Global Hydrogen Energy Unit

Tokyo Tech Research Units

Overview

Hydrogen is a secondary energy source with high potential to contribute to the goal of realizing a low-carbon society and bringing about a change in energy structure. In order to make hydrogen energy a practical reality, however, it is necessary to explore the development of elemental technology and systems as well as industrial and social structures to identify and address issues of importance. The Global Hydrogen Energy Unit was established to evaluate a wide range of issues from a multilateral, subjective, and scientific perspective through industry-government-academia collaboration centered around Tokyo Tech. The unit also identifies bottlenecks in problem solving and determines development goals related to the technology and systems required to realize a hydrogen energy society.

Research goals

The goal of the Global Hydrogen Energy Unit is to establish a global-scale hydrogen supply chain which converts unused overseas energy to hydrogen and transports it to Japan. Specifically, the unit plans to separate brown coal into CO_2 and hydrogen in Australia, store the CO_2 underground, and transport liquefied hydrogen to Japan for storage and conversion to energy. The unit will also link this with the use of hydrogen energy generated from renewable energy sources in Japan. The Global Hydrogen Energy Unit conducts research on the organization of accurate and subjective information, creates new value, designs and evaluates systems, and identifies and solves technical development problems.

Research Unit Leader **Ken Okazaki**

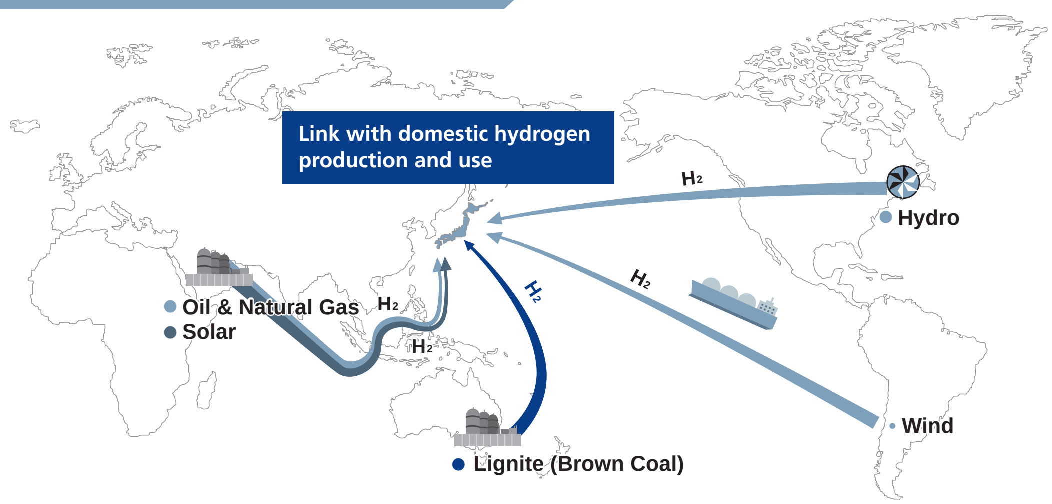
Profile

- 2015 Institute Professor (Professor Emeritus), Tokyo Institute of Technology
- 2007-2011 Dean, Graduate School of Engineering, Tokyo Institute of Technology
- 2000 Professor, Department of Mechanical and Control Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology
- 1998 Professor, Department of Mechanical Engineering and Science, School of Engineering, Tokyo Institute of Technology
- 1992 Professor, Tokyo Institute of Technology
- 1984 Associate Professor, Toyohashi University of Technology
- 1980 Lecturer, Toyohashi University of Technology
- 1978 Assistant Professor, Toyohashi University of Technology
- 1978 Doctor of Engineering, Department of Mechanical Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology
- 1973 Bachelor of Engineering, Department of Mechanical Engineering, School of Engineering, Tokyo Institute of Technology

Unit members

- Adjunct Professor Michio Hashimoto
- Adjunct Professor Takuya Oda
- Professor Tomohiro Nozaki
- Professor Akira Yamada
- Associate Professor Yuya Kajikawa
- Adjunct Professor Yoshihisa Sato
- Professor Manabu Ihara
- Professor Yukitaka Kato
- Professor Ichiro Yamanaka

Global hydrogen supply chain



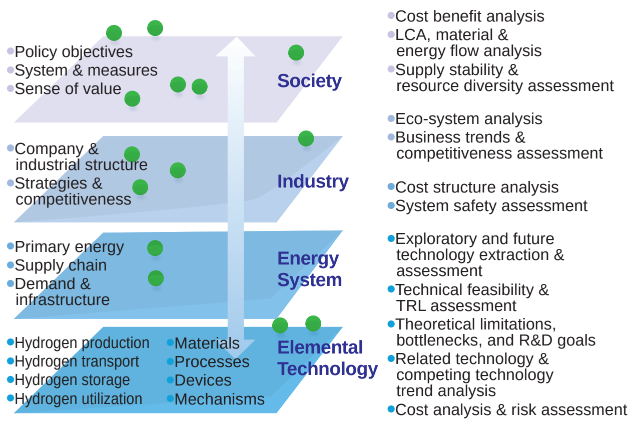
Why was this research unit established?

In order to realize a hydrogen energy society, it is essential to organically link universities that provide outstanding technology and research, industries that promote the commercialization of hydrogen energy, and governmental agencies that establish and execute policy. From our subjective position as a university, we established the Global Hydrogen Energy Consortium through industry-government-academia collaboration within the Global Hydrogen Energy Unit. The unit operates the consortium and facilitates multilateral assessment, the development of technology for elements and systems, and the exchange of information among members.

What are the strengths of this research unit?

Tokyo Tech has a wide range of achievements in energy-related research and education that it has accumulated over the years. In 2012, the Environmental Energy Innovation Building was completed at the Ookayama Campus and the original smart power grid management system "Ene-Swallow" was initiated. Experts in innovation and technical assessment are participating in the research along with specialists on campus to push technological and system advancements. Our strength is that this unique Research Unit can engage in global and open collaboration in a wide range of activities with other consortium members.

