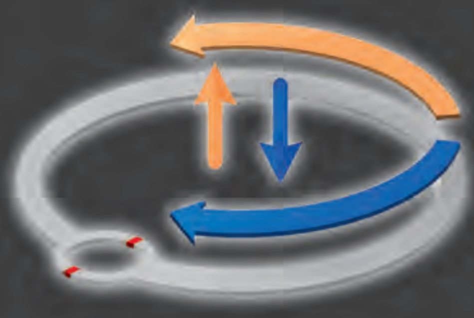
(3) General methodologies to express optimization problems with the Ising model.

Research Unit Leader **Hidetoshi Nishimori**

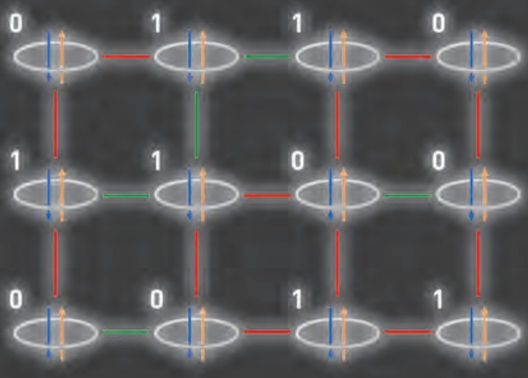
Profile

2018	Professor, Institute of Innovative Research, Tokyo Institute of Technology
2016	Dean, School of Science, Tokyo Institute of Technology
2011	Dean, Graduate School of Science, Tokyo Institute of Technology
1996	Professor, School of Science, Tokyo Institute of Technology
1990	Associate Professor, School of Science, Tokyo Institute of Technology
1984	Assistant Professor, School of Science, Tokyo Institute of Technology
1982	Doctor of Science, Department of Physics, School of Science, The University of Tokyo
1982	Research Associate, Department of Physics, Rutgers University
1981	Research Associate, Department of Physics, Carnegie-Mellon University
1977	Bachelor of Science, Department of Physics, Faculty of Science, The University of Tokyo

Quantum Bits and Annealing



In the quantum world, very small metal circuits at ultra-low temperature accommodate electric currents circling clockwise and anti-clockwise simultaneously, which are used to represent “0” and “1” simultaneously in a quantum bit (qubit). This is in marked contrast to the conventional computer, which uses bits that can only be set to a single state of "0" or "1".



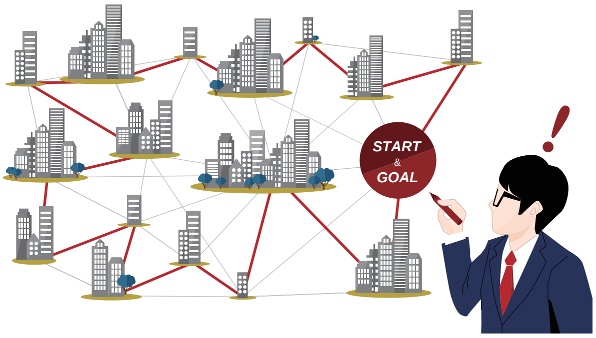
As we turn on the interactions between qubits, the possibility of superposition of two states “0” and “1” is reduced at each qubit, and the system eventually settles to a single state.

Finding solutions to society’s problems through quantum computing

Q Why was this research unit established?

With the rapid progress of quantum computing in recent years, establishing basic theories and systematic theoretical guidelines has become imperative. This Unit engages in comprehensive research, from basics to applications, in global and open environments, to support the adoption of quantum annealing in industry and society.

The traveling salesman problem（TSP）



As a prototypical example of combinatorial optimization problems, TSP seeks the shortest route a salesman can take to visit each city on a given map exactly once before returning to the origin. To apply quantum annealing to TSP, we express TSP in a quantum mechanical formula to find the solution using quantum-parallel processing.

Q What are the strengths of this research unit?

Unit Leader Nishimori established quantum annealing theory. He has been engaging in scientific exchanges with Google and NASA in quantum computing studies and participated in the establishment of standard IEEE quantum computing terminology. A world-class research team has been established for quantum annealing.

Q What is the path to achieving the unit’s goals?

The goal of this Unit is to address speed, error correction, and other topics in quantum annealing. The Unit also entered into a partnership with the "Q+HPC data-driven research center for creation of science and technology" at Tohoku University through which they will promote research and development in a broad range of topics in basic research and applications. The Unit also aims to become a base for the formation of academia-industry consortiums, with the goal of applying quantum annealing to solve the problems faced by society.

Contact us

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Quantum Computing Unit

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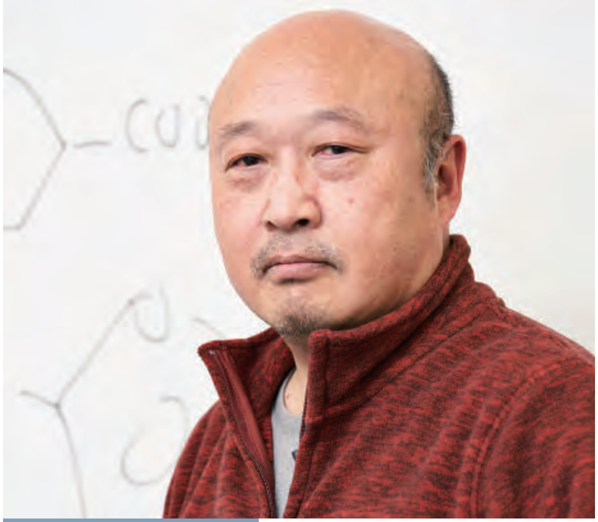
Tokyo Tech
Research Units

Sustainable Chemical Resource Production Unit

Overview

Our aim is to produce chemical raw materials in a sustainable way without using limited fossil resources such as coal, oil, and natural gas in order to establish industrial processes that are better for the environment and realize non-petroleum plastics. The Innovative Heterogeneous Catalysis Unit, which existed until Fiscal 2018, created an innovative catalyst process. This made it possible to produce raw materials for plastics and high-performance polymers from biomass, and established a roadmap toward a non-petroleum plastic society. This research unit will work to establish the world's first industrial process for the mass-production of polymer raw materials, etc., by utilizing the developed catalysts in collaboration with companies.



Research Unit Leader **Michikazu Hara**

Profile

2016	Professor, Institute of Innovative Research, Tokyo Institute of Technology
2006	Professor, Materials and Structures Laboratory, Tokyo Institute of Technology
2000	Associate Professor, Chemical Resources Laboratory, Tokyo Institute of Technology
1999	Postdoctoral fellow, Pennsylvania State University
1995	Assistant Professor, Chemical Resources Laboratory, Tokyo Institute of Technology
1992	Corporate Research and Development Center, Toshiba
1992	Doctor of Science, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology

Unit members

- Associate Professor Debraj Chandra
- Assistant Professor Masashi Hattori

Research goals

To establish a mass production method utilizing the developed catalysts for the following useful materials made from organic resources such as waste wood and other biomasses as well as uneatable portions of plants instead of petroleum in order to create a new industry.

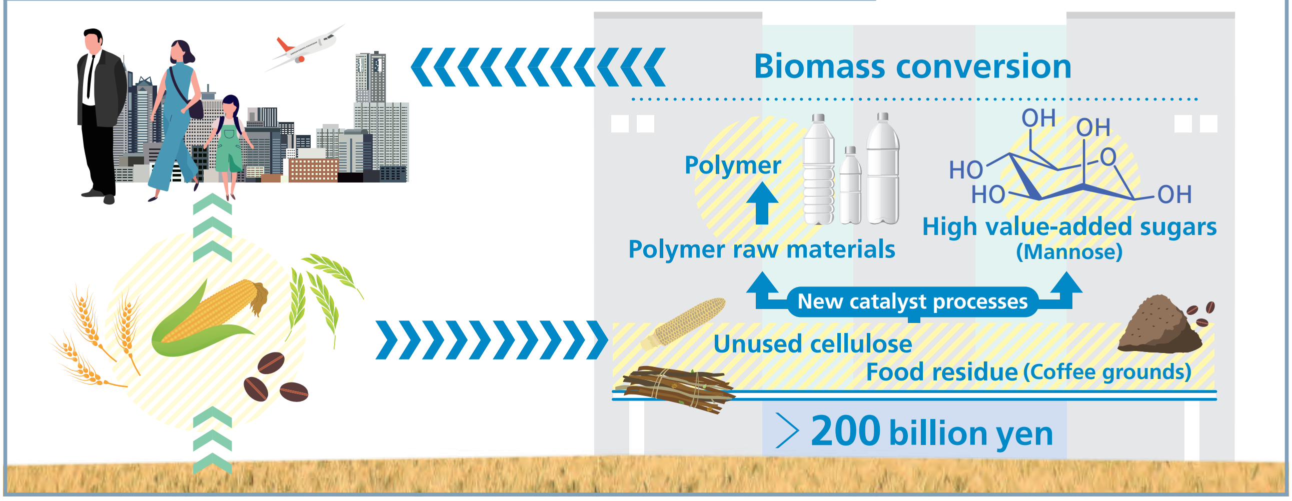
(1) Commercial production of high-performance carbohydrates like mannose, which has an antiviral activity-promoting effect, using the unused portions of foods such as food peelings and coffee grounds

