RESEARCH @TOKAI +
Research Trend Information
Vol. 2 2018.7

The City in Harmony

How to make a nature and human friendly city through all-round research collaboration

General Research Organization Project

Development of Energy Generation & Transmission Systems for Harmony of Humans, Cities, & the Sun

INDEX

It has been a long time since "sustainable development" became a catchphrase describing the restriction of the consumption of limited resources and the shift towards renewable energy, including natural energy sources. In Japan, where the fragility of heavily concentrated energy systems was clearly displayed in the 2011 Great East Japan Earthquake, the development of community-based energy systems capable of stable power generation and transmission closer to local living areas is an urgent necessity. The Environment/Energy System Research Unit represented by Associate Professor Koji Tomita of the Department of Chemistry, School of Science aims towards the creation of efficient cities using natural energy by combining wireless power transmission technology and city planning with perovskite solar cells, which hold high promise as next-generation power generation systems, and thermoacoustic engines, which reuse waste heat. We requested Associate Professor Tomita, Associate Professor Inamori, and Professor Kajita, who work on the respective themes of power generation, power transmission, and urban development, to provide an overview of this project.

Creating, transmitting, and using energy. Comprehensive energy research that could be achieved only at a university

Tomita: The study of "energy generation and transmission systems" refers to energy research in a broad sense, encompassing the totality from power generation to produce electrical energy, transmission to send it, and urban development where the people who use it live.

The organic perovskite solar cells that I am in charge of are a new type of solar cells that have similar power generation efficiency to the silicon crystalline solar cells that are currently in wide use. Silicon does produce excellent solar cells, but there is the issue that a large amount of power is necessary for their manufacturing process. Perovskite cells require little energy to produce and can ultimately be used just by adhering them where power generation is needed. Since they are more lightweight than silicon cells, they can be placed on roofs without requiring reinforcement and can be adhered to vertical surfaces such as walls, and so I think they will lead to changes in building design and the very way solar cells are used.

Organic perovskite solar cells also have the issue of more rapid degradation. In order to put them to practical use, we would like them to last a few years, but they do not yet have that level of reliability. Aside from heat and light, causes of degradation include a complex interaction of oxygen, water vapor, and the power generation voltage, so it is not easy to understand. There is still very little useful reference information on the matter, and so we are now establishing basic research on the subject.

Another power generation method involves thermoacoustic engines, which use waste heat from machinery and infrared rays in sunlight that are not used by solar cells. The heat produced in car engines is used for heating in the winter, but is currently not used for any other application. Harnessing this energy would increase efficiency.

Specifically, these engines use the temperature difference between where heat is applied and where it is not applied. Gases have the property of expanding when heated and contracting when cooled, so if one end of a thin tube is heated while the other is cooled, the air within the tube expands at the heated section and contracts at the cooled section, generating an oscillation. This oscillation is

Koji Tomita
Associate professor, Department of Chemistry, School of Science, Tokai University

Representative of the study "Development of Energy Generation and Transmission Systems for Harmony of Humans, Cities, and the Sun." Synthesizes photocatalysts and light-emitting materials using water-soluble titanium complexes, hydrothermal methods, and polymerizable complex methods.

Mamiko Inamori
Associate professor, Department of Electrical and Electronic Engineering, School of Engineering, Tokai University.

Aims to combine the perspectives of electrical power engineering and communications engineering to build a wireless power transmission system that anybody can use with ease and that has both high efficiency and reliability.

Yoshitaka Kajita
Professor, Department of Civil Engineering, School of Engineering, Tokai University.

Aims to investigate efficient urban facility and land use to build sustainable cities while shedding light on the diverse issues facing urban zones in the areas of city planning and transportation planning.

NATURAL ENERGY ..... TRANSMISSION ..... CITY PLANNING .....

audible to humans as sound, which is converted to electricity using a linear generator that can generate power using vibrations.

Inamori: As the name implies, wireless power transmission is the technique of wirelessly sending electrical power. Wireless communication is already a part of today's infrastructure, but the concept of wireless transmission not just of information but of power as well is not new. It was demonstrated at MIT in the 2000s and has since been the subject of active research and development.

There are three methods of wireless power transmission, but the use of electromagnetic induction has a high efficiency of 80-90% despite a short working distance and is already in practical use. Mobile terminals that are charged just by placing them in a certain location use this method. However, attempts to increase the transmission distance currently face the issue of reduced efficiency. Supposing that 100 units are transmitted and only 50 are received, what we are currently studying is the question of what happens to the lost 50 units. Our goal is to analyze this loss in order to increase efficiency. Misalignment of the battery charger and the power supply device also causes a drop in efficiency. We are also studying using information communication to align the position.