The Goal of the Tokyo Tech Global Hydrogen Energy Research Unit "Neutral, subjective, diversified evaluation (Technology Assessment)"



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

The Global Hydrogen Energy Unit's initial 5-year plan was based on the requirements for achieving the desired energy society in the next 30 years. We plan to first establish a system for the subjective and diversified assessment of introduction and use of hydrogen both in and outside of Japan. In FY 2016, the Unit scheduled to start joint assessment with industry, government, and universities with the goal of encouraging external funding. Based on this assessment, in FY 2017 and 2018, the Unit will examine the identified issues and implement specific research projects that focus on solving top priority problems. In FY 2019, we plan to establish a foundation to facilitate the application of our achievements to advance to the next stage.

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Global Hydrogen Energy Unit

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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 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.

Research Unit Leader **Misako Takayasu**

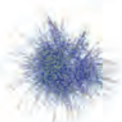
Profile

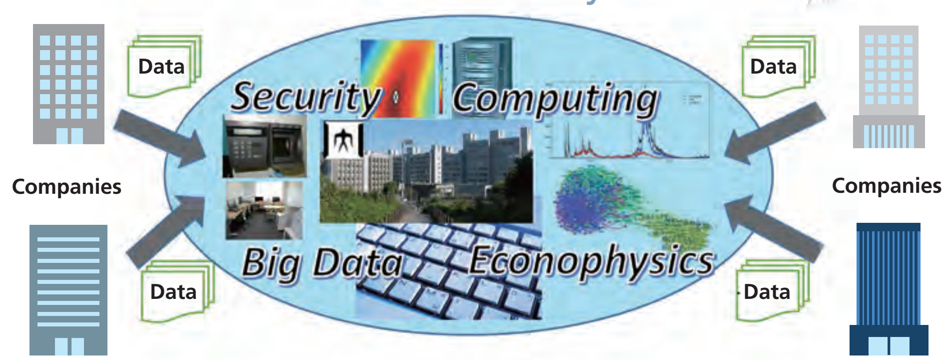
- 2016 Associate Professor, Institute of Innovative Research, Tokyo Institute of Technology
- 2015 Associate member, Science Council of Japan (Committee on Physics and Informatics)
- 2007 Associate Professor, Department of Computational Intelligence and Systems Science, Interdisciplinary Graduate School 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

Unit members

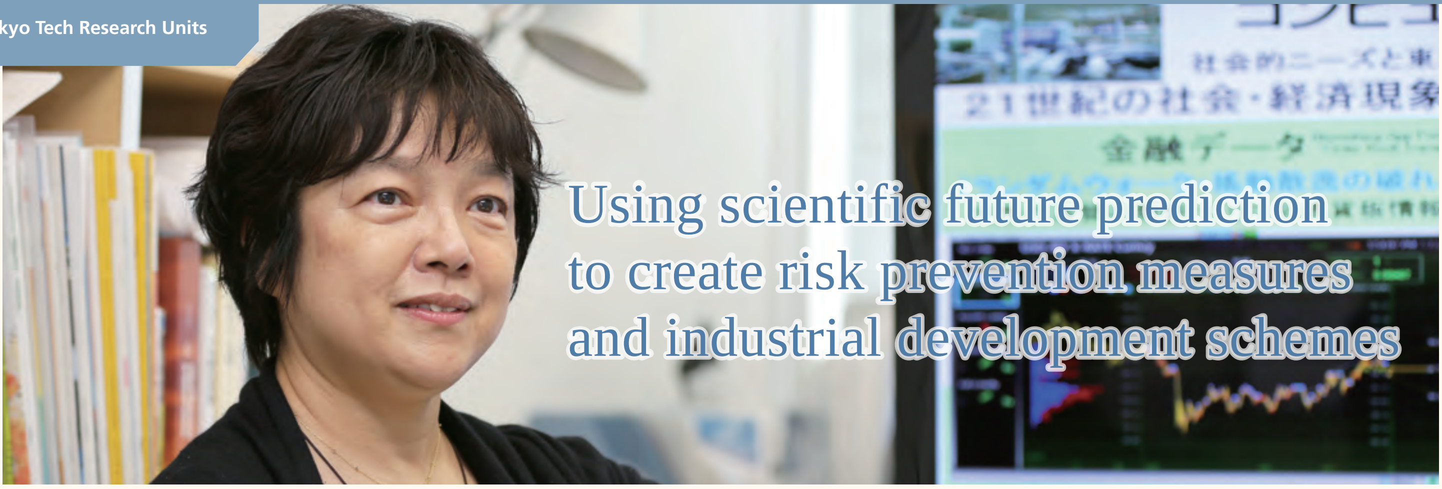
- Assistant Professor Kiyoshi Kanazawa
- Professor Wakaha Ogata
- Professor Yoshiyuki Kabashima
- Professor Hiroshi Deguchi
- Associate Professor Isao Ono
- Adjunct Professor Hideki Takayasu
- Adjunct Assistant Professor Koutaro Tamura

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

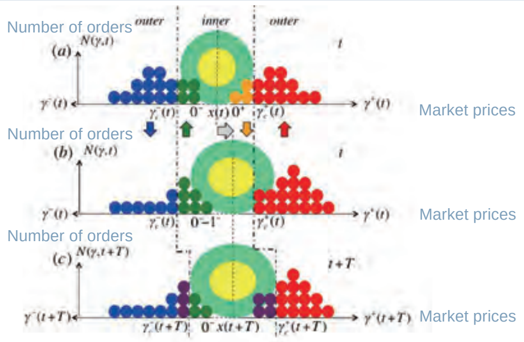
Why was this research unit established?

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.

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)

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.

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Advanced Computational Drug Discovery Unit

Tokyo Tech Research Units

Overview

Molecular simulation is a method of calculating molecular activity to analyze the physical and chemical properties of compounds used in innovative drug discovery. Bioinformatics and systems biology are applied to analyze biological data using information-science methodologies such as artificial intelligence, bigdata analysis and machine learning. Integrating these methods, the Advanced Computational Drug Discovery Unit (ACDD) develops *in silico* technology for innovative drug discovery from an academic point of view through large-scale GPU computation using the TSUBAME supercomputer. Utilizing and complementing biochemical research conducted by pharmaceutical companies, the unit aims to establish methods of innovative drug discovery through open innovation with industries.