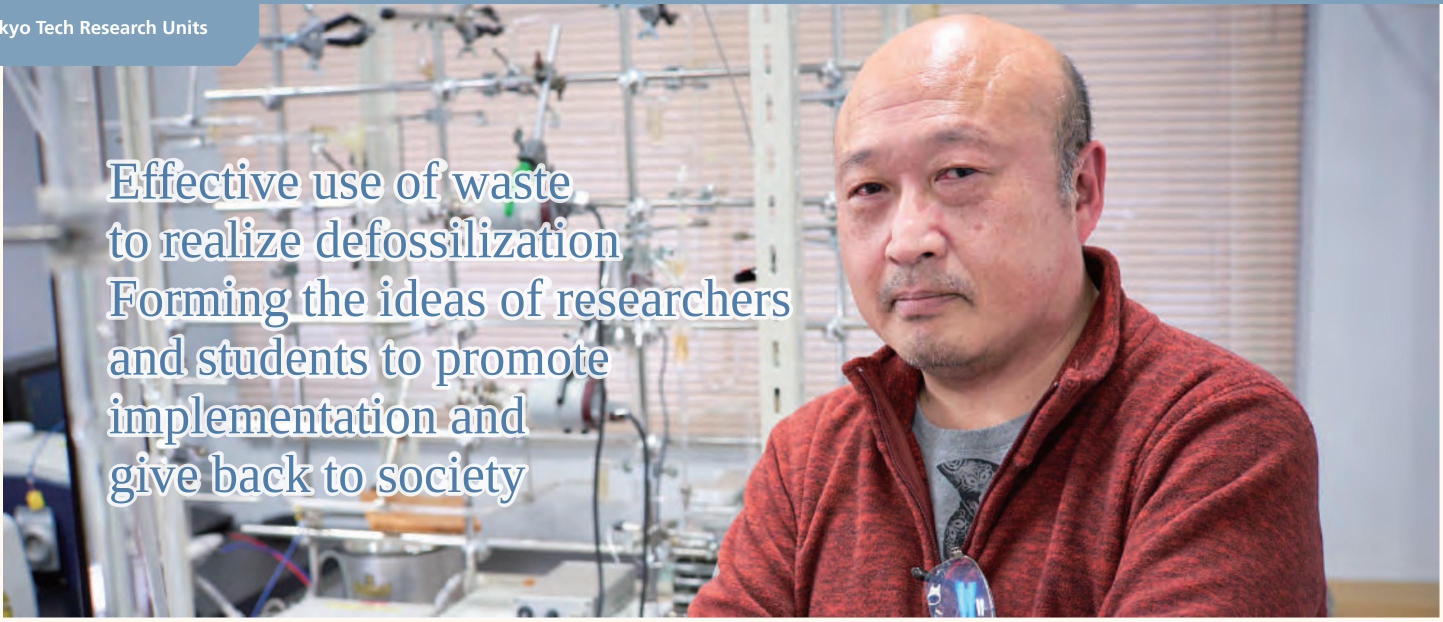
Mannose has been used for pharmaceuticals, but production costs are high and its usages are limited. If this technology becomes practical, it will be possible to reduce costs to a third, and this would have a major impact on society.

(2) Commercial production of engineering plastics and high-performance polymer raw materials from carbohydrates to realize non-petroleum plastics

It will be the world's first industrial process for production of polymer raw materials from carbohydrates. The market for polymer raw materials is over 200 billion yen, so the impact on the industry is great.

Biomass conversion by new catalyst processes





Effective use of waste to realize defossilization Forming the ideas of researchers and students to promote implementation and give back to society

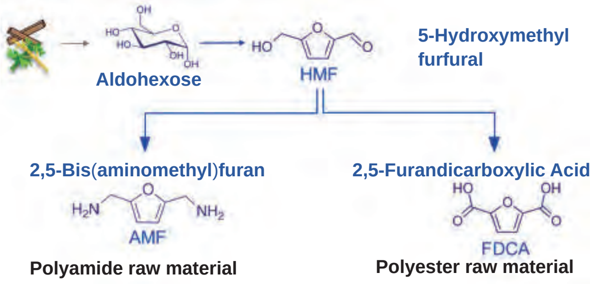
Q Why was this research unit established?

Petroleum is an indispensable part of our lives. Petroleum is used not only for transportation fuel, it is also used in clothing. But if society relies solely on that, resources will be depleted. Therefore, our predecessor, the Innovative Heterogeneous Catalysis Unit, established a technology to produce carbohydrates, high-performance polymers, and engineering plastics from biomass such as waste wood and the "leftovers" from the food industry. For example, they succeeded in extracting mannose from coffee grounds. Mannose is able to activate immune cells (macrophages), so if it could be manufactured at lower cost and in large quantities, it could be used not only for pharmaceuticals but also for food and drinks, and for animal feed. Our unit is aiming to establish industrial processes for mass production and to create new industries by cooperating with companies regarding these technologies.

Q What are the strengths of this research unit?

The strength of this unit is its ownership of unique catalysts. Because we have these catalysts, it is possible for us to create world-first industrial processes. The catalyst for producing mannose from coffee grounds is also innovative. Currently, in Japan, more than 1 million tons of coffee grounds are disposed of each year as valueless waste. This catalyst allows us to produce the useful substance mannose, which has an antiviral activity-promoting effect. In addition, these catalysts are the result of the flexible ideas of students and postdocs. The limitless potential from our young members is another of our strengths.

Biomass conversion：Sugars → Polymer raw materials



Q What is the path to achieving the unit's goals?

Regarding the industrial process for polymer raw materials and the mannose production process developed in this unit, we are proceeding with research at one location in collaboration with companies for implementation to society. We will ask manufacturers, trading companies, and others to join in order to quickly develop suitable processes for commercial production. If these production processes can be put to practical use, it will be possible to reduce the consumption of fossil resources, which will help protect mankind and our planet.

Contact us

Tokyo Institute of Technology
Sustainable Chemical Resource Production Unit

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April 2019

Tokyo Tech
Research Units

Heterogeneous and Functional Integration Unit

Overview

Semiconductors for CPU and memory indispensable for personal computers and smartphones have improved performance through device shrinkages. However, we are encountering the physical limits of shrinking using conventional technology. The three-dimensional large-scale integration (3D LSI) technology that we developed has special vertical interconnect technology and special ultra-thinning technology for semiconductor die stacks, and improves performance while making the stacks smaller and thinner. Using this technology, we will integrate multiple semiconductor functions into a one-stack module, and our goal is to surpass the limits of shrinking devices two-dimensionally. Further, we will apply matured know-how of the semiconductor manufacturing process to heterogeneous fields and endeavor to create new industries in biotechnology and agricultural engineering.

Research Unit Leader

Takayuki Ohba

Profile

2013 Tokyo Institute of Technology, Professor
2004 The University of Tokyo, Professor
1984 Fujitsu Limited
National Chiao Tung University (NCTU), Visiting Professor
Ph.D received from Tohoku University in 1995

Unit members

- Professor Yasuko Yanagida
- Associate Professor Hiroyuki Ito
- Associate Professor Kim Young Suk
- Professor Hiroshi Kudo
- Professor Tomoji Nakamura

Research goals

To extend the Wafer-on-Wafer (WOW) Alliance, a global platform for industry–academia research started in 2008, we will pursue the following themes.

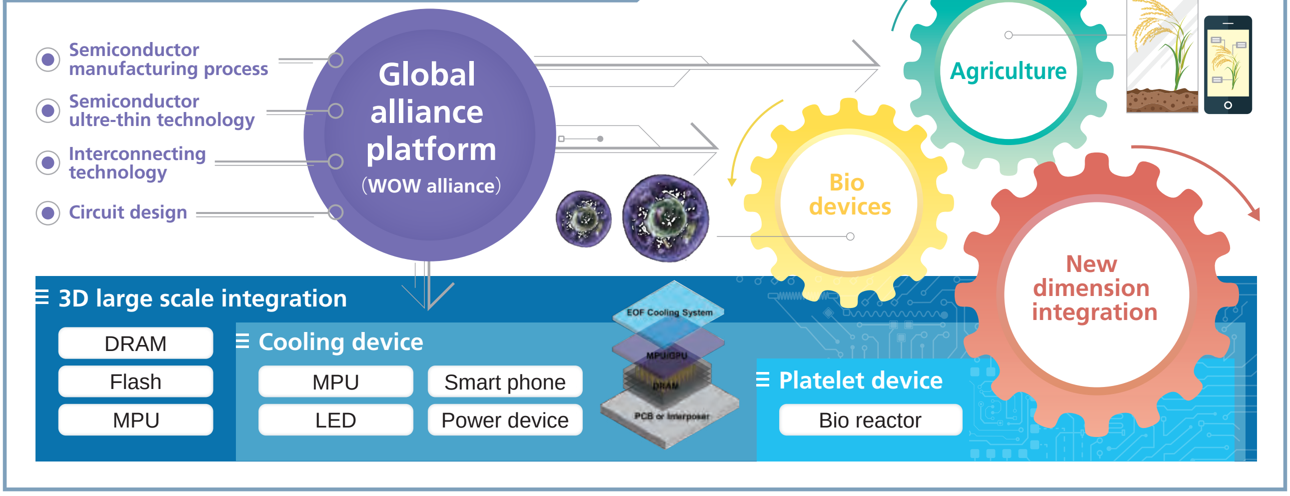
【Three-dimensional integration technology】 We will use the ultra-thinning technology and the vertical interconnect technology possessed by the WOW Alliance to integrate semiconductors three-dimensionally and create a next-generation semiconductor that is higher in performance and lower in power consumption. Furthermore, this work will accelerate the ultra-miniaturization of not only large-scale computing devices such as servers, but various devices equipped with semiconductors to 1/1000th of their current size.

【Cooling technology】 By combining ultra-small cooling devices with three-dimensional stacked semiconductors, our work will allow for simplification of cooling technology and application to the miniaturization of IoT and mobile devices.

【Biotechnology】 We are developing MEMS devices that replicate the vital reactions that take place inside an organism. Specifically, the goal is to apply the semiconductor manufacturing process to prototype a platelet-producing device mimicking the structure and functions of the capillaries inside the spinal cord. We aim to realize stability and improved speed of platelet production at low cost by using fluid mechanics analysis to optimize the structure of the micro-fluid system.

【Agricultural co-engineering】 To reveal the conditions for a plant's maximum output, we will make it possible to monitor "what a plant wants." We will develop closed-system cultivation devices based on semiconductor manufacturing technology to control the growth environment and draw out the plant responses at high reproducibility. We will also create multimodal sensing technologies to quantify the various responses.

