



# Global Hydrogen Energy Unit

## 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<sub>2</sub> and hydrogen in Australia, store the CO<sub>2</sub> 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**

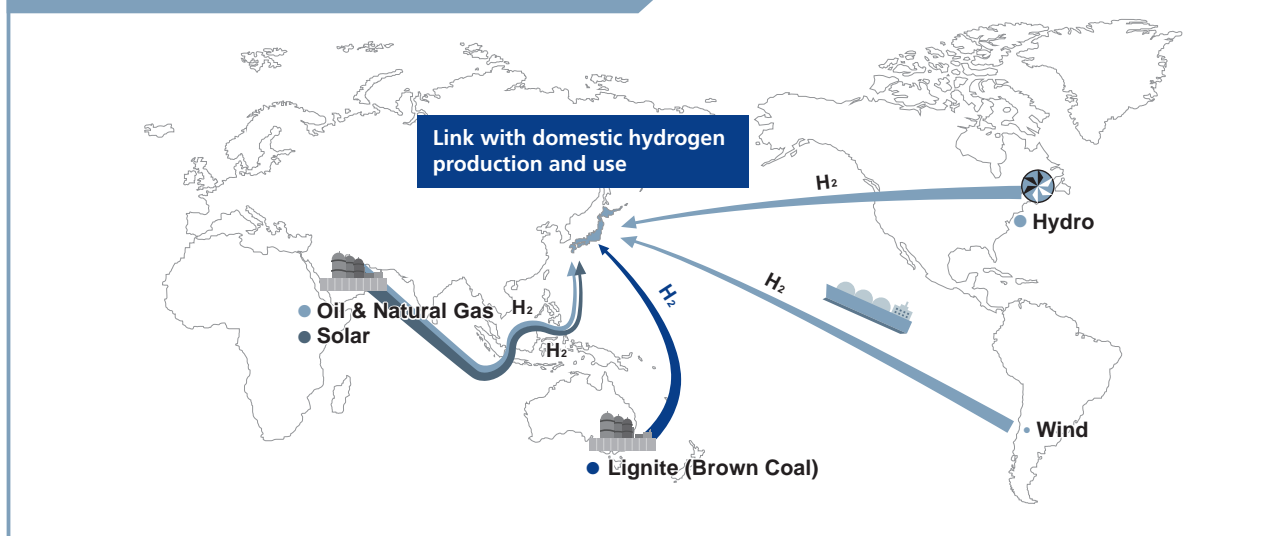
### Profile

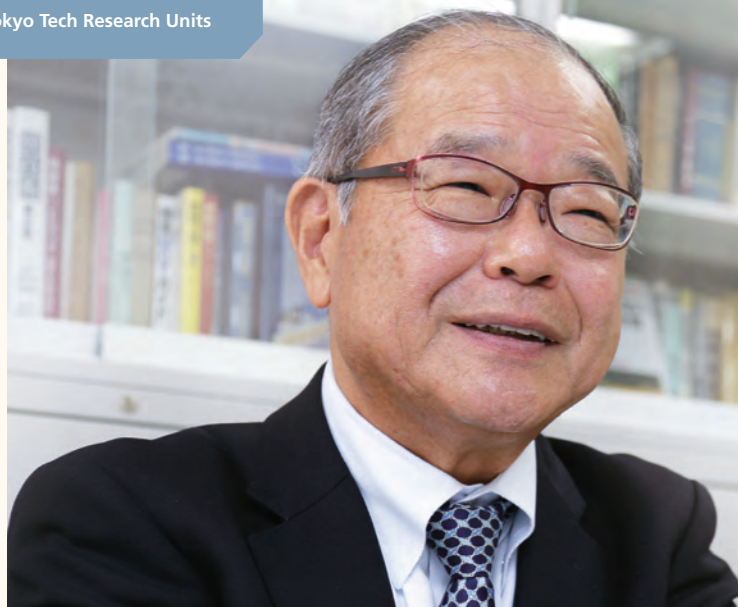
2015 Institute Professor (Professor Emeritus), Tokyo Institute of Technology  
2007-2011 Dean, Graduate School of Engineering, Tokyo Institute of Technology  
2000 Professor, Department of Mechanical and Control Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology  
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 Yukioka Kato
- Professor Ichiro Yamanaka

## Global hydrogen supply chain





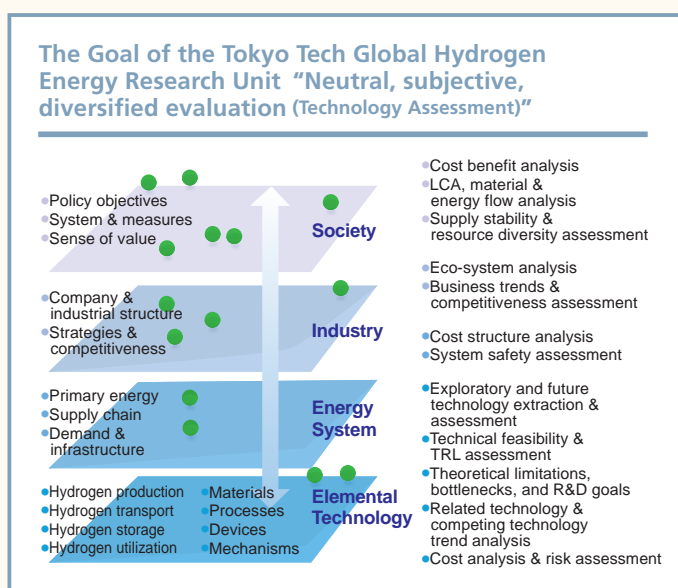
In order to realize a hydrogen energy society, universities, industries, and government agencies must be organically linked

## Q 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.

## Q 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.



## Q 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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# 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 formulate 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**