Research Unit Leader **Masakazu Sekijima**

Profile

2016 Associate Professor, Institute of Innovative Research, Tokyo Institute of Technology
2009 Associate Professor, Global Scientific Information and Computing Center, Tokyo Institute of Technology
2008 Planning Officer, Planning Headquarters, National Institute of Advanced Industrial Science and Technology
2003 Research Scientist, Computational Biology Research Center, National Institute of Advanced Industrial Science and Technology
2002 Research Staff, Computational Biology Research Center, National Institute of Advanced Industrial Science and Technology
2002 Ph.D., Department of Biotechnology, Graduate School of Agricultural and Life Sciences, University of Tokyo

Unit members

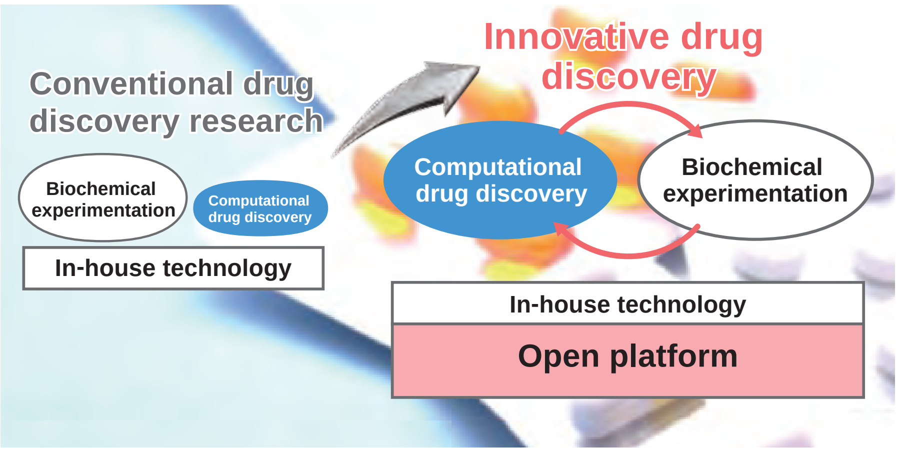
- Professor Yutaka Akiyama
- Professor Akihiko Konagaya
- Associate Professor Takashi Ishida
- Associate Professor Shintaro Sengoku
- Visiting Associate Professor Teruki Honma
- Assistant Professor Masahito Ohue

Research goals

It is essential for future innovative drug discovery to develop ideas and methods that facilitate beneficial collaboration between universities and corporations. ACDD sets the goal of realizing open innovation and aims to realize the establishment of an open drug discovery environment within five years. The unit will establish an advanced computational drug discovery model while focusing on the following three themes:

- Open utilization of the drug discovery environment by Tokyo Tech and pharmaceutical companies
- Establishment of an open-participation type *in silico* drug discovery contest
- Provision of education for industry professionals through the *in silico* drug discovery training program

Advanced Computational Drug Discovery Unit



A new Tokyo Tech research unit aiming to form an open platform for experimental studies on innovative drug discovery through integration of computational technology and experimental biochemistry

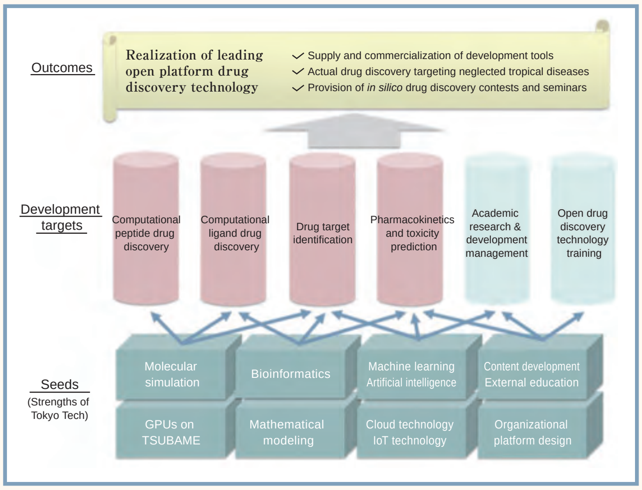
In line with the current trend, the concept of openness in drug discovery can be extended to other fields

Why was this research unit established?

Drug discovery is expensive, with development costs for a single drug often reaching USD 2.5 billion. In addition, security is extremely important because any leak of information can cause significant damage to a project. This creates obstacles to effective collaboration between pharmaceutical companies and researchers. In addition, projects tend to be discontinued if good results are not achieved in a short period of time. This means that, due to insufficient trials and errors, companies and researchers cannot compile enough data to mutually complement each other's efforts. There are not enough people to analyze the data, which forces a dependence on methods that are not suitable for project conditions, thereby preventing breakthroughs. The Advanced Computational Drug Discovery Unit was established to take the initiative in making drug discovery technology open and accessible for universities and startups.

What are the strengths of this research unit?

We have shared our know-how with pharmaceutical companies. This came about through a consortium on neglected tropical diseases (NTDs), diseases for which therapeutic drug development has been slow because they affect mainly impoverished areas. The consortium focuses on drug discovery as a social contribution project. It is important to have serious discussion and two-way exchange of know-how on new drug discovery through collaboration between companies and universities. This concept of openness should not be limited to the field of drug discovery, but should be allowed to pervade other fields and industries.



Tokyo Tech uses the supercomputer TSUBAME to great advantage by employing it to identify compounds for drug discovery. Unit members are confident that the accumulation of experimental results in cooperation with partners who conduct biochemical research using the extracted compounds will prove highly effective for drug discovery.

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

After we establish the corporate consortium in April 2016, the unit will hold drug discovery contests for five years. These contests will be open to everyone. ACDD also plans to initiate *in silico* drug discovery training programs for working adults, and symposiums in cooperation with overseas universities such as the Indian Institute of Technology Madras. We believe that these projects will prove effective in developing highly skilled professionals and in establishing an open and accessible drug discovery environment that contributes to collaboration between universities and companies.

Meanwhile, the unit is transferring technical methods for drug discovery to the TSUBAME supercomputer, establishing servers for open and accessible drug discovery, sharing and comparing results, and applying data to advanced drug discovery utilizing a platform that will lead to the establishment of a stable foundation for research and development.