Creating new industries by utilizing semiconductor manufacturing process



- Semiconductor manufacturing process
- Semiconductor ultre-thin technology
- Interconnecting technology
- Circuit design

Global alliance platform
(WOW alliance)

Agriculture

Bio devices

New dimension integration

≡ 3D large scale integration

- DRAM
- Flash
- MPU

≡ Cooling device

MPU	Smart phone
LED	Power device

≡ Platelet device

- Bio reactor

An assembly of businesses from different fields focusing on semiconductor technology and aiming to become a technology platform based on win-win collaboration

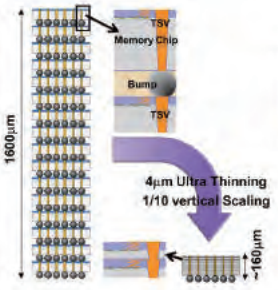
Q Why was this research unit established?

The technology for semiconductors in personal computers and smartphones was developed on a two-dimensional plane. In the case of CPUs, its performance is improved by shrinking devices to increase the number of transistors per unit area. However, that scenario for improving performance will reach its end in the near future. The industry is valued at 400 billion USD as a global market, and stagnation for its technology would greatly impact the global economy. However, expectation for AI and IoT is likely to increase demand for the miniaturization of semiconductors in association with performance. With the WOW Alliance, an industry–academia research platform, we have been pursuing research and development of vertical interconnect technology and ultra-thinning technology for high integration of semiconductors. We have started this new unit to apply these technologies to improve performance of semiconductors and to integrate multiple thinner and smaller semiconductors with different functions into one and thereby respond to the needs of society.

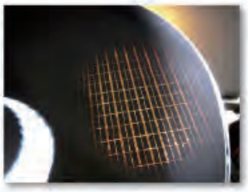
Q What are the strengths of this research unit?

Our feature is the co-development resulting from semiconductor processes, design, materials, process equipment, and a group of Tokyo Tech specialists. Businesses of different industries working together makes it possible for us to pioneer heterogeneous fields and share knowledge. This unit's strength is its potential to maximize the cost–performance of investment in development during the so-called "valley of death" phase by a single business. Using this strength, we are able to overcome development of next-generation products to the prototype level. With biotechnology, we will realize a system (a mechanism) utilizing ultra-small bio-MEMS devices to produce rare bioproducts stably and at low cost. Agricultural co-engineering is the application to analysis of the growth process of plants using know-how of semiconductor manufacturing. We would like to unravel the "feelings" of plants that have survived for hundreds of millions of years. We started these biotechnology and agriculture projects from the idea: what would happen if we layered together different technologies, like three-dimensional heterogeneous function integration technology?

Ultra thin semiconductor technology



Total thickness of 16-layers is 1/10 of the conventional thickness



Light Transparence on 4-mm DRAM 300 mm Wafer

Q What is the path to achieving the unit's goals?

We will continue our work on our proof-of-concept for three-dimensional integration of semiconductors and achieve ultra-small, ultra-low power consumption. We will then develop it further and combine a CPU, a communication module, and other components into one high-density stacked chip to enable the creation of ultra-small, high-performance IoT devices and even smartphone-sized ultra-high-performance servers. In agricultural engineering, we will establish the conditions for maximizing a plant's output in a closed environment and start applying it in large-scale production plants. These paths will require participation, by not only domestic companies, but also business abroad. We aim to become a technology platform creating one new industry after another as a result of a dream team of heterogeneous functions assembled from Asia and the rest of the world.

Contact us

Tokyo Institute of Technology
Heterogeneous and Functional Integration Unit

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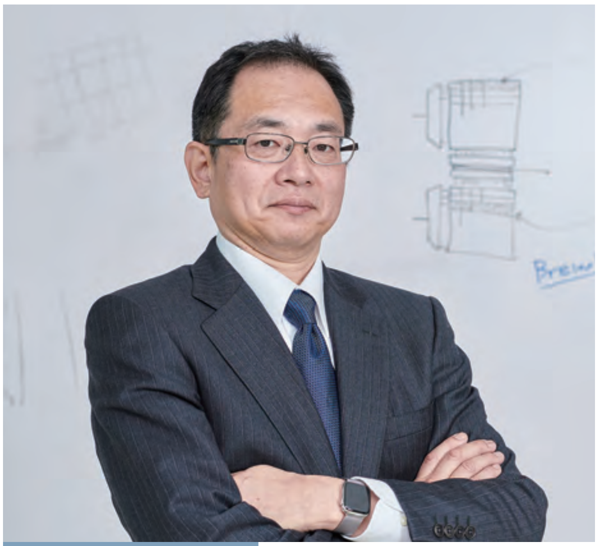
Tokyo Tech
Research Units

AI Computing Unit

Overview

In recent years, great strides in artificial intelligence (AI) have been made, with deep neural networks (DNN) at the center. However, AI computing is not limited to DNN but covers a broad range of machine learning fields, and also extends into data mining and big data processing. To traverse these realms exhaustively and efficiently utilize vastly increasing data, new hardware, rather than an extension of existing hardware, must be developed. The aim of this research unit is to establish the research and development infrastructure for hardware that will make the next generation of AI computing possible: technology that is markedly higher in energy and cost efficiency than what is currently available and also superior in autonomy and safety. We also aim to create a place for more people to participate in this field and flourish in industry-academia collaboration.



Research Unit Leader **Masato Motomura**

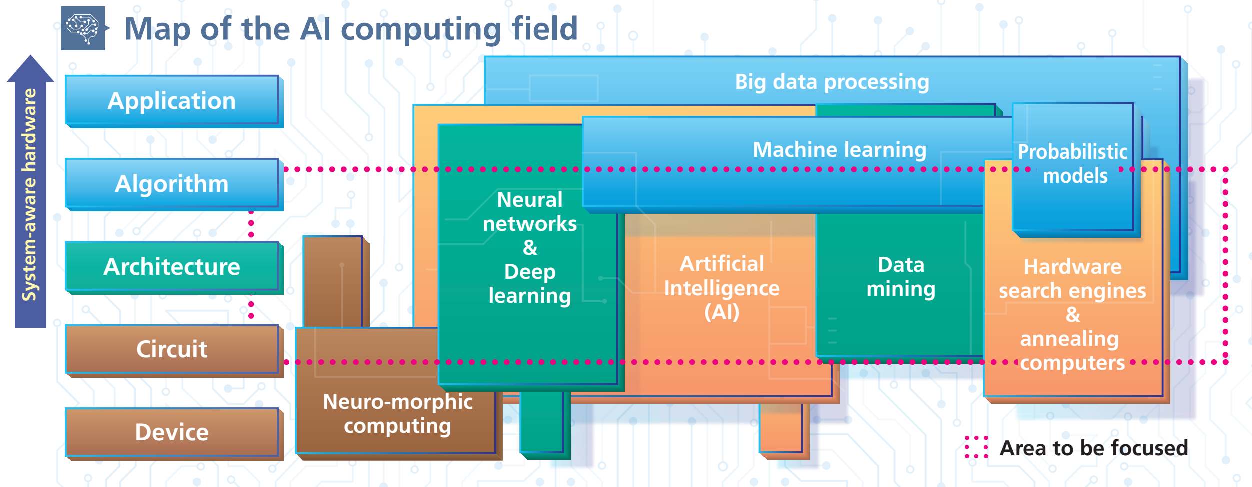
Profile

2019	Professor, Institute of Innovative Research, Tokyo Institute of Technology
2011	Professor, Course of Electronics for Informatics, Graduate School of Information Science and Technology, Hokkaido University
2009	NEC System IP Core Research Laboratories
2004	NEC Electronics Corporation
2001	NEC Electron Devices
1996	Doctor of Engineering, Kyoto University
1992	NEC Silicon Systems Research Laboratories
1991	Visiting Researcher, Massachusetts Institute of Technology
1987	NEC Microelectronics Research Laboratories
1987	Master of Science, Kyoto University

Research goals

I have worked for many years in reconfigurable hardware, a type of hardware which allows changes to be made to its circuit configuration according to what is being processed. What is special about this architecture is that, since it allows computing to always be performed using the optimum hardware configuration, processing speed is faster than conventionally possible, as well as highly energy efficient. Furthermore, since it can make use of large-scale data processing structures in parallel processing, it is highly compatible with AI computing. Since fiscal year 2018, with this architecture as a basis, we have been advancing AI computing through projects under the Grant-in-Aid for Scientific Research (S), New Energy and Industrial Technology Development Organization (NEDO), and Japan Science and Technology Agency (JST). Though the specific field of AI computing investigated in each project differs, this research unit will provide the R&D infrastructure enveloping all of these fields. In the future, I hope this unit will grow to become Japan's central facility for AI computing research.

An architecture platform that will drive AI computing



Working to develop innovative hardware and bring forth the next generation of AI computing

Why was this research unit established?

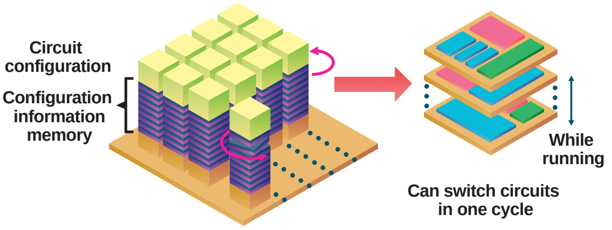
Computing on existing computers is done using a “procedural” approach, where commands are executed in serial. However, a “structural” approach, where data can be used as is and processed in parallel, is more suitable for AI. Another factor is that progress in microfabrication technology for semiconductors is reaching its end. With such issues, reconfigurable hardware is gaining attention as the computing technology that will allow for next-generation structural information processing. But for this to become a reality, AI algorithm and system-aware hardware research need to be coordinated and pursued with agility. As we spread the importance of this goal throughout the world, I also hope to cultivate new talent to carry on in this field in the future.