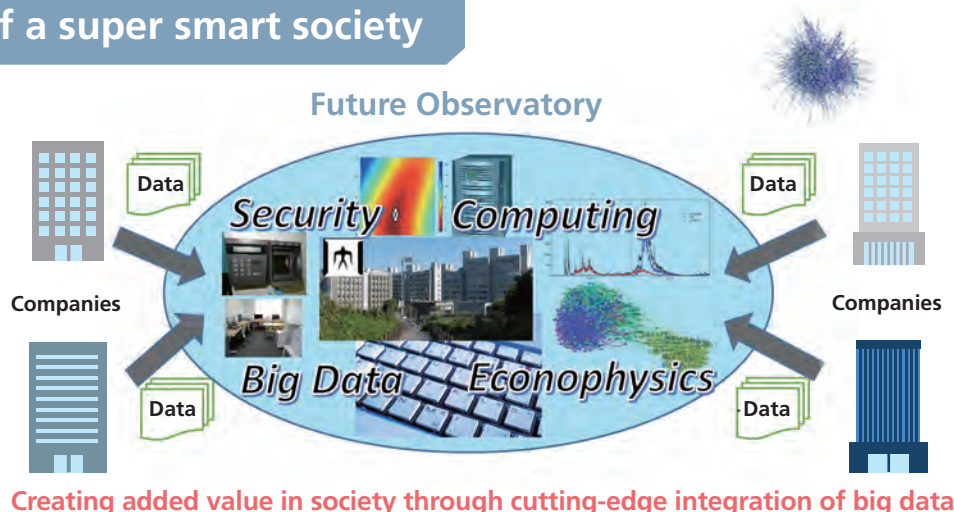
### Profile

- 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







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

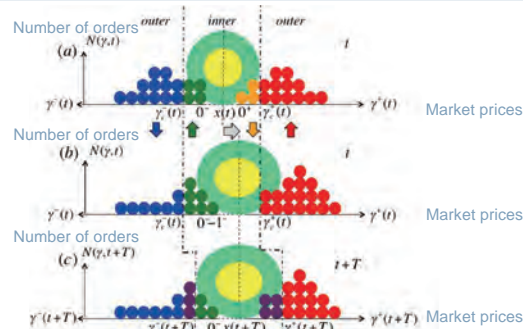
### Q Why was this research unit established?

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.

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# Advanced Computational Drug Discovery Unit

## 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 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



Research Unit Leader **Masakazu Sekijima**

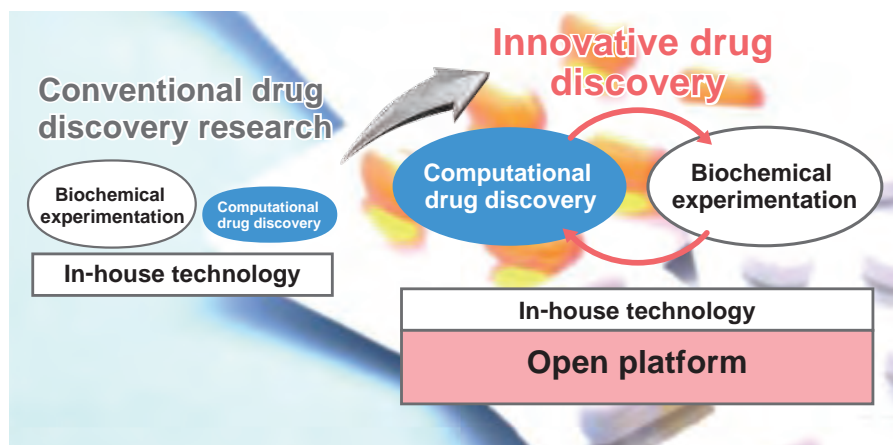
### Profile

- 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

## 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

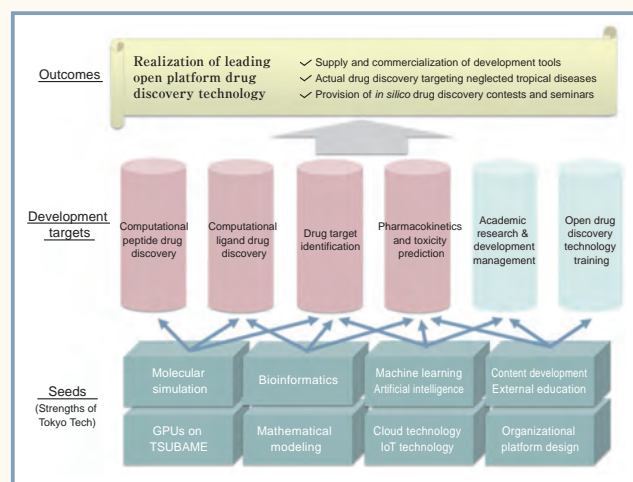
## Q Why was this research unit established?

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.

## Q 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.



## Q 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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# Hybrid 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 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.