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Advanced Computational Drug Discovery Unit

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Hybrid Materials Unit

Tokyo Tech Research Units

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

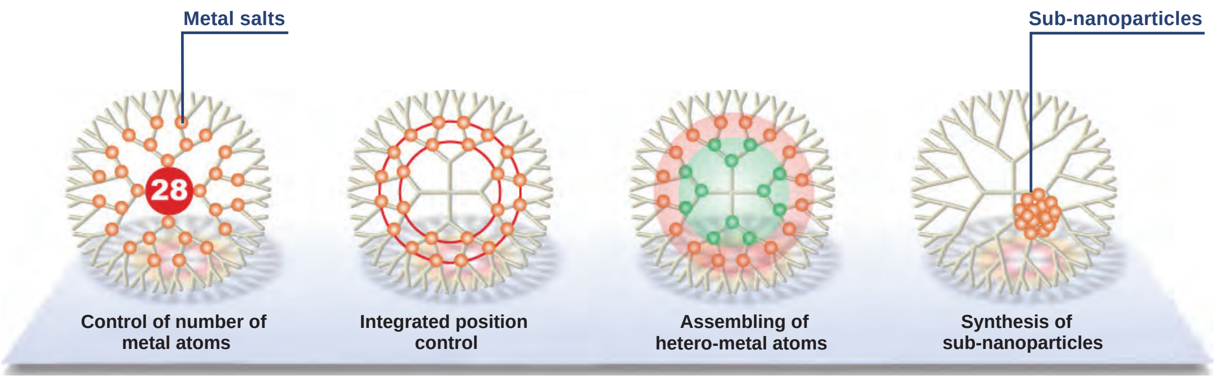
Profile

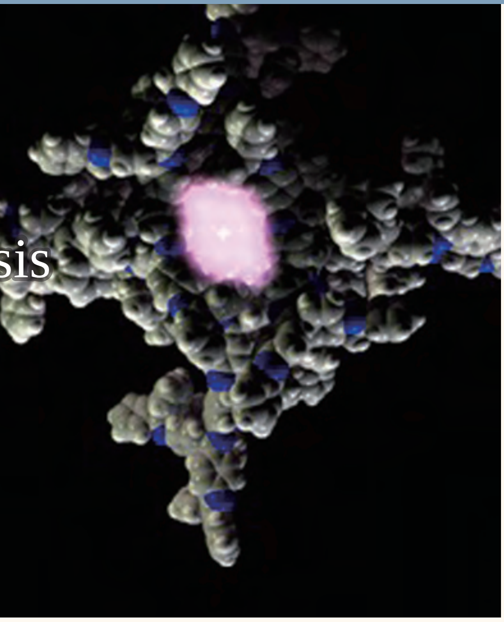
2016 Professor, Institute of Innovative Research, Tokyo Institute of Technology
2010 Professor, Chemical Resources Laboratory, Tokyo Institute of Technology
2002 Professor, Faculty of Science and Technology, Keio University
1997 Associate Professor, Faculty of Science and Technology, Keio University
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





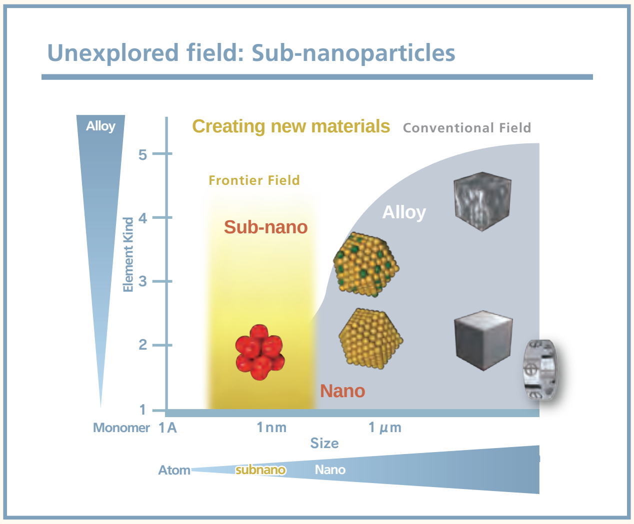
Progressing in sub-nanoparticle synthesis and discovering new materials with functions beyond our imagination

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.



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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Hybrid Materials Unit

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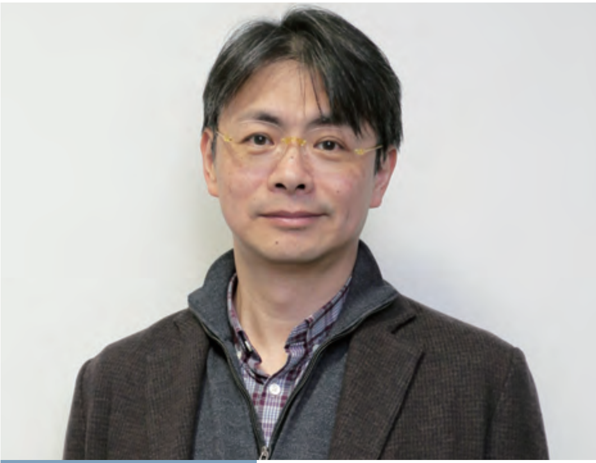
Biointerfaces Unit

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**

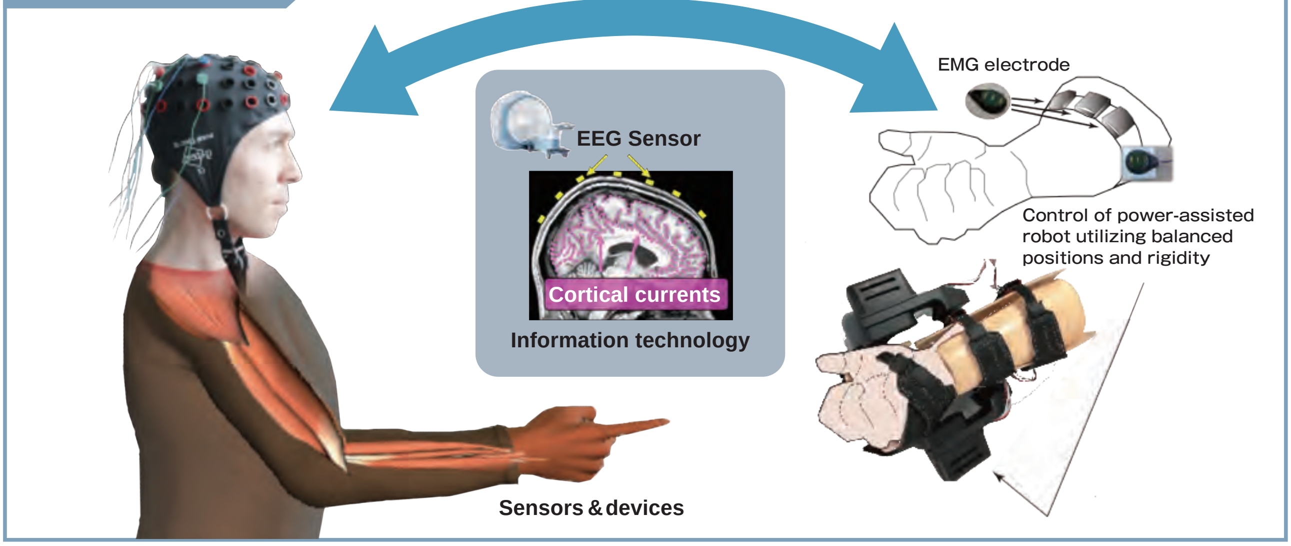
Profile

- 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 Marie Tahara
- Associate Professor Kotaro Tadano
- Professor Susumu Kajiwara
- Professor Yoshitaka Kitamoto
- Professor Scott Makeig, University of California San Diego
- Associate Professor Nicolas Schweighofer, University of Southern California

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.