What are the strengths of this research unit?

Much research is being done worldwide in AI computing architecture, but most focuses on how to use existing computers in parallel. Meanwhile, there are many original technologies in the field of reconfigurable hardware that were developed in Japan. Even when viewed globally, we are ahead in technology and in accomplishments. For this reason, by focusing on reconfigurable hardware technology and collaborating closely with various research institutions and industries in AI, I believe we can become a dominant force in this global, highly competitive field of AI computing.

Reconfigurable hardware

Multiplex configuration information architecture and circuit



Unlike traditional logic circuits with fixed functions, reconfigurable hardware allows for changes in circuit configuration according to application needs. The AI Computing Unit is developing hardware offering even greater flexibility and software-friendliness, capable of dynamically changing configuration, even while running.

What is the path to achieving the unit’s goals?

First, within the next several years, in each field of AI computing we aim to prototype reconfigurable hardware that is capable of high-speed processing and two orders of magnitude more energy efficient than existing designs. The target is an AI computing engine for built-in systems in vehicles, robots, IoT devices, and other applications that will utilize edge computing. It is important to foresee where AI algorithms are headed and have a meta-level architecture with the flexibility to adopt new ideas. We will also work on forming the basis for coordinating between software and hardware.

Contact us

Tokyo Institute of Technology
AI Computing Unit

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June 2019

Tokyo Tech
Research Units

Homeostatic Mechanism Research Unit

Overview

Many organisms have the ability of homeostasis to maintain body temperature, blood pressure, osmotic pressure of body fluids, blood sugar level, and other parameters of their internal environment within a certain range, despite variations in the external environment. This ability, gained through evolution, is crucial to maintaining life. Homeostasis is made possible by the delicate communication of the brain and nervous system with organs, or that of organs with each other. For example, when an organism becomes dehydrated, sodium concentration within the body fluids rises, creating an appetite for fluid and decreasing the amount of urine. However, the mechanisms that trigger these maintenance functions are not fully understood. Our research interests focus on the homeostatic mechanisms especially for the three areas: body fluid homeostasis, blood pressure, and obesity.

Research Unit Leader **Masaharu Noda**

Profile

2019 Specially Appointed Professor, Research Unit Leader, Homeostatic Mechanism Research Unit, Institute of Innovative Research, Tokyo Institute of Technology
1991 Professor, Division of Molecular Neurobiology, National Institute for Basic Biology (NIBB); Professor, Basic Biology, the Graduate University for Advanced Studies (Sokendai)
1989 Visiting Scholar, Max Planck Institute for Developmental Biology
1985 Assistant Professor, Kyoto University Faculty of Medicine (Molecular Genetics)
1984 Assistant, Kyoto University Faculty of Medicine (Medical Chemistry)
1983 Researcher, Grant-in-Aid for Encouragement of Scientists, Japan Society for the Promotion of Science (JSPS)
1983 Doctor of Medical Science, Graduate School of Medicine, Kyoto University
1979 Master of Engineering, Graduate School of Engineering, Kyoto University

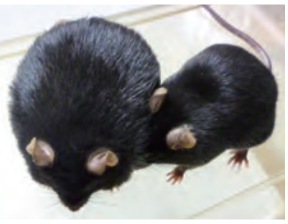
Research goals

- In *body fluid homeostasis*, we discovered that the brain has a system that monitors the fluctuation of sodium concentration in body fluids and that there are neurons that drive intakes of fluids or salts. Our goal is to understand the control mechanisms underlying these nervous systems.

- *Blood pressure* is greatly affected by factors such as salt, stress, and obesity. We have identified the brain mechanisms underlying salt-induced elevations in blood pressure. This unit seeks to uncover the mechanisms responsible for blood pressure elevations caused by stress and obesity. Additionally, we will aim to reveal the mechanisms by which combinations of multiple factors cause even higher elevations in blood pressure.

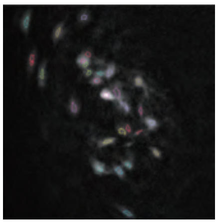
- In *obesity*, as it progresses, fat accumulates not only in fat cells, but also in the liver and other organs. Since accumulation of ectopic fat causes various diseases, we also intend to elucidate the mechanisms that control fat accumulation.

Understanding the central mechanisms of homeostasis and leading to drug discovery



- Control of blood pressure by salt, stress, and obesity
- Control of water/salt-intake behaviors according to body fluid conditions
- Control of obesity and ectopic lipid accumulation

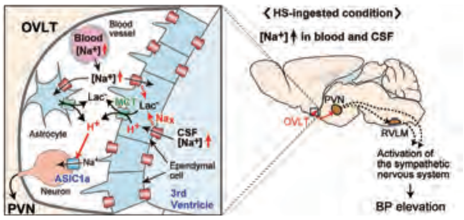
→



Analysis of neural activity by *in vivo* calcium imaging

- Genetic manipulation
- Optogenetics
- Real-time imaging

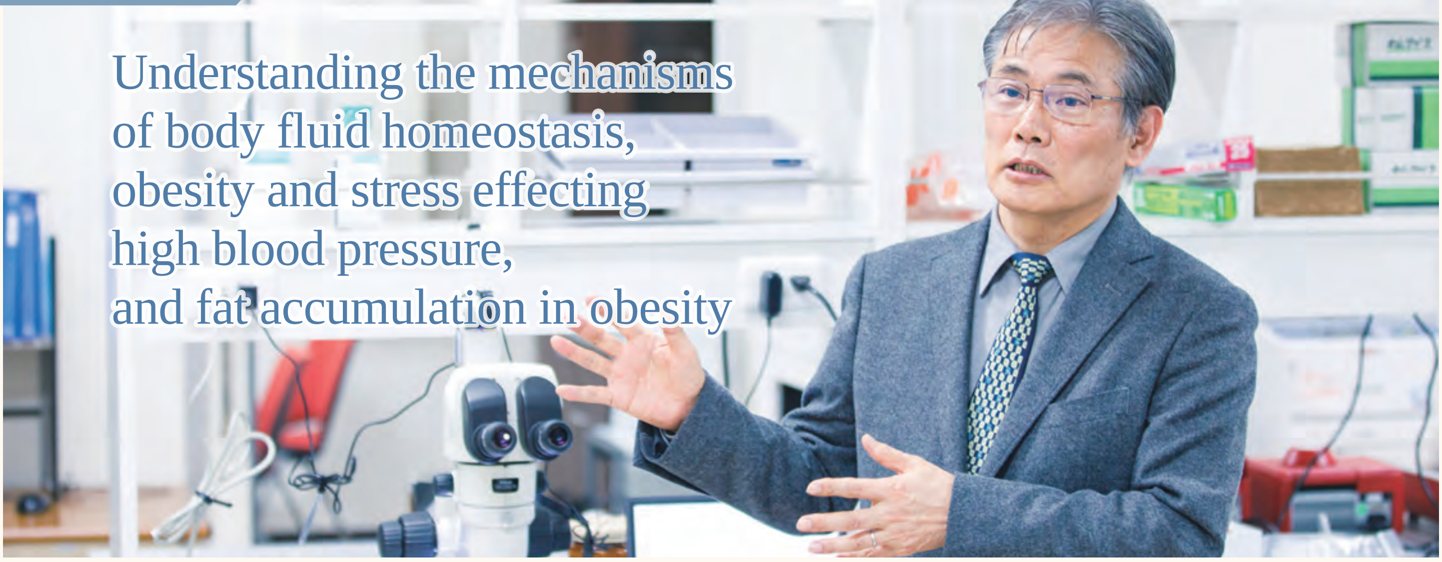
→



Central mechanisms responsible for salt-induced hypertension

Elucidation of brain mechanisms

→ **Development of breakthrough drugs**



Understanding the mechanisms of body fluid homeostasis, obesity and stress effecting high blood pressure, and fat accumulation in obesity

Q What are the strengths of this research unit?

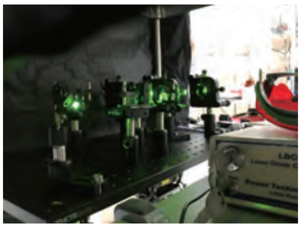
Our laboratory has developed multiple techniques in molecular biology and neurophysiology to investigate the functions and physiological roles of neurotransmitters and ion channels. Recently, we identified the sensor in the brain that monitors sodium concentration in body fluids. We showed that it plays a central role in water and salt intake behavior and the onset of hypertension. In our research on metabolism, we have already identified enzymes that are responsible for controlling insulin and leptin receptor activity. Currently, we are using optogenetics to artificially control a specific neural activity, as well as imaging technique to monitor the activity of individual neurons in real time. This allows us to analyze, directly and in detail, the roles of specific neural circuits and their control mechanisms.

Q What is the path to achieving the unit's goals?

In the first three years, using the latest techniques such as optogenetics and calcium imaging to manipulate and examine the activity of specific neural pathways in real time, we will elucidate the neural circuits and neural mechanisms that regulate blood pressure and water/salt appetite. We will also uncover the mechanisms regulating fat accumulation by using genetically modified mice. Then, in the following two years, we will look in depth at the mechanisms for information integration when blood pressure is regulated by multiple factors. In addition, we will work to develop ways to suppress the accumulation of ectopic fat.

Equipments for real-time measurement

Mouse brain operation equipment



Laser equipment for irradiating brain nuclei

Q How will this research unit's achievements impact future society?

Various drugs are being developed for treating hypertension by acting on the peripheral nervous system, blood vessels, and the kidney. However, it is difficult to completely control blood pressure, and doctors always tell their patients to reduce their salt intake. This is because the role of the central nervous system in blood pressure control is not well understood. Similarly, with obesity, which is closely related to blood pressure, we do not know how fat is distributed to fat tissue and organs, such as the liver. If we could prevent hypertension and the accumulation of ectopic fat, it would greatly reduce the prevalence of metabolic syndrome, a cause of strokes and heart ailments. I believe that our unit's work to understand these mechanisms will lead to the development of new drugs and radically change medical treatments.