One of the benefits of wireless power transmission is being able to charge anytime, anywhere. Electric cars are currently charged using a power supply cord, but wireless charging would improve user-friendliness, and the ability to charge the car just by parking the vehicle would allow it to be driven immediately in the event of a disaster.

Kajita: If these technologies can be put to practical use, I believe it will greatly change urban life. Just as electronic toll collection (ETC) contributed to reducing congestion on roads, wireless information transmission has brought convenience to a variety of movements, which I believe has had a high economic effect. In addition, smartphone apps are being used for car and bicycle sharing in urban areas, which has also been changing transportation behavior. If wireless power transmission is used in conjunction with electric vehicles, and electric cars become widespread and can be easily charged at parking lots and the like, this would lead to improved living environments by taking advantage of the land currently used by gasoline stations for such purposes as increasing greenery.

Figure 1 is a 2000:1 scale miniature urban district displayed at Technical Show Yokohama 2018, which took place in Yokohama in February of this year, and it includes as much of our research results as possible. In the future, we will study urban landscapes using this, and we will investigate energy management including calculating the amount of power generation and power consumption of the entire area resulting from the installation of efficient natural energy facilities based on human activities and the land use situation.

Complementary information and perspectives: differences between fields keep it interesting in team play between two academic schools and five departments

Tomita: The three of us are not the only team members. We have Dr. Katsumata from the Department of Chemistry, School of Science, Dr. Isomura from the Department of Electrical and Electronic Engineering, and Dr. Iwamori from the Department of Mechanical Engineering, who are studying solar cells. The project also employs a postdoctoral scholar, Dr. Shahiduzzaman. For thermoacoustic engines we have Dr. Hasegawa from the Department of Prime Mover Engineering, and Dr. Kaneko, Dr. Sagawa, and Dr. Kimura from the Department of Electrical and Electronic Engineering.

Kajita: Our current team was not assembled all at once, but instead, it grew gradually through connections between related aspects of our fields.

Tomita: That is true. Tokai University has professors in a very wide variety of fields, and so we felt that by forming a team among these fields, we could perform truly wide-ranging research on energy as a whole. There are scholars engaged in individual issues such as batteries or power transmission at other universities, but forming a team results in complementing each other where we may individually lack certain information, and broadening each other's perspectives. By using this point in time to share knowledge and technology among different fields that would eventually come together in the process of practical application anyway, there is the benefit of being able to investigate their use ahead of time.

Inamori: I was very happy to be able to work with Dr. Kajita. Engineering is supposed to be useful in the world, but I surprisingly do not get to see much practical application in my daily research, and academic conferences in general are also entirely occupied with discussing technology. Not only has it been informative, but it has also been my privilege to be able to see how my analysis results and the formulas that I solved myself are being utilized in cities.

Kajita: Civil engineering contributes to society by preparing the facilities that form the very social foundations for humanity, but in today's mature society, how those facilities are used and made useful is important. More than ever before, we must have discussions with the end users and consider what is necessary to what extent and for what purposes. It is difficult to study facilities taking into consideration new technology just within the bounds of civil engineering alone, and so it has been quite enjoyable in this project to be able to work together with individuals from other fields as well. For example, learning about the new technology of solar cells that can be applied to walls gave rise to the perspective of how to incorporate these into cities. This is something that we definitely would not have conceived of if we had worked alone.

Tomita: If it were just a matter of gathering information, this would be possible through the internet. However, it is easier to convey what is interesting through discussions with experts on a more subjective level in the positive sense of the phrase. Student research presentation events are held jointly, and as explaining something to people with different fields of specialization requires the explainer to have a thorough understanding of the topic, it seems that this is also a good lesson for those students as well.

Kajita: It is common for simple questions from students in other fields to actually have important implications.

Tomita: That is true. Through coming into contact with the perspectives of other fields, I have had good opportunities to take a step back and reflect

on myself, such as on whether I am overly absorbed in my field of specialization, or whether my research is generally needed.

We go forward as a team towards practical application: The past and future of power generation, transmission, and urban development.

Tomita: The efficiency of perovskite solar cells is currently about 17%, and we have reached a level on par with the leading groups in the world. We will continue studying the causes of their degradation while developing products that can be applied in locations where silicon cells are hard to use. Silicon solar cells are black, but for example, by making green solar cells would reduce their visual impact when used in locations such as parks.

Inamori: The use of wireless power transmission using electromagnetic induction has spread to a certain extent. The resonant type is usable over moderate distances, but on the other hand, it only has an efficiency of 50-60%. By studying where this lost portion goes, we would like to contribute to increasing that efficiency. A number of institutions are studying increasing efficiency by changing the circuitry or developing systems, but analyzing loss is very basic research with very few people studying it.

I will also continue studying the use of digital wireless communication technology, which I have been involved with for quite some time. I would like to continue studying how to deliver electricity, which was produced as a result of quite a bit of effort, to a distant location in an efficient manner, while at the same time keeping in mind the overall picture of power transmission systems.

Kajita: I would like to utilize a variety of technological developments in urban development that is friendly to both the natural environment and humans. Natural energy is being rolled out primarily in Europe, but it is important to consider a balance between improving efficiency and the burden on the environment. I would like to properly incorporate the results of the other professors' development and aim to improve the utility value of the energy field overall, as well as improve its design qualities including its appearance as part of the scenery.

Figure 1. Miniature model of a seaside city produced for Technical Show Yokohama 2018

Lightweight and highly efficient perovskite solar cells are installed on the roofs and walls of buildings to provide the electrical energy consumed by the individual buildings. We envisioned that thermoacoustic engines installed at the waterfront could use the thermal difference between heat from the sun and the cool water. Parking lots have embedded wireless power supply devices that can charge electric cars.

Team members of research project, "Development of Energy Generation & Transmission Systems for Harmony of Humans, Cities, & the Sun"

CREATE ENERGY

Organic perovskite solar cells

Dept. of Chemistry
- Koji Tomita
- Tetsuhiro Katsumata
- Md. Shahiduzzaman

Dept. of Mechanical Engineering
- Satoru Iwamori

Dept. of Electrical and Electronic Engineering
- Masao Isomura

Thermoacoustic engines

Dept. of Prime Mover Engineering
- Shinya Hasegawa

Dept. of Electrical and Electronic Engineering
- Tetsuya Kaneko
- Kohei Sagawa
- Hideki Kimura

TRANSMIT ENERGY

Wireless power transmission

Dept. of Electrical and Electronic Engineering
- Mamiko Inamori

SUSTAINABLE CITIES

City/ transportation Planning

Dept. of Civil Engineering
- Yoshitaka Kajita

東海大学総合研究機構
TOKAI UNIVERSITY GENERAL RESEARCH ORGANIZATION

Tokai University General Research Organization

The general research organization was founded in April 1976 to fulfill the social mission of research at the university, to stimulate international activity, and to contribute to the development of human society. It has organically integrated a broad range of research activities on campus, has consolidated research, administration, and development, has actively promoted joint research with outside institutions as well as commissioned research, and has aimed to achieve its goals on the basis of active research cooperation between industry, government, and academia.

- Project research
- Research incentive grants
- Research startup support
- Research workshop subsidy
- Product development subsidy
- Academic book publishing subsidy
- Subsidy plan for dissertation editing expenses
- Okinawa research and education subsidy
- Research facility enhancement plan

Kinzanji miso developed and sold as a result of the "product development subsidy."

QOL Close Up

Good news for the increasing population of diabetes patients: The development of a simple method for chemically synthesizing insulin preparations

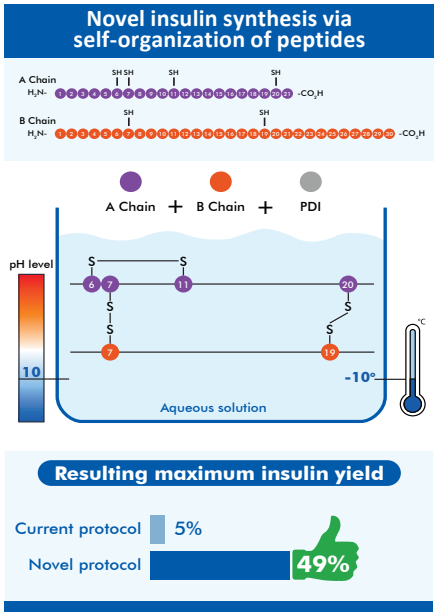
Insulin, which has the effect of lowering blood sugar levels, is an intravenously injected preparation used by diabetes patients. Because of its characteristic molecular structure, its chemical synthesis has been considered difficult. The structure of insulin is made up of two polypeptide chains (A-chain and B-chain) linked together by disulfide (SS) bonds between sulfur atoms (chemical symbol S). However, just mixing the A-chain and B-chain results in SS bonds within each polypeptide chain and very little of the target insulin molecule (maximum yield of about 5%). There have previously been many proposals for synthesis techniques that are able to selectively cross-link the SS bonds between the A-chain and B-chain, but they have all required multi-step operations and a highly proficient experimental technique, and so have not resulted in a widespread, efficient methodology.

Through joint research with Osaka University, Tohoku University, and Fukuoka University, Junior Associate Professor Kenta Arai and Professor Michio Iwaoka of the School of Science at Tokai University discovered the entire mechanism by which insulin acquires its structure through self-organization within an aqueous solution of the A-chain and B-chain that make up the molecule. Prior research by this group had indicated that both polypeptide chains had the latent property of self-organizing to form insulin. Their study in question reviewed simple methods of merely mixing the A-chain and B-chain in an aqueous solution without using complex synthesis techniques, aiming to improve yield.

When they studied and searched for the conditions under which insulin was most efficiently produced based on the mechanism revealed in the study, favorable yield was obtained at -10°C and pH 10.0. Furthermore, adding a very small amount of a biological enzyme (protein disulfide isomerase: PDI) that promotes cross-linking with SS bonds in the proteins was confirmed to reduce the reaction time and improve yield. The highest yield obtained under the optimum conditions for the reaction solution was approximately 49%.

The advantage of this method was that it was able to improve insulin yield by returning to a basic and simple method of mixing the A-chain and B-chain at approximately a 1:1 ratio. This process does not use any genetic engineering methods, and so it does not require any elaborate production facilities or skilled laboratory technicians. In the future, it is very promising for application as a new insulin production technique based on chemical synthesis methods.

These research results were also published in the electronic edition of the international chemistry journal "Communications Chemistry" based in the UK, dated May 3, 2018 (Thursday).



Researchers in this project

Kenta Arai

Junior Associate Professor, Department of Chemistry, School of Science. Develops methods for artificially controlling the formation of the three-dimensional structure of proteins (folding) from the perspectives of both biophysics and organic chemistry.

Michio Iwaoka

Professor, Department of Chemistry, School of Science. Uses experimental and theoretical approaches to shed light on the principles underlying protein folding.

NEWS & EVENTS

Presented by Tokai University

Hirameki☆Tokimeki Science "An introduction to hands-on science museums and art museums: The work of curators and fascinating Nihonga art"

Would you like to get out of school to see art and culture while learning about the work of curators and experiencing fascinating Japanese paintings?

Time/Place: July 28, 2018 (Sat.)/Tokai University, Shonan Campus, Matsumae Memorial Hall

Tokai University Research and Training Vessel BOSEIMARU

Hirameki☆Tokimeki Science "The mysteries of the oceans: The BOSEIMARU is a floating laboratory"

Would you like to learn various properties of the ocean from samples and data collected by our vessel?

Time/Place: July 28, 2018 (Sat.)/Tokai University Research and Training Vessel BOSEIMARU docking wharf, Shizuoka

Industry-Academia Collaboration Fair 2018

Presenting opportunities that enables each company to actively interact with diverse researchers in Tokai University.

Time/Place: August 8, 2018 (Wed.)/Tokai University, Takanawa Campus, Tokyo

2nd Tokai University "Agriculture, Food, Health" QOL Seminar

A seminar that presents the research results and findings from Tokai University to attendees from municipalities and industries involved in agriculture, fisheries, food processing, and healthcare.

Time/Place: September 28, 2018 (Fri.)/ Tokai University Marine Science Museum, Shizuoka

Exhibited by Tokai University

The 20th Japan International Seafood Show

An exhibition and a lecture series that introduce the research of the Department of Fisheries, School of Marine Science and Technology.

Time/Place: August 22 (Wed.) to 24 (Fri.), 2018/Tokyo Big Sight

Innovation Japan 2018

Organizational and individual exhibitions that introduce the research such as "Glocal monitoring system," "Advanced glycation end products," "Solar cells," and "Artificial dermis" promoted by Tokai University.

Time/Place: August 30 (Thu.) to 31 (Fri.), 2018/Tokyo Big Sight