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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

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

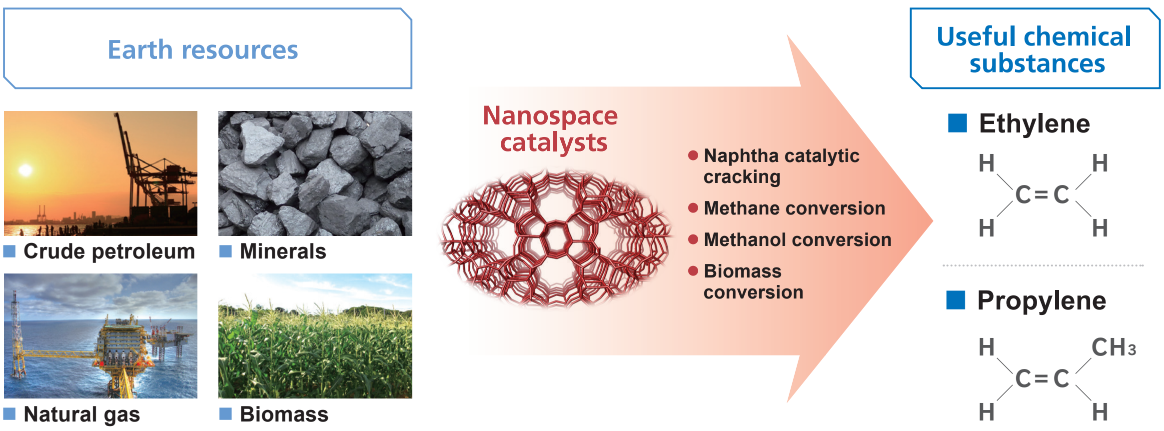
Unit members

- 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



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

Q 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.

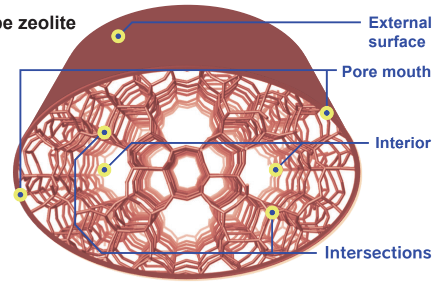
Q What are the strengths of this research unit?

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



Q 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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All-Solid-State Battery Unit

Overview

Smart phones, tablets and other mobile devices have become essential to our daily lives, and the paradigm shift to electric vehicles is expanding globally. The traditional power source employed in these devices has been the lithium-ion battery, which contains a liquid electrolyte. However, safer, more compact, and higher-performing batteries are greatly sought after. The superionic conductor (solid electrolyte) developed by Professor Ryoji Kanno functions over a broad range of temperatures, and its material allows ions to move within the structure selectively at high speed. It delivers outstanding safety and stability, does not leak, and has a high energy density, making it a key technology for all-solid-state batteries. The All-Solid-State Battery Unit leverages its lead in the development of superionic conductors to promote the commercialization of all-solid-state batteries.

Research Unit Leader **Ryoji Kanno**

Profile

2018 Unit leader, All-Solid-State Battery Unit and Professor, Institute of Innovative Research, Tokyo Institute of Technology
2016 Professor, School of Materials and Chemical Technology, Tokyo Institute of Technology
2001 Professor, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
1989 Associate Professor, Faculty of Science, Kobe University
1985 Doctor of Science, Osaka University
1980 Research Associate, Faculty of Engineering, Mie University
1980 Master of Science, Inorganic & Physical Chemistry Division, Graduate School of Science, Osaka University
1978 Bachelor of Science, Department of Chemistry, School of Science, Osaka University

Unit members

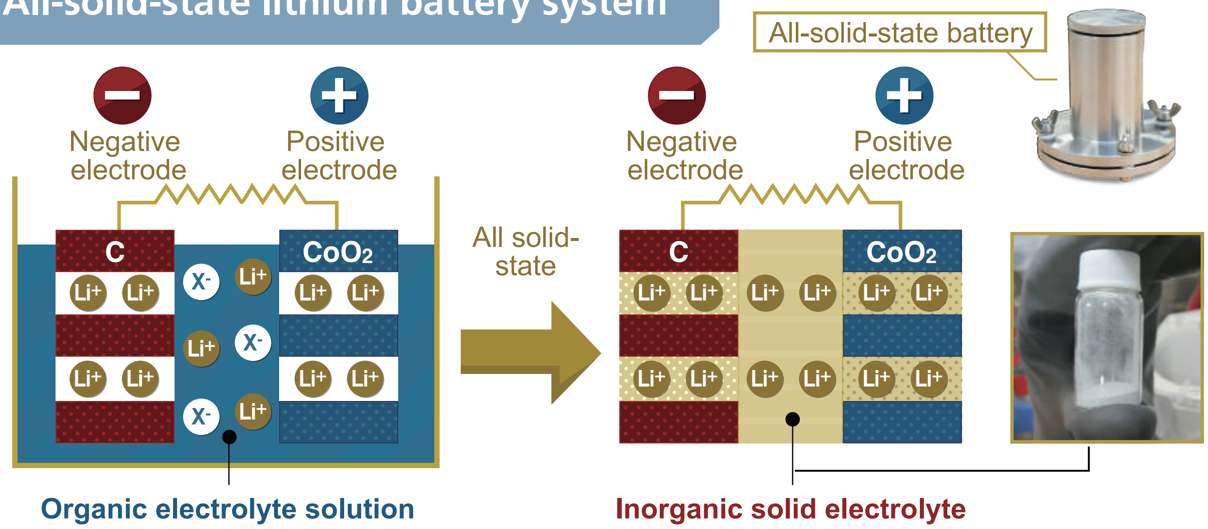
- Associate Professor Masaaki Hirayama
- Assistant Professor Kota Suzuki
- Professor Hitoshi Kawaji
- Specially Appointed Professor (IP Strategy) Hidemi Takahashi
- Professor Hajime Arai
- Associate Professor Fusao Kitamura
- Assistant Professor Takeyoshi Okajima