Contact us

Tokyo Institute of Technology
Homeostatic Mechanism Research Unit

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January 2020

Tokyo Tech
Research Units

Fukushima Reconstruction and Revitalization Unit

Overview

Under the "Great East Japan Earthquake Reconstruction Project," the reconstruction and revitalization of Fukushima is a key social issue. Because of the accident at the Fukushima Daiichi Nuclear Power Station, a large amount of radioactive material (mainly radioactive cesium (Cs)) was discharged into the environment, and contaminated water and debris generated by melting fuel made it difficult to decommission the reactor. In this research unit, we are pursuing the following three topics to support reconstruction and revitalization of Fukushima.

1. Promoting the decommissioning of the reactor, including treating contaminated water and solid waste, and removing debris
2. Resolving issues related to wide-area contamination caused by the radioactive cesium
3. Rehabilitating industry and developing human resources based on the Innovation Coast Framework

Research goals

For our unit's three research topics, we seek to achieve the following goals:

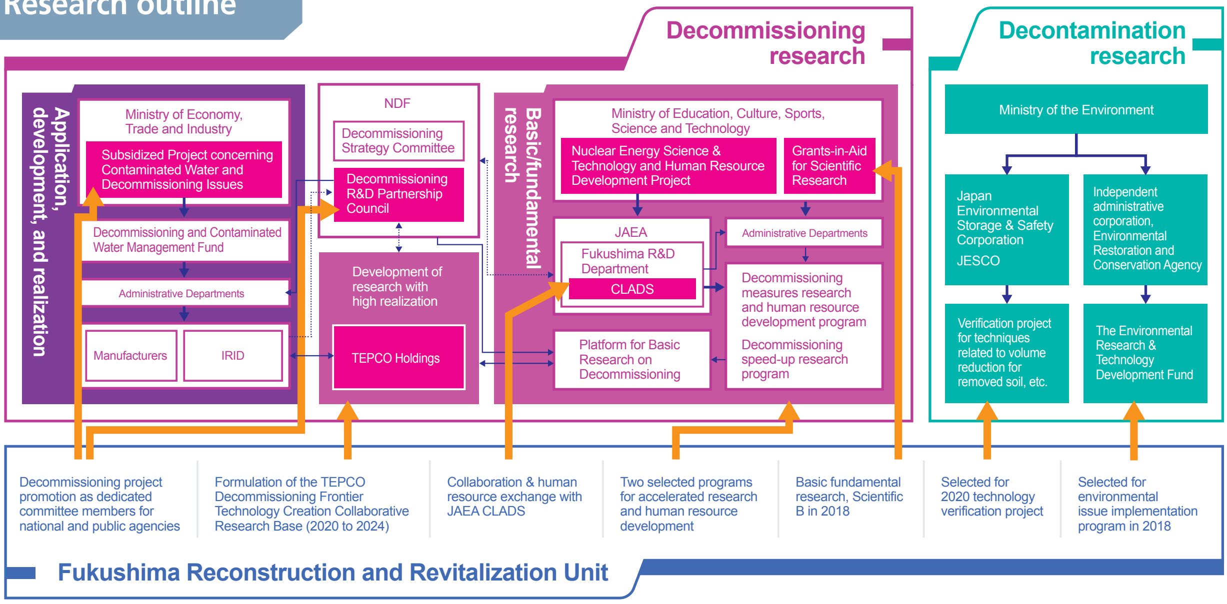
1. Establishing volume reduction and stabilization/solidification techniques for the secondary radioactive waste generated by contaminated water from the Fukushima Daiichi Nuclear Power Station or from treatment of contaminated water generated when removing debris. We will provide vital support in decommissioning the Fukushima Daiichi Nuclear Power Station by gathering expertise at Tokyo Tech for areas such as development of decommissioning techniques appropriate for the disaster site and based on collaboration with TEPCO (Figure: Research outline).
2. Developing basic fundamental technology for recovery and high-volume reduction/solidification methods of radioactive Cs from the 750,000 m^3 of highly contaminated soil, which requires physiochemical treatment (Figure: Researching treatment of contaminated soil). This will make it possible to finalize disposal within 30 years as promised by the national government.
3. Gathering academic knowledge to reconstruct the living environment in the Hamadori area, which was severely damaged by the nuclear power station accident, promoting industrial development contributing to the Innovation Coast Framework, and fostering necessary human resources for the reconstruction of Fukushima.

Research Unit Leader **Kenji Takeshita**

Profile

October 2019:	Senior Aide to the Executive Vice President for Research, Tokyo Institute of Technology
April 2018:	Director (Professor), Laboratory for Advanced Nuclear Energy, Tokyo Institute of Technology
April 2010:	Professor, Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology
November 2002:	Associate Professor, Chemical Resources Laboratory, Tokyo Institute of Technology
une 1996:	Assistant Professor, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
June 1992:	Senior Researcher, Institute of Research and Innovation
April 1987:	Researcher, Institute of Research and Innovation

Research outline



Decommissioning research

Decontamination research

Application, development, and realization

Ministry of Economy, Trade and Industry

Subsidized Project concerning Contaminated Water and Decommissioning Issues

Decommissioning and Contaminated Water Management Fund

Administrative Departments

Manufacturers

IRID

NDF

Decommissioning Strategy Committee

Decommissioning R&D Partnership Council

Development of research with high realization

TEPCO Holdings

Basic/fundamental research

Ministry of Education, Culture, Sports, Science and Technology

Nuclear Energy Science & Technology and Human Resource Development Project

Grants-in-Aid for Scientific Research

JAEA

Fukushima R&D Department

CLADS

Administrative Departments

Decommissioning measures research and human resource development program

Decommissioning speed-up research program

Platform for Basic Research on Decommissioning

Ministry of the Environment

Japan Environmental Storage & Safety Corporation JESCO

Independent administrative corporation, Environmental Restoration and Conservation Agency

Verification project for techniques related to volume reduction for removed soil, etc.

The Environmental Research & Technology Development Fund

Decommissioning project promotion as dedicated committee members for national and public agencies

Formulation of the TEPCO Decommissioning Frontier Technology Creation Collaborative Research Base (2020 to 2024)

Collaboration & human resource exchange with JAEA CLADS

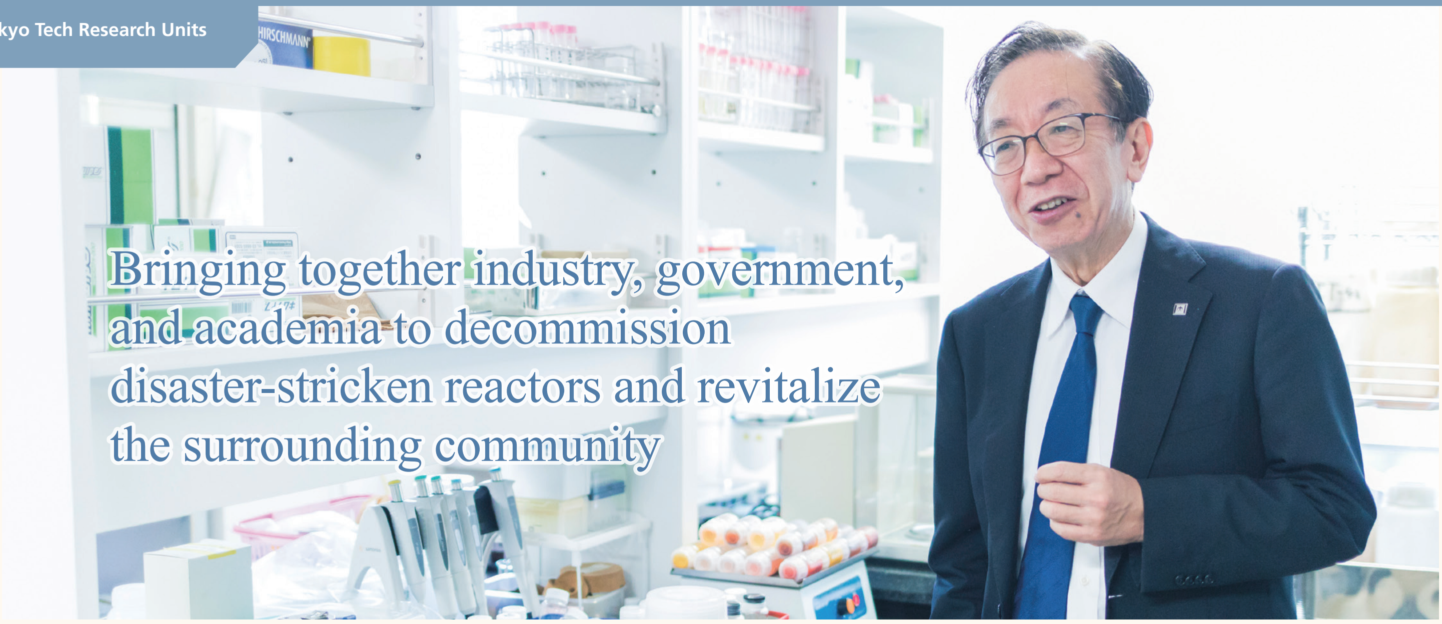
Two selected programs for accelerated research and human resource development

Basic fundamental research, Scientific B in 2018

Selected for 2020 technology verification project

Selected for environmental issue implementation program in 2018

Fukushima Reconstruction and Revitalization Unit

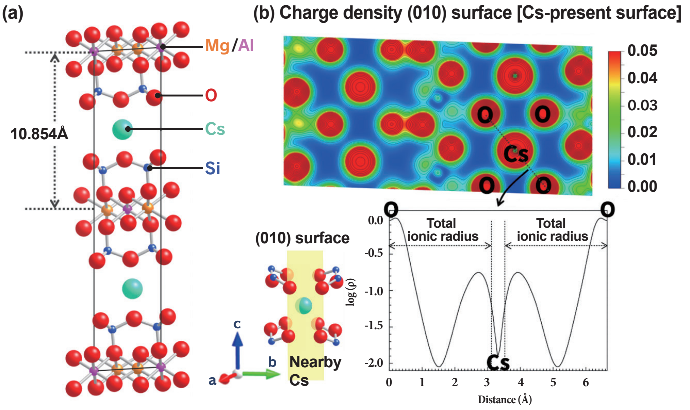


Bringing together industry, government, and academia to decommission disaster-stricken reactors and revitalize the surrounding community

What are the strengths of this research unit?