Research Unit Leader

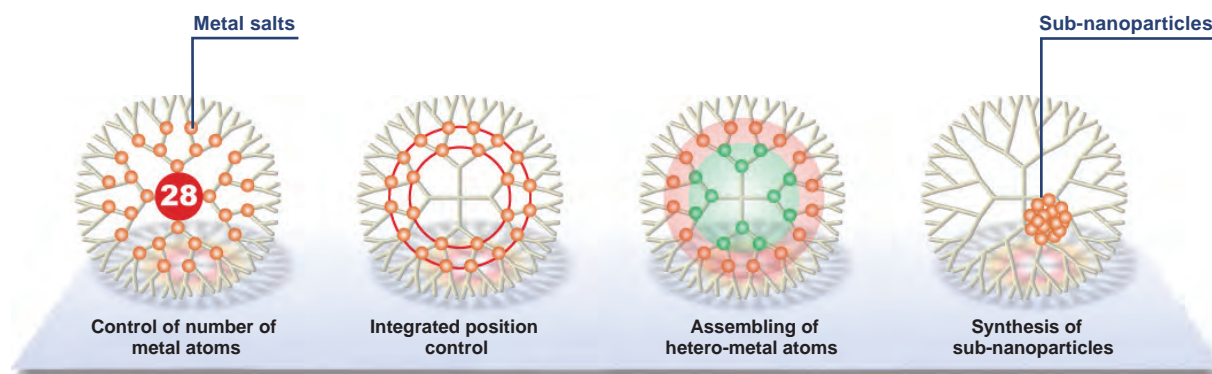
**Kimihisa  
Yamamoto**



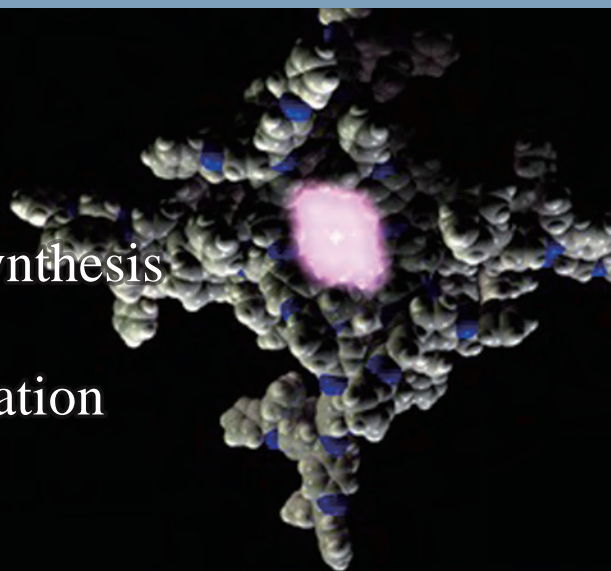
### Profile

- 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

## Atom hybrid method



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



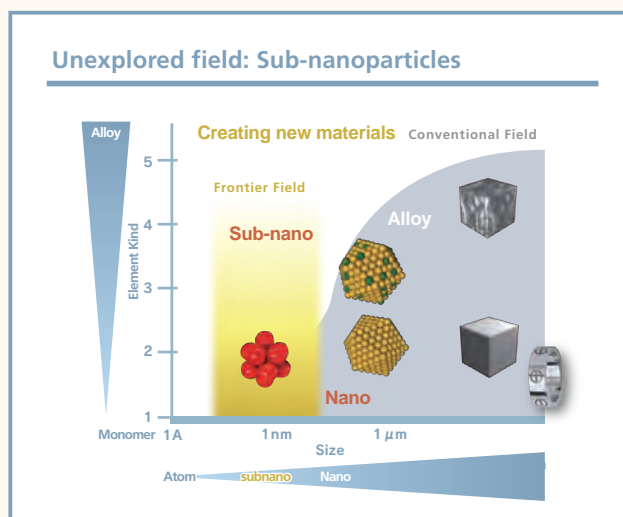
## Q Why was this research unit established?

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.

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Hybrid Materials Unit

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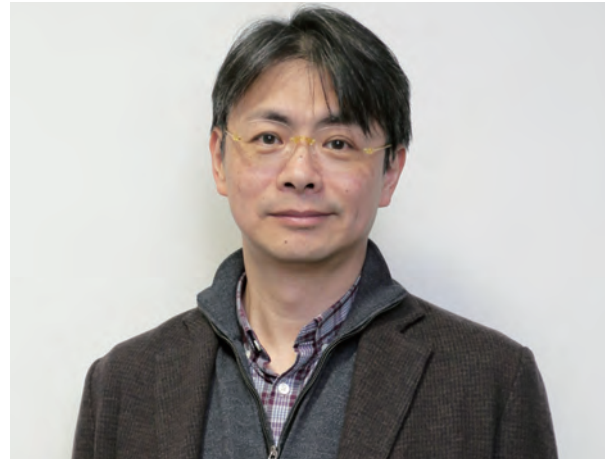
# Biointerfaces Unit

## 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**

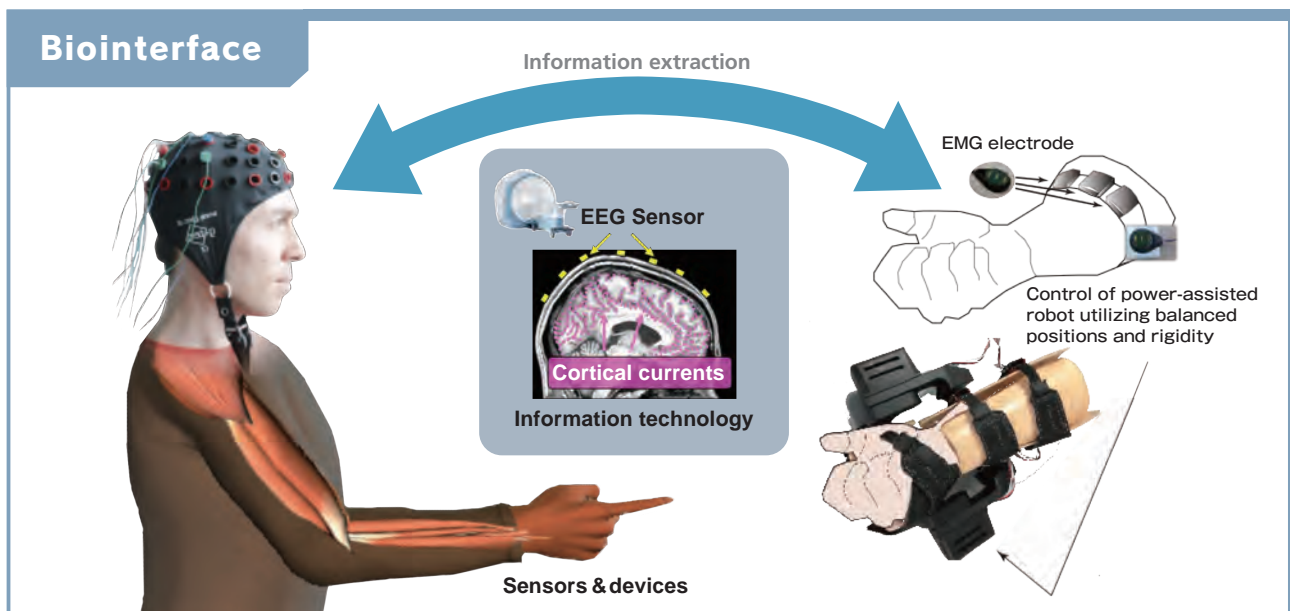
### Profile

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

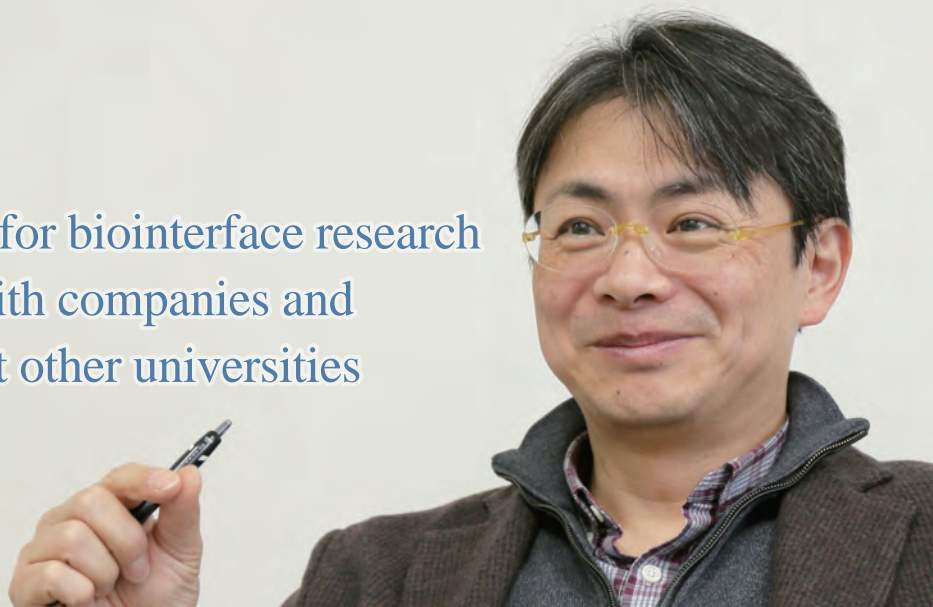
### Unit members

- 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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# Innovative Heterogeneous Catalysis Unit

## Overview

The Innovative Heterogeneous Catalysis Unit aims to develop and commercialize innovative catalysts that surpass existing concepts. Catalysts are used to accelerate chemical reactions when synthesizing compounds from ingredients, and have supported industrialization in the form of food and petrochemical production. Still, new catalysts must be developed and improved to preserve natural and other scarce resources, and to prevent environmental pollution. The unit sets the goal of developing and realizing mass production of environmentally friendly solid catalysts.

## Research goals

To replace petroleum as an ingredient in a broad range of products, the Innovative Heterogeneous Catalysis Unit aims to develop catalyst technology capable of producing glucose from organic resources made from biomass such as weeds, waste wood, and inedible parts of plants, and converting the glucose to a wide range of chemical resources. The unit aims to secure resources that serve as alternatives to petroleum while reducing CO<sub>2</sub> emissions. In addition, the Innovative Heterogeneous Catalysis Unit also works on improving the efficiency and commercialization of new electrode catalysts produced from ammonia, catalysts discovered in joint research with Professor Hideo Hosono at the Materials Research Center for Element Strategy. These new catalysts can be produced at atmospheric pressures and temperatures lower than those required for the Haber-Bosch process. Requiring only half the energy compared to conventional methods, the unit is looking to implement downsized plants for electrode catalysts in ammonia synthesis that can be operated in developing countries and countries without adequate infrastructure. The Innovative Heterogeneous Catalysis Unit is also promoting the development of new solid catalysts and research to clarify their mechanisms.

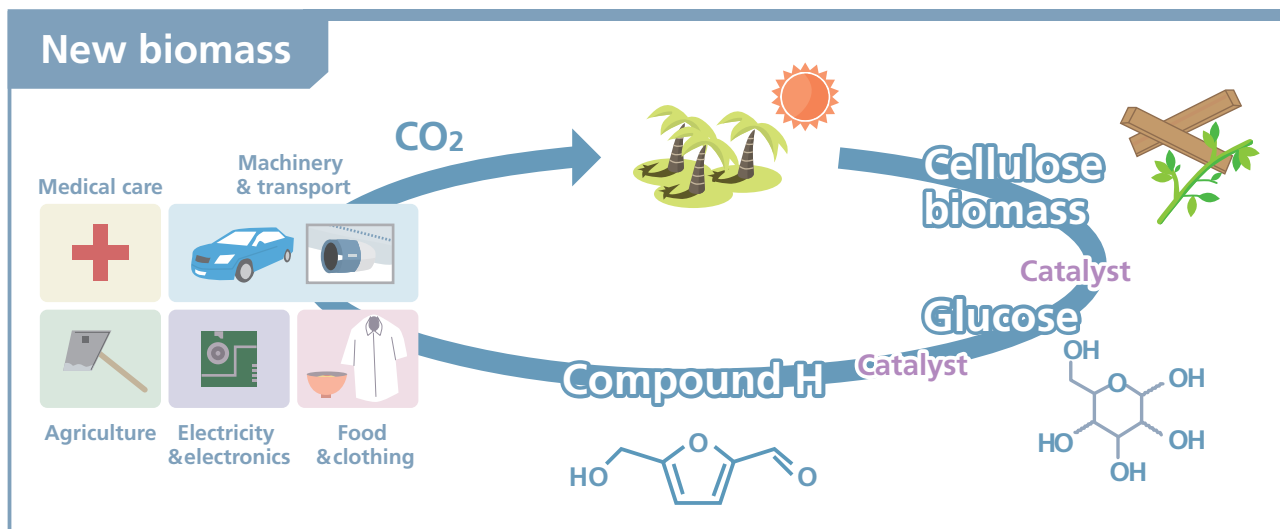


Research Unit Leader **Michikazu Hara**

### Profile

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 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

## New biomass







## Developing new catalysts and establishing new theories together with students and other researchers

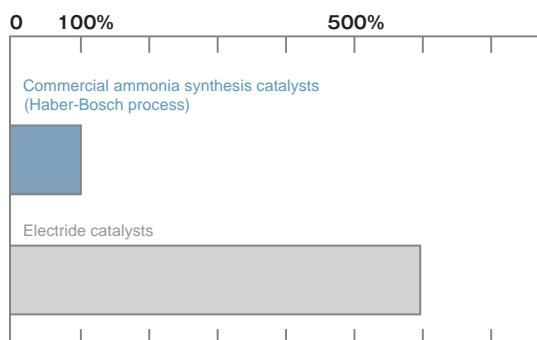
### Q Why was this research unit established?