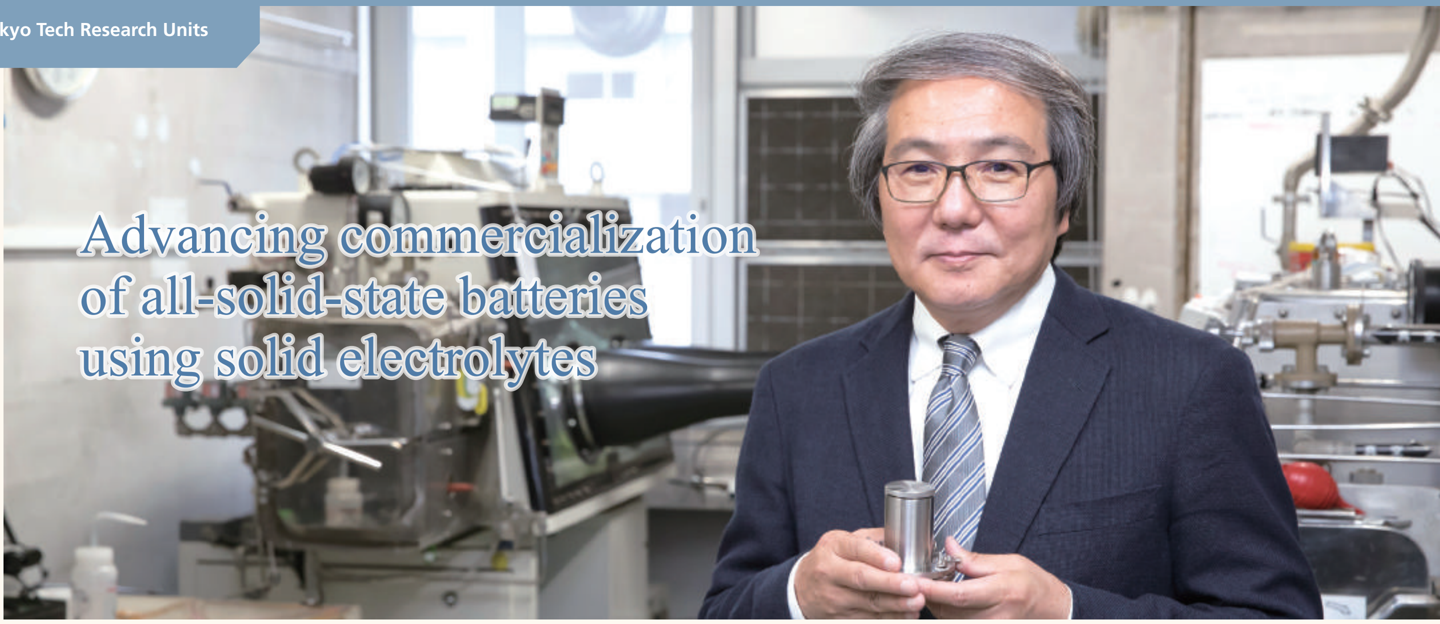
Research goals

Development of solid electrolyte materials as a key technology for all-solid-state batteries

(1) Development of methods for synthesizing superionic conductors in large amounts for commercialization
(2) Development of fundamental process technology for commercialization of composite electrode materials
(3) All-solid-state battery prototyping and practical use evaluations (environmental impact assessments)
(4) Demonstration of high performance and functionality through verification of principles and advanced analyses

All-solid-state lithium battery system





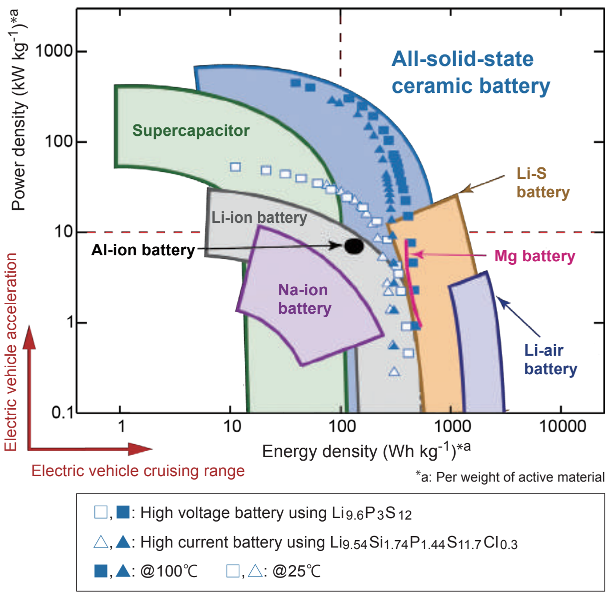
Advancing commercialization of all-solid-state batteries using solid electrolytes

Why was this research unit established?

We established this research unit to focus university resources on advancing research, development, and commercialization of all-solid-state batteries. This research unit facilitates collaborations with academia, industry, and government; supports adoption of all-solid-state batteries for mobile devices, electric vehicles, and a wide range of other products; and seeks to open new fields and industries that will apply all-solid-state batteries.

Advances in science are leading to batteries with unprecedented capabilities

All-solid-state batteries from novel materials offer improvements over conventional energy devices.



What are the strengths of this research unit?

In 2011, we discovered the material LGPS, a solid electrolyte with high ionic conductivity; and in 2016, we discovered further derivatives of the solid electrolyte. In 2017, we developed a low-cost, all-purpose solid electrolyte by combining tin and silicon. The research has resulted in several key patents.

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

While we continue development of solid electrolytes providing greater ionic conductivity and stability, we are also working to improve output and lifetime through atomic-level analyses of electrochemical surfaces, the findings of which will feed back to materials analysis. To evaluate the materials, we explore a wide range of parameters utilizing not only regular firing methods, but also high-pressure and thin-film synthesis, as well as materials informatics. Furthermore, we are working to establish a research strategy that ensures cooperation with industry to advance commercialization and creation of new systems to form consortiums. We also participate in national projects involving energy strategy, promote research and development of methods for synthesizing superionic conductors in large quantities for commercialization, and carry out academic-industry-government collaborations for the advancement and application of all-solid-state batteries.