1. We have established a collaborative research base with TEPCO (5-year plan from fiscal 2020 to 2024), allowing Tokyo Tech faculty members to work directly with engineers from TEPCO to identify research areas based on the needs at the actual site.
2. Two of our topics were selected for large-scale basic fundamental research (MEXT: Nuclear science and technology / human resources development promotion project based on collected wisdom), so we can proceed with basic fundamental research necessary for promoting decommissioning. Moreover, research unit leader Kenji Takeshita is a member of the "Subsidized Project concerning Contaminated Water and Decommissioning Issues" by METI and of the "Decommissioning R&D Partnership Council" of the Nuclear Damage Compensation and Decommissioning Facilitation Corporation (NDF), providing access to the latest information as we proceed with research on the decommissioning project.

Researching treatment of contaminated soil



Estimated stable structure (a) and charge density (b) of Cs^+ absorbed in contaminated soil by first-principles calculation (vermiculite)

What is the path to achieving the unit's goals?

1. Towards resolving wide-area contamination issues at Fukushima, we conduct research through the "Verification project for techniques related to volume reduction for removed soil, etc." carried out by the Japan Environmental Storage & Safety Corporation under the Ministry of the Environment. Furthermore, we are conducting research using equipment at the interim storage facility in accordance with the policies of the Ministry of the Environment.
2. We will continue appropriate development of decommissioning techniques based on the needs of the disaster site learned through the collaborative research base with TEPCO and based on the latest decommissioning policy acquired through the council of the NDF and Agency for Natural Resources and Energy.

What impact will the unit's research have on society?

The reconstruction and revitalization of Fukushima after the 2011 Great East Japan Earthquake and subsequent accident at Fukushima Daiichi Nuclear Power Station is one of the most important issues facing the national government. In our research unit, we will pursue three research topics: (1) purification of contaminated soil across Fukushima Prefecture, and high volume reduction and solidification / final disposal of radioactive materials, (2) treatment and disposal of secondary waste from water treatment for promoting decommissioning of the Fukushima Daiichi Nuclear Power Station, and (3) industrial rehabilitation of the Fukushima coast (Innovation Coast Framework), including development of necessary human resources for quickly resolving this national issue. The techniques developed here could be applied in initial responses to future accidents that may occur at any of the 400 nuclear power stations operating throughout the world. The work of our research unit would support emergency preparedness, and thereby have a significant impact on society.

Contact us

Tokyo Institute of Technology
Fukushima Reconstruction and Revitalization Unit

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October 2020

Tokyo Tech
Research Units

Nano Sensing Unit

Overview

Healthy and safe food is fundamental to society's happiness and well-being. Our goal is to apply ultrahigh-sensitivity accelerometer systems in providing sustainable medical care and food production. Accelerometers are able to detect temporal changes in three dimensions in physical space, and are already used in various technologies, such as smartphones and self-driving vehicles. The ability to measure minute amounts of acceleration that cannot be detected by existing sensors would make it possible to predict changes in humans and other living organisms, and it is expected that this will lead to ultra-early diagnosis of diseases and improvements in animal welfare. It also has the potential to open up new paradigms in other fields.

Research Unit Leader **Hiroyuki Ito**

Profile

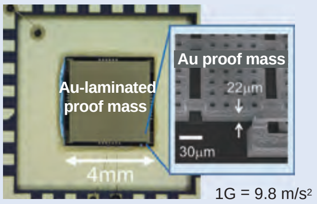
2016	Associate Professor, Institute of Innovative Research, Tokyo Institute of Technology
2013	Associate Professor, Advanced Microdevices Division, Precision and Intelligence Laboratory, Tokyo Institute of Technology
2008	Researcher, Platform Technology Research Laboratory, Fujitsu Laboratories Ltd.
2007	Assistant Professor, Advanced Microdevices Division, Precision and Intelligence Laboratory, Tokyo Institute of Technology
2006	Visiting Researcher, Intel Corporation
2006	Research Fellow (PD), JSPS Research Fellowship for Young Scientists
2006	Ph.D., Department of Advanced Applied Electronics, Tokyo Institute of Technology

Research goals

To systematize, commercialize, and industrialize our technology, we are pursuing the following themes: in fundamental research, "development of ultrahigh-sensitivity accelerometer systems", and in applied research, "early diagnosis of intractable neurological diseases based on low-level mechanomyography" and "prediction and early detection of illnesses in cattle". In ultrahigh-sensitivity accelerometers, we are working on significantly reducing device and circuit noise in order to be able to measure microgravity-level accelerations, equivalent to those in environments such as space stations. For early diagnosis of neurological diseases, we are focusing on Parkinson's disease (PD). There is no basic treatment for PD, but its onset and progress can be delayed through early diagnosis. As for early detection of illnesses in cattle, if we can accurately detect minute changes in the animals' behavior, and simultaneously internal sounds such as ruminal activity, it would be possible to identify risks to production, which could greatly impact the livestock industry. We are also aiming to take the lead in Japan's integrated circuit field in cooperation with other research groups, as well as to train early-career researchers.

Contributing to sustainable medical care and food production for the happiness and well-being of society

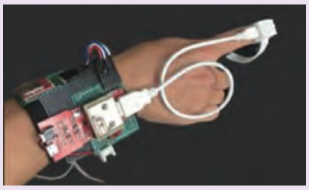
Basis Measurement of nano-G acceleration



Seeds →

← Needs

Application From monitoring to early diagnosis and risk prediction



Intractable neurological diseases

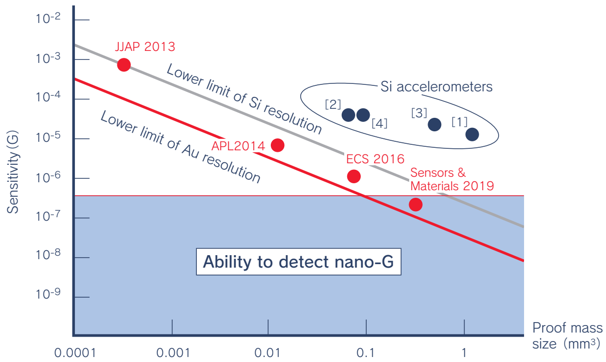
Livestock

Applying ultrahigh-sensitivity accelerometry in animal welfare and early diagnosis of neurological diseases

What are the strengths of this research unit?

We have developed accelerometers with some of the highest sensitivities yet achieved, and for the first time in the world, have successfully applied these to the measuring of very week mechanomyograms, which are the weak vibrations generated by muscles. Currently, the mainstream in the medical and other fields is performing image analysis using AI. But the advantage of using the accelerometers developed in our unit is that neural activity and in-vivo information can easily be acquired non-invasively. Skill is needed to use the sensors due to their high sensitivity, so it is also important to develop based on understanding of how they will be used in the field. This unit includes researchers from various backgrounds, so another strong point is that we can simultaneously promote both basic and applied research.

Sensitivity of capacitive accelerometers



1. IEEE JMEMS, 13, 2004, "An In-Plane High-Sensitivity, Low-Noise Micro-g Silicon Accelerometer With CMOS Readout Circuitry"
2. IEEE Sensors J., 8, 2008, "A Monolithic CMOS-MEMS 3-Axis Accelerometer With a Low-Noise, Low-Power Dual-Chopper Amplifier"
3. Proc. IEEE SENSORS 2009, "Micro-G Silicon Accelerometer Using Surface Electrodes"
4. Sensors and Actuators A, 172, 2011, "Pull-in-based mg-resolution accelerometer: Characterization and noise analysis"

Compared to conventional accelerometers that use silicon (Si) as the proof mass, using gold (Au) increases the sensitivity by at least one order of magnitude. This unit will pursue even greater sensitivity, and work with industry to achieve practical application.

What is the path to achieving the unit's goals?

We are working to significantly reduce noise in our accelerometer systems so that within three years, it will be possible to measure micro-G level acceleration. To reach commercial adoption, we will collaborate with industry on triaxialization, low power consumption, high linearity, and wirelessness. At the same time, we will develop prototypes for measuring muscle activity and cattle behavior, and continually conduct early-stage, proof-of-concept experiments in order to reach practical application.

What impact will the unit's research have on society?

In Japan alone, over 150,000 people are severely affected with PD. If the research of this unit enables early detection of the PD, rehabilitation treatments such as physical therapy can be prescribed prior to the stages requiring medication. This will help to alleviate deterioration of quality of life and medical costs. In regards to food production, our work will provide solutions to issues such as increased environmental impact and improving production efficiency in harmony with the increasing demand for meat. Also, creating new measurement technologies can have other incalculable benefits for both academia and industry. The sensors that are being developed by this unit will make it possible to detect new symptoms that up to now have not been noticed, and predict major changes that will occur later. We expect utilization to spread to other areas, such as structural inspection and predicting natural disasters.

Contact us

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Nano Sensing Unit

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May 2020

Tokyo Tech
Research Units

BioMedical AI Research Unit

Overview

Deep learning in the field of artificial intelligence (AI) has been garnering attention as an innovative technology in the circles of both academia and industry. Deep learning is being studied and applied throughout the world to bring about the Fourth Industrial Revolution. Its applications in biomedical fields in particular have been designated as a priority in several countries due to its growth and future potential. Deep learning has also received significant attention from industry because of the rapid expansion of the market scale. The BioMedical AI Research Unit (BMAI) is working to develop new AI fundamental technologies that advance current deep-learning methods, and to promote its applications in the biomedical fields (diagnostic support, imaging, etc.) and their translation in clinical practice.