We want to accelerate collaboration with companies, develop biomass conversion catalysts, and improve and commercialize electrified synthetic ammonia catalysts. Companies play a significant role in the commercialization of projects as their strengths lie in market research and cost planning. Small plants and large laboratories are necessary to ensure safety, and the Innovative Heterogeneous Catalysis Unit can provide such an environment.

### Q What are the strengths of this research unit?

The unit can work on a series of processes, from the development of advanced catalyst materials to their commercialization and utilization in society. Although existing catalysts and production methods have been improved, there are many other problems that cannot be solved through improvement alone. In order to solve these problems, the unit will develop new catalysts and establish new theories working together with students and other researchers. Commercialization in cooperation with companies will help Tokyo Tech return the benefits of the Institute's research to society. This meaningful research will lead to solutions to population problems, food shortages, and environmental issues.

Comparison of ammonia synthesis capability



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

In terms of making chemical resources from biomass, the processes required to produce glucose from inedible parts of plants are in the final stage of development. Currently, we are engaged in the development of catalysts to produce polyester, heat-resistant resin, and plastics utilizing materials made from glucose.

Electrified ammonia synthesis catalysts are now being verified with private companies at plant sites in a joint project promoted by the Advanced Low Carbon Technology Research and Development Program (ALCA) of the Japan Science and Technology Agency. Within a few years, the Innovative Heterogeneous Catalysis Unit is planning to commercialize small, decentralized ammonia plants with the goal of implementing them in regions with food shortages in a period of five years.

#### Contact us

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 Catalysis Unit**

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# Advanced Nuclear Fuel Cycle Unit

## Overview

The Advanced Nuclear Fuel Cycle Unit develops technology for the processing of high-level radioactive waste produced in the nuclear fuel cycle. The unit's goal is to establish a safe, environmental preservation-type low-emission nuclear fuel cycle that significantly reduces environmental load and radiation risk. The unit also develops technology to remove radioactive materials from the ground and treats contaminated water at the Fukushima Daiichi nuclear power plant. The Advanced Nuclear Fuel Cycle Unit makes proposals for the removal of contaminated water, promotes the exchange of opinions with local residents, and creates scenarios to form agreements that lead to problem solving.

## Research goals

Conventional wisdom holds that high-level radioactive waste generated by spent nuclear fuel should be vitrified at a reprocessing plant and cooled at an interim storage facility before final burial underground. The unit follows this concept in promoting research and development in vitrification (Fig. 1-2). The Advanced Nuclear Fuel Cycle Unit also develops technology to recover and separate platinum-group elements, which produce a large amount of solids in the vitrified objects (Fig. 1-3), and centrifugal extractors that separate highly radiotoxic fission product elements, which reduce storage efficiency (Fig. 1-4). The unit's five-year plan is to develop these technologies, increase their scale, verify efficiency, and pursue commercialization.

Separating minor actinide (MA), a transuranium element, from high-level radioactive waste and burning MOX fuel with uranium (U), plutonium (Pu), and MA significantly reduces radiotoxin in the waste. This will make it possible in the future to control waste at ground level. The unit also conducts research on fast breeder reactors with the goal of significantly improving uranium usage and reducing waste generation (Fig. 1-5).



Research Unit Leader **Kenji Takeshita**

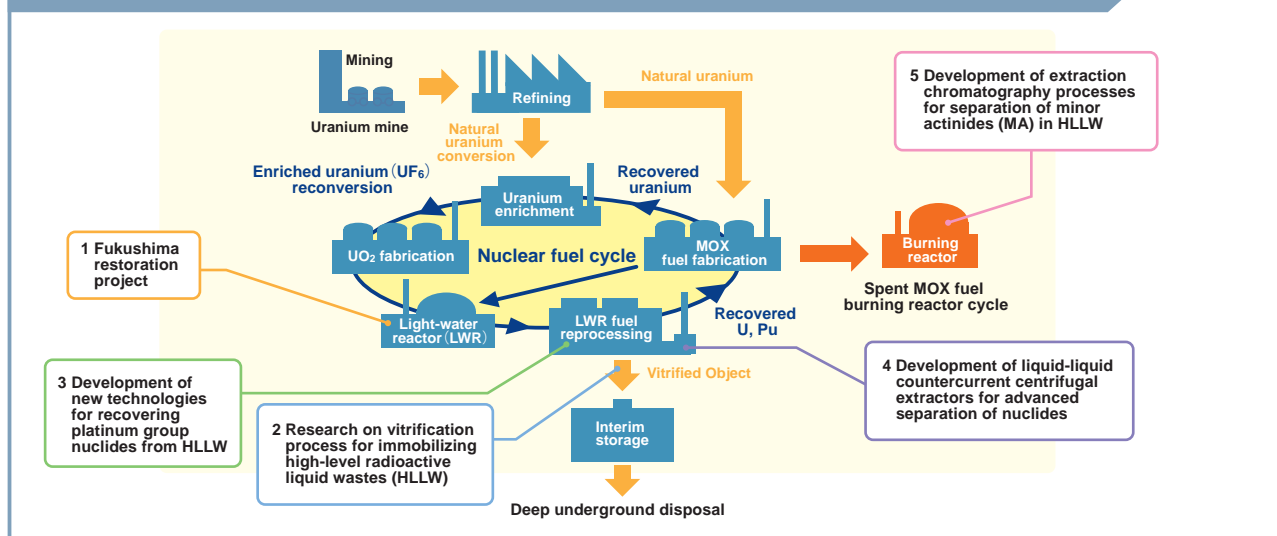
### Profile

- 2016 Professor, Institute of Innovative Research, Tokyo Institute of Technology
- 2010 Professor, Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology
- 1996 Associate Professor, Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology
- 1992 Chief Researcher, Institute of Research and Innovation
- 1987 Researcher, Institute of Research and Innovation
- 1987 Doctor of Engineering, Department of Nuclear Engineering, Graduate School of Science and Engineering, Tokyo Institute of Technology

### Unit members

- Researcher Yusuke Inaba
- Researcher Miki Harigai
- Professor Emeritus Yoshio Nakano
- Adjunct Specialist Kazuo Utsumi
- Professor Jun Onoe, Nagoya University
- Adjunct Lecturer Shinta Watanabe, Nagoya University
- Yasuo Ayame, Japan Atomic Energy Agency
- Ippei Amamoto, Japan Atomic Energy Agency
- Takashi Onishi, Japan Atomic Energy Agency
- Tsuyoshi Yaita, Japan Atomic Energy Agency
- Hirochika Naganawa, Japan Atomic Energy Agency
- Researcher Hideharu Takahashi
- Researcher Makoto Nishikawa
- Professor Emeritus Masaki Ozawa
- Professor Tetsuji Yano

Fig.1 Environmental preservation-type nuclear fuel cycle





## Expanding the Nuclear Fuel Cycle Project to reduce global warming and secure energy for the future

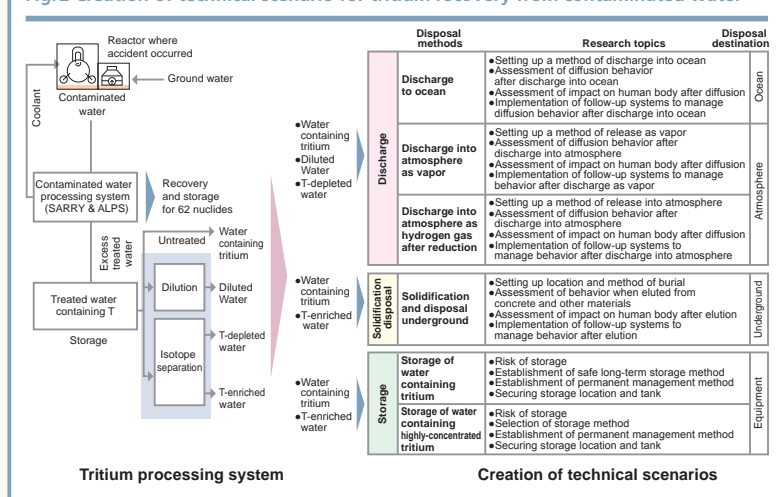
### Q Why was this research unit established?

The Nuclear Fuel Cycle Project started in 2008 with a focus on the five sub-projects explained in the Research goals to address issues in the development of an environmental preservation-type nuclear fuel cycle. The Advanced Nuclear Fuel Cycle Unit utilizes previous research findings to establish a wide range of measures based on technology and the social sciences in response to energy policy. In the near future, we will be required to strike the best balance of a wide range of energy policy options. To prepare for this we must consider such options now. The unit places priority on expanding the Nuclear Fuel Cycle Project to contribute to the reduction of global warming and securing energy for the future.

### Q What are the strengths of this research unit?

Tokyo Tech is proud of its many specialists in the fields of technology and social sciences, and is strong at creating multidisciplinary teams of specialists in the physical sciences, environmental engineering, nuclear power, and a wide range of other areas. Specialists with differing viewpoints from outside Tokyo Tech also participate to ensure balance. The Advanced Nuclear Fuel Cycle Unit continues to apply knowledge and skill in technology and the social sciences to provide a wide range of solutions to social issues associated with nuclear power.

Fig. 2 Creation of technical scenario for tritium recovery from contaminated water



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

We have conducted research on vitrification for seven years, and technical development to recover platinum-group elements for five years. The goal is to complete both technologies within the next five years.

The Advanced Nuclear Fuel Cycle Unit is moving forward to achieve stable energy supply utilizing the fast-breeder reactor cycle by 2080. We have already used five years for research on MA separation technology, which is essential for the fast-breeder reactor cycle. The Japan Atomic Energy Agency (JAEA), where I am a research fellow, is planning to promote joint research on advanced separation of MA with the United States Department of Energy National Laboratories.

Through the Fukushima Daiichi nuclear power plant project, we will perform technical development for the processing of contaminated soil, and provide scenarios for the processing and treatment of contaminated water in several years, and attempt to reach an agreement with residents within two years after that. As an example, Fig. 2 shows a treatment method for tritium contained in contaminated water. The unit will provide technical scenarios for the separation and concentration of tritium, discharge through dilution, and evaporation processing, and engage in discussions with residents at an early stage to reach an agreement. The process of forming an agreement with residents will help the national government make its decisions.

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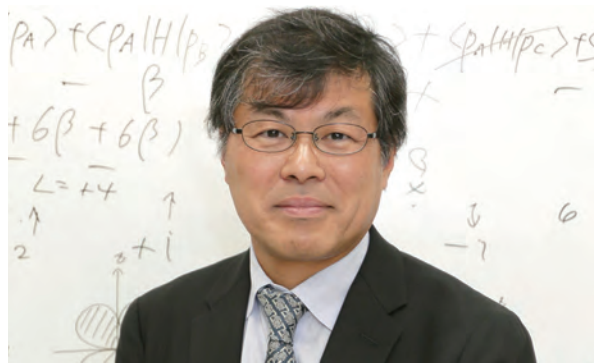
# Clean Environment Unit

## Overview

The Clean Environment Unit works on the real-time detection of airborne substances which cause environmental pollution. By understanding the distribution and severity of pollution, and by clarifying its causes, the unit aims to realize a clean environment. Specifically, it promotes research utilizing resonance-enhanced multiphoton ionization (REMPI), detecting and analyzing a wide range of hazardous substances such as PM 2.5 and automobile exhaust in the atmosphere. The unit also applies the technology to analysis of materials and promotes its use in material sciences. Based on its fundamental research findings, the Clean Environment Unit also develops and improves apparatus in which REMPI is employed.

## Research goals

Identification of substances in the atmosphere requires complicated pretreatment such as separation by chromatography and concentration by solvent evaporation. However, REMPI makes it possible to ionize the substances to be identified by adjusting the wavelength of the laser light, enabling detection in real time. This is called *resonance enhancement*, which the unit can apply to the analysis of constituents of solid materials by vaporizing them with focused ion beams. The Clean Environment Unit further promotes fundamental research aiming to improve the sensitivity and resolution of REMPI. The unit also works on the commercialization of supersensitive solid material analysis apparatus utilizing REMPI for application in the analysis of radioactive elements in Fukushima, and material analysis of semiconductors and steel.



Research Unit Leader **Masaaki Fujii**

### Profile

2016 Professor, Institute of Innovative Research, Tokyo Institute of Technology  
2014 President of Japan Society for Molecular Science  
2014 Trustee of the Spectroscopical Society of Japan (until present)  
2003 Professor, Chemical Resources Laboratory, Tokyo Institute of Technology  
1999 Director, Laser Research Center for Molecular Science, Institute for Molecular Science, Okazaki National Research Institutes  
1997 Professor, Institute for Molecular Science, Okazaki National Research Institutes  
1993 Associate Professor, Department of Chemistry, School of Science and Engineering, Waseda University  
1993 Researcher, Precursory Research for Embryonic Science and Technology 21 (Light and Material area), Japan Science and Technology Agency  
1988 Visiting scientist under US-Japan Collaboration on Solar Energy, Cornell University  
1987 Doctor of Science, Tohoku University  
1985 Research Associate, Department of Chemistry, Faculty of Science, Tohoku University  
1985 Withdrew from doctoral degree program with full credits, Department of Chemistry, Graduate School of Science, Tohoku University  
1982 Bachelor of Science, Department of Chemistry, Faculty of Science, Tohoku University

### Unit members

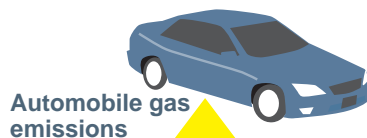
- Adjunct Associate Professor Shun-ichi Ishiuchi
- Assistant Professor Mitsuhiro Miyazaki
- Professor Tetsuo Sakamoto, Kogakuin University

## Laser multiphoton ionization analysis



**Combustion furnace gas analysis & active operation control**

Large-size furnace : 1740 units in Japan

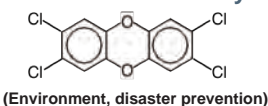


**Automobile gas emissions**

**Laser ionization analysis utilizing REMPI**



**Atmospheric and environmental analysis**



**Expansion to fine particle history analysis, transboundary pollution, and material analysis**

## Expanding new technology created through Tokyo Tech's fundamental research to environmental and material analysis

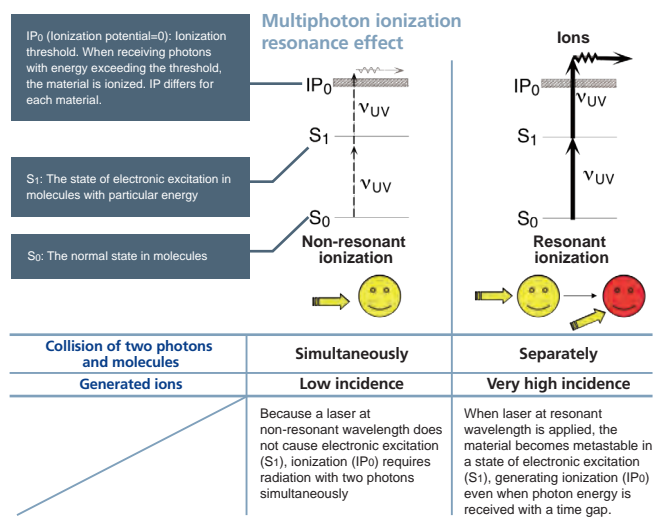
### Q Why was this research unit established?

We established the Clean Environment Unit to expand new technology created by fundamental research at Tokyo Tech to environmental and material analysis. Although we can conduct fundamental research such as the development of measurement technology and apparatus at universities, it is essential to apply the technology in cooperation with companies and other universities both at home and abroad to return benefits to society. The unit engages in joint domestic and overseas projects and industry-university collaboration in a full and organic manner to develop useful apparatus.

### Q What are the strengths of this research unit?

REMPI has been developed in the field of physical chemistry, and application of this technology to analytical chemistry allows us to detect constituents that we want to observe by adjusting the wavelength of laser light without the need for chemical processing such as extraction and concentration. Compared with existing measurement methods, the sensitivity is significantly higher, about 100 million times higher, making it capable of detecting at the atomic and molecular levels. The greatest advantage is that REMPI technology can be utilized in both fundamental research and applications. The unit can advance research by making use of the existing network of specialists and companies in a wide range of areas such as analysis of the atmosphere, environment, automobile exhaust, and materials. It may also be useful in collaborative medicine-engineering research in areas such as cancer screening through breath analysis.

#### Mechanism of resonance-enhanced multiphoton ionization



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

The Clean Environment Unit sets the goal of commercializing single particle history analysis apparatus. In cooperation with specialists in environmental sciences, the unit analyzes fine particulates in the atmosphere to clarify cross-border transport that may cause global warming and environmental pollution, and creates useful apparatus to understand the impact of these phenomena. We also develop new apparatus to handle materials that are difficult to analyze with existing devices, and conduct detailed analyses at high sensitivity and resolution targeting broader subjects of measurement.

Contact us

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# 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<sub>2</sub> 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 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<sub>2</sub> and water.



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

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

### Earth resources



■ Crude petroleum



■ Minerals

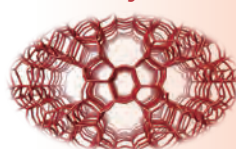


■ Natural gas



■ Biomass

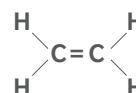
### Nanospace catalysts



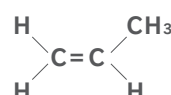
- Naphtha catalytic cracking
- Methane conversion
- Methanol conversion
- Biomass conversion

### Useful chemical substances

#### ■ Ethylene



#### ■ Propylene





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



## 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.

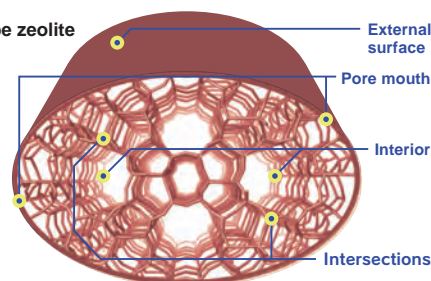
## Q What are the strengths of this research unit?

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

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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 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



Research Unit Leader **Ryoji Kanno**

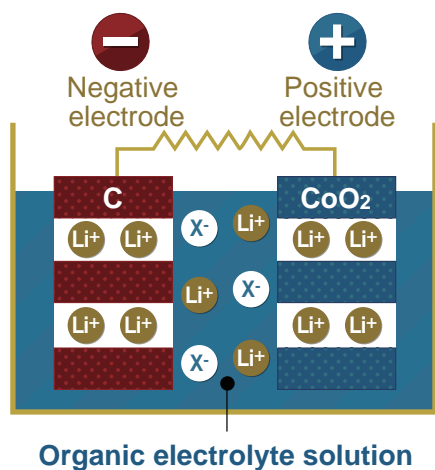
### Profile

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

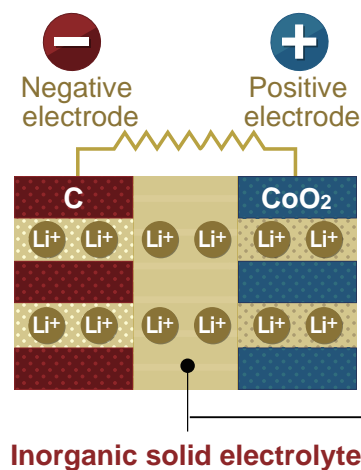
### Unit members

● 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

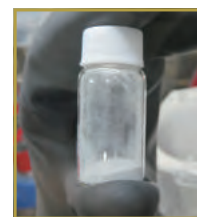
## All-solid-state lithium battery system



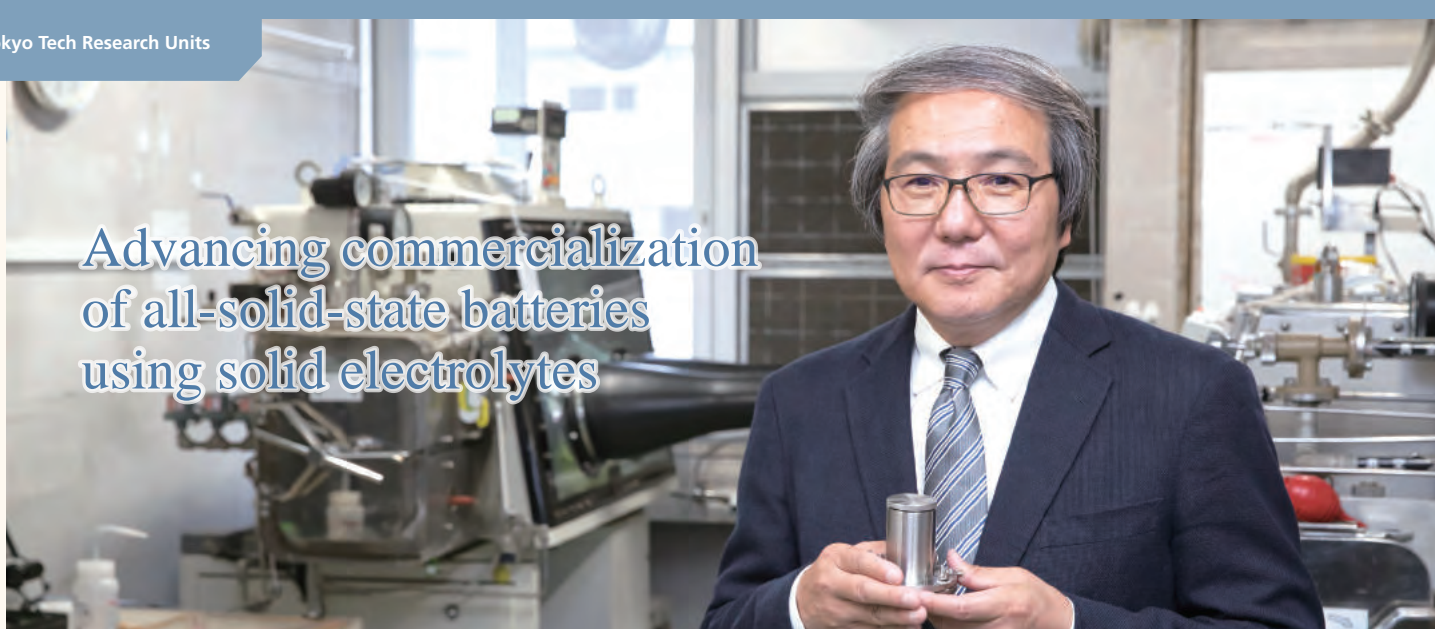
All solid-state



All-solid-state battery



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



### Q 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.

### Q What are the strengths of this research unit?

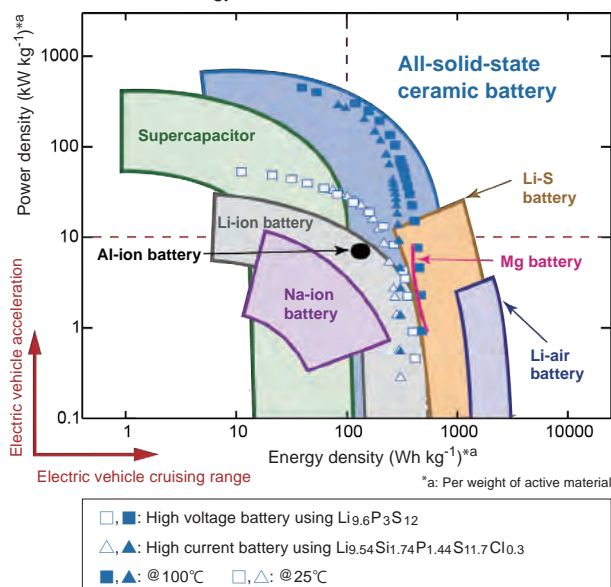
In 2011, we discovered the material LGPS, a solid electrolyte with high ionic conductivity; and in 2016, we discovered further derivatives of the solid electrolyte. In 2017, we developed a low-cost, all-purpose solid electrolyte by combining tin and silicon. The research has resulted in several key patents.

### Q 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.

#### Advances in science are leading to batteries with unprecedented capabilities

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



#### Contact us

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