Contact us

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All-Solid-State Battery 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.

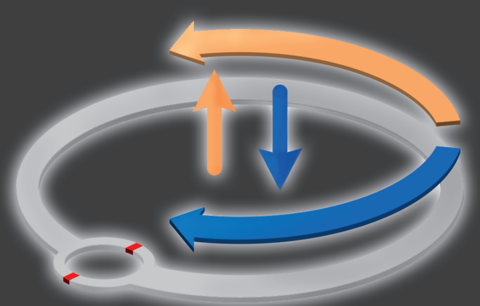
(3) General methodologies to express optimization problems with the Ising model.

Research Unit Leader **Hidetoshi Nishimori**

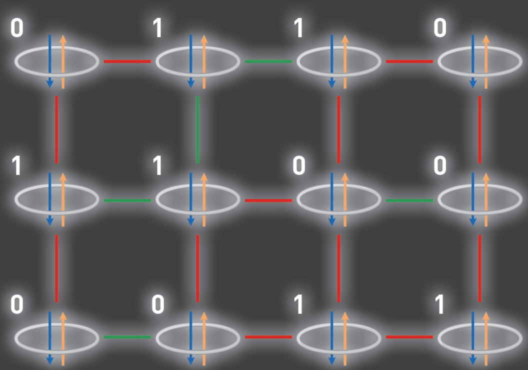
Profile

- 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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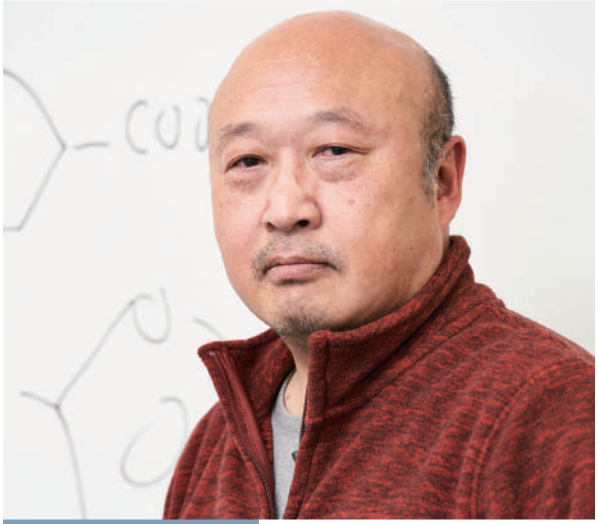
Tokyo Tech Research Units

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.

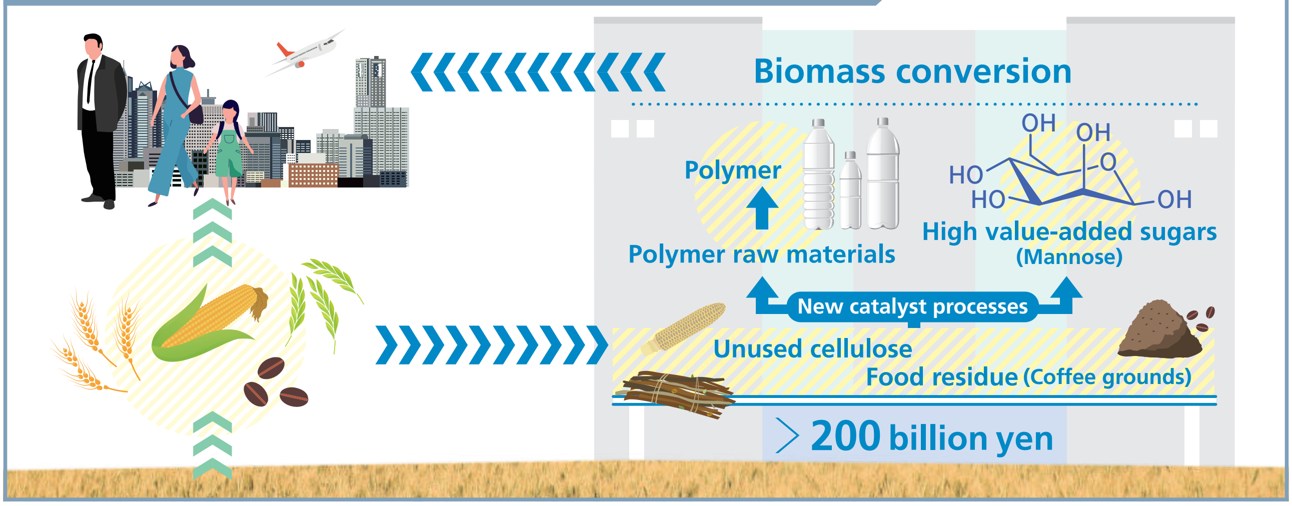
(1) Commercial production of high-performance carbohydrates like mannose, which has an antiviral activity-promoting effect, using the unused portions of foods such as food peelings and coffee grounds