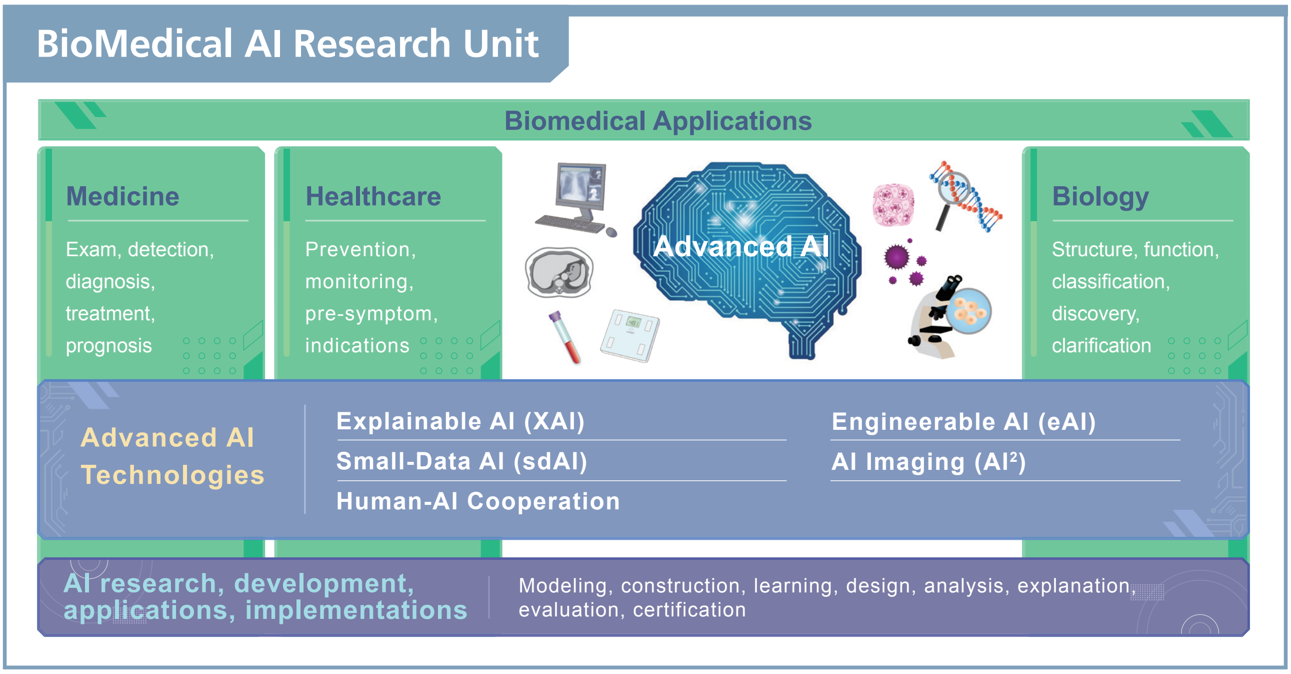
Research Goals

Deep learning is revolutionizing various fields. Things which were not possible with conventional technologies are now achievable, and performance levels that could not previously be reached are now attainable. Simply by providing big data, deep learning can automatically study a problem and produce a final result. Applications of deep learning to biomedicine, however, are hindered by the following major problems: 1) It is difficult to apply deep learning in the areas where acquiring big data is difficult; 2) since a deep-learning model learns everything automatically, the model becomes a "black box;" and 3) since deep learning is data-driven, there is no methodology for designing the model in accordance with requirements. This research unit will develop next-generation deep-learning platforms that solve these problems, and it will promote their biomedical applications and implementations in clinical practice. The research unit will conduct these activities through collaborations with medical schools and industry, while it will also educate and produce world-leading talents in AI.

Research Unit Leader **Kenji Suzuki**

Profile

2021 Professor, Institute of Innovative Research,
Tokyo Institute of Technology
2017 Specially Appointed Professor, Institute of Innovative Research,
Tokyo Institute of Technology
2014 Associate Professor, Medical Imaging Research Center,
Illinois Institute of Technology
2007 Assistant Professor, Graduate Program in Medical Physics,
The University of Chicago (joint appointment)
2006 Assistant Professor, Department of Radiology, The University of Chicago
2004 Research Associate (Assistant Professor),
Department of Radiology, The University of Chicago
2002 Research Associate, Department of Radiology, The University of Chicago
2001 Visiting Research Associate, Department of Radiology,
The University of Chicago
2001 PhD in Engineering, Nagoya University



BioMedical AI Research Unit

Biomedical Applications

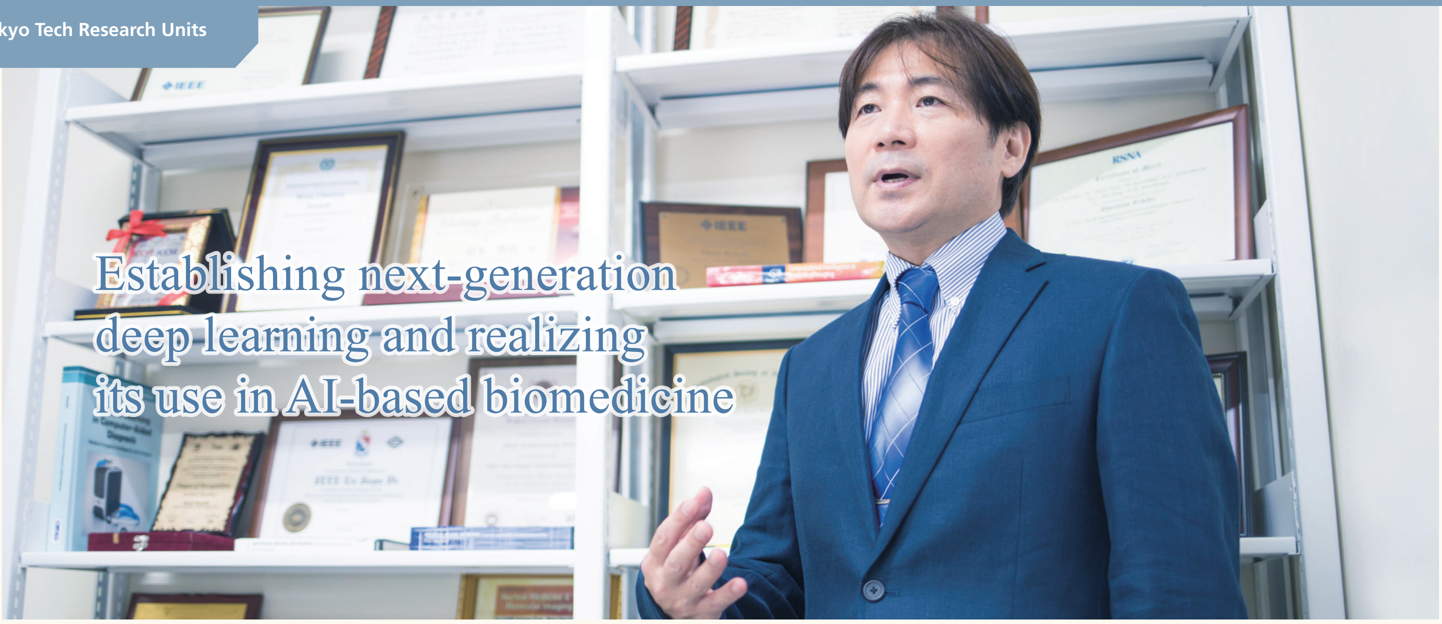
Medicine
Exam, detection, diagnosis, treatment, prognosis

Healthcare
Prevention, monitoring, pre-symptom, indications

Biology
Structure, function, classification, discovery, clarification

Advanced AI Technologies
Explainable AI (XAI)
Small-Data AI (sdAI)
Human-AI Cooperation
Engineerable AI (eAI)
AI Imaging (AI²)

AI research, development, applications, implementations
Modeling, construction, learning, design, analysis, explanation, evaluation, certification



Establishing next-generation deep learning and realizing its use in AI-based biomedicine

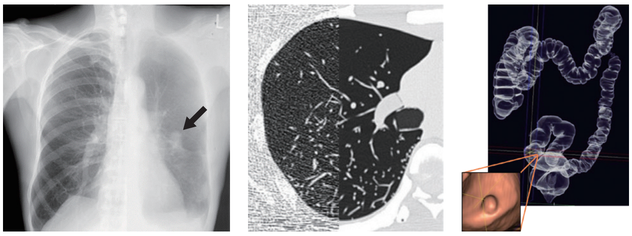
What are the strengths of this research unit?

In the BioMedical AI Research Unit, by utilizing our knowledge, skills, and know-hows of deep-learning research and implementations in medicine over the last 25 years, we will develop next-generation deep-learning models that solve the problems of current deep learning. We will also promote research, development, and applications of biomedical AI. There are countless research organizations throughout the world that apply existing deep-learning models to their own fields. However, there are few research organizations that develop brand-new deep-learning models from scratch. Furthermore, even on a global level, it is rare for these research organizations to bring brand-new models to real-world applications. Our research unit will achieve such goals through joint research with physicians, researchers, and companies, within Japan as well as abroad.

What is the path to achieving the unit's goals?

The three major problems with current deep learning mentioned earlier will be solved in the national research projects of the NEDO and JST. 1) Our original deep-learning model can learn from a relatively small amount of data. We will generalize this unique learnability to build new general models that can learn from small amount of data. 2) We will generalize our pioneering "white box" technology to explain deep-learning models. 3) We will generalize our pioneering methodology for designing deep-learning models. By using these new fundamental AI technologies, we will promote the real-world implementations of biomedical AI in diagnostic support and medical imaging.

