Chemistry

Chemical compounds with antiviral activities against positive-sense single-stranded RNA viruses

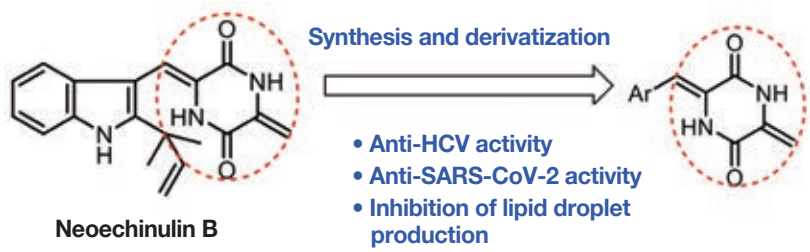
Kouji KURAMOCHI (Professor, Department of Applied Biological Science, Tokyo University of Science)

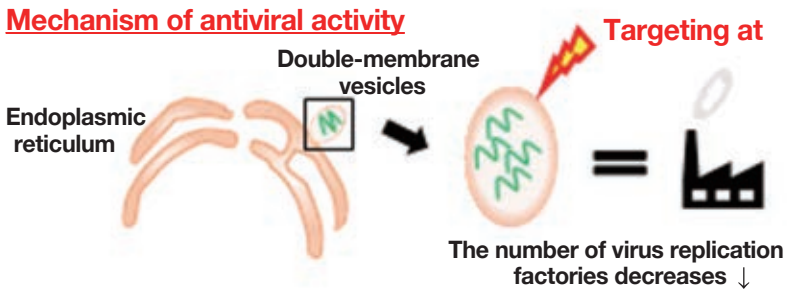
Summary of Research

We have discovered a group of compounds with antiviral activities against positive-sense single-stranded RNA viruses such as SARS-CoV-2, hepatitis C virus (HCV), and poliovirus. The most significant characteristics of the compounds are that their molecular targets are host-cell derived instead of virus-derived. This means that the compounds can change the expression levels of host cell genes thereby inhibiting the virus from growing in cells. The uses of conventional antiviral drugs are limited to treatment of infections caused by specific viruses. In contrast, these compounds, which have antiviral activities against viruses, can be used as an all-purpose anti-multiviral drug for the treatment of variety of infections.

Research Results

A natural product neoechinulin B (Neo B) was identified as a compound that inhibits replication of HCV. Our study revealed that this compound acts as an antagonist of liver X receptor (LXR) and reduces the expression levels of LXR downstream genes, thereby disrupting the formation of lipid droplets and double-membrane vesicles and inhibiting HCV particles formation and genome replication. We have also found that Neo B has antiviral activities against positive-sense single-stranded RNA viruses such as SARS-CoV-2 and poliovirus. Furthermore, we established a method of synthesis of a series of Neo B derivatives, with which we successfully obtained derivatives with a higher activity.





Comparison with Conventional or Competitive Technology

- We have developed an antiviral drug against positive-sense single-stranded RNA viruses such as HCV and SARS-CoV-2
- In addition to its antiviral activities, the antiviral drug can also inhibit production of lipid droplets
- The drug may be used for the treatment of not only viral hepatitis, but also nonalcoholic steatohepatitis

Expected Applications

- Treatment of infections
- Treatment of nonalcoholic steatohepatitis
- Prevention of liver cancer, arteriosclerosis, myocardial infarction, and strokes

Challenges in Implementation/ Expectations for Business and Other Research Partners

- Joint research for nonclinical studies
- Conducting a clinical study jointly if safety and pharmacological activity are demonstrated

Points

- **This technology can be used to develop anti-multiviral drugs targeting positive-sense single-stranded RNA viruses.I n addition to the application for antiviral drugs,t he compound's capability to inhibit lipid droplet production can be utilized for the development of drugs for nonalcoholic steatohepatitis**

Future Developments

By March 2023: Obtaining compounds with a higher activity
April 2023: Start of nonclinical studies
April 2025: Start of preparation for clinical studies

Keywords
Positive-sense single-stranded RNA virus, severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), hepatitis C virus (HCV), nonalcoholic steatohepatitis (NASH)

■ Intellectual Property:
Novel compound, agent against positive-sense single-stranded RNA, inhibitor of lipid droplet formation (Japanese Patent Application No. 2020-190)

■ Public Funding Programs Used:
FY2018–2021: Research Program on Hepatitis from the Japan Agency for Medical Research and Development (AMED)
FY2021: Research Program on Emerging and Re-emerging Infectious Diseases from the AMED

Energy

Creation of new noble-gas hydrides toward hydrogen society

Kazuo WATANABE (Associate Professor, Department of Chemistry, Faculty of Science Division I, Tokyo University of Science)

Purpose of Research

The expectation for a hydrogen society has been on the rise recently. Hydrogen, as a gas, is not easy to handle and extensive research is underway on hydrogen-containing compounds (hydrogen carriers) that make it easier to store and transport hydrogen at ambient temperature and pressure. This study aims at practical applications of noble-gas hydrides (NgH_x, Ng: a noble gas, H: hydrogen, x: 2, 4, 5 18 etc.), which our group has discovered, as a safe and inexpensive hydrogen carrier as well as a fuel with higher energy density than hydrogen gas.

Summary of Research

Synthesized noble-gas hydrides, in which hydrogen atoms are bonded with chemically inert noble gas atoms. After irradiating the ion beam of a noble gas onto a metal surface, hydrogen gas is introduced, and the surface temperature is raised to form noble-gas hydrides. Confirmed noble-gas hydrides are HeH_x, NeH_x, ArHx and KrH_x (x = 2, 4, 5, 18 etc.).

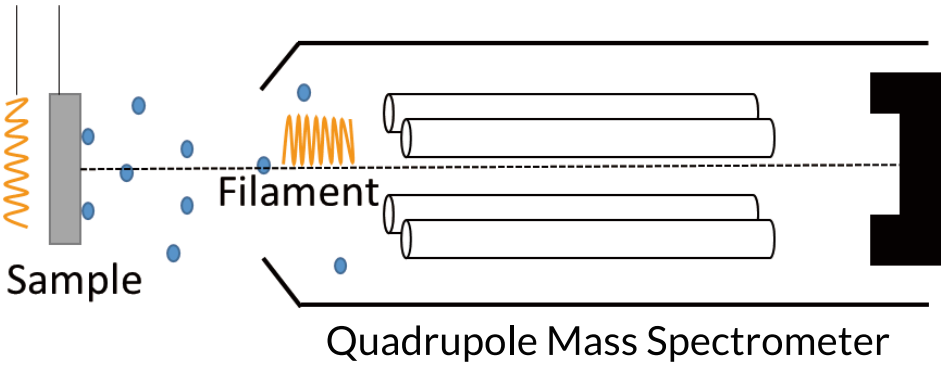


Figure: Production of noble-gas hydrides through a temperature-programmed desorption process and detection of them

Comparison with Conventional or Competitive Technologies

- Liquefiable at higher temperatures than hydrogen gas. Easier and less expensive to store and transport
- A clean and CO_2-free fuel consisting of hydrogen and a noble gas only
- Has a higher energy density than hydrogen gas (e.g. ArH_{18} has 9 times as many hydrogen atoms as hydrogen gas)

Expected Applications

- Fuel (e.g. for automotive hydrogen internal-combustion engines and rocket engines)
- Hydrogen carrier (e.g. for fuel cells)
- Synthetic reagent (e.g. for hydrogenation reactions)

Challenges in Implementation

- Confirmed that hydrides are formed with helium, neon, argon and krypton. Their quantities are insufficient for analysis of material properties
- Experiments under low vacuum or ambient pressure in view of mass production
- Search for less expensive catalysts and new synthesis schemes
- Accomplishment of technologies for low-cost and scalable production

What We Expect from Companies

- Hope for collaborative research with companies that possess technologies in catalyst development and chemical-plant development
- Introduction to transportation (automotive and aerospace) companies applying hydrogen engines, rocket engines and fuel cells, and electric cooperatives

Points

- **Easier to store and transport than hydrogen gas**
- **Higher energy density than hydrogen gas**
- **Argon hydride, a hydrogen energy medium using argon, is an inexpensive and safe gas**

Future Developments

March 2022 Starting sales

■ Intellectual Property: International Patent Application No. PCT/JP2020/26472

Pharmacog-enomics

Efficient production of chiral sulfoxides by light irradiation

Hideyo TAKAHASHI (Professor, Department of Pharmacy, Faculty of Pharmaceutical Sciences, Tokyo University of Science)

Summary of Research

Many drugs contain sulfoxides in their chemical structures. Since sulfoxides are chiral, each enantiomer is differentiated in the living body, and exhibits outstanding bioactivity. We are aiming to develop drugs by producing enantiomerically pure sulfoxides by light irradiation.

Details of Research

Sulfoxides (oxidized sulfur) exist in enantiomers (S and R). Enantiomerically pure sulfoxides (S-enantiomer or R-enantiomer) easily converted to racemates (mixtures of S-enantiomer and R-enantiomer) by light irradiation. It is possible to separate one enantiomer from racemate, and the proper light irradiation of the residual enantiomer provides racemate. By repeating a series of processes: (1) separation of one enantiomer, and (2) irradiation of the residual enantiomer with light to convert racemate, we can obtain desired enantiomer quantitatively with >99% ee.

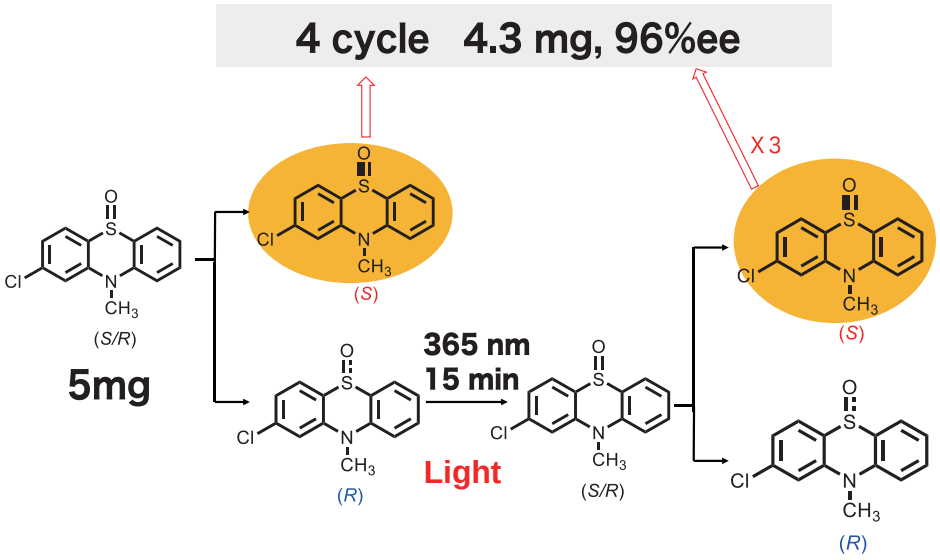


Figure: Successful proliferation of enantiomer

Comparison with Conventional or Competitive Technologies

- [Existing] Asymmetric synthesis of compounds with enantiomerically excess was possible, however, it was difficult to provide completely enantiomerically pure compounds by asymmetric synthesis .
- [Our method] By repeating a series of processes: (1) separation of one enantiomer, and (2) irradiation of the residual enantiomer with proper light irradiation to provide racemate, we can obtain desired enantiomer quantitatively with >99 %ee. There's no need to synthesize compounds.

Expected Applications

- Synthesis of drugs containing sulfoxides
- Expansion of the method using recycling by HPLC
- Expansion of the method using a photoreactor

Challenges in Implementation

- Examination of optimization such as optimal wavelength for each compound
- Examination of conditions to improve the photoreaction speed
- Establishment of generality applicable to other drugs

What We Expect from Companies

- Desire for technical development with companies with a large-scale photoreaction technology
- Desire for drug discovery research with companies developing chiral drugs
- Introduction to companies considering advancement into analytical fields

Points

- **No chemical synthesis required**
- **Can obtain sulfoxides of one desirable enantiomer at a yield of almost 0%**
- **Low cost,as only light irradiation is required**

Future Developments

March 2020	Achieve 9% ee optical purity and 9% yield
April 2020	Apply to other drugs containing sulfoxides
April 2021	Expand to photoreaction of other functional groups

■ Intellectual Property:
International Patent Application No. PCT/JP2020/ 32053
■ Prototype: Available
■ Sample: Available

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2022.04

Communication and information processing

Authentication based on verifiable encryption with private digital identity

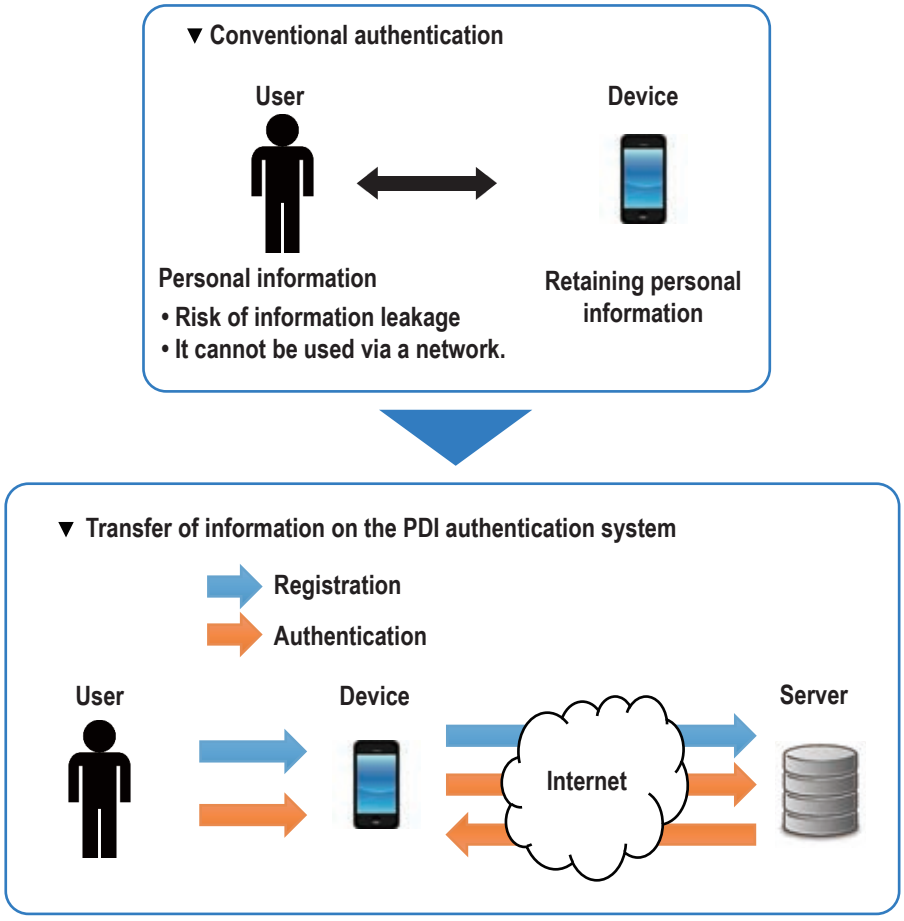
Satoshi IRIYAMA (Associate Professor, Department of Information Sciences, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

As information communication technology has advanced, it has become possible to buy all sorts of products and services remotely through the Internet. In these cases, users have to give their personal information such as name, age, and address to service providers. This may cause problems such as unwanted distribution of excessive advertisements and personal data leakage from companies' databases.

Summary of Research

Aiming to simultaneously protect privacy and retain convenience, in this research we have developed an original technology that encrypts information selected by the user as his/her identification and carries out rapid verification using its secure algorithm without any decryptions.



*PDI: Private Digital Identity

Comparison with Conventional or Competitive Technologies

Conventional situation: Some processing methods have encrypted information without decryption.

Problems with conventional systems:

- There is a risk of information leakage because personal data (such as biometric data and PINs) are placed together and stored in a single place.
- Safety is pursued at the expense of data processing speed.

This new technology: It assures sufficient processing speed, safety, and reduction in internal memory use.

Expected Applications

- Reduction in workload at front desks of private lodgings and hotels, coworking spaces, and home security services
- Admission control at event venues and improvement in public Wi-Fi security
- Use by people such as children and seniors who are not familiar with smartphones

Challenges in Implementation

- Current status: The system is working in the laboratory, and some pilot systems with server and core SDK are ready.
- Tasks to do: Create a business model such as an appropriate form of use.

What We Expect from Companies

We hope to conduct joint research with a company that has database or personal authentication technology. In addition, this technology would be useful for companies developing IoT products and companies planning to venture into Cloud services.

POINT

- **No need to exchange keys**
- **The risk of information leakage is reduced because personal information is encrypted and not decrypted**
- **The entry cost is low because the server can be entrusted to a third party**
- **Does not use smartphones**

■ Intellectual Property: International Patent Application
No.PCT/JP2018/045 "Encrypted Data Processing System and Program"
■ Prototype: Present

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2022.04

Bio

A novel chemical that promotes accumulation of Jasmonic acid, a plant hormone

Kazuyuki KUCHITSU (Professor, Department of Applied Biological Science & Director, Interdisciplinary Agricultural Science and Technology Course, Graduate School of Science and Technology, Tokyo University of Science)

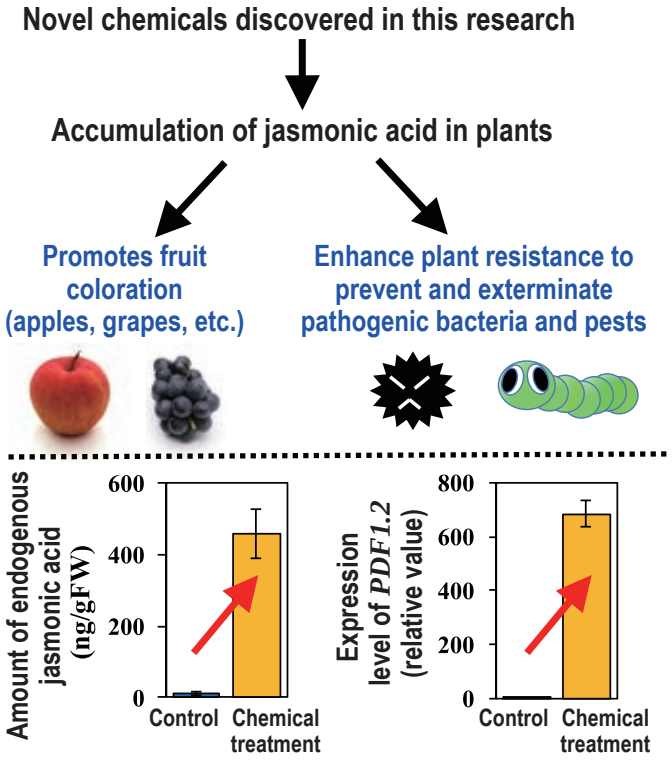
Kouji KURAMOCHI (Professor, Department of Applied Biological Science & Director, Interdisciplinary Agricultural Science and Technology Course, Graduate School of Science and Technology, Tokyo University of Science)

Purpose of Research

Jasmonic acid is a plant hormone that controls plant growth including fruit coloration, and plant defense responses against pests and diseases. Although jasmonic acid analogs have been developed and used as agrochemicals to date, it has been difficult to control the amount of jasmonic acid in plants. The aim of this research is to find novel chemicals that promote the accumulation of jasmonic acid in plants and develop novel technology to control plant growth and defense responses including enhance the plant resistance against pests and diseases.

Summary of Research

We have discovered a chemical that has the effect of increasing the amount of endogenous jasmonic acid in plants. Our research has shown that when a model plant is treated with this chemical, the amount of endogenous jasmonic acid in plants and the expression level of a marker gene that responds to jasmonic acid drastically increases.



Amount of endogenous jasmonic acid 24 hours after chemical treatment (left) and expression level of the PDF1.2, a marker gene for jasmonic acid pathway (right)

POINT

- Increases endogenous jasmonic acid amount in plants
- Induces jasmonic acid responses of plants

Comparison with Conventional or Competitive Technologies

○ Conventional

- Agricultural chemicals containing a jasmonic acid derivative as an active component are already used in agriculture.

○ This research

- As the novel chemical has an action mechanism completely different from that of conventional chemicals such as jasmonic acid analogs, the novel chemical could be used for unprecedented applications such as control of pests and diseases.

Expected Applications

- Promotion of fruit coloration
- Control of plant pathogenic bacteria
- Pest control

Challenges in Implementation

- It has been confirmed that if a model plant is treated with the novel chemical in a laboratory, the amount of jasmonic acid increases.
- Effectiveness for various plants is being examined and the structure is being optimized.
- Field assessment is necessary ahead of practical implementation

What We Expect from Companies

Open to partnership opportunities with interested corporations.

- Practical application based on field assessment
- Product development as an agricultural material

Future Developments

Present	Structure-activity relationship test, test of effectiveness on resistance to disease and insect damage
2020	Field assessment

■ Intellectual Property: International Patent Application No. No. PCT/JP2019/50992 "Jasmonic acid endogeny promoting agent, and method for promoting jasmonic acid endogeny"

■ Sample: Available

Communication and information processing

Particle size analyzer technique using image processing

Naoyuki AIKAWA (Professor, Department of Applied Electronics, Faculty of Advanced Engineering, Tokyo University of Science)

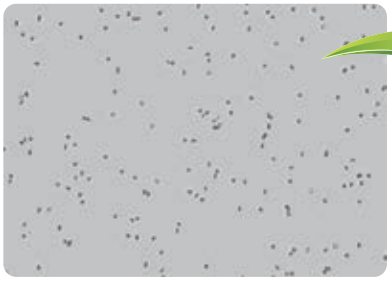
Purpose of Research

Detection of tumor cells circulating in the blood is usually conducted by visualization using reagents and microscopic observation by physicians. However, it requires effort and cost, and individual differences may occur during microscopic observation; therefore, a convenient method to detect tumor cells is required. Tumor cells circulating in the blood are large and distorted compared with normal cells, and a particle size analyzer may aid in detection to some degree. However, commercial particle size analyzers target industrial products and are not appropriate for blood cell analysis. Therefore, this study aimed to develop a particle size analyzer technique that was appropriate for blood cells. In addition, the analysis technique placed an emphasis on versatility.

Summary of Research

Using an image processing technology, the size and shape of blood cells were measured from the images of blood, and the particle size distribution for each shape was obtained. Based on this information, an algorithm that detects cells that have a high probability of being tumor cells circulating in the blood was developed. Compared with conventional particle size analyzers, the analyzer used in our research has a higher resolution. In addition, the software used for conventional particle size analyzers can only be used for that specific analyzer; however, our software can be used with ordinary personal computers, and as long as a microscope image of blood is available, detecting cells with a high probability of being tumor cells circulating in the blood is possible.

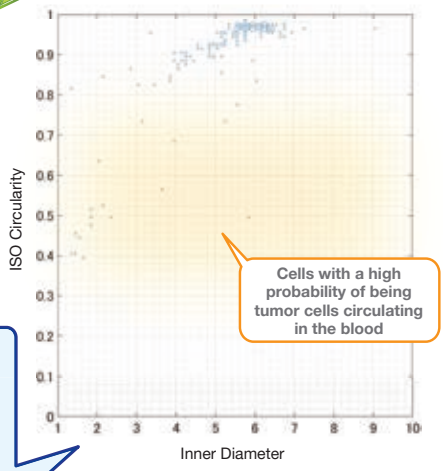
Analysis of a blood image using the software



Blood image of a 14-year-old female dog (Welsh Corgi) with liposarcoma (under the skin of the right shoulder).

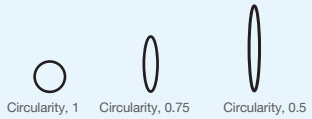
Blood Image

Result of blood cell size distribution analysis



x-axis: Inner diameter

y-axis: Circularity = Diameter of the circle with the same area as the cell / Diameter of circle with same circumference as the cell



* If the diameter is large and circularity is small, it has a high probability of being a tumor cell circulating in the blood.

Comparison with Conventional or Competitive Technologies

- Shape, size, and distribution in a blood image of 3840 × 2748 pixels are measurable in approximately 2 s.
- Robust to noise
- High resolution

Expected Applications

- Software to detect tumor cells circulating in the blood using a blood image.

Challenges in Implementation

- Increasing the number of detection experiments to improve precision and to validate robustness to noise

What We Expect from Companies

We are looking to collaborate with a company that would develop the user interface of this software and work on it commercialization.

Points

- **Optimal for particle size distribution measurement of blood cells**
- **Usable with an ordinary personal computer (does not require specialized equipment)**
- **Measurement is possible with a microscope image of blood (no blood sample required)**

Future Developments

- Speeding-up of processing with a graphics processing unit (GPU)
- Classification of detected blood cells

■Awards:

- The Institute of Electrical Engineers of Japan, Prize of Progress from the Technical Committee (2013.03.07)
- IEEE Information Theory Society Japan Chapter Travel Support Award for Young Researchers (2012.10.30), etc.

Nanotech-nology

Forming technique of Moth-eye structure with high-hardness and anti-fouling effect

Jun TANIGUCHI (Professor, Department of Applied Electronics, Faculty of Advanced Engineering, Tokyo University of Science)

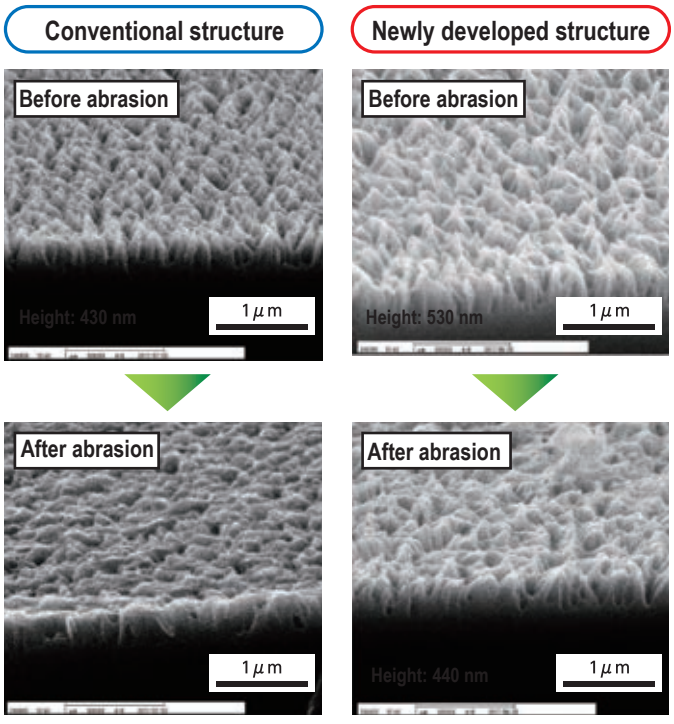
Purpose of Research

Because the moth-eye structure is nanometer-scale fine, it has the disadvantage that it is easy to break when its surface is touched by a finger, and that fingerprints are hard to wipe off. This research has been aiming to solve this problem and make the moth-eye structure usable for touch panels and other similar applications.

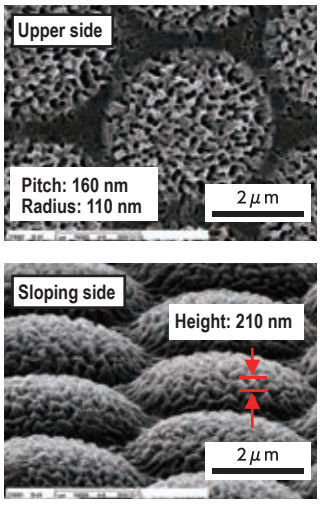
Summary of Research

Simply irradiating a glassy carbon (GC) substrate with an oxygen ion beam can form a moth-eye structure (patent registered). The moth-eye structure comprises nanometer-scale needles, which reduce reflected light in the visible wavelength range. This nanostructure, however, has such low strength that it is usually vulnerable to the touch of a finger. The newly developed technique transfers the moth-eye structure on a GC substrate to a special UV-curing resin surface to obtain such high strength that touching it does not damage the structure. In addition, this UV-curing resin contains anti-fouling components that make it possible to wipe off substances such as fingerprints. Because this resin is transparent and has a moth-eye structure, it improves visibility in addition to having an anti-reflective effect. Furthermore, we have developed a technique to form this moth-eye structure on a microlens array, making it possible to configure a microlens array with a reflectivity of 0.6% and a water contact angle of 147°.

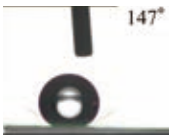
<Friction durability>



<Formation on a curved surface>



<Water contact angle>



Contact angle: 147°

Newly ←developed moth-eye film

Comparison with Conventional or Competitive Technologies

- Touching the structure with a finger does not break it. Substances such as oil attached by touch can be wiped off. Has an anti-reflective effect.
- The reflectivity is less than 0.3% in the visible range. Attached synthetic sweat can be wiped off.
- Can be also formed on a curved surface such as a lens.

Expected Applications

- Protection of touch-panel surfaces
- Protection of the surfaces of mobile devices such as smartphones and tablet PCs, and their visibility-improving films
- Visibility improvement of displays and similar surfaces, prevention of reflection off solar cell surfaces, and similar applications
- Applying antireflective, antifouling, and water-repellent properties to optical components such as lenses

Challenges in Implementation

Currently, the maximum moldable size is 50 × 75 mm. For larger areas, multiple molds have to be connected, which requires eliminating traces of junctures.

What We Expect from Companies

- Application of moth-eye films to products
- Further improvement of moth-eye films

We are looking for companies to conduct joint research on these topics.

Points

- **Moth-eye structured films with high strength, anti-fouling characteristics, and low reflectivity**
- **Mass-production feasible by a nano-imprinting technology**
- **Technique can also apply the moth-eye structure to curved surfaces**

Future Developments

We will conduct R&D on creating large-area moth-eye films.

- Associated System: JST A-STEP "High-risk Challenge" type
- Intellectual Property: Japanese Patent Application No. 2007-208624 "Anti-reflection structure body, method of producing the same and method of producing optical member"
- Prototype: Present
- Sample: Available

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2022.04

Device

Development of a next-generation low-power transistors capable of operating at frequencies ranging from gigahertz to terahertz

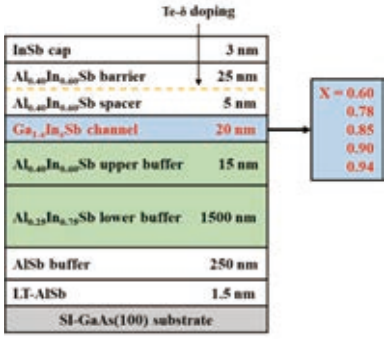
Hiroki FUJISHIRO (Professor, Department of Applied Electronics, Faculty of Advanced Engineering, Tokyo University of Science)
Satoshi ENDOH (Professor, Department of Applied Electronics, Faculty of Advanced Engineering, Tokyo University of Science)

Purpose of Research

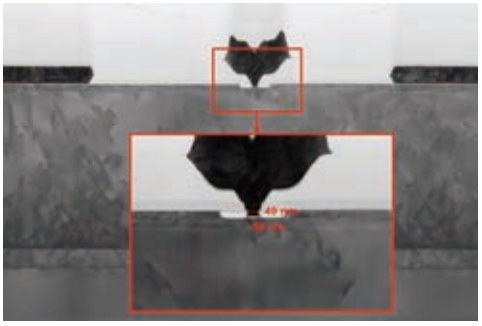
For technologies such as next-generation communications, unexplored sensing technologies, and ultimate computing to be achieved, new high-frequency low-power transistors are required. To develop such devices, we are conducting research into transistors using Sb-based compound semiconductors that exhibit high electron mobility.

Summary of Research

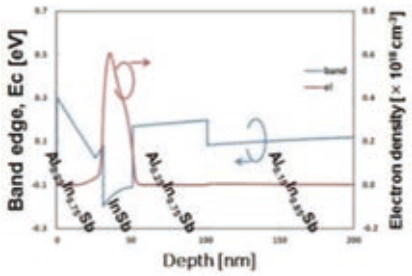
To develop a high electron mobility transistor (HEMT) that can operate at frequencies ranging from the millimeter-wave band to the terahertz wave band (30 GHz–3 THz) using Sb-based compound semiconductors, we carried out the design and analysis of the device by means of a Monte Carlo simulation of HEMT using an InSb-based material, fabricated and evaluated the HEMT epitaxy structure using a molecular beam epitaxy (MBE) apparatus, and then fabricated and evaluated the device.



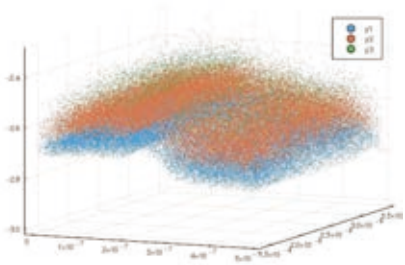
Layered structure of GaInSb quantum well channels using step buffers.



Cross-sectional TEM image of the prototype GaInSb channel HEMT (gate electrode length: ~θ nm)



The band structure and electron density distribution of the strain-controlled InSb HEMT



Cross-sectional TEM image of the prototype GaInSb channel HEMT (gate electrode length: ~θ nm)

Points

- **High-frequency operation (θ GHz3 THz)**
- **Low-power consumption**

Comparison with Conventional or Competitive Technologies

InSb exhibits electron mobility that is more than 50 times higher than that of Si, and it is attracting attention as the third-generation electronic material following GaAs- and InAs-based materials. It is possible to produce a material that will deliver a world-leading performance that is superior to that of GaAs- and InAs-based materials by applying the following: a device structure design that makes full use of band engineering and strain engineering; thin film growth at the atomic layer level that realizes the design; and ultrafine processing at the nanometer level.

Expected Applications

The terahertz range of the invisible light and electromagnetic spectrum is regarded as being a suitable bandwidth for unexplored sensing technologies, next-generation communications, ultimate computing, and the like. It is expected to be applied in a variety of fields, including manufacturing, telecommunications, medicine, biotechnology, agriculture, and security. InSb-based HEMT can make a significant contribution to the realization of applications such as an ultimate-performance low-power transistor that is capable of operating in the terahertz range.

Challenges in Implementation

We aim to stably achieve a high-level transistor performance in the terahertz range and further pursue the formation of an IC.

What We Expect from Companies

The Sb-based semiconductor is attracting attention not only as a high-speed high-frequency transistor, but also as a channel material for LEDs, light detectors, and the like in the terahertz to mid-far infrared range. We are searching for companies and research institutions that can work together on developing practical uses for this material.

Future Developments

2021: Achieve high quality for Sb HEMT structure crystal
Achieve high speed for Sb HEMT
2022: Evaluate low noise characteristics for Sb HEMT

- Awards: Distinguished Services Award for Electronics Society Initiatives received from the Institute of Electronics, Information and Communication Engineers (2011)
- Awards: Paper presentation Award of Electron Device Technical Committee received from the Institute of Electronics, Information and Communication Engineers (2021)

Device

Wireless energy transmission

Kenji SHIBA (Associate Professor, Department of Applied Electronics, Faculty of Advanced Engineering, Tokyo University of Science)

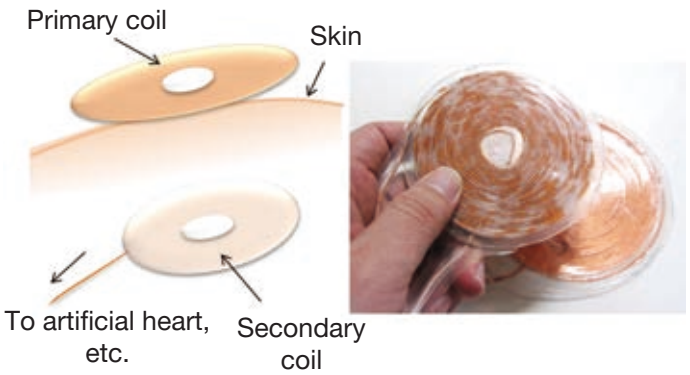
Purpose of Research

The wireless energy transmission using electromagnetic induction or magnetic resonance has already been put into practical use. However, this technology has the following problems: 1) output voltage is fluctuated depending on distance between coils, 2) transmission efficiency decreases depending on distance between coils, 3) output voltage is fluctuated due to load fluctuation, 4) electromagnetic radiation noise is high, and 5) safety to the human body is not confirmed yet. Thus it can be used on the limited condition. This study has a purpose to overcome such a conventional problem and to develop the technology for wireless energy transmission which enables safe and risk-free charging.

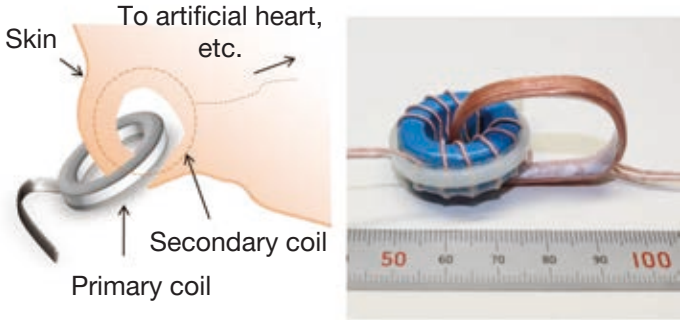
Summary of Research

This wireless energy transmission system offers excellent benefits including: being safe for persons nearby, high energy transmission efficiency (9% , coil to coil), constant output voltage (= electrical power) even under variable loads, constant output voltage even if the relative positions of the primary and secondary coils change, and low electromagnetic noise.

Flat air-core coil system



Externally-coupled coil system



Comparison with Conventional or Competitive Technology

Two transformer systems (flat air-core coil system and externally-coupled coil system shown in the left figures) have been demonstrated. In either system, the secondary coils are implanted for long-term usage. Safety testing on experimental animals is underway.

Expected Applications

- Wirelessly charging household appliances with several tens- or hundreds-watt (charging mobile device, in particular mobile phone or smartphone, rechargeable vacuum cleaner, rechargeable electric power tools, etc.)
- Wireless energy transmission for implantable medical equipments (such as ventricular assist device)
- Charging connector for electric vehicle, etc.

Challenges in Implementation

The implantable medical equipment has a main problem that the medical equipment requires design and manufacture of a specific medical packaging. When it is used for the household appliance or the electric vehicle, finally, dosimetry evaluation and EMC evaluation are also needed according to the output voltage.

What We Expect from Companies

Designing transformers requires consideration of coil materials, the number of turns, the number of layers, outer diameter, inner diameter, and use or non-use of ferrite cores. In addition, the intensities of the radiated magnetic field and electric field are related to regulations on electromagnetic interference wave and electromagnetic effects on living bodies, and transformers should be designed to suppress their intensities within the regulations' limits. These requirements are not easy to satisfy. Our laboratory can perform the design, taking these into account, and help our clients to design safe and high-efficient transformers.

Future Developments

We aim to design transformers that can transmit energy through a space as great as 1 m, recognizing the difficulties of doing so.

- Awards: JSAO Best Paper Awards (2001) in Circulatory System, etc.
- Intellectual Property: Japanese Patent Application No. 2014-146119 "Wireless Energy Transmission Apparatus and Electrical Device"
- Prototype: Present
- Sample: May be provided. Decision on this made after discussion with requester.

Medical and bio

OTN (over 1000 nm)-NIR in vivo imaging system

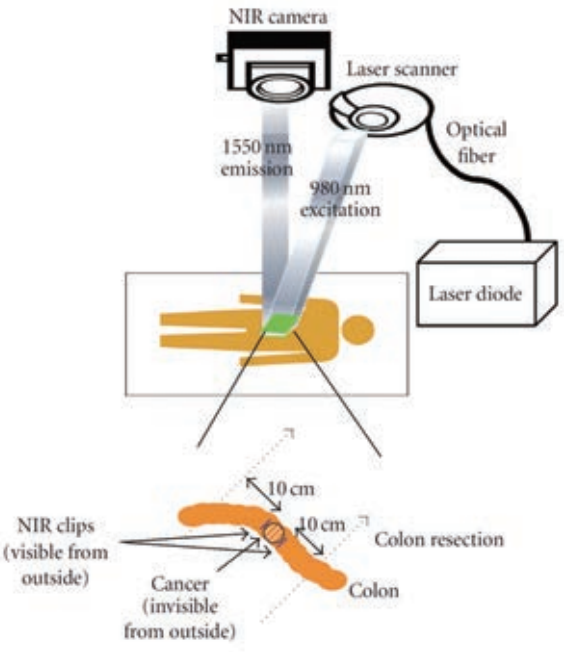
Kohei SOGA (Professor, Department of Materials Science and Technology, Faculty of Advanced Engineering, Tokyo University of Science, Imaging Frontier Center)

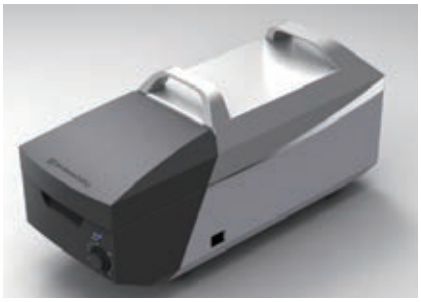
Purpose of Research

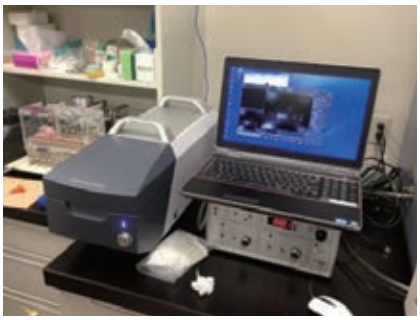
Fluorescent imaging is one of the most important basic technologies in fields of biology and medicine. Visible or near-infrared light with a short wavelength, either of which is currently used, has limitations in observation depth and clearness due to strong light scattering and autofluorescence. Meanwhile, the 1000-nm or more near-infrared light (OTN-NIR) is expected to provide the observation depth of several centimeters, compared favorably with conventional depth of several millimeters. However, the wavelength region 1,000 nm or more cannot be observed because a silicon CCD camera can only capture the images with a wavelength less than 1000 nm.

Summary of Research

This technology achieves to realize OTN-NIR fluorescence in-vivo bioimaging, in so-called “the second biological window” by developing an imaging system equipped with InGaAs CCD camera and a diode laser excitation and rare earth-containing ceramics nanoparticles (RED-CNP) as fluorescent probes at the same time.







Portable OPT
(jointly developed with Shimadzu Corporation)

Comparison with Conventional or Competitive Technology

- Bioimaging in OTN-NIR
- Enable measurement insensitive to light scattering and autofluorescence
- Imaging with several cm depth

Expected Applications

- Imaging for small animals
- Imaging for diagnosis and medical care
- DDS kinetic analysis in the pharmaceutical field

Challenges in Implementation

- The imaging device for small animal research has been already developed with Shimadzu Corporation and launched onto the market.
- We will do the projects on 1) implementing the imaging device for diagnosis and medical care, and 2) developing various kinds of the fluorescent probes.

What We Expect from Companies

We are finding the company as a collaborative project partner, who is willing to develop the imaging device for diagnosis and medical care, the novel fluorescent probes, and 3D imaging technology utilizing the depth imaging.

Points

- **Capable of imaging deep part of a living body**
- **Capable of highly-accurate measurement without effecting cell or vital environment**
- **Capable of real-time measurement or long-time measurement**

Research Schedule

December 2014: Launch the imaging device for small animal onto the market (Shimadzu Corporation)

April 2017: Produce a prototype of the imaging device for diagnosis and medical care

April 2022: Start the clinical applications & Launch the imaging device for diagnosis and medical care onto the market

December 2027: Launch the imaging device for diagnosis and medical care onto the market

- Awards:
  JSDMD Symposium, “Best Lecture Awards” (April 11, 2009)
  Japanese Bioimaging Society, “Best Image OLYMPUS Awards” (November 2, 2006)
- Intellectual Property:
  Japanese Patent 6798, “Optical Imaging Device”
- Prototype: Present
- Sample: Available

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2022.04

Energy and environment

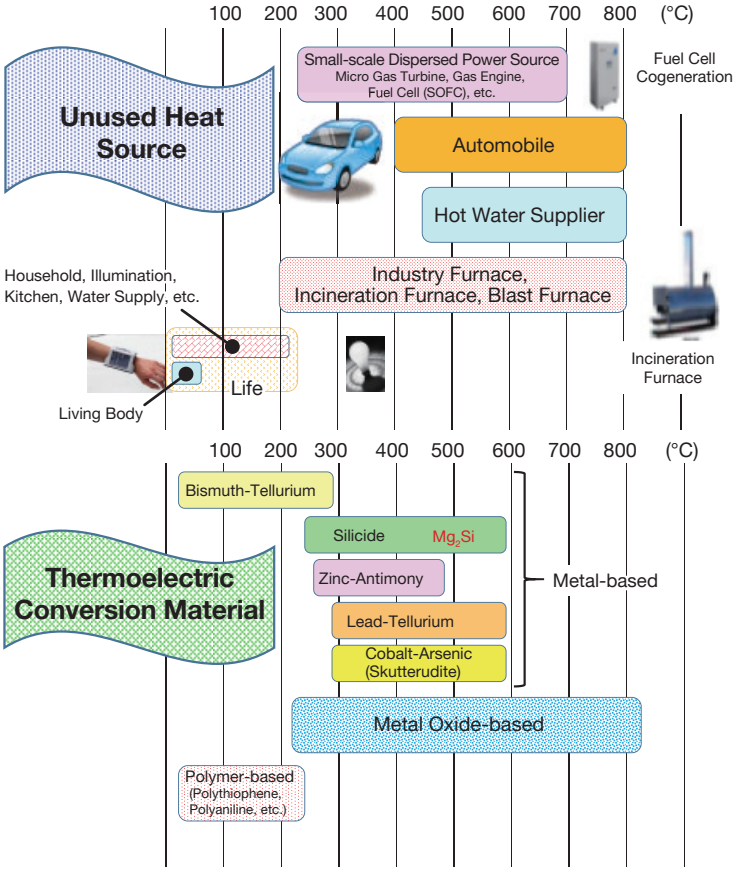
Thermoelectric waste heat recovery by environmentally benign materials

Keishi NISHIO (Professor, Department of Materials Science and Technology, Faculty of Advanced Engineering, Tokyo University of Science)
Tsutomu IIDA (Professor, Department of Materials Science and Technology, Faculty of Advanced Engineering, Tokyo University of Science)
Hiroaki ANNO (Professor, Department of Electrical Engineering, Faculty of Engineering, Sanyo-Onoda City University)

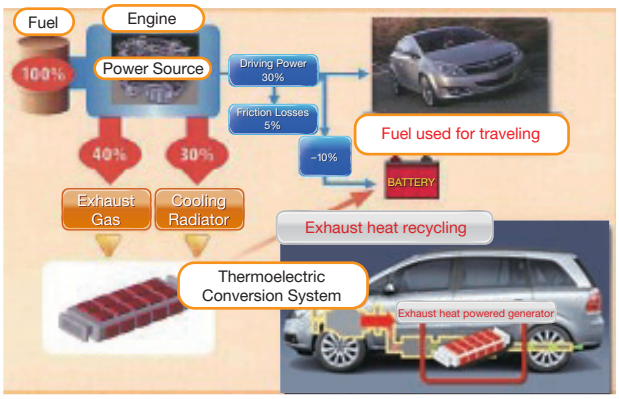
Purpose of Research

Waste heat is one of the important energy sources. Establishing thermoelectric conversion technology that generates highly useful electric energy from waste heat is important to develop the elemental technology essential for reducing carbon dioxide by improving energy utilization efficiency. The researchers have focused on molecular architecture, crystal structure, electronic property, etc. of the material, controlled semiconductor characteristics exhibition, electrical conductivity and heat conductivity, in order to implement high-performance thermoelectric conversion material, and searched proper material satisfying the conditions considering availability and safety as the raw material while securing high performance. Moreover, the researchers promote industry-academia-government cooperation at home and abroad, and work on development of power generation system, i.e. module which can efficiently utilize exhaust heat from automobiles or industry furnaces, and natural heat such as solar heat, ground heat and bioheat.

Summary of Research



We have studied how to find, how to improve, and how to utilize various thermoelectric conversion materials, including but not limited to inorganic, silicide, organic materials. The power generation module for automobile has been developed using magnesium silicide (Mg_2Si) among such materials, via industry-academia-government cooperation at home and abroad.



Points

- **Research on thermoelectric conversion materials corresponding to heat sources in various temperature regions**
- **Good for the ecology and resources**

Expected Applications

Fuel consumption is improved and CO_2 emission is reduced by converting exhaust heat from the automobile to electricity and recollecting it as the energy. This technology is expected to utilize the exhaust heat from the industry furnace or the incineration furnace, as well as from the automobile.

Comparison with Conventional or Competitive Technology

The conventional thermoelectric conversion material typically includes scarce or toxic elements, but this new material uses easily-available and safe elements only. The future subject is to realize recycling the exhaust heat from the automobile.

Challenges in Implementation

- Further improve thermoelectric conversion characteristics
- Evaluate and improve mechanical properties, durability and service life
- Evaluate and improve economic efficiency

What We Expect from Companies

We are finding a partner who is willing to develop the materials usable in the various fields.

Future Developments

We have studied various materials; especially regarding Mg_2Si, we carry out the performance improvement and preparation of a module prototype.

For corresponding to CARS 2020 Action Plan, we promote the development through industry-academia-government cooperation.

■ Associated Institution: Unused Heat Energy Conversion Division of GUAS
■ Intellectual Property: Japanese Patent Application No. 2012-517173 "Method for Manufacturing Thermoelectric Conversion Module and Thermoelectric Conversion Module" (filing several applications associated to organic and inorganic thermoelectric conversion material and modules at home and abroad)

Measurement technology

Electrical and optical hydrogen gas sensor with Pt/WO_3 thin films

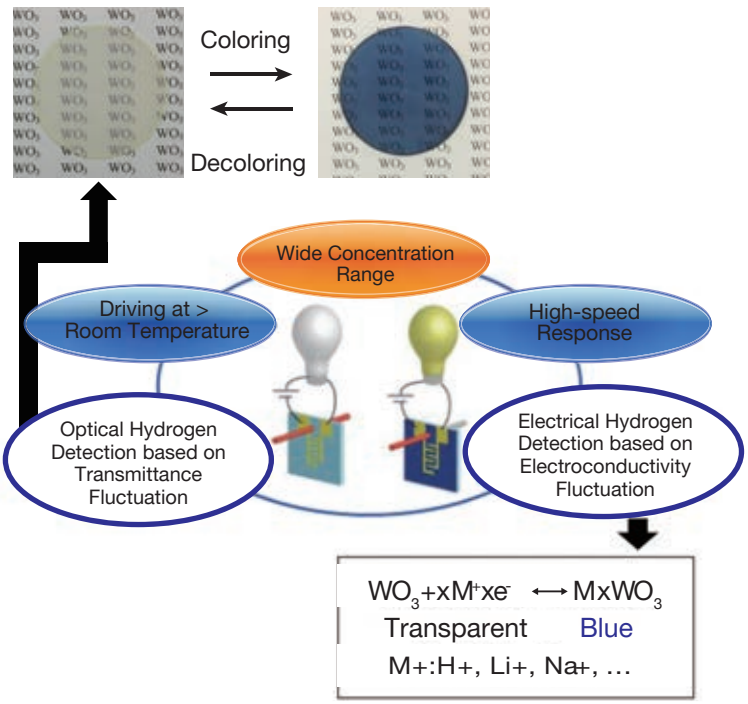
Keishi NISHIO (Professor, Department of Materials Science and Technology, Faculty of Advanced Engineering, Tokyo University of Science)

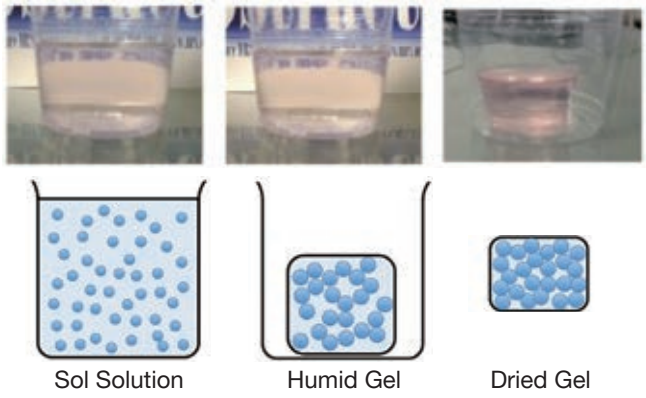
Purpose of Research

Hydrogen energy is one of the most prospective energy sources since it has been employed in various applications, such as a fuel cell, a hydrogen vehicle, etc. However, the hydrogen gas reaches the flammability limit when about 4% to 7% of the hydrogen is contained in the atmosphere, and thus leakage prevention becomes very important. The electrical type or catalytic-combustion type hydrogen sensor has been conventionally used, but it has disadvantages that a detectable concentration range is limited and a detection speed is slow. An object of this study is to implement the hydrogen gas leakage detection with high-speed in the wide concentration range. The study focuses on a material structure, characteristics usable for detection and a device structure.

Summary of Research

A film of oxide (WO_3) is prepared with a sol-gel method, and Pt/WO_3, WO_3 carrying platinum, is further formed on a glass substrate. The researchers have discovered that the hydrogen gas can be detected within the wide concentration range by making the optical/electrical synergy sensor using gas chromism of Pt/WO_3, that is, by combing two physical properties, light and electricity. The high-speed response is realized by controlling microstructure and crystalline of the film prepared with the sol-gel method.





Adjusting Metal Oxide Film by Sol-Gel Method

Only a portion sprayed with hydrogen gas is colored.

Points

- **It can distribute to safe management of hydrogen which attracts attention as the future energy**
- **Good for the ecology and resources**

Expected Applications

- Hydrogen gas sensor: measuring and managing under the concerning conditions including fixed quantity from thin concentration close to the flammability limit, which especially requires the high-speed response

Challenges in Implementation

- Collaboration with measuring techniques
- System architecture

Future Developments

We have a plan to utilize especially the Pt/WO_3 film formed on the glass substrate as the hydrogen gas sensor in the industry-academia-government cooperation, and to search and develop other materials.

What We Expect from Companies

We are finding a partner who is willing to employ and utilize this technology in the various fields.

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2022.04

Bio

Application of plant aroma-mediated biological interactions to agri-system and healthy food science

Gen-ichiro ARIMURA (Professor, Department of Biological Science and Technology, Faculty of Advanced Engineering, Tokyo University of Science)

Purpose of Research

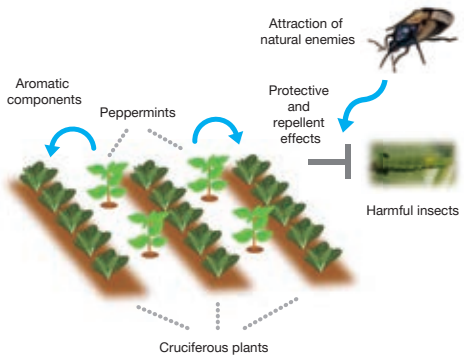
In the present study, we used transgenic plants and medicinal plants that emit volatile terpenes to elucidate the pharmaceutical (such as anti-inflammatory effects on the colon), anti-stress, and other advantageous effects of terpenes and to establish a basis for applications of such "medical aromatic plants." In addition, aromatic plants including mints can also be used as "agricultural aromatic plants" that can promote the attraction of the natural enemies of harmful insects and promote inter-plant communication.

Summary of Research

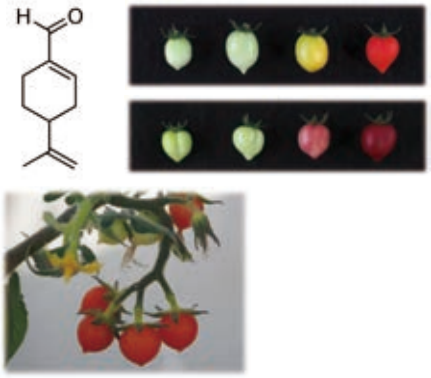
Among the aromatic chemicals produced by plants, terpenes have anti-inflammation, anti-cancer, relaxation (anti-stress), and many other health-promoting effects and are therefore attracting worldwide attention from researchers and physicians. In recent years, the development of terpene production systems using plant factories and microorganisms such as yeast, and basic research for incorporating inter-organism communication via volatile terpenes as agri-biotechnology in production systems have progressed. A patent application has been filed for some results of the research and a specific commercialization project is being considered. We focus on terpenes that have various physiological activities and are developing agricultural aromatic plants that regulate communications between plants and the natural enemies of harmful insects and between plants, and medical aromatic plants that are expected to have health-promoting effects including anti-inflammatory effects using tomatoes and other plants.

Development of production systems using mints as companion plants

Pest control technology for cruciferous vegetables using aromatic components emitted from peppermints (Japanese Patent Application No. 2017-214231)



Development of plants producing secondary metabolites that have health-promoting effects



Specific Examples

- Anti-inflammatory functions of tomatoes containing a large amount of betalain (plant pigment)
- Improvement of intestinal environment by aromatic components of Perilla frutescens

Comparison with Conventional or Competitive Technologies

Conventionally, some unique terpenes are used as the active components for foods and drugs. Because our product is a live plant, the active ingredients of the plant are of ease to be utilized and functional for multiple purposes.

Expected Applications

- Agricultural aromatic plants (including mints) can protect co-cultivated crops from pests without using agricultural chemicals.
- Medical aromatic plants can be used to provide scientifically proven health-promoting components at low costs.

Challenges in Implementation

- Identification of genes that produce and regulate effective aromatic components.
- Creation/production of functional plants.
- Genome editing (using CRISPR/Cas 9).

What we Expect from Companies

Practical applications and marketing of the agricultural and medical aromatic plants generated by the present study.

Points

- **Novel applications of aroma-based plant communication**
- **Use of anti-pest and health-promoting effects of volatile terpenes**
- **Creation/production of agricultural and medical aromatic plants with novel functions**

■ Intellectual Property: Japanese Patent Application No. 2017-214231 "Methods of immune activation of cruciferous plants and production methods of immune-activated cruciferous plants"
■ Publication: Arimura G., Nishihara M. (2018) Plant Plot: Botany of Aroma and Color published by Beret Publishing Co., Ltd. (Tokyo) pp. 159
■ Reference: Uemura T., Yashiro T., Oda R., Shioya N., Nakajima T., Hachisu M., Kobayashi S., Nishiyama C., Arimura G. (2018) Intestinal anti-inflammatory activity of perillaldehyde. Journal of Agricultural and Food Chemistry 66:3443-3448
Sukegawa S., Shiojiri K., Higami T., Suzuki S., Arimura G. (2018) Pest management using mint volatiles to elicit resistance in soy: mechanism and application potential. The Plant Journal, in press

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2022.04

Machinery

Collaboration with medicine and engineering based on biomechanics

Hiroshi TAKEMURA (Professor, Department of Mechanical Engineering, Tokyo University of Science)

Purpose of Research

We are conducting research on measurement, modeling, and control of human body motions, focusing on robotics and biomechanics. Our activities cover a wide range from basic research to applied research of human body functions, as well as animal behavioral analysis and development of medical devices.

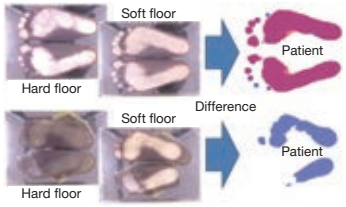
Summary of Research

Our wide variety of research themes are roughly categorized below and some of them will be outlined.

■ Research Theme Related to Feet
(1) Early screening of diabetic neuropathy focusing on foot sole images
(2) A rehabilitation device in consideration of the ankle joint rotation axis
(3) Evaluation method for leg bone shape and tibial joint alignment in patients with osteoarthritis
(4) Counting the number of a mouse's scratching motions using time-subtraction imaging
(5) Development of automatic measurement system of a cow's BCS using deep learning

■ Research Themes Related to Medical Devices Development
(6) Measurement devices of orthodontic force and moment
(7) Recognition of gastrointestinal stromal tumor with a near-infrared spectroscopic camera
(8) Early screening for diabetic neuropathy
(9) An endoscopic device using near infrared light

(1)



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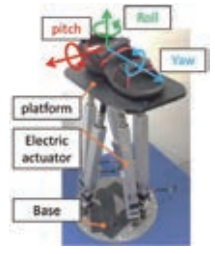

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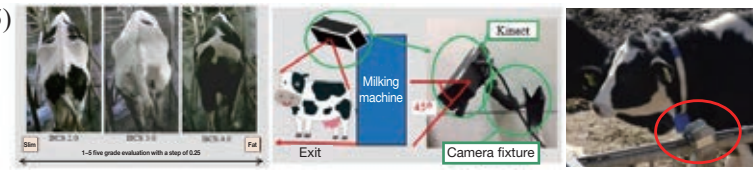

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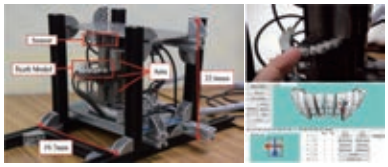

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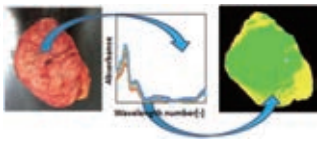

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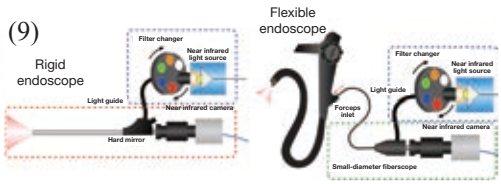


Comparison with Conventional or Competitive Technology

In the research related to feet, we elucidate the structure, function, and motion mechanism of human feet by operating the cycle of medical/experimental motion measurement to digital human modeling and to numerical simulation analysis. Analyses using models close to real things have enabled feedback to the development system.

Expected Applications

- Development of medical devices
- Development of medical/welfare equipment
- Development of automatic measurement systems using deep learning
- Others

What We Expect from Companies

We hope to collaborate with companies who are willing to work with us to achieve the objectives of our research/development projects and put their results into practice.

Points

- **We are conducting research on measurement,m odeling and control of human motions,f ocusing on robotics and biomechanics.**
- **We are also working actively on developing medical devices and medical/welfare equipment.**

Past/Current Efforts and Future Developments

We are also actively collaborating with external research institutions, and are conducting research and development of medical/welfare equipment in collaboration with external medical institutions and other related organizations.

■ Joint-research Partners: Many achievements of joint-research projects with public institutions (Advanced Industrial Science and Technology [AIST], RIKEN, National Cancer Center Hospital East, National Agriculture and Food Research Organization [NARO], and medical universities) and other private institutions
■ Intellectual Property: Japanese Patent No. 5995215 "Cancer Cell Region Extraction Device, Method, and Program," Japanese Patent No. 6666010 "Approaching Device," PCT/JP2020/032439 "Abnormal State Estimation Device, Sole State Estimation Device, System, and Program," and others

Energy and environment

Day-ahead forecasting technologies for PV systems

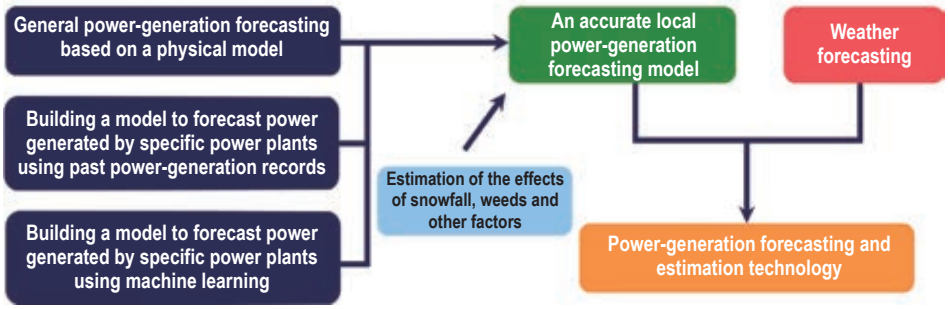
Yuzuru UEDA (Professor, Department of Electrical Engineering, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

More and more Photovoltaic (PV) systems will be installed in the future as the mass-introduction of the renewable energy takes hold. While they are reliable with the projected operation period of 20 years or longer, the amount of power they generate depends on the weather conditions, which vary day by day. Therefore, for the post-FIT era, it is important to accurately predict power generations day ahead, considering the power-generation properties, equipment configurations (which differ from plant to plant), the effects of shadows at different times of the day, and the daily weather conditions. The aim of this study is to develop a technology for analyzing power-generation properties applicable to various PV systems from residential systems to mega-solar, as well as a technology for forecasting power generation a day ahead.

Summary of Research

Progress in technology for predicting the flux of solar radiation has made it possible to accurately forecast the amount of solar radiation in specific areas such as power-plant locations and certain regions. In this study, we are creating a model for accurately predicting power generation that considers the configurations and features of PV systems in a targeted area, and developing technology to forecast and estimate power generation that combines usefulness evaluations on such forecasts for power producers and aggregators, anticipating the post-FIT era. This power-generation forecasting and estimation technology uses, as input, a variety of data including past power-generation records and weather conditions and forecasts, and combines several models including a physical model, a model using past results and a model using machine learning, with the goal of achieving accurate predictions.



Points

Accurate day-ahead power-generation forecasting for the post-FIT era

Comparison with Conventional or Competitive Technologies

The features of each power plant can be considered by combining various methods including a physical model, a model using past results and a model using machine learning. We are developing machine learning model witch does not require long-term data, and a forecasting method that does not depend on a system's scale or configuration.

Expected Applications

- Forecasting power generated by a residential PV systems on the next day
- Forecasting the power generated by a large-scale PV systems on the next day
- Estimating power generation and assessing business feasibility when planning a power plant

Challenges in Implementation

Pursuing further accuracy via prediction and analysis using detailed chronological data on a number of power plants

What We Expect from Companies

- Power producers that kindly provide us with power-generation data
- Joint research proposals that combine power-demand data, including energy management, to utilize power-generation forecast data

Future Developments

Power-generation forecasting of individual PV systems using flux in solar radiation estimated from satellite data.

■ Associated System:
NEDO, Technology development for driving PV systems as primary power sources/Advanced common fundamental technology development/Development of technology for predicting flux in solar radiation, aiming at power-generation forecasting in the near future/"Research and development on power-generation forecasting and estimation technology" is ongoing (from July 2020 to February 2023).

Device

Flow visualization, analysis and control

Hitoshi ISHIKAWA (Professor, Department of Mechanical Engineering, Faculty of Engineering, Tokyo University of Science)

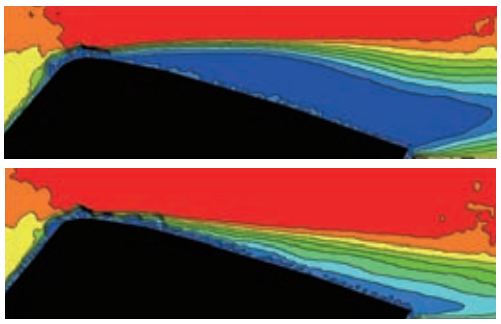
Purpose of Research

Fluid machinery, such as pipelines, wings, pumps and blowers, are widely used in engineering application. But it is difficult to study and analyze the behavior of their working fluids, such as air, water and oil, since most of them are invisible. By using dedicated measuring instruments and utilizing our expertise, our laboratory can visualize flows and efficiently measure flow velocity and flow structure. We propose flow control technologies and develop devices that are useful for improving the efficiency of fluid machinery.

Summary of Research

We can visualize flows using smoke-wire, tracer and other techniques, and can measure flow rates and flow velocities using flowmeters, hot-wire anemometers, and particle image velocimetry (PIV), etc. Objects brought into our laboratory can be measured using our wind tunnel equipment, and we can also conduct analysis under multiple conditions using numerical simulation.

Wind tunnel equipment with 400 × 400 mm outlet



Flow visualization (separation from a wing)

Optical control of fluid viscosity

Comparison with Conventional or Competitive Technologies

- Ability to visualize invisible fluids
- Measurement instruments specifically designed for measuring flow rates and flow velocities
- Abundant expertise regarding fluid control
- Two approaches to analysis: experiment and numerical simulation

Expected Applications

- Proposing design specifications for equipment
- Performance evaluation and improvement of equipment
- Proposing and developing control methods and devices to suppress flow transition and separation
- Optical methods for controlling fluid viscosity

Points

- **Flow visualization**
- **Flow velocity measurement using hot-wire anemometers and PIV,an d vector analysis**
- **Wind tunnel equipment with an outlet of 0× 0n m,an d other advantages**

Future Developments

We also aim to develop new types of flow-control devices such as plasma actuators and optical methods to control the viscosity of fluids.

- Research Structure: Successful history of conducting joint research with public and private institutions
- Awards: Awarded for our contributions by the Fluids Engineering Division, Japan Society of Mechanical Engineers
- Technical Guidance: Abundant experience in providing technical guidance

Machinery

Ultra-light cellular (micro lattice) structure manufactured by metal 3D printer

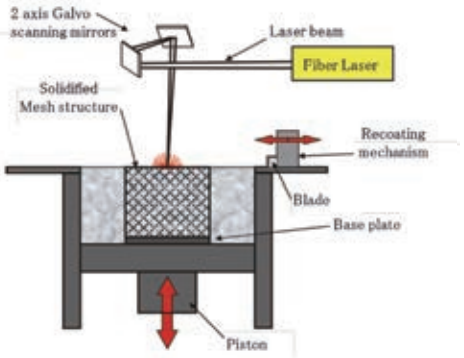
Kuniharu USHIJIMA (Professor, Department of Mechanical Engineering, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

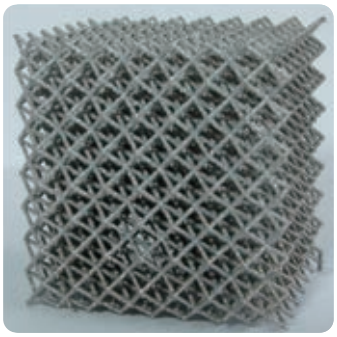
In order to realize the main purpose of material mechanics—namely, utilizing materials safely without waste—this study was undertaken with the aim of developing a manufacturing technology with a refined structure through the use of a metal 3D printer and to evaluate the mechanical characteristics of formed objects using numerical simulation analysis.

Summary of Research

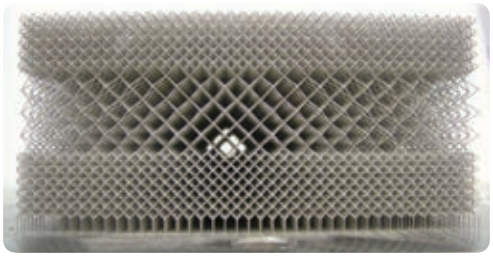
An ultra-light cellular (micro lattice) structure, which is expected to be widely applicable in fields ranging from medicine to aerospace, was produced using a metal 3D printer utilizing an additive manufacturing (AM) technology. The mechanical properties of the formed objects were then evaluated using numerical simulation analysis.



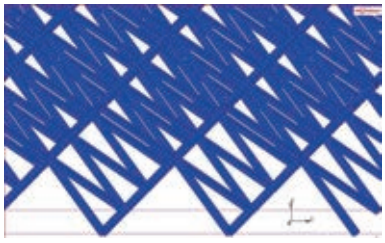
Modeling of a lattice structure by exploiting the characteristics of a metal 3D printer



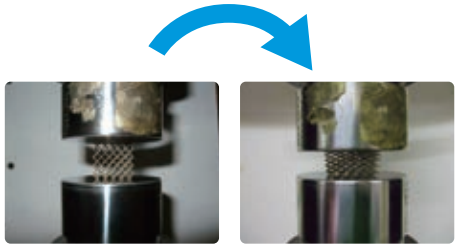
Example lattice structure #1



Example lattice structure #2



Numerical simulation analysis



Strength evaluation test

Comparison with Conventional or Competitive Technologies

- The lattice structure has a specific strength that is equivalent to a honeycomb structure but is more lightweight.
- The lattice structure has a large surface area, offering improved heat radiation.

Expected Applications

- Can be used as an impact absorption material for vehicles
- Can be used to manufacture a highly efficient heatsink since it can be designed to have an internal structure that allows for thermal conductivity control

What We Expect from Companies

We are now searching for companies with which we can carry out joint research to develop new applications for lattice structures.

Points

- **Optimization of lattice structures using numerical simulation analysis technologies**
- **Formation of an actual lattice structure using the metal 3D printer at the Tokyo University of Science's Tribology Center and performing of an evaluation test**

Future Developments

- Development of a heat insulation structure and a heat radiation structure using the new cell structure
- Development of a new light-weight metal structure using a textile structure
- Development of a spatially expandable structure by imitating origami (the Japanese art of paper folding)

■ Prototype: Completed
■ Sample: Available

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2022.04

Medical and welfare

Human assist technology cultivating a new market

Hiroshi KOBAYASHI (Professor, Department of Mechanical Engineering, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

To research and develop seeds for innovative technologies to realize the world where “whoever lives can live independently”.

Summary of Research

- Develop a human assist suit assisting muscle force: MUSCLE SUIT®
- Active walker that allows a person with a gait disorder to walk in a right posture without falling
- Develop a reception robot that can communicate with hyper-realistic voice and facial expressions
- Develop new mechanismcal toilets
- Measure muscle fatigue
- Automate identification of compositions of steel materials, and more

<MUSCLE SUIT for lower-back support>

Points

Our university actively collaborates with the companies to proceed R&D of “Only One, Worldwide unique robots and machines for actually helping and assisting people in viewpoint of the human, considering productization.

Future Developments

We have established a venture corporation, INNOPHYS CO., LTD., for producing the MUSCLE SUIT®, on December 27. 2013.

INNOPHYS CO., LTD. has been commercializing a series of products developed at the lab, and has shipped more than 13,000 units of MUSCLE SUIT® (July 2020).

- Intellectual Property: Japanese Patent No. 05505740, “Waist Assistance Device,” and many others
- INNOPHYS CO., LTD. (Representative: Daigo Orihara)
  Address: 6th Floor, GRAN FIRST Kanda-Kon'yacho, Kanda-Kon'yacho 15 banchi, Chiyoda-ku, Tokyo
  Tel. +81(0)3-6260-7970
  Main Businesses: Development, Design and Sale of Motion-Support Devices

Device

Tribology research activities in TUS

Shinya SASAKI (Professor, Department of Mechanical Engineering, Faculty of Engineering, Tokyo University of Science), etc.

Purpose of Research

The tribology can be applied to various fields, and it requires broad knowledge of science and technology. Since the systematized techniques in order have not been established yet, this subject tends to be shunned by field researchers. However, there are lots of unavoidable problems related to the tribology existed within mechanical system design and machine maintenance. Hence, we have been working on the research in order to develop unique key technology from the viewpoint that tribology is one of the strategically important technologies for enhancing competitiveness of industrial products.

Summary of Research

- Evaluate tribological features (Standardization, development of evaluation equipment)
- Fundamental mechanism (Super low friction, zero wear, tribo-chemical reaction)
- Surface analysis (Chemical and mechanical analysis of tribo-surface and layers)
- Evaluate nano-properties of surfaces (Nanoindentation, SPM)
- Develop a lubrication system for special environments by using new lubricants (Ionic liquid as a lubricant for high-temperature and high vacuum conditions)
- Develop technology for producing a functional surface by using a metal 3D printer
- Surface modification (Soft-mater and hard coatings, surface texturing)
- Design and evaluate high-functional bearings (Sliding bearing, rolling bearing or novel bearings)

Production: metal 3D printer, laser fine processing, coating, etc.

Tribology feature evaluation: develop international standard and evaluation device

Analysis/interpretation: shape measurement, nano-property evaluation (SPM), adsorption property (QCM), wettability evaluation and various surface analyses

Points

Tribology is very important and fundamental technology within a wide range of science and technology for creating the new product groups. Tribology is useful for improving mechanical system performances (high-energy efficiency,h igh reliability,l ong service life,h igh accuracy and low cost)

Both investigation and understanding the tribological phenomenon must to be understood correctly in order to perform troubleshooting or maintenance of the products. When the new product is developed,t he tribo-element which is an essential component of the machine system tends to become a problem.S uch a problem should be solved by the design technique based on the tribology.I f you find any problems or obstacles related to the tribology or you want to get more information on mechanism and evaluation,p lease contact us

Future Developments

Open “Tribology Center” at Katsushika Campus on April 2015
International Tribology Conference 2015(held by Japanese Society of Tribologists, Site: TUS Katsushika Campus)

■ Associated System:
Support project of open platform construction in university, one of 2013 Local Innovation Promotion Projects supported by Ministry of Economy, Trade and Industry
Subsidy for collaborative creation program
(support for maintenance of facilities and equipments within university)

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2022.04

Tribology

Low-wear, low-friction material; urushi lacquer containing a solid lubricant

Masaaki MIYATAKE (Associate Professor, Department of Mechanical Engineering, Faculty of Engineering, Tokyo University of Science)

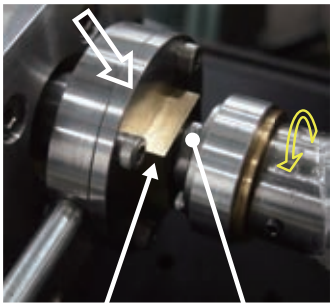
Purpose of Research

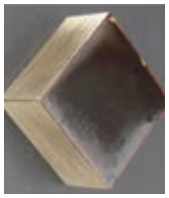
Urushi lacquer is a natural resin material, which has long been used in Japan as a hard coating material for tableware, armor and other items. As a resin material with excellent chemical and wear resistance, this research focuses on urushi lacquer, and aims to study the friction and wear properties of sliding materials made from urushi lacquer with PTFE added as a solid lubricant.

Summary of Research

In this research, we prepared a sliding material by hardening urushi lacquer with PTFE added as a solid lubricant, and conducted friction tests using a ring-on-plate friction tester under dry conditions. The results indicated that adding PTFE to urushi lacquer resulted in a low friction coefficient equivalent to that of 100 wt% PTFE, and a high degree of wear resistance equivalent to that of hardened urushi lacquer.

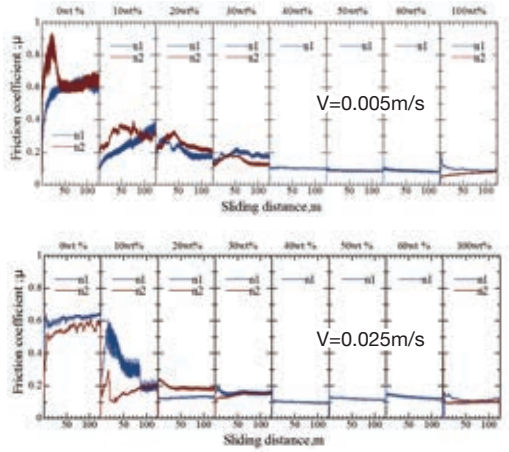
Ring-on-plate friction tester



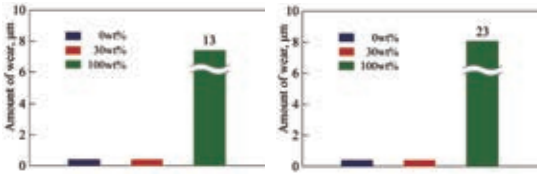


Test piece

Mating material



Friction coefficient measurement results



Wear measurement results

Comparison with Conventional or Competitive Technologies

Materials with a low effect on human health are required for the resin sliding parts of food processing machines, since, in manufacturing processes, small amounts of harmful substances may elute from the synthetic resins used in machine parts. In addition, there is a need for resin materials that are resistant to the chemicals in cleaners. This research aims to solve these issues.

Expected Applications

- Bearings for the reciprocating sliding parts and rotating parts of food processing and water treatment machines, etc.
- Materials applied to and hardened on metal and other base materials (wear-resistant coatings)
- Impregnants for lamination and hardening of woven and unwoven fabrics, such as cotton cloth (fiber reinforcing resins)

Challenges in Implementation

- Optimization of hardening conditions of urushi lacquer and PTFE
- Performance measurements under a wide variety of test conditions (load, temperature and various environmental conditions)
- Testing of materials containing solid lubricants other than PTFE, and testing for comparison with competing materials

What We Expect from Companies

- With the aim of utilizing this material for the bearings in the reciprocating sliding parts and rotating parts of food processing and water treatment machines, etc., we would like to conduct joint research with companies involved in this area.

Points

- **The effects of wear debris on human health are low,d ue to the use of urushi lacquer,a n atural material with a long and successful history as a coating material for tableware**
- **Low-friction,l ow-wear sliding materials are produced by adding PTFE solid lubricant to urushi lacquer**

Future Developments

- Investigation to optimize the hardening conditions for urushi lacquer mixed with PTFE or other solid lubricants
- Conduction of performance evaluations under environmental conditions that have not been examined before, such as high-temperature and water circulation environments

■ Intellectual Property: Japanese Patent Application No. 2016-093303
"Sliding composites, sliding part materials and their manufacturing methods"
■ Prototype: Available
■ Sample: Available

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2022.04

Machinery

Newly developed aerostatic porous bearings manufactured using direct metal printing technology

Masaaki MIYATAKE (Associate Professor, Department of Mechanical Engineering, Faculty of Engineering, Tokyo University of Science)

Background of Research

Metal powder sintering 3D printers are not only able to produce durable, complex shapes, but are also able to provide air permeability to arbitrary places of the processed part by adjusting the laser intensity when sintering the metal powder. In this study, we tried to improve the performance of a mechanical element called an aerostatic porous bearing using a metal powder sintering 3D printer, which can not only manufacture parts by adding shapes but also to "add functions," such as making it air permeable, to arbitrary places of the manufactured part.

Summary of Research

An aerostatic porous bearing is a mechanical element that floats moving parts of a mechanical device in a noncontact manner by a pressurized film of air, and is widely used for precision processing machines and precision measurement instruments. By utilizing the advantages of the metal 3D printer, it is possible to (1) simplify the structure by integrally manufacturing the porous material and the support structure, and (2) to control the air permeability at arbitrary place of the porous material by adjusting the laser intensity at the time of molding.

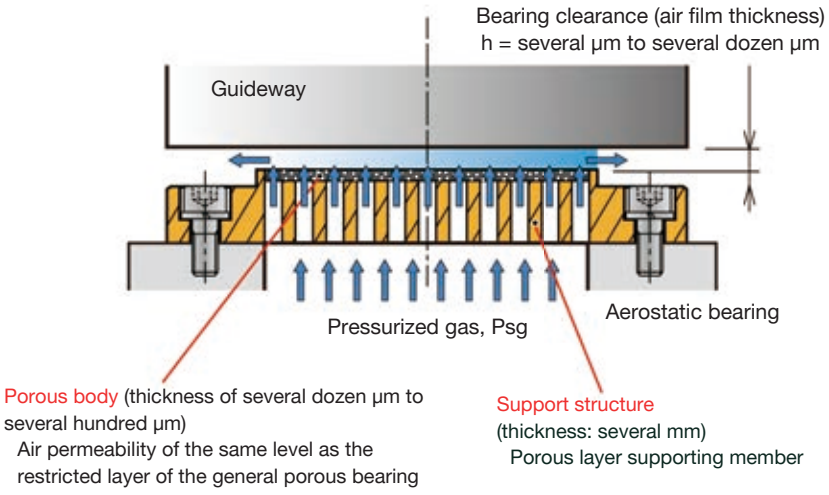


Figure: Aerostatic porous bearings in which the porous layer and the support structure are manufactured integrally using a metal powder 3D printer

Comparison with Conventional or Competitive Technology

○ Porous air bearings currently on the market
- Fabricated using several mm thick porous material.
- Surface choking modification is necessary to prevent unstable vibrations (pneumatic hammer).
- It is necessary to control air permeability and choking level of the porous material at the time of mass production, and will be cost consuming.

○ New technology
- The structure is simplified by manufacturing the porous layer to be 1 mm thick or less, and the support structure integrally using metal 3D printer.
- It is possible to arbitrarily adjust the air permeability of the porous layer during manufacturing.
- Bearings with higher performance than conventional products can be manufactured.

Expected Applications

- Guide mechanism of precision processing machines
- Guide mechanism of precision measuring instruments
- Noncontact levitation device

Challenges in Implementation

- Application to radial bearings supporting rotating shaft
- Optimization of porous layer air permeability
- Cost reduction of metal powder used in the 3D printer

What We Expect from Companies

- We hope to collaborate with companies that are considering the use of static pressure air bearings in movable parts such as precision processing machines and measuring instruments or the manufacturing of hydrostatic gas bearings.

Points

- **Simplification of structure by integral manufacturing of porous material and support structure**
- **Control of air permeability at arbitrary places in the porous material by adjusting the laser intensity at the time of molding**

Future Developments

- Currently, application to radial bearings supporting rotating shaft is proceeding.
- We are working on optimizing porous layer permeability to realize greater performance.

■ Intellectual Property: Japanese Patent Application No. 2018-085277
"Aerostatic porous bearings and manufacturing method of the same"
■ Prototype: Available

Device

Low cost high performance on-orbit equipment using commercial-off-the shelf devices

Shinichi KIMURA (Professor, Department of Electrical Engineering, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

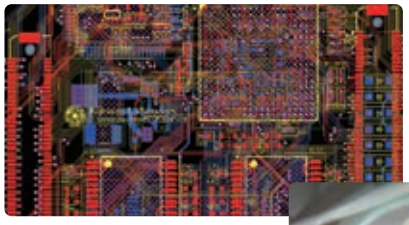
To repair/recover an artificial satellite in orbit, highly autonomous search for and approach to the satellite is necessary. On the other hand, outer space devices have limited functions and are also extremely expensive, making the above difficult. We have investigated commercial parts (of automobiles, mobile phones, etc.) that can work in outer space and developed systems with software that can deal with malfunctions, for low-cost high-performance satellite-borne devices which we have made and which have been adopted for IKAROS, Hayabusa 2, and many other missions.

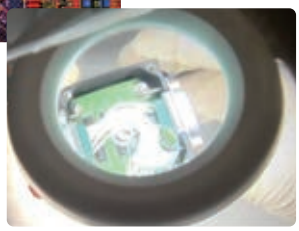
Space computer

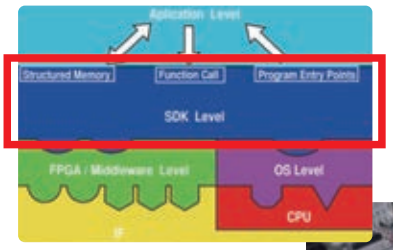
Camera installed in Hayabusa2 (left) and an image of the touchdown (right)

Summary of Research

In the present study, we are developing high-performance, satellite-borne devices at low cost based on the following three technologies and our experience in many satellite missions.







Points

- Outer space computer
- World's smallest outer space camera

1) Orbit environment compatibility evaluation technology for commercial devices

Before a commercial device is put into orbit, its compatibility with the orbit environment (radiation, high vacuum, etc.) must be evaluated. We have established such an evaluation technology and a collection of commercial devices which have successfully operated on orbit. Using these resources, we can develop a camera and a computer suitable for a wide range of missions.

2) Satellite-borne circuit board design technology

In order to manufacture ultra-small, high-performance, satellite-borne devices from commercial parts, a circuit/board design technology is required. The world's smallest space camera, etc. developed in our laboratory shows the excellence of our satellite-borne device design technology.

3) Software technology for advanced AI

High performance and reliability depend on not only hardware but also software technologies. Based on our software resources nurtured over many missions, a flexible and reliable software platform has been developed. Our software simulator, when connected to hardware, can reproduce the behavior of a satellite under various conditions. This provides a system for effective hardware testing.

Future Developments

- Ultra-small, deployable outer space camera module.
- Controller/image acquisition and processing unit for extreme environments.

- Successfully participated in IKAROS, Hayabusa 2, and many other satellite missions
- Prototype: engineering modules, etc. made

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2022.04

Manufacturing technology

Miniature fuel cell with monolithically fabricated Si electrodes – Multi-layer catalyst by electrochemical atomic layer deposition –

Masanori HAYASE (Professor, Department of Mechanical Engineering, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

There are increasing expectations regarding compact power sources for the industrial use of drones and utilization of various types of robots. However, despite the clean energy image of fuel cells, they are fueled by hydrogen produced mainly from fossil fuel. In light of this situation, we are developing miniature fuel cells that can be fueled by biomass-derived hydrogen. In this research, we have, in order to achieve compatibility with biomass-derived hydrogen, developed a catalyst that is highly resistant to carbon monoxide and requires little platinum.

Summary of Research

In order to miniaturize fuel cells using MEMS technology, catalytic layers were previously formed by depositing porous platinum on silicon substrates. Although this achieved high power density fuel cells, reducing the amount of platinum used remained a problem. At the same time, the search continued for a catalyst that is highly resistant to carbon monoxide, a large quantity of which is contained in biomass-derived hydrogen. Excellent properties were obtained by depositing a small amount of platinum on porous palladium, but it was found that hydrogen absorbed into and discharged from the palladium caused the catalytic layer to break. This research aims to create a catalytic layer using electrochemical atomic layer deposition, with palladium and platinum being precisely deposited on the superficial layer of a core made of porous gold.

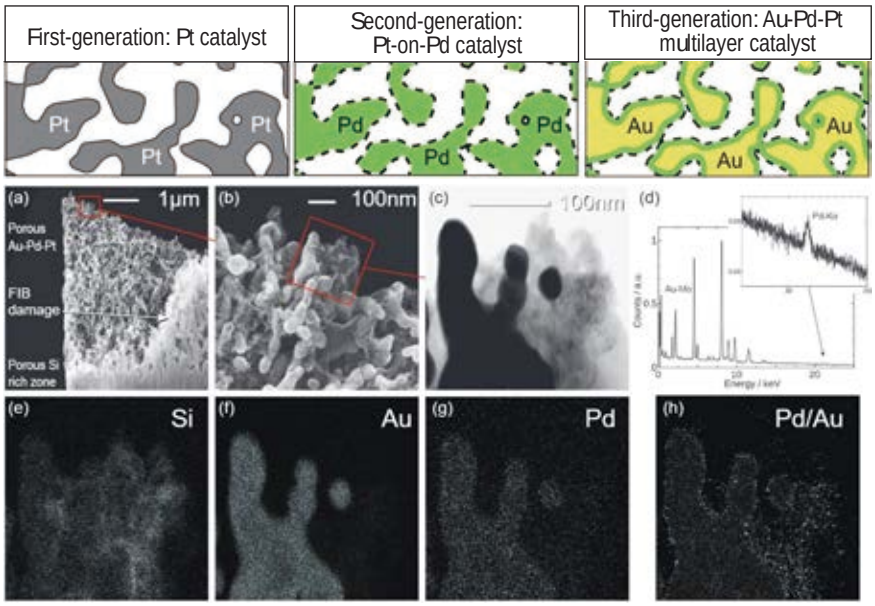

Figure: Third-generation Au-Pd-Pt catalyst

Points

- **Reduction in amount of platinum used (approx. 5 μg/cm²)**
- **High resistance to carbon monoxide**
- **High-power MEMS fuel cells**

Comparison with Conventional or Competitive Technology

- This is a unique technology that forms high-performance catalyst using a porous gold structure—suitable for MEMS fuel cells—as a base.
- In our previous research, a core shell structure was formed on metal microparticles through electrochemical atomic layer deposition.
- There is little research that uses porous gold as a base.
- Using porous gold as a base allows precise electrochemical atomic layer deposition to be achieved.

Expected Applications

- Portable power sources
- Moderately quiet power sources for drones and robots
- Promotion of use of biomass-derived hydrogen

Challenges in Implementation

- It is currently unclear how competitive this technology is with respect to the performance and cost of fuel cells for general-purpose devices.
- Optimization of the catalytic layer structure (number of UPD-SLRR processes, porous Au layer)

What We Expect from Companies

- We would like companies to offer popular products that use biomass hydrogen fuel cells.

Future Developments

By 2018: Succeeded in demonstrating prototype cells using Au-Pd-Pt catalyst
By 2019: Enhancing power output (for smartphones); ongoing
Succeeded in increasing the pore size to improve catalyst performance
From 2020 onward: Studying combination with fuel tanks and other accessories
From 2020 onward: Searching for industrial partners and venture companies

■ Intellectual Property: Japanese Patent Application No. 2016-159735
"Silicon substrates with catalytic layer, fuel cells, and method for manufacturing silicon substrates with catalytic layer"
■ Prototype: Available
■ Sample: Samples of cells prepared with Au-Pd-Pt catalyst

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2022.04

Machinery

Three-dimensional printing of continuous-fiber composites

Ryosuke MATSUZAKI (Professor, Department of Mechanical Engineering, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

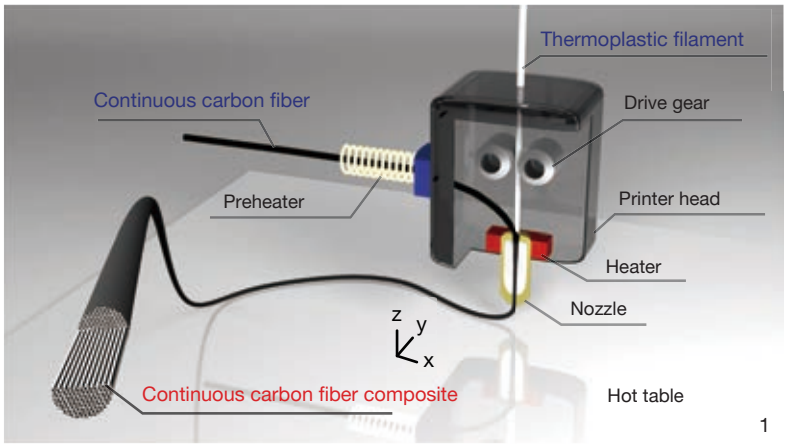
Three-dimensional (3D) printers that use resin are now available on the market. It is well known that they easily form simple and complicated 3D objects without using molds or jigs. However, they can only produce structures that are too low in strength to be used as high-quality components for industrial products. This research uses continuous fiber-reinforced resin composite materials to develop 3D printers that can make high-strength and high-rigidity products that support people's lifestyles, such as structural members of automobiles and aerospace equipment as well as medical and welfare equipment.

Summary of Research

This technology not only enables single-stroke drawing using continuous carbon fiber composites, but also controls the directions of fibers and the fiber content in local regions of an object in accordance with how it will be used. It also computes and proposes optimal material conditions, leading to new product structures and usages.

High-strength 3D shape forming with a continuous carbon fiber 3D printer

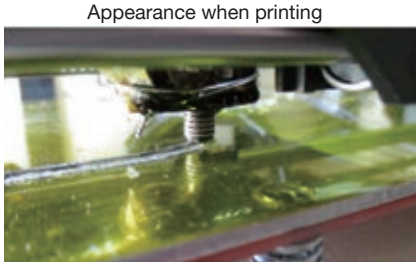
• A printing nozzle blends continuous carbon fiber with thermoplastic resin.



1

Test piece

Appearance when printing



Comparison with Conventional or Competitive Technologies

- Using continuous carbon fiber dramatically improved the tensile strength and rigidity of a structure compared with commercially available industrial use 3D printers (powder sintering, photo-fabrication, and fused deposition modeling).
- Using thermoplastic resin significantly reduced production cost and lead-time compared with conventional thermosetting CFRP.

Expected Applications

- Structural members of automobiles and aerospace equipment
- Medical equipment and welfare equipment such as rehabilitation assist devices
- Sports gear and recreational facilities

Challenges in Implementation

We have already developed elemental technologies such as continuous carbon fiber 3D printing, fiber cutting, and optimization of fiber orientation. To put the technology into practice, we will increase the volume content of fiber to the level equivalent to that of conventional CFRP products.

What We Expect from Companies

This technology is useful for companies that need to manufacture a large variety of high-strength components in small lots. We would like to conduct joint R&D activities with companies that have the technologies to manufacture finished devices or those who plan to expand their business into the 3D printer field. We would also appreciate the support needed to start a venture firm.

Points

- **Lightweight,h igh strength,an d high rigidity**
- **Controlling the orientation and content of reinforcing fiber**
- **Significant reduction in production cost by on-the-spot impregnation of fiber into thermoplastic resin**

Future developments

August 2016: Finalize the specifications of a large prototype.

March 2017: Complete assembly of the prototype.

April 2017−: Exhibit the prototype at an event and ship samples.

(Plan to develop a small-type concurrently.)

■Associated System: Strategic Core Technology Advancement Program
(Supporting Industry Program)
: NEDO Project, Next Generation Structural Material Creation
−Development of Processing Technology
■Associated Institutions:
Tokyo Institute of Technology, Nihon University, JAXA, and others
■Intellectual Property: PCT/JP2015/65300, and others
■URL of This Project: http://www.rs.tus.ac.jp/composites2/

Disaster prevention

An image-feature enhancement and interpretation system for crack detection of concrete surface based on feature composite moving image inducing visual illusion

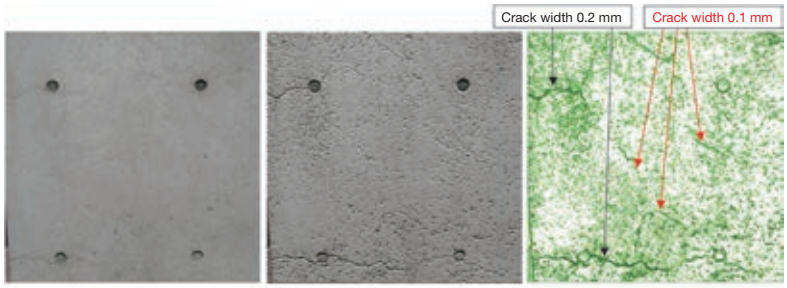
Hirohito KOJIMA (Professor, Department of Civil Engineering, Faculty of Science and Technology, Tokyo University of Science)
Hayato OHWADA (Professor, Department of Industrial Administration, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

Images of concrete surfaces that are taken to find cracks are basic data for maintenance management of a concrete structure. Features included in such an image are often hard to interpret and thus are generally processed for image enhancement. However, conventional processing methods are not effective and tend to result in image degradation. To facilitate the crack detection of concrete surfaces, we have developed an optical illusion-inducing image interpretation support system. This allows real-time feature enhancement/support for interpretation of a video taken during inspection.

Summary of Research

We developed a method for combining images of features which maintains image quality and creates an afterimage optical illusion whose effect is to sharpen the whole image and thus make cracks on a concrete surface more visible. Spatial frequency components corresponding to changes in density among the frames of the feature composite moving image are calculated, and the power (amplitude) of each spatial frequency component is determined, allowing objective evaluation of the image visibility. Inspection of actual concrete surfaces demonstrated that this system composed of general-purpose devices such as a video camera and laptop performs adequately.



Original image | Optical illusion-inducing feature composite moving image (composite-imaged features are dispersed) | Moving image for visibility evaluation

Video recording & real-time analysis

<System components>
- PC (laptop or tablet)
- Video camera (UV, visible light, or near IR)
- Hyperspectral camera

Points

- Quick inspection, even in dark places such as inside tunnels and underneath bridges
- Supports on-site real-time analyses and subsequent analysis/graphing of captured images
- Sharpens various images obtained by observation (still and video images) and enhances image features (using optical illusion) (Applicable to various images obtained in the UV, visible, near-IR, and microwave ranges)
- Acquires video and still images displayed on a screen and processes them in real time (Real-time processing of video and still images displayed on existing systems)
- An idea creation support system that operates together with other existing systems

Comparison with Conventional or Competitive Technology

In our system, embossed images (virtually irradiated from 8 directions) are sequentially displayed to the user to provide a composite moving image of particular features that induces visual illusions (i.e., pseudo-rotational and persistent of vision). Conventional feature enhancement processing has the problem of image degradation. This optical illusion inducement provides image enhancement/sharpening while maintaining the quality of the original image. In addition, using DFT to calculate spatial frequency components, our system can quantitatively and objectively evaluate image visibility, which is evaluated subjectively in conventional methods.

Expected Applications

- Crack inspection of concrete structures.
- Interpretation, detection and graphing of crack propagation (in RC beam bending/shear test videos, etc.).
- Inspection aid in dark places (tunnel, etc.) (IR image acquisition and analysis available).
- Real-time image feature enhancement for drone videos

Challenges in Implementation

- Development of more portable systems, e.g. mountable on a UAV.
- Application to ultraviolet cameras and hyperspectral cameras.

What We Expect from Companies

Seeking for a joint research companies, local government or structure maintenance firms in evaluating the VIS system's applicability.

Future Developments

From April 2017 VIS system sales start
From June 2017 Application of concrete surface inspection VIS system (including UAV video)
From September 2019 Examination of function expansion of VIS system
From December 2020 Implementation of VIS version upgrade
From January2020 Expansion of applicable fields of VIS system, industry-academia collaboration activities (Various videos and still images)

■Intellectual Property:
Japanese Patent No. 04868509, Japanese Patent No. 05046119, Japanese Patent No. 05246770, Japanese Patent No. 5769295, Japanese Patent No. 6021053, Japanese Patent No. 6742036
■Patent license agreement entered into with four companies.
■Technical instruction contracts are available.

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2022.04

Environment

CO_2 capture, storage and release technology using photoenergy

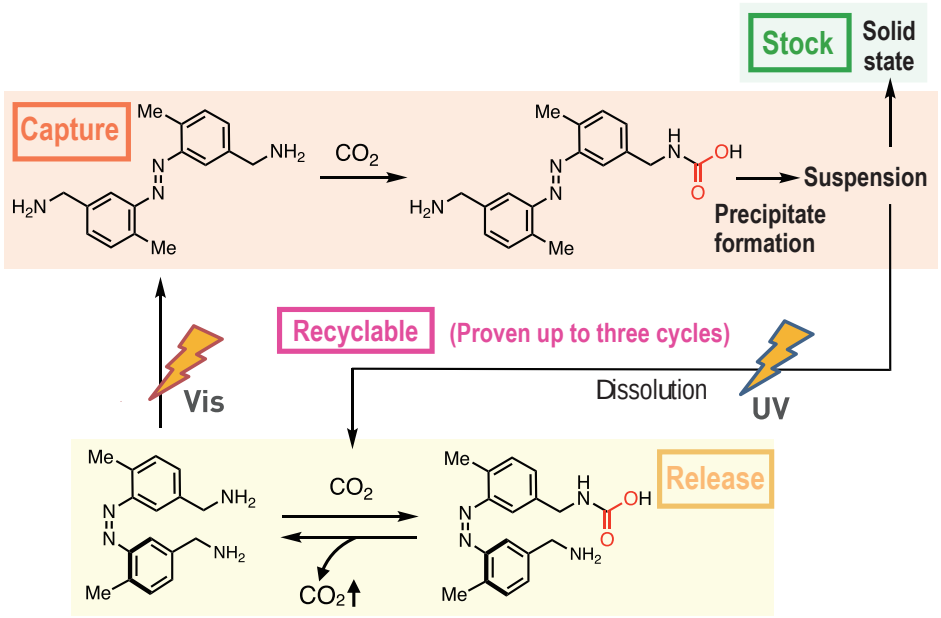
Tatsushi IMAHORI (Associate Professor, Department of Industrial Chemistry, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

In the Earth's carbon cycle, atmospheric CO_2 has been greatly increasing. Unless appropriate measures are taken to reduce atmospheric CO_2, CO_2 may increase further in the atmosphere to exacerbate global warming and deplete fossil carbon resources. To resolve the increase of the atmospheric CO_2, there is demand for developing technologies that capture CO_2 and convert it into usable materials as carbon resources with net zero CO_2 emissions. With the aim of demonstrating the technologies, in this research we have developed a chemical absorption method that uses photoenergy to capture, storage and release CO_2.

Summary of Research

In this research we have developed a molecule that changes its structure with optical photoenergy. Photo-irradiation switches the chemical state of this molecule reversibly between two states: one is outstanding at absorbing CO_2 and the other is poor. Using this property, we have succeeded in efficiently controlling the capture, stock and release of CO_2 by photo-irradiation arbitrarily and repeatedly.



Comparison with Conventional or Competitive Technologies

- [Conventional situation] Energy-consuming processes such as heating/decompression are required to release CO_2, which induces problems such as indirect CO_2 emissions via consumption of fossil energy, high energy cost, and limited available treatment facilities.
- [This technology] It uses limitlessly available sunlight without consuming exhaustible fossil energy to comprehensively reduce CO_2.

Expected Applications

- Capture/storage of CO_2 from flue gas of factories such as thermal power plants and from the atmosphere
- Promotion of growing plants with captured CO_2 (plant factories, plastic greenhouses and plant culturing)
- CO_2 cycling in living spaces (closed environments, underground spaces, submarines and space stations)

Challenges in Implementation

- Search for molecules more efficient at CO_2 capture/release and stabler in CO_2 storage (especially improvement of CO_2 release efficiency)
- Development of a system that uses the renewable energy of sunlight
- Expansion of the operating scale
- Development of a prototype equipment (instrument development)
- Improvement of analysis accuracy (equipment development)

POINT

- **Achieves CO_2 capture/release without heating/decompressing process → Reduction in CO_2 recycling costs and expansion of applications of CO_2 capture/utilization technologies**
- **CO_2 recycling technology that does not use exhaustible fossil energy**
- **Enables comprehensive CO_2 reduction in the atmosphere, leading to climate change mitigation**

What We Expect from Companies

- Collaboration in development of separation/focusing techniques for using UV/visible light in sunlight
- Joint development of a prototype equipment
- Improvement of analysis accuracy (joint development of an equipment)
- Supply of molecules in large amounts for practical use

Future Developments

Improvement of the capture/release efficiency by optimizing the structure
Evaluation and improvement of durability
Development of a sunlight utilization system
Completion of a prototype equipment

■ Associated System: JST-Mirai Program
"Realization of Low-Carbon Society by creating Game Changing technology"
■ Intellectual Property: Japanese Patent Application No. 2019-036824
■ Sample: Available

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Pharmacog-enomics

Development of molecular targeted medicines using Ridaifens (RIDs) from G1 to G5 synthesized in TUS

Isamu SHIINA (Professor, Department of Applied Chemistry, Faculty of Science Division I, Tokyo University of Science)

Purpose of Research

Our synthetic team is researching reaction methods that can improve the synthetic yield of pharmaceutical products to the maximum. Ridaifen (RID) can be prepared readily from aromatic aldehydes, allylic nucleophiles, and aromatic nucleophiles in the presence of Lewis acid catalysts by the three-component coupling reaction which was developed at our laboratory as the key process. Development research on drugs for treating leukemia, cancer, osteoporosis, and hyperlipidemia, as well as antimicrobial agents using this agent, is ongoing. Furthermore, a compound that exhibits inhibitory action on cancers that have become resistant to "Velcade," a therapeutic for multiple myeloma, has been discovered. We have a variety of RIDs that have structural features designed from the first generation (G1) to the fifth generation (G5).

Summary of Research

To date, we have provided a compound library of RIDs, which are compounds originally developed at our university using the three-component coupling reaction, and explored several lead compounds for new drugs through investigating structure-pharmacological activity correlations. Ridaifen-B (RID-B) exhibits antitumor activity and outstanding cytostatic effects on certain cancer cell lines.

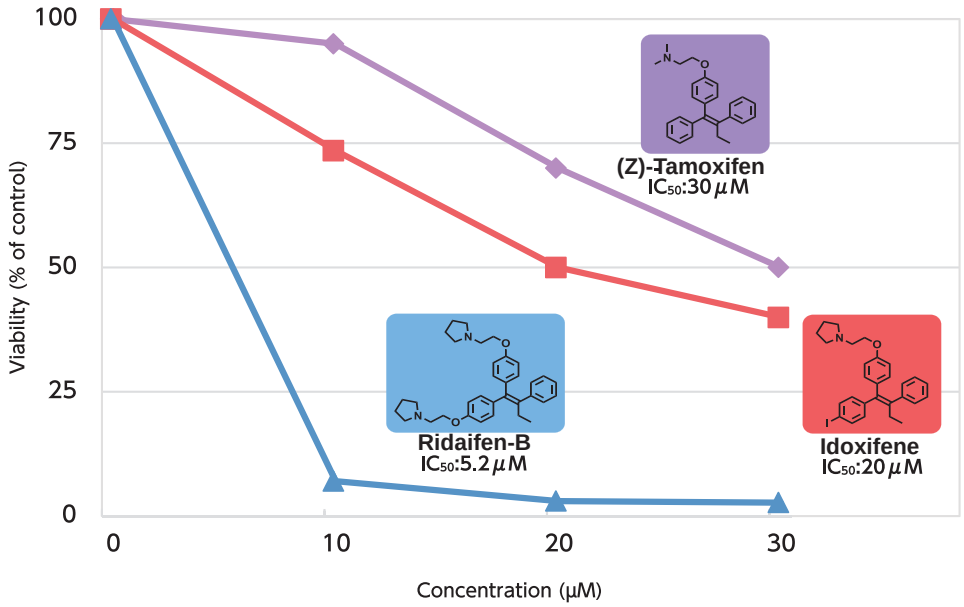


Figure: Potent antitumor activity of ridaifen-B

Points

- **High-efficiency synthesis of Ridaifens using the three-component coupling reaction developed at our university**
- **Low-cost synthesis**
- **Construction of a library of artificial compounds**

Comparison with Conventional or Competitive Technologies

○ Existing (examples)

- Anticancer agent, paclitaxel (Taxol®): Synthesized in 51 steps
- Anticancer agent, M-COPA, under development at our laboratory: Synthesized in 20 steps

○ This research

- "Ridaifens": Synthesized in 4 to 10 steps

Expected Applications

- Therapeutics for leukemia
- Anticancer agents
- Therapeutics for osteoporosis
- Therapeutics for hyperlipidemia

Challenges in Implementation

- Analysis of mechanism
- Development from in vitro to in vivo
- Acquisition of POC in preclinical studies
- Optimization of compound structure
- Establishment of mass-synthesis method

What We Expect from Companies

- Cooperation in exploration of uses
- Cooperation in performance of in vivo studies
- Joint application for large-scale AMED research funds
- Technical cooperation with GLP-level synthesis and GMP synthesis

Future Developments

March 2015 Start of marketing (RID-B: leading compound)
March 2019 The total synthesis yield achieved 50%.
March 2021 Candidate development compound: GLP-level synthesis
March 2022 Preclinical studies of the candidate development compound

- Associated system: AMED Project for Advanced Drug Discovery and Development
- Award: Award for Science and Technology, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology 2015
- Intellectual Property: Patent No. 05234558 "Anticancer agents containing tamoxifen analogues as active ingredients"
- Sample: Supply is possible after conclusion of contract.

Nanotech-nology

New mechanical stress sensing rubbers from paper materials

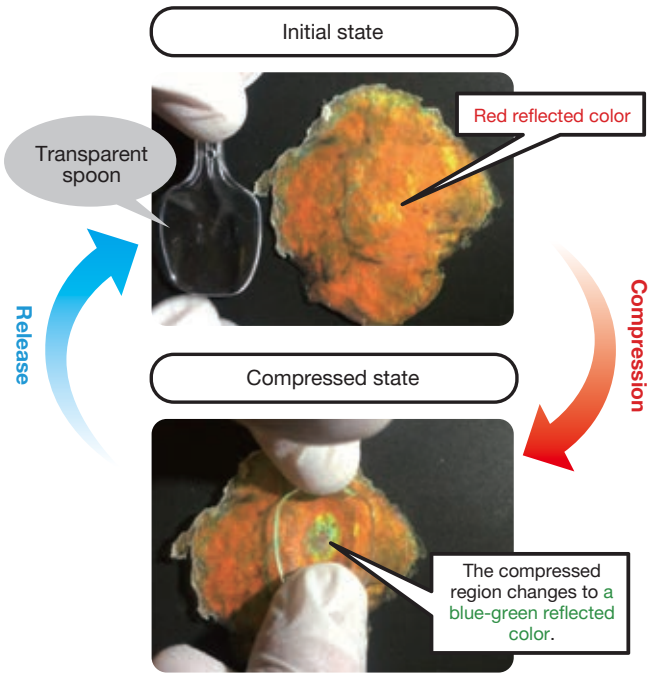
Seiichi FURUMI (Professor, Department of Applied Chemistry, Faculty of Science Division I, Tokyo University of Science)

Purpose of Research

Cellulose, the main component of paper, cotton and wood, is a natural polymer in which glucose is polymerized as a straight chain, and it has long been a familiar material in our daily lives. In this study, we synthesized a new cross-linking cellulose derivative into which a functional group has been introduced that has an unsaturated bond in the lateral chain; through this means we succeeded in producing a cellulose liquid crystal elastomer film that has both special visible light reflection properties and rubber elasticity. Furthermore, we also discovered that this can be used for strain sensors capable of sensing mechanical pressure in real time.

Summary of Research

In this study, we have developed a new rubber material (elastomer) that can sense mechanical pressure through reflected color, and which uses cellulose~~t~~ he main component of paper~~a~~ s its raw material. Focusing on the features of low cost cellulose, which is friendly both to the environment and human body, we have created a new cellulose liquid crystal elastomer film that~~du~~ e to its unique molecular designe~~-~~ xhibits Bragg reflection throughout the whole visible wavelength range, and also possess rubber elasticity. For example, when mechanical compressive force is applied to this cellulose liquid crystal elastomer film, one of its characteristics is that reflected color changes reversibly from red to blue-green in the compressed region only, allowing verification of the visualization of stress sensing.



Comparison with Conventional or Competitive Technology

- Conventional: Exhibits reflection characteristics derived from cholesteric crystals.
- This study: Achieved rubber elasticity in addition to reflection characteristics.
- Conventional liquid crystal elastomer: Manufactured mainly by chemical synthesis performed on materials derived from petroleum.
- Liquid crystal elastomer in this study: Can be created using cellulose, a natural polymer, as the raw material.

Expected Applications

- Sensors for social infrastructure capable of detecting distortion, such as in concrete.
- Wearable sensors that can be affixed to human skin.
- Inexpensive reflective displays with a low burden on the environment.

Challenges in Implementation

- Quantitative evaluation of interrelation between rubber elasticity and reflection characteristics of cellulose liquid crystal elastomer film.
- Optimization of cellulose liquid crystal elastomer film conditions such that it exhibits excellent rubber elasticity.

What We Expect from Companies

- We are hoping to conduct collaborative research with private companies specializing in chemistry, precision instruments, architecture, and medical care.

Points

- **Raw material is cellulose,w hich is abundant on earth,an d is friendly to the human body and environment**
- **The cellulose liquid crystal elastomer film,w ith its special reflection characteristics and rubber elasticity,c an be prepared using a simple chemical reaction**
- **It can be used not only in displays and as a coloring material,b ut also as a distortion sensor**

Future Developments

In cooperation with various private companies, we aim not only to research and develop new cross-linking cellulose derivatives but also use them in sensors and displays.

- Associated System: Grant-in-Aid for Scientific Research, Basic Research (B), JST Adaptable and Seamless Technology Transfer Program through Target-driven R&D (A-STEP)
- Intellectual Property: Japanese Unexamined patent Application Publication No. 2018-048289 Japanese Patent Application No. 2018 0106J apanese Patent Application No. 2018 0829
- Prototype: Available
- Sample: Available
- Awards: 12th Funai Academic Award, 2nd IMRA JAPAN Award, and 10 others

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Pharmacog-enomics

Development of drug/antigen administration system using self-gelatinizable nucleic acid technology

Makiya NISHIKAWA (Professor, Department of Pharmacy, Faculty of Pharmaceutical Sciences, Tokyo University of Science)

Purpose of Research

A sustained release drug delivery system that continuously releases any incorporated therapeutically active substance is a useful way to obtain long-term efficacy. In terms of application to living bodies, substances should be highly biocompatible, biodegradable and injectable. In this research, we selected DNA as a material fulfilling all these requirements. In addition, since DNA stimulates innate immunity depending on its base sequence, we foresee being able to develop systems with different properties such as immunostimulatory and immunologically inert systems.

Summary of Research

Use of the property of DNA to form duplex structures between complementary DNA strands makes it possible to design multipodal DNA nanostructures that can form hydrogels by self-organization. The new technique involves preparing hydrogels consisting only of DNA, salts and water by self-organization, and makes it possible to develop delivery systems that contain drugs and proteins such as antigens for sustained release.

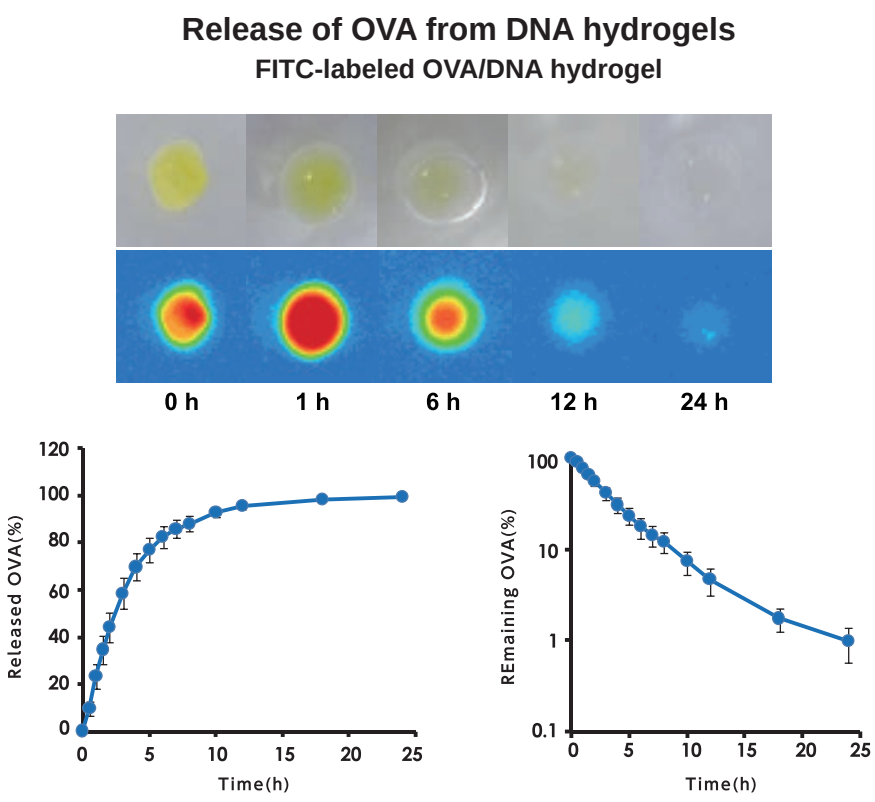

Figure: Release of OVA from DNA hydrogels (FITC-labeled OVA/DNA hydrogel)

Comparison with Conventional or Competitive Technologies

- DNA hydrogels: Biocompatible and biodegradable
- Possible to control physiological activities by controlling base sequences and steric structures
- Possible to design DNA hydrogels with immunoadjuvant activities

Expected Applications

- Sustained release drug delivery system
- Immunoadjuvant
- Cellular administration adjuvant

Challenges in Implementation

- Need for safety evaluations of individual nucleic acids
- Studies to optimize unit structures for each purpose of use, incorporated material and administration method/route
- Evaluation of efficacy in clinical studies

What We Expect from Companies

- Introduction to vaccines targeted for cancers and infections
- Assisting drug development/formulation research
- Joint clinical development of drugs by applying this technique

POINT

- **Gelatinization does not require heating or chemical reactions**
- **Administration by injection is possible with easy sol-gel transition by pressurization**
- **The substances are biodegradable**

■ Intellectual Property: WO2012/144560 “Self-gelatinizable nucleic acids”
■ Prototype: Present

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Bio

High-throughput screening and identification of novel chemicals enhancing plant defense against pathogens/pests

Kazuyuki KUCHITSU (Professor, Department of Applied Biological Science, Faculty of Science and Technology, Tokyo University of Science)

Nobutaka KITAHATA (Assistant Professor, Department of Applied Biological Science, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

Control of pests and diseases is a critical issue in crop production, since biotic factors cause economic losses of $220 billion. Since traditional chemical pesticides have disadvantages such as the emergence of drug resistant organisms and the toxicity to beneficial symbiotic organisms and insects, i.e. possible disturbance of ecosystem, an entirely novel approach to protect crops from pathogens and pests is needed.

Plant defense activators, chemicals that boost defense/immune responses of plants, have excellent advantages as new type of low-toxicity pesticides which does not lead to emergence of drug resistant organisms. The plant immune system consists of two major pathways, involving salicylic acid (SA) and jasmonic acid (JA)/ethylene (ET). Only a few plant defense activators that activate only the SA pathway are available in the market, and these have only narrow application, mostly limited to rice pests.

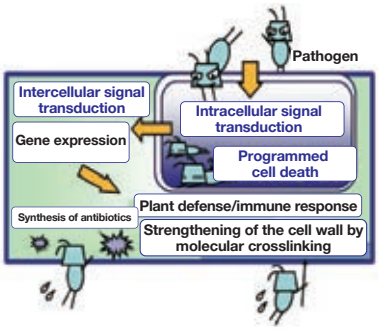
Summary of Research

Advantage of plant activator as pesticide

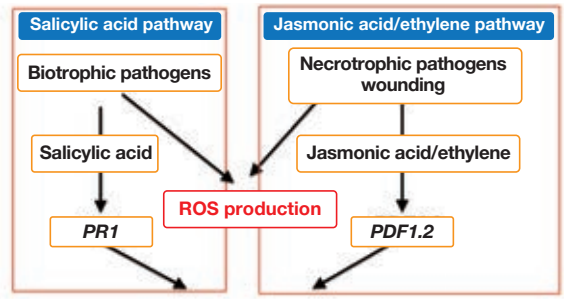
Fungicides/insecticides
Chemicals directly kill pathogens or pests

Plant defense activators
Chemicals activate plant's immune system

Plant immune responses



New plant defense activators for jasmonic acid/ethylene pathway



Target of known plant defense activators

New type of plant defense activators for this pathway

We have developed a novel high throughput screening system for plant defense activators (PCT filed), and have discovered novel putative plant defense activators that activate the JA/ET pathway or both of the above pathways, and that are expected to enhance defense responses against a wider spectrum of necrotrophic pathogens and pests.

Comparison with Conventional or Competitive Technology

Traditional chemical pesticides have disadvantages of toxicity to beneficial symbiotic microorganisms and insects, as well as disturbance of eco-system. In contrast, Plant defense activators, chemicals that boost defense/immune responses of plants, have excellent advantages as new type of low-toxicity, environment-friendly pesticides to avoid emergence of drug resistant organisms. We have developed a novel efficient high throughput screening system for plant defense activators.

Expected Applications

- Development of novel pest control methods for organic and pesticide-free farming.
- Reduction of the dose of traditional pesticides by the enhanced plant defense/immune responses.

Challenges in Implementation

- Identification/optimization of more lead compounds from a larger chemical library.
- Field test of the identified activator candidates.

What We Expect from Companies

Partnership opportunities are open to interested corporations.

Points

- **Plant defense activators are a novel type of pesticides which can preserve the ecosystem and environment in a field and avoid the emergence of drug resistant organisms**
- **We have established a high-throughput system for screening plant defense activators**
- **We have identified putative novel plant defense activators that can activate two major immune pathways in plants**

Future Developments

In vivo (whole plant) testing of the identified chemicals (secondary evaluation) is now going on.
Select high-potency activator candidates (2015).
Field test start (2016).

■ Intellectual Property: JP2013-501828 "Method for plant defense activators, plant defense activators, and method for enhancing immune responses"

Energy

Development of new cathode materials for magnesium secondary battery

Yasushi IDEMOTO (Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

In recent years, research on high-performance next-generation secondary batteries has been underway to address safety issues and limitations of electricity storage capacity. In particular, research is being conducted both in Japan and abroad on magnesium secondary batteries that use magnesium ions as mobile ions. Magnesium secondary batteries have the potential to achieve a high energy density, but to date no promising materials have been discovered as cathode materials for them. This research is aimed at exploring cathode materials for magnesium secondary batteries that have better characteristics than the cathode materials used for existing lithium-ion batteries.

Summary of Research

Aiming to bring about more-advanced generation high-capacity secondary batteries that surpass lithium-ion batteries, we have successfully made new cathode materials for magnesium secondary batteries. These batteries are said to have the potential for a theoretical cathode capacity 1.5 times higher than lithium-ion batteries. We have developed two types of cathode active materials for magnesium secondary batteries: a spinel type (initial discharge (actual example): 39 mAh/g) and a rock-salt type (initial discharge (actual example): 160 mAh/g).

Comparison of cathode material performance between magnesium secondary batteries and lithium-ion batteries

Battery	Cathode material	Usage	Theoretical capacity (mAh/g)	Output	Energy density (Wh/kg)	Safety	Cost	Stable supply of raw material
Mg	Rock-salt type $MgNi_{0.8}Co_{0.2}O_2$	Stationary	470	Under development	1175	◎	◎	◎
Mg	Spinel type $MgCo_2O_4$	Stationary	260*	Under development	650	◎	◎	◎
Li	Layered rock-salt type $LiCoO_2$	Stationary, portable	274 (140*)	◎	530	△	×	△
Li	Spinel type $LiMn_2O_4$	Stationary, portable	148 (110*)	◎	440	△	○	○
Li	Layered rock-salt type $Li(Ni_{1/3}Co_{1/3}Mn_{1/3})O_2$	Stationary, portable	280 (200*)	○	700	△	△	△

* The spinel type has a theoretical capacity of 520 mAh/g when phase transition to the rock-salt type is taken into consideration.

Points

- High capacity and high energy density
- Low cost (free of rare metals)
- High safety

Comparison with Conventional or Competitive Technologies

- The maximum cathode capacity of lithium-ion batteries (existing technology) per unit weight of cathode active material is 250 mAh/g.
- The cathode materials used in this technology already have sufficient potential as cathode materials for future secondary batteries. However, the electrolyte and anode material to be used in combination with these cathode materials have not been developed yet.

Expected Applications

- Safe stationary storage battery
- Low-cost (free of rare metals) portable storage battery

Challenges in Implementation

- Development of electrolyte with a high withstand voltage for detaching Mg in the rock-salt type
- Exploration of new compositions of spinel-type structures that can operate with a combination of high-capacity and high-cycle characteristics and establishment of ways to operate them for practical use

What We Expect from Companies

We think this technology can be realized by researching material compositions that can reach the theoretical capacity.

We hope to conduct joint research with companies that have technology for synthesizing oxide ceramics.

It would be effective for companies that are developing electrolytes or have technology to produce advanced battery cells to adopt this technology.

Future Developments

April 2013	Start of research
December 2014	Successful development of spinel type
April 2015	Successful development of rock-salt type
April 2016	Production of prototype battery

- Associated System: JST Strategic Basic Research Programs Advanced Low Carbon Technology Research and Development Program
- Intellectual Property: Japanese Unexamined Patent Application Publication No. 2016-164103 “Method for producing Magnesium composite oxides,” Japanese Unexamined Patent Application Publication No. 2017-004770 “Positive electrode active material for Magnesium secondary battery, positive electrode for Magnesium secondary battery, and Magnesium secondary battery”
- Sample: Available

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2022.04

Material

Silica hollow particles prepared with facile process and their application

Hideki SAKAI (Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

Silica hollow particles have excellent characteristics such as low density, low refractive index, substance encapsulation ability, etc., and are used in lightweight materials and heat insulation materials. If the particle size can be controlled to be 100 nm or smaller, they can be expected to be applied to anti-reflection coatings and the carriers of drug delivery systems (DDS). One method of synthesizing silica hollow particles is the soft template method, which uses molecular assemblies formed by surfactant as templates, and research into this method has been actively conducted in recent years as this process is easy to do and substances are easily encapsulated in the hollow space. However, the low dispersion stability of the manufactured hollow particles has been a challenge in improving this method. In this study, we used vesicles as a soft template and aimed to synthesize silica hollow nanoparticles with excellent dispersion stability by changing pH stepwise during the forming period of silica.

Summary of Research

This technology is related to the soft template method for producing hollow silica particles, using vesicles formed by surfactant as templates. By changing the pH of the manufacturing process stepwise, hollow silica particles with a uniform diameter of 100 nm or below can be obtained. In this method, vesicles are used as templates so that various substances can be supported inside the hollow silica particles. By controlling retention and release, the particles can be made to adapt to various applications.

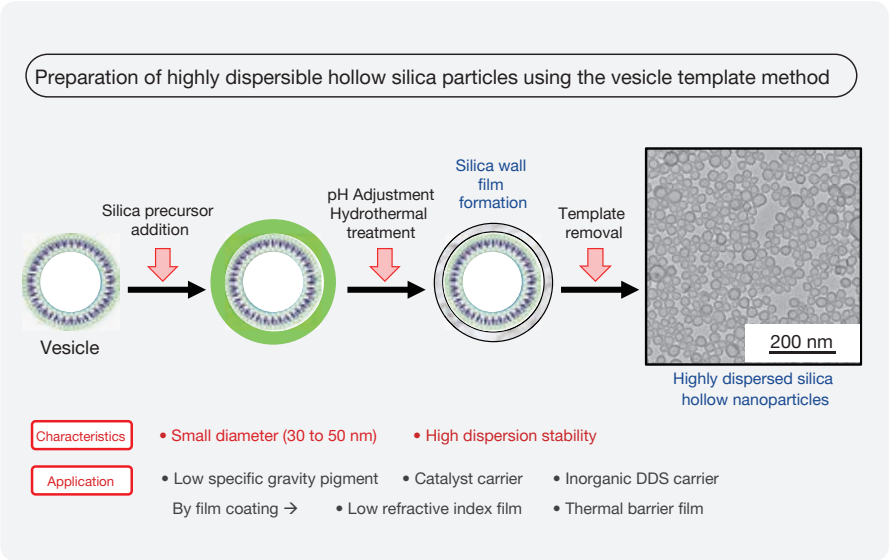


Figure: Preparation of silica hollow nanoparticles with vesicles as templates

Points

- **Nano-sized hollow particles can be prepared by a facile process**
- **Substances can be supported inside hollow silica particles**
- **Excellent dispersion stability is retained in water system (Stable dispersion for 1 year or more)**
- **Suitable for coating processes etc.and superior in environmental affinity**

Comparison with Conventional or Competitive Technology

- Conventional: The majority is manufactured by the hard template method.
- Conventional method: It is difficult to encapsulate substances inside the silica particles, and applications were limited to their properties as “hollow” silica particles.
- This technology: Both “hollow” and “encapsulating substances” silica particles can be developed to meet various needs.

Expected Applications

- Inorganic anti-reflection film making use of low refractive index characteristics
- Inorganic DDS material for diagnosis
- Development into thermal barrier/thermal insulation paint
- Supported type catalyst

Challenges in Implementation

- Small amount of surfactant remains even after washing → Establishment of complete removal method

What We Expect from Companies

We seek cooperation with industries in fields working in low refractive index inorganic films, transparent thermal barrier films, highly dispersible pigments, etc. in hollow particle formation and application of not only silica, but also other various materials.

Also, we hope to cooperate with industry for the development of silica particles for DDS, which include diagnostic reagents.

Future Developments

November 2017	Start cooperation with companies
October 2018	Completed method for preparing hollow particles other than silica
January 2020	Start sales of silica hollow particles

- Awards: JACM Annual Conference, Gold Poster Awards
- Intellectual Property: Japanese Patent Application No. 2014-166604, Japanese Unexamined patent Application Publication No. 2016-041643 “Method for Producing Hollow Silica Particles and Hollow Silica Particles”
- Prototype: Not available
- Sample: Available

Disaster prevention

IoT system for disaster prevention, evacuation, and mitigation on urban buildings

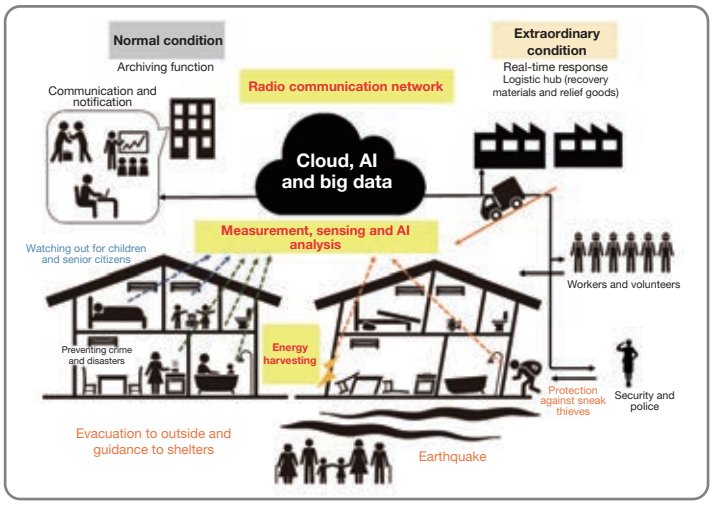
Takumi ITO * (Professor, Department of Architecture, Faculty of Engineering, Tokyo University of Science *Research leader)
Takahiro YAMAMOTO (Professor, Department of Physics, Faculty of Science and Technology, Tokyo University of Science)
Takayuki KAWAHARA (Professor, Department of Electrical Engineering, Faculty of Engineering, Tokyo University of Science)
Mikio HASEGAWA (Professor, Department of Electrical Engineering, Faculty of Engineering, Tokyo University of Science)
Takashi NAKAJIMA (Associate Professor, Department of Applied Physics, Faculty of Science Division I, Tokyo University of Science)
Yoichiro HASHIZUME (Associate Professor, Oshamambe Division, Institute of Arts and Sciences, Tokyo University of Science)

Purpose of Research

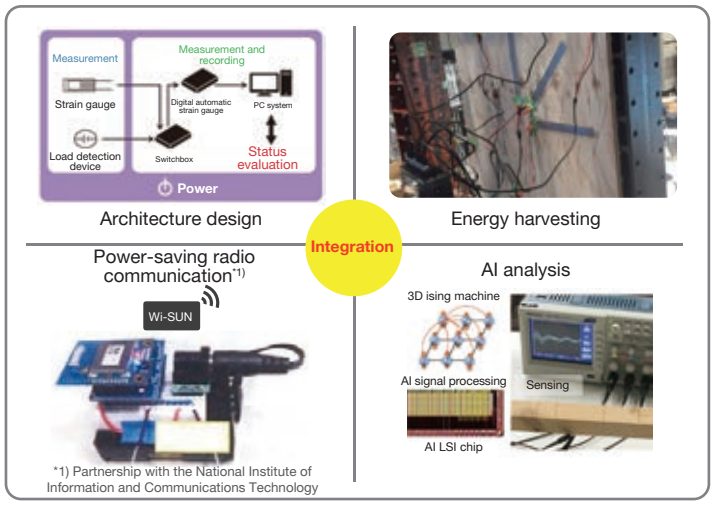
Japan is at the forefront of seismic technology. Still, the damage from recent earthquakes calls for viable measures for ensuring safety in damaged buildings and cities, going beyond the traditional assumption of the perfect avoidance of seismic damage. The development of an intelligent house in this research applies the concept of IoT so that buildings can sense and report any pain or discomfort.

Summary of Research

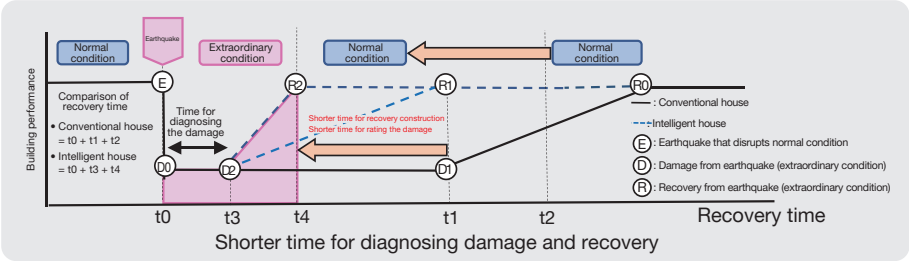
We propose a new IoT-based building system that detects, analyzes, diagnoses and notifies human activities and damage from earthquakes. Such an intelligent house features: 1) energy harvesting to supply power to sensor and radio devices, 2) power-saving radio communication network and 3) AI analysis and diagnosis system in order to effectively prevent disaster (seismic design of building), facilitate evacuation (quake diagnosis, life protection, and relief) and mitigate disaster (resilience to ensure rescue and quick recovery of the building).



Schematic illustration of an intelligent house applying IoT



Element technologies for achieving an intelligent house



Shorter time for diagnosing damage and recovery

Characteristics of Our Intelligent House

- Energy harvesting for powering sensor and radio devices
- Power-saving radio communication network
- Big data analysis with AI

Advantages of Our Intelligent House

- Quick information of damage and recovery status
- Quick recovery of affected building
- Monitoring of children and senior citizens, and protection against crimes, sneak thieves and disasters

What We Expect from Companies

- Joint research on element technologies
- Proposal of new research fields

Points

- **An intelligent house that embodies IoT**
- **Energy harvesting,p ower-saving radio communication, and AI analysis**
- **Quicker damage diagnosis and recovery from earthquakes**

Future Developments

- Consolidation of element technologies based on discussing performance target and on-site research
- Consolidation of architectural design method for installing an IoT system

■ Associated System: JST Strategic Basic Research Programs (Sakigake)
■ Intellectual Property: Patent application PCT/JP2016/080628
■ Prototype: A demonstration unit is available
■ Sample: A test building for on-site research can be visited

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2022.04

Bio

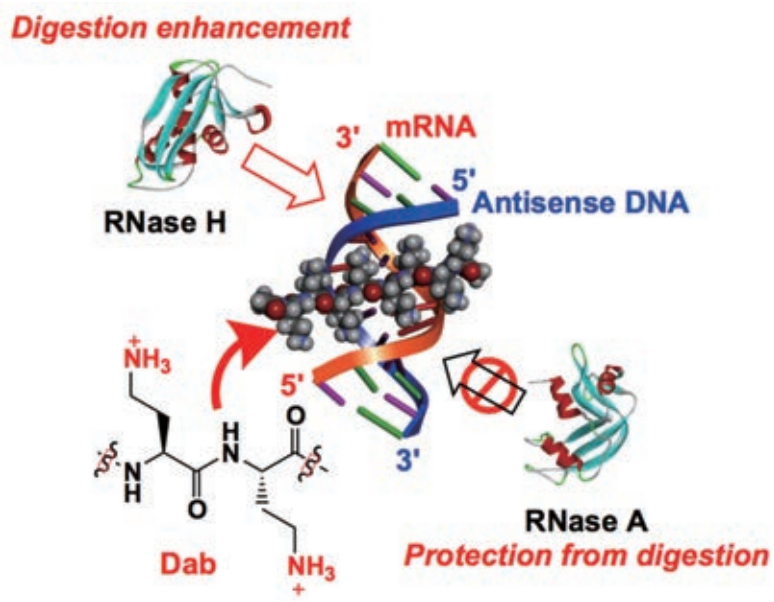
New molecular technologies for stabilization and activation of nucleic acid drugs

Takeshi WADA (Professor, Department of Medicinal and Life Science, Faculty of Pharmaceutical Sciences, Tokyo University of Science)

Purpose of Research

Recently, there has been an increase in the development and research on nucleic acid drugs, such as antisense nucleic acid, ribonucleic acid interference (RNAi) medicine, and aptamers. Problems that must be solved for implementation of nucleic acid drugs include improvement in in vivo stability of nucleic acid molecules and establishment of delivery technology. As one methodology to solve these problems, this research focuses on the development of artificial cationic molecules that specifically bind to nucleic acid drugs with double-stranded nucleic acid, such as short interfering RNA (siRNA) and deoxyribonucleic acid (DNA)/RNA heteroduplex oligonucleotide (HDO), and not only protect these molecules from degradation enzymes in vivo but also improve physiological activity itself.

Summary of Research



Novel artificial cationic oligosaccharide and artificial cationic peptide

Points

- Binds to double-stranded nucleic acid drugs and significantly improved thermodynamic stability and nuclease resistance of the double strand
- Improves activity of RNase H,w hich digests target mRNA

Conventionally, cationic carrier molecules used as drug delivery system (DDS) for nucleic acid drugs require excessive administration. The ratio of the number of cationic functional groups and number of anionic functional groups in a complex is expressed as the N/P ratio, but normally, N/P of 2 or above is required to ensure sufficient in vivo stability of nucleic acids. We are developing molecules that specifically recognize and strongly bind to nucleic acid molecules with defined higher-order structure in this research. In particular, anticipating application to double-stranded nucleic acid drugs such as siRNA and DNA/RNA heteroduplex oligonucleotide, we have developed artificial cationic molecules (artificial cationic oligosaccharides and artificial cationic peptides) that recognize specific higher-order structure of such double-stranded nucleic acids and specifically bind to them.

It was found that cationic peptides that recognize defined structures of double-stranded nucleic acids and selectively bind to them can selectively inhibit the activity of nucleic acid-degrading enzymes such as RNase A, and conversely, has the ability to improve specific nuclease activity such as RNase H. Using the cationic peptides developed in this research, it is anticipated that effective methodology to achieve stabilization and high activity of nucleic acid drugs can be developed.

Future Developments

Nuclease resistance, RNase H activity, intracellular introducing efficiency, and gene-expression suppression effect of artificial cationic molecule and double-stranded nucleic acid drug complexes have been evaluated in vitro.

In the future, we plan to conduct in vivo functionality evaluation, synthesize conjugates with ligand molecules, and evaluate organ-specific delivery and gene-expression inhibition.

■ Associated System: JST-CREST
Establishment of Molecular Technology towards the Creation of New Functions
* This research is in collaboration with Professor Takanori Yokota at Tokyo Medical and Dental University

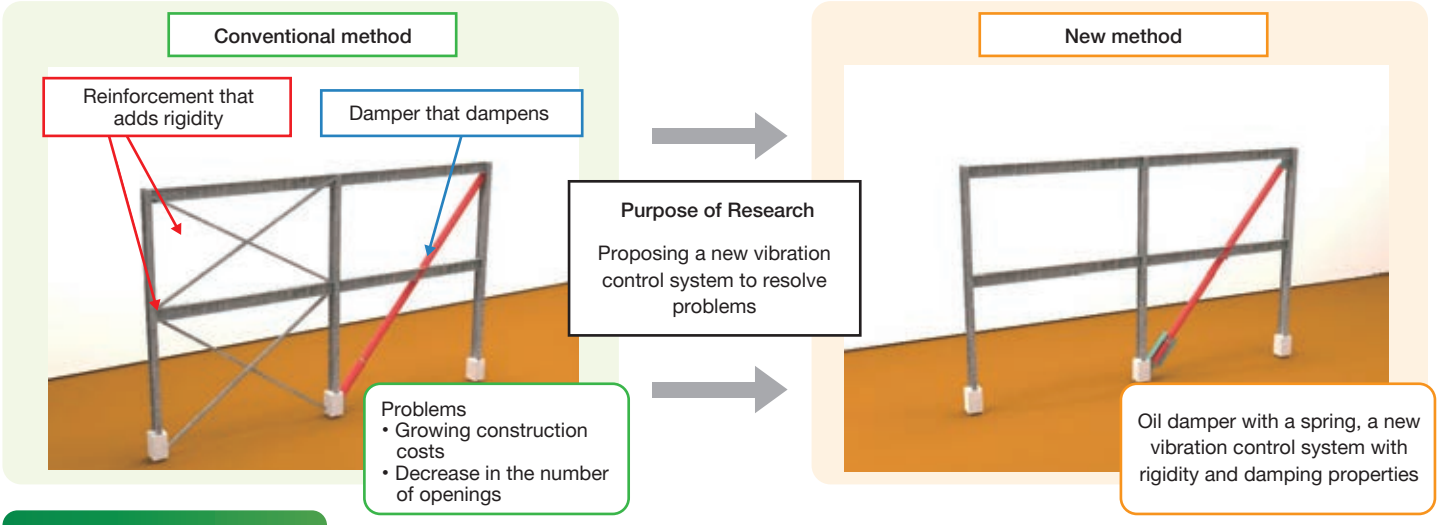
Architectural devices

Development of new oil damper for architectural vibration control and experimental research on structural characterization

Osamu TAKAHASHI (Professor, Department of Architecture, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

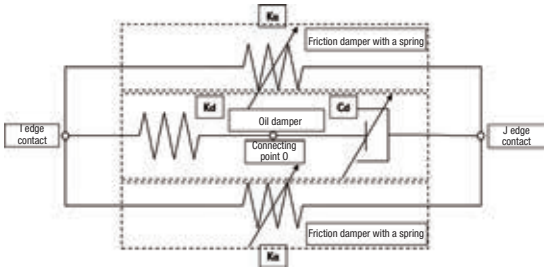
Develop a new vibration control system to solve problems with methods used when reinforcing buildings based on old earthquake standards.



Summary of Research

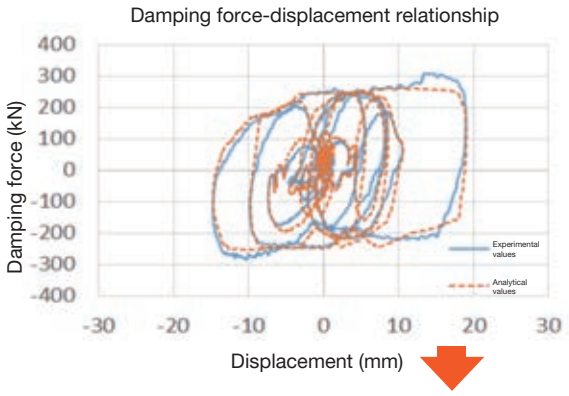
The oil damper with a spring is a new vibration control damper that combines an oil damper for building vibration control and visco-elastic and highly damping materials.

Oil damper with a spring as a test body



Analytical model of the oil damper with a spring

Comparison of the results of experiments and those of analysis



- With respect to random input waves, the results of analysis enable tracing of the results of experiment with sufficient accuracy.
- Use of the analytical model of the proposed oil damper with a spring enables analysis of vibration in the structural design of actual buildings.

Points

- **The new oil damper with a spring is more rigid and damping than the conventional type of building oil damper**
- **At the time of design, temperature dependency does not need to be considered in the range of temperatures at which the damper is expected to be used (room temperature to +50°C)**

Future Developments

We will examine the vibration characteristics and structural safety of the damper in order to apply it to actual buildings.

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2022.04

Architectural devices

Structural design and engineering for future buildings by unknown materials

Osamu TAKAHASHI (Professor, Department of Architecture, Faculty of Engineering, Tokyo University of Science)

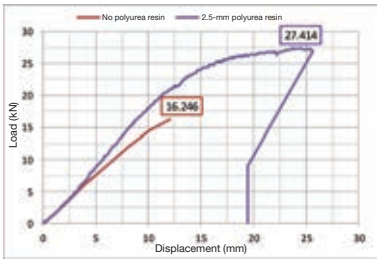
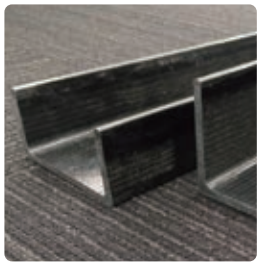
Purpose of Research

Our laboratory conducts research to find new materials not often used as structural members of buildings, and use them as architectural structural materials.

Usage as architectural structural materials

(1) **High-performance rope intertwined with high-strength aramid fiber**
(2) **Polyurea resin (synthetic resin coating)**
(3) **Carbon fiber reinforced plastic (CFRP)**

Summary of Research

Material	Outline	Key points	Usages, advantages and issues
 **High-strength aramid fiber (para-aramid fiber)**	 Used as a bracing member for timber framing	• High-strength aramid fiber is light and very strong in comparison with steel frames and other common structural members. • High-strength aramid fiber is highly flexible and can withstand acid and alkali.	**Usage** • Seismic reinforcement and maintenance **Advantages** • Lightness • Outdoor usage is possible. **Issues** • Weight reduction of joint parts • Jointing methods
 **Polyurea resin (synthetic resin coating)**	 **Relationship between load and displacement (timber)** Comparison based on the thickness of polyurea resin	• Polyurea resin is very strong and elastic. • The load-bearing capacity of a specimen with polyurea resin applied increases by up to 1.7 times compared with that of a specimen without polyurea resin applied.	**Advantage** • Increased bending strength and deformation-following characteristic **Issue** • Reinforcement of timber and concrete block walls
 **CFRP**	**Comparison of the physical values of CFRP and steel** CFRP (NCF): Tensile strength (kN/mm²) 0.60; Specific gravity (kg/m³) 1550 Steel (SS400): Tensile strength (kN/mm²) 0.40; Specific gravity (kg/m³) 7850 * NCF: Non-crimp fabric	• The tensile strength of CFRP is 1.5 times that of steel. • The specific gravity of CFRP is approximately one fifth that of steel. • CFRP is light and very strong compared with steel.	**Advantage** • Increased member strength • Reduced fixed load • Reduced seismic load • Reduction of transportation and construction cost **Issue** • Methods of jointing members • Usage in actual designs

Future Developments

Continuing research for practical use

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2022.04

Architectural devices

Structural design and consulting about aseismic isolation buildings

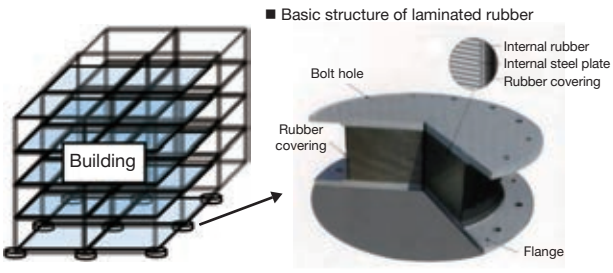
Osamu TAKAHASHI (Professor, Department of Architecture, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

We conduct research on seismic isolated structures that are effective against the risk of earthquake.

Problems with existing seismic isolators

- Laminated rubber with metal plugs: Negative effects of lead on humans and the environment
- High-damping rubber: Needed to be replaced due to the mislabeling incident



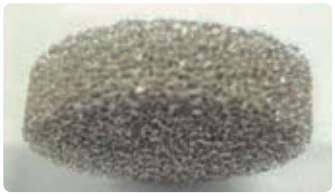
Research conducted in our laboratory

(1) Development of laminated rubber with the use of plugs made of materials that are not toxic to humans or the environment,an d can be manufactured and discarded at low cost

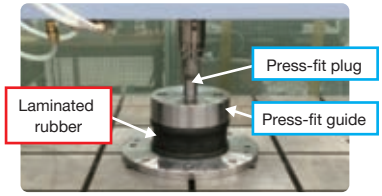
(2) Research on structural safety when laminated rubber is replaced

Summary of Research

(1) Development of laminated rubber with foam metal used as a plug

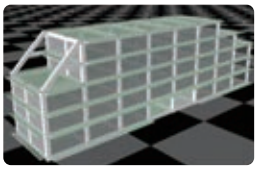


Foam metal

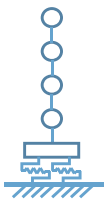


Press-fitting of a foam metal plug

Compression sheer test of laminated rubber



Three-dimensional model of an analytical building



Analytical model

Primary characteristic period (seconds) by eigenvalue analysis

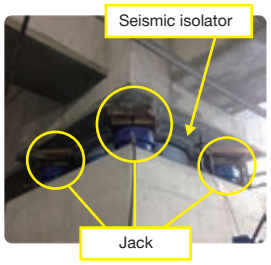
Laminated rubber	Longitudinal direction
eRB	2.71
LRB	3.21
HDR	4.36
SnRB	2.91
Foam metal and silicone rubber	**3.15**
Only foam metal	**3.42**

(White: Manufactured product, Yellow: Developed product)

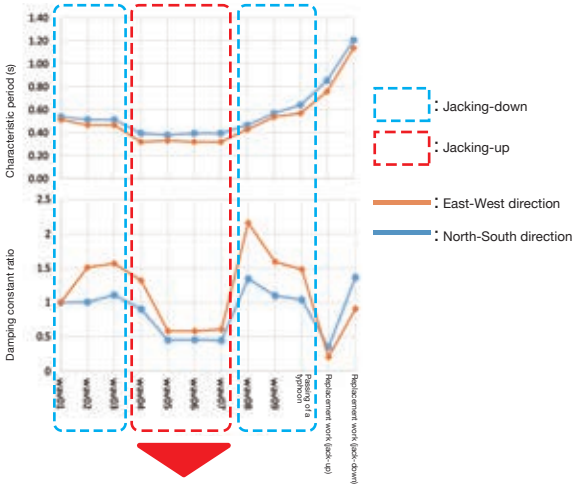
- The effect of seismic isolation of the developed product was confirmed.
- The damping function of the developed product was unsatisfactory.
- It is necessary to reconsider using nickel chrome and silicone rubber.

(2) Structural characteristics when replacing laminated rubber

When we replaced the laminated rubber, **we measured the microtremors** while the building was being jacked up and jacked down.



We evaluated **the natural period and the damping constant** through frequency analysis of the measurements.



During jacking-up,

(1) the natural period gets shorter and the rigidity gets larger, and

(2) the damping constant gets smaller.

Future Developments

Improving the performance of plugs for practical use

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2022.04

Functional materials

Ceramic electret for electrostatic vibration power generation

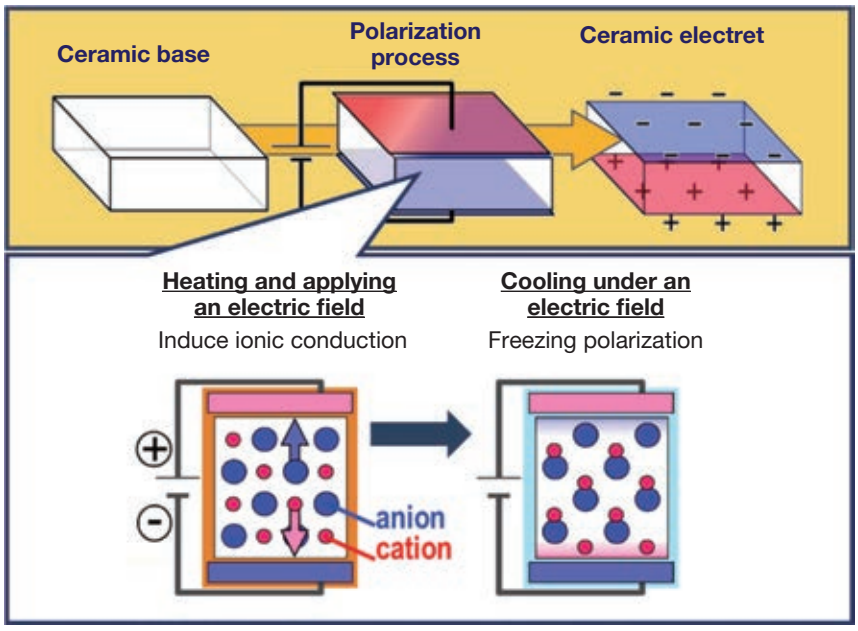
Yumi TANAKA (Associate Professor, Department of Industrial Chemistry, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

Some small-size vibration power generators use what is known as “environmental vibrations,” which are generated by the movement of people, vehicles, and machines, as a power source. Recently, there has been a move to put this type of generator to practical use. Electrostatic vibration power generation is a vibration-to-power conversion method that uses an electret, which is a material that stably holds static electricity. This research aims to develop a ceramic electret for electrostatic vibration power generation.

Summary of Research

While many types of electrets use polymers as the base material, this research uses a ceramic base material that exhibits properties that are in between those of dielectrics and ionic conductors depending on temperature. To turn a ceramic base into an electret, apply a DC electric field and heat to the material to induce ionic polarization in it, and then cool it under the electric field to room temperature to freeze the polarization. Using this method, we have developed an electret that holds a surface potential exceeding ± 4000 V.



Points

- Generates a surface electric potential of ± 4000 V or higher on a planar element
- Has a heat resistant property superior to polymers (maintains the surface electric potential up to about 80°C)
- The surface electric potential can be increased by laminating multiple films

Comparison with Conventional or Competitive Technologies

- Surface charge density is dramatically increased (double-digit increase or more).
- Surface charge stability is dramatically improved (semi-permanent).

Expected Applications

- Vibration power generators for devices with a power consumption of microwatts to milliwatts (Such as sensor nodes for wireless sensor networks)
- Special substrates that exhibit a peculiar selective adsorption property for ions and molecules using a local electric field

Challenges in Implementation

We have developed a high-performance bulk ceramic electret with a thickness of about 1 mm. Making a thin-film electret is the main challenge before this technology can be put to practical use. It is necessary to establish a technology that applies a high surface electric potential to a film with a thickness of tens of microns.

What We Expect from Companies

We hope to conduct a joint research program with a company that holds a ceramic thin film manufacturing technology or a company that is developing vibration power generators and plans to advance into the IoT market.

- Associated System: JST’s CREST program, Grants-in-Aid for Scientific Research
- Intellectual Property: Japanese Patent Application No. 2014-141797 “Electret Materials and Manufacturing Method,” and others
- Prototype: Completed

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2022.04

Device

Wearable healthcare devices based on printable electrochemistry

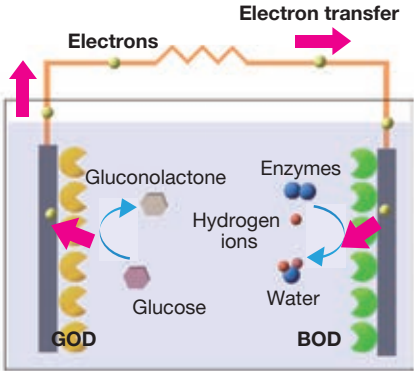
Isao SHITANDA (Associate Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science)

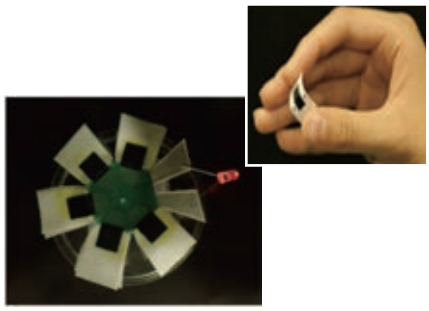
Purpose of Research

To develop thin biological information monitoring devices (wearable healthcare devices) equipped with self-driven biofuel cells, which generate electric energy at the same time as monitoring by using the biological substances found in sweat and urine. We will use advanced printing technologies to make wearable devices significantly thinner, lighter, more productive, and less expensive than the wearable devices that are already on the market, and we will make them able to catch the first signs of diseases, assist in day-to-day health management, prevent lifestyle diseases, and help manage other healthcare issues by measuring various vital signs (such as activity level, pulse (heart rate), and amount of sweat).

Summary of Research

This technology offers a mechanism in which the device serves as both the power source and the sensor. The device reacts with enzymes to generate electric energy using substances in body fluid such as glucose, and then it uses that energy to send signals from a transmitter. Furthermore, the devices are composed of inexpensive materials, such as paper, so they can be manufactured with a simple printing process.





Diaper battery

5 cells in series (0.34 mW)

Bandage battery

4x4 cells are arrayed (1 mW)

Comparison with Conventional or Competitive Technologies

We are proposing new self-driven wearable devices that contain a power generator that offers high biological compatibility and is easy on the human body, as well as being completely environment-friendly, convenient, and inexpensive.

Expected Applications

- Day to day health management and prevention of lifestyle diseases
- Prevention of heat stroke and measurement of fatigue level during sport activities and mountain climbing
- Monitoring of the health of workers in special working environments
- Reduction of the burden on caretakers by embedding the devices in diapers

Challenges in Implementation

We have confirmed that the urinal sugar cells are able to generate electric energy and wirelessly transmit data by using artificial urine. In the future, we need to implement and evaluate the devices in diapers.

What We Expect from Companies

We believe this technology will be beneficial for companies developing biosensors and those seeking to expand their businesses into the healthcare field.
We hope to collaborate with companies that have the technologies to communicate with wearable devices as well as companies that focus on integrating technologies into IoT systems.

Points

- **Enables measurement of the level of biological substances**
- **Costs less but has better performance than other methods of energy harvesting**
- **Simple,s afe structure and disposable as it is made of paper**

Future Developments

January 2016 to March 2021
Material development → Manufacture and evaluation technology development → Mounting technology development
(We are planning to demonstrate the devices in the year of the 2020 Tokyo Olympics and Special Olympics, which is the last year of the A-STEP Project)
We always welcome ideas for new applications and proposals for collaborative research.

■ Associated System:
JST Adaptable and Seamless Technology Transfer Program through Target-driven R&D
A-STEP Strategic theme-focused type
(Project period: January 2016 to March 2021)
■ Partners: Tsukuba University, Riken, and other institutes
■ Prototype: Completed

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2022.04

Bio

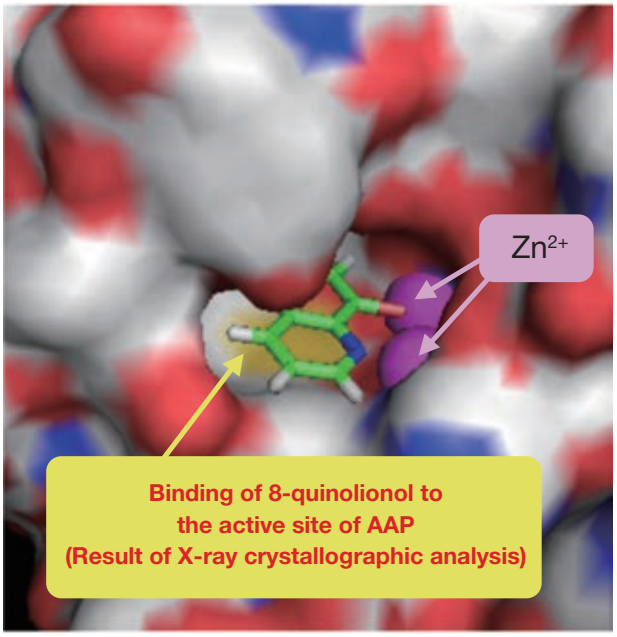
Solution for multi-drug resistance bacteria

Shin AOKI (Professor, Department of Medicinal and Life Science, Faculty of Pharmaceutical Sciences, Tokyo University of Science)

Purpose of Research

With the introduction of antibiotics, it was thought that the battle against infection had ended. However, antibiotic-resistant microbes (drug-resistant bacteria) have appeared and is now an issue of global challenge since there are no effective therapeutic methods against them. In addition, the appearance of multi-drug resistant bacteria has become a new threat and effective countermeasures are required. Recently, inhibiting "metallo-β-lactamase," an enzyme that leads to multi-drug resistance in pathogens, is gaining interest. At our laboratory, through research on metallic zinc complexes, we have focused on enzymes that selectively inhibit enzymes that contain zinc and are developing drug agents to inhibit the activity of enzymes that contain zinc such as metallo-β-lactamase. At the same time, we are designing molecules with lower toxicity and developing a reactivation method.

Summary of Research



Metallo-β-lactamases are considered to be the most dangerous among β-lactamases and degrade almost all antibiotics that include penicillins, cephams and carbapenems. Bacteria (*Pseudomonas aeruginosa*, *Acinetobacter*, *E. coli* and *Klebsiella pneumoniae*, etc.) that carry the gene for this enzyme on a transmissible plasmid have strong pathogenicity and may cause infection not only in the hospital, but also to the general public.

Among metallo-β-lactamases, there are dinuclear zinc enzymes with two zinc molecules in the active center (Class B) and there are currently few drugs (inhibitors) that effectively inhibit these enzymes.

Our laboratory is applying basic research on metallic zinc complexes to develop dinuclear zinc enzyme inhibitors. Specifically, we have analyzed the structure of the active site of these enzymes in detail and searched for inhibitors that can bind to the zinc ions. However, inhibitors to metal enzymes are metalloligands which lead to toxicity. Therefore, we are investigating prodrugs that protect the ligand site to lower toxicity but can also be deprotected and reactivated at the right time and place.

Through these activities, we are aiming to develop a novel antibacterial agent against dinuclear zinc enzymes such as β-lactamase while avoiding multi-drug resistance.

Points

- **Search for compounds that bind to the active site of dinuclear zinc enzymes and analyze mechanism of binding in detail using X-ray crystallography**
- **This compound was found to inhibit the dinuclear zinc enzyme AAP (Amino-peptidase from *Aeromonas Proteolytica*)**
- **A protective group was introduced to reduce toxicity of these compounds and we developed a method to eliminate the group under physiological conditions**
- **Knowledge,t echniques and know-how which are related to complex chemistry in water**

Future Developments

- Selection of optimal compound from those known to bind to the active site
- Evaluation of enzyme inhibitory potency of the selected compound *in vitro*
- Molecular design and synthesis to lower toxicity (prodrug)
- Safety and efficacy evaluation *in vivo*
- Collaborative research with domestic and global partners

■ Research Organization: This research is a collaborative study with Kengo Hanaya at the Faculty of Pharmacy, Keio University.

Device

Event-driven intelligent system using piezoelectric materials

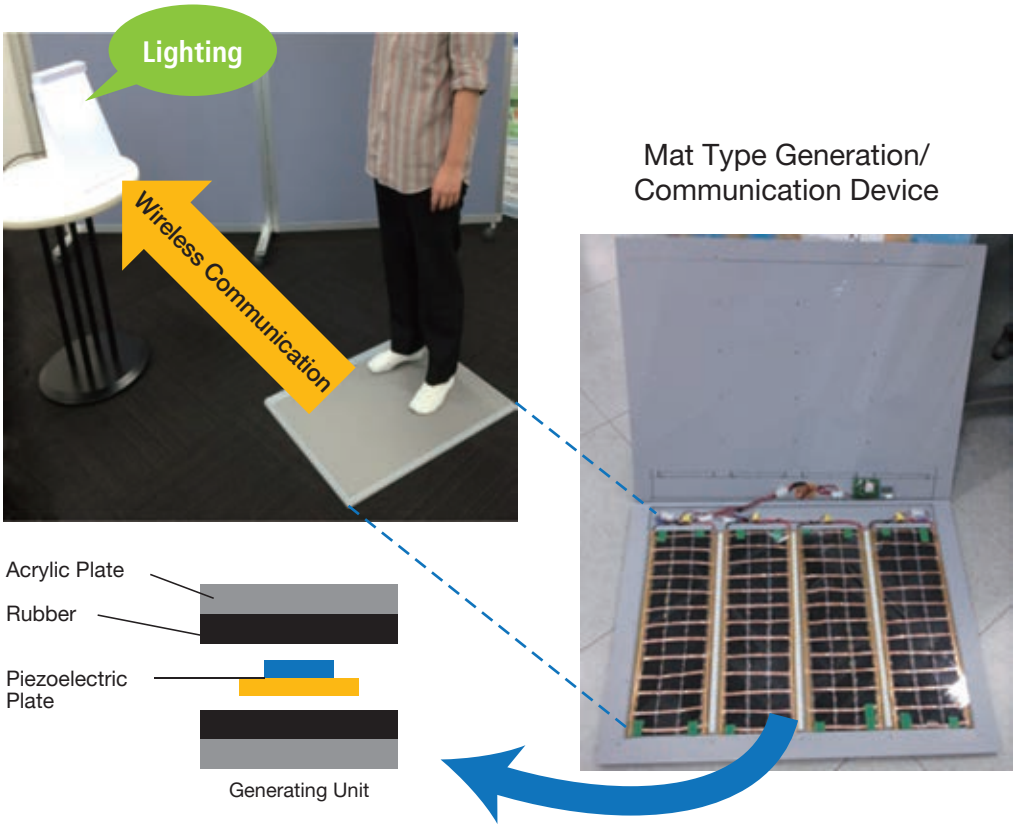
Soichiro OKAMURA (Professor, Department of Applied Physics, Faculty of Science Division I, Tokyo University of Science)
Takashi NAKAJIMA (Associate Professor, Department of Applied Physics, Faculty of Science Division I, Tokyo University of Science)
Yoichiro HASHIZUME (Associate Professor, Oshamambe Division, Institute of Arts and Sciences, Tokyo University of Science)

Purpose of Research

To develop a monitoring system in order to solve problems of graying society and social anxiety, and to implement a simple diagnosis system for aging infrastructure.

Summary of Research

We have developed a mat generating electricity with a force brought by human or automobile passing on the mat. This technology can provide various pieces of information associated with walking or traffic via wireless communication using the electricity generated by such mat “without a battery or a wiring.”



Comparison with Conventional or Competitive Technology

A battery has been generally used when sensor information needs to be sent by wireless. However, it is able to supply electricity to the wireless communication element almost permanently without charging or replacing the battery by employing this technology.

Expected Applications

- Walking sensor mat for monitoring hospital patients or persons in need of in-house nursing care (available to be adopted even at a location where a human-body detecting infrared sensor cannot be installed)
- Automatic door
- Alarm/warning system for roadways, platforms or plants

Challenges in Implementation

Application method and communication device/protocol should be developed and improved to establish more stable transmission.

What We Expect from Companies

Undertake collaborate projects for improving the wireless communication device/protocol, and for proving benefits to create use cases.

Points

- **Capable of sending sensor information semipermanently at a location where the battery is difficult to be charged or replaced**
- **Provide a wireless communication system operable independently even at the time of a disaster or emergency**
- **Available to be employed under cryogenic,h igh-temperature or vacuum environment where the battery is difficult to be used (the piezoelectric materials can generate electricity in a high-temperature region covering from ultralow temperature to several hundred degrees)**

Future Developments

Researches will be proceeded to improve wireless communication distance and traffic with upgraded characteristics, and to attain miniaturization and light-weighting.

■Intellectual Property:
Japanese Patent Application No. 2014-238235 “Generator”

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2022.04

Medical and bio

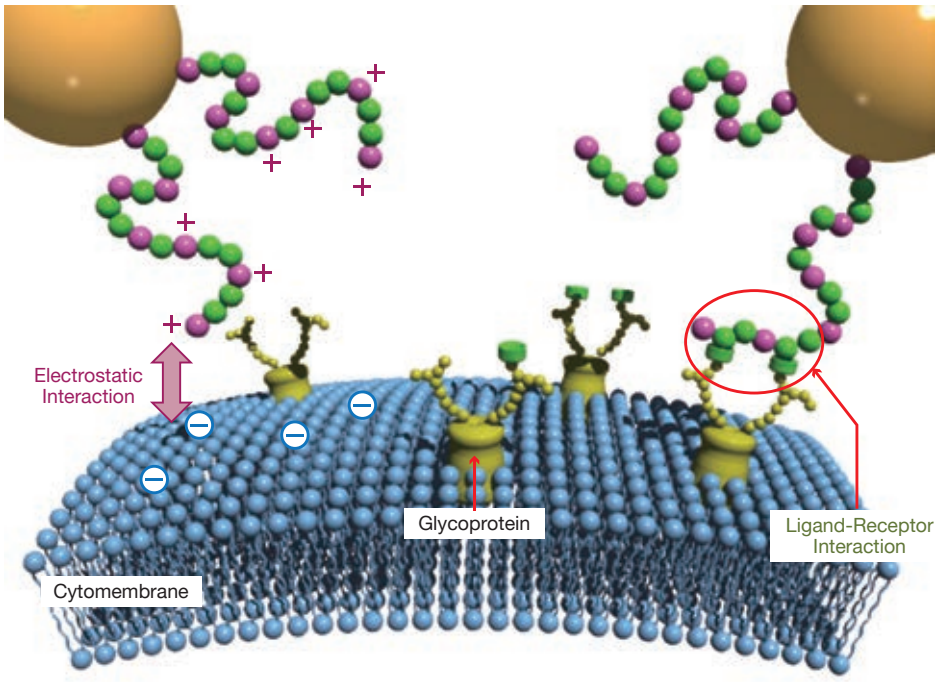
Nanoparticle for highly cell targeting technology

Hidenori OTSUKA (Professor, Department of Applied Chemistry, Faculty of Science Division I, Tokyo University of Science)

Purpose of Research

Photothermal therapy is a treatment for curing cancer using external light stimuli, which wins attentions as a minimally-invasive therapy since it does not need a surgical treatment. For efficiently achieving the hyperthermic therapy, nanoparticles need to be designed so as to have excellent in vivo biocompatibility (avoidance of capture by reticuloendothelial system (RES) around a liver or a spleen), tumor clustering and heating efficiency. In this study, we aim at implementation of more effective hyperthermia therapy through synthesizing nanorod particles having such functions. The surface of golden nanorod with high heat-exchange efficiency is subjected to surface modification which allows the surface to accumulate tumor electrostatically and receptor-specifically. Compared with the conventional technology, this novel therapy is able to promote incorporation into cell with three-orders higher specificity and to provide the safer hyperthermia therapy.

Summary of Research



All-in-one Particle in Photothermal Therapy

Electrostatic Interaction

Since the cellular surface is negatively charged due to dissociation of carboxylic group or phosphoric group, the cation unit is nonspecifically accumulated on a surface of tumor cell by the electrostatic force.

Sugar Chain-Receptor Interaction

The sugar chain is bound to the protein on the cellular surface; it is specifically bound to various receptor molecules and selectively transferred into the cell.

Photothermal Effect

It is possible to convert the absorbed optical energy to the thermal energy. The tumor cell can be cured by effective hyperthermic impact.

Points

- **Accumulation on cellular surface by electrostatic interaction of cation unit**
- **Selective coupling and cell transfer due to ligand unit**
- **Effective hyperthermia therapy**

Future Developments

- Pharmacokinetic studies are currently in progress. After the pharmacokinetic experiment is finished, in vivo pharmacology tests using model animals are expected.
- Cytomembrane-specific cellular surface of this study is confirmed to be useful for delivery of cytotoxic antitumor agent.
- We aim at undertaking collaborate projects with pharmaceutical and DDS R&D companies, and acquiring sponsored research funds.

■ Associated System:
NEDO Next Generation R&D for Function Substitution Technologies

■ Awards:
Award for Encouragement of Research in Materials Science 2011, 2010 and 2001 by MRS-Japan
Japan Biomaterial Science Encouragement Award 2005
STAM Highlights 2013 (the most popular articles 2013)

■ Intellectual Property:
Japanese Patent Application No. 2014 0[illegible]4 " Molecular Carrier for Intracellular Delivery"

■ Prototype: Present ■ Sample: Available

Medical and bio

Nonenzymatic, enantioconvergent dynamic kinetic resolution (DKR) of racemic 2-(1H-Pyrrol-1-yl)alkanoic acids as α-amino acid equivalents

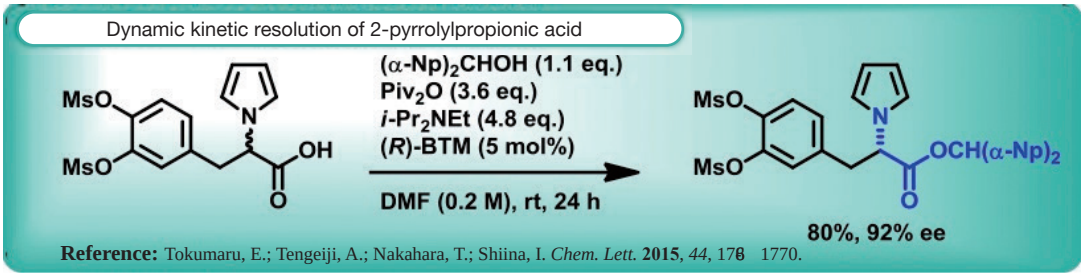
Isamu SHIINA (Professor, Department of Applied Chemistry, Faculty of Science Division I, Tokyo University of Science)

Purpose of Research

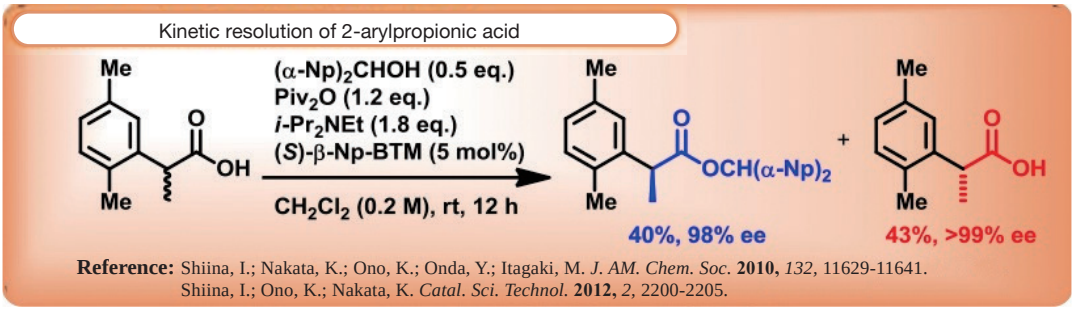
We have developed "dynamic kinetic resolution (DKR)" in which optically-active ester can be obtained at a yield of almost 100% by combining asymmetric esterification with recemization (I. Shiina, K. Ono, K. Nakata, Catalysis – Science & Technology, 2, 2200–2205 (2012). [Cover Feature Article] [Hot Article] [Most Accessed Article]).

Furthermore, we have also developed a novel synthesizing process which provides optically-active amino acid equivalent with excellent selectivity by realizing DKR in a manner of applying the racemic 2-(1H-Pyrrol-1-yl)alkanoic acid to this reactions.

Summary of Research



Reference: Tokumaru, E.; Tengeiji, A.; Nakahara, T.; Shiina, I. *Chem. Lett.* **2015**, *44*, 178 1770.



Reference: Shiina, I.; Nakata, K.; Ono, K.; Onda, Y.; Itagaki, M. *J. AM. Chem. Soc.* **2010,** *132*, 11629-11641.
Shiina, I.; Ono, K.; Nakata, K. *Catal. Sci. Technol.* **2012,** *2*, 2200-2205.

- Convert racemic carboxylic acid to optically-active carboxylate ester
- Synthesize optically-active 2-arylpropionic ester at a yield of almost 100%
- Synthesize optically-active α-amino acid ester at a yield of almost 100%
- Capable of selective synthesizing one of enantiomers directly without racemic form separation following synthesis of racemic drug or medicinal intermediate

Points

- **Selective synthesis of racemic α-amino acid**
- **Need not to separate/divide synthesized racemic form**
- **Yield of almost 100%**

Future Developments

- Find other synthesis processes or solutions for shortening of synthesis time
- Expand a range