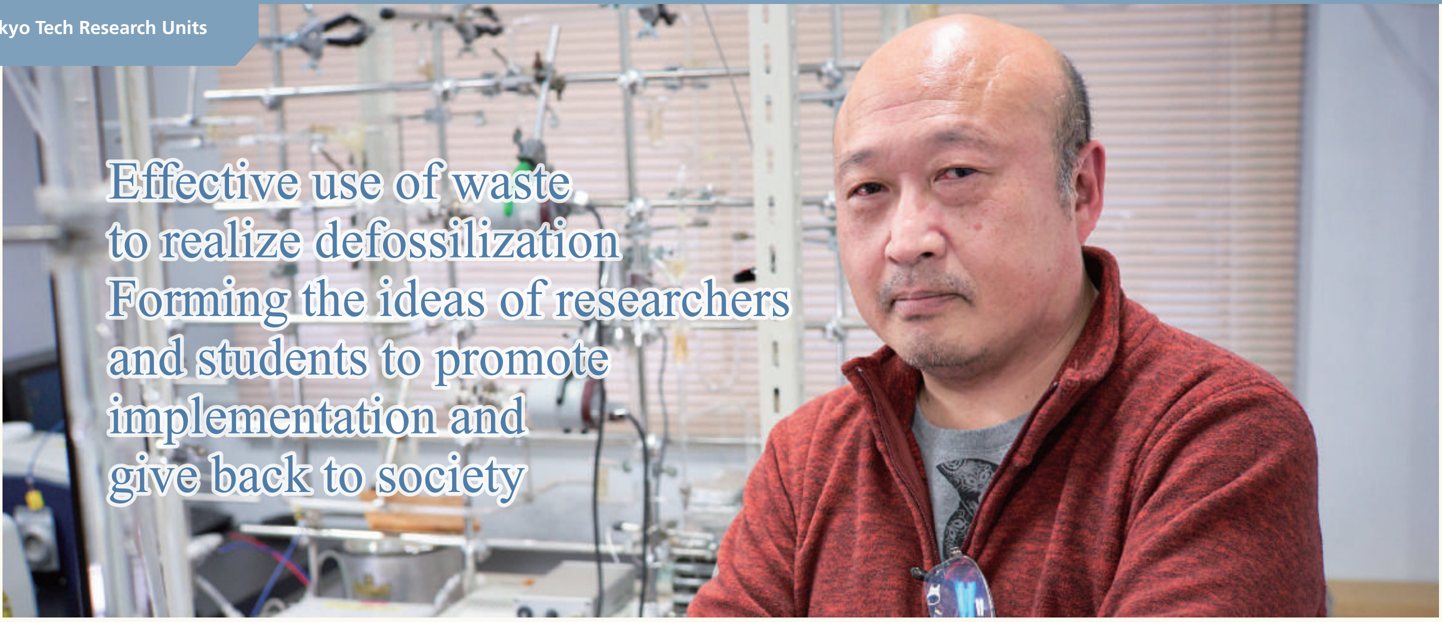
Mannose has been used for pharmaceuticals, but production costs are high and its usages are limited. If this technology becomes practical, it will be possible to reduce costs to a third, and this would have a major impact on society.

(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





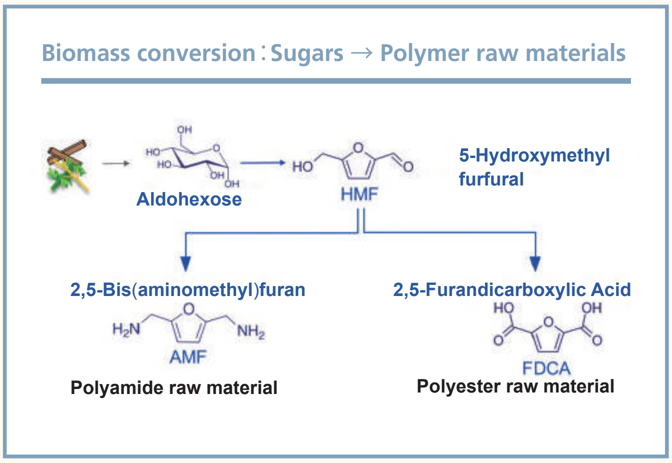
Effective use of waste to realize defossilization Forming the ideas of researchers and students to promote implementation and give back to society

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.

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.



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

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Sustainable Chemical Resource Production Unit

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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.

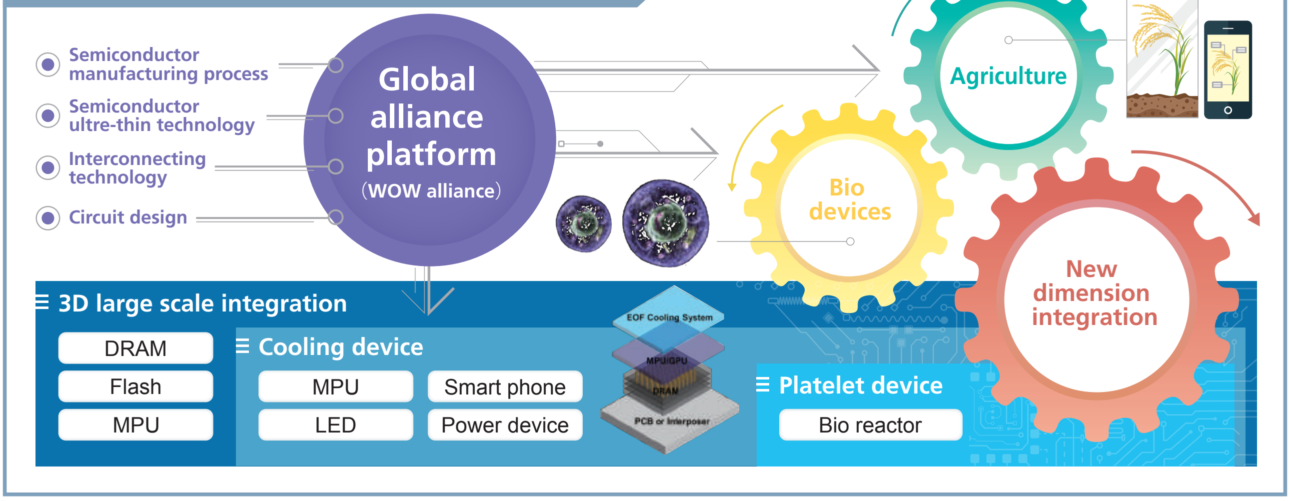
【Three-dimensional integration technology】 We will use the ultra-thinning technology and the vertical interconnect technology possessed by the WOW Alliance to integrate semiconductors three-dimensionally and create a next-generation semiconductor that is higher in performance and lower in power consumption. 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



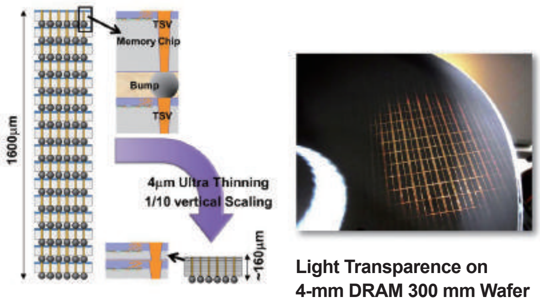
An assembly of businesses from different fields focusing on semiconductor technology and aiming to become a technology platform based on win-win collaboration

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?

Ultra thin semiconductor technology



Light Transparence on 4-mm DRAM 300 mm Wafer

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

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?

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

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Heterogeneous and Functional Integration Unit

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