AI Imaging and AI-assisted Diagnosis



Removal of bone components and detection of a lung cancer (arrow) using our AI imaging

Virtual high-dose CT made from ultra-low dose CT using our AI imaging

Polyp detection from the image of the colon using our AI-assisted diagnosis

What impact will the unit's research have on society?

Since the AI technologies we are developing can solve the fundamental problems of deep learning, their applications are expected to become a global trend with a significant academic impact. Graduate students, researchers, and engineers who participate in this AI research are expected to become leaders in the AI fields and play important roles throughout the world. The applications of our new fundamental AI technologies in the biomedical fields and their implementations will contribute greatly to the global market, which is forecasted to grow to several trillion yen by 2025. In addition to the AI field, this work will also contribute to developments in the fields of medical sciences and healthcare. Their implementations are expected to reduce morbidity and mortality rates, and to improve people's health.

Contact us

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BioMedical
AI Research Unit

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June 2021

Tokyo Tech
Research Units

VCSEL Photonics Unit

Overview

The vertical cavity surface emitting laser (VCSEL), invented by Professor Emeritus Kenichi Iga of Tokyo Institute of Technology, has become a key component in “Internet-of-Things” applications such as fiber-optic communications, face recognition in mobile phones, and LiDAR for autonomous driving. At the VCSEL Photonics Unit, we develop core technologies for the next generation of information and communication technology, Beyond 5G. Ultra-high-speed high-capacity optical communications, high-resolution 3D sensing, and other technologies based on VCSEL photonics are expected to become the foundation of all industries and society by the 2030s. Forty-four years have passed since the invention of the VCSEL. We are working to promote further technological and social developments through VCSEL photonics.

Research Unit Leader **Fumio Koyama**

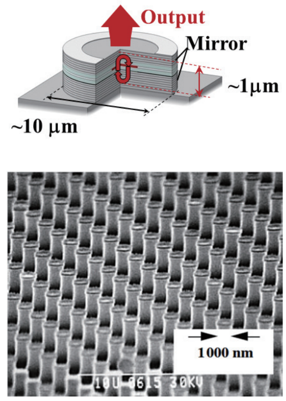
Profile

2020	Professor, Institute of Innovative Research, Tokyo Institute of Technology
2018	Director-General/Professor, Institute of Innovative Research, Tokyo Institute of Technology
2016	Director/Professor, FIRST, Tokyo Institute of Technology
2000	Professor, Precision and Intelligence Laboratory, Tokyo Institute of Technology
1988	Associate Professor, Precision and Intelligence Laboratory, Tokyo Institute of Technology
1985	Research Associate, Precision and Intelligence Laboratory, Tokyo Institute of Technology

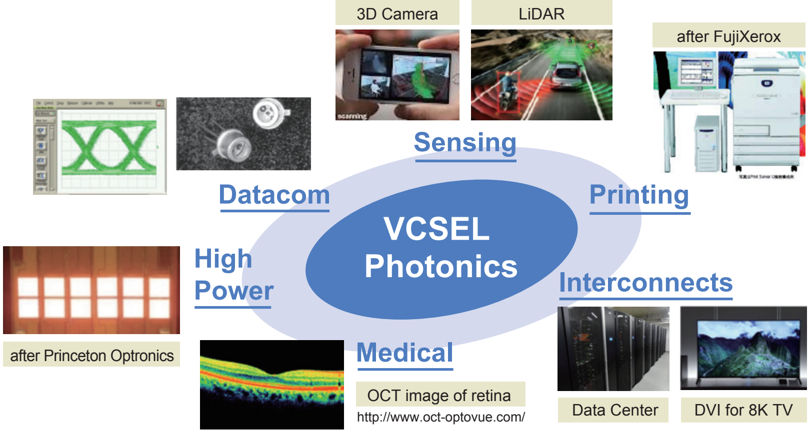
Research Goals

Our research unit will pursue the following goals:
(1) Development of a next-generation edge cloud computing infrastructure that supports Beyond 5G ultra-high capacity wireless communications, particularly research on co-packaged optics and ultra-compact optical transceivers using VCSEL arrays.
(2) Development of ultra-high-speed, low-power consumption, low-cost VCSELs used for large-capacity front hall networks connecting wireless base stations, and ultra-high-speed single-mode optical fiber transmission technology.
(3) Development of the next generation in 3D sensing technology: LiDAR is a key sensing technology in autonomous driving systems that allows for scanning of the surroundings in 3D. We will develop a solid state, ultra-high resolution beam deflector without moving parts.

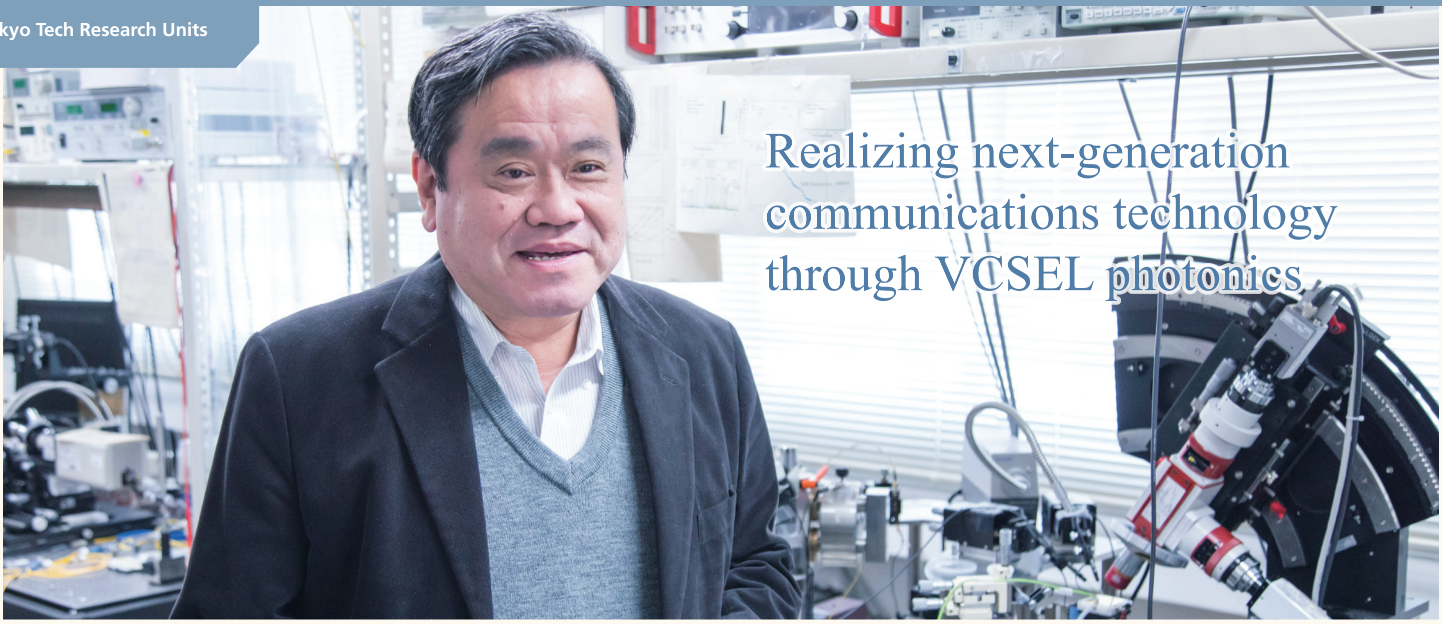
VCSELs and their Application Fields



VCSEL and their 2D array



Various Applications of VCSEL Photonics



Realizing next-generation communications technology through VCSEL photonics

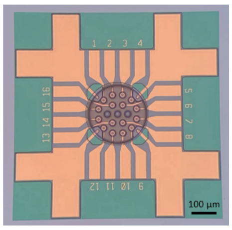
What are the strengths of this research unit?

Starting first with the realization of continuous room temperature operation of VCSELs, we have been working to improve the performance of VCSELs and create new functions. We have developed world-leading core technologies such as low-power consumption and high-speed VCSELs, as well as the world's highest resolution solid-state optical deflector. We are also promoting social implementation through joint research with industry, government, and academia in programs such as the NICT Beyond 5G R&D Promotion Project, NEDO Post 5G Information and Communication Systems Infrastructure Reinforcement R&D Project, and JST A-STEP industry-academia collaboration.

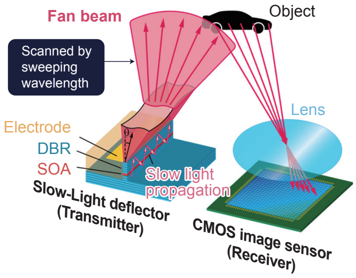
What is the path to achieving the unit's goals?

Thanks to the new structure of laterally coupled cavity VCSELs, we have established an ultra-high-speed modulation that greatly expands the modulation bandwidth. We are pushing the limit of modulation bandwidth and low power consumption beyond existing semiconductor laser technologies. In addition, we aim to realize ultra-high-resolution beam deflection with giant angular dispersion in a VCSEL amplifier structure. We will support implementation of these advanced technologies through joint research with industry, government, and academia.

Massively parallel optical interconnect and laser radar using VCSELs



VCSEL array for ultra-parallel high-speed interconnects



Solid state high-resolution LiDAR

What impact will the unit's research have on society?

Our research is expected to lead to low power consumption, low cost, and high-density optical interconnects that enable ultra-high-speed data transmissions of 100Gbps to 1Tbps. It could contribute to the development of 6G mobile communication networks and power-saving in datacenter networks, which are the core infrastructure of our information society. The evolution of autonomous driving technology by high-resolution 3D sensing and virtual reality by 3D cameras on mobile phones will advance adoption of cyber-physical systems, sensing and digitizing the real world and projecting it into cyberspace. Through this research unit, we will expand the applications of VCSELs to various fields.

Contact us

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VCSEL Photonics Unit

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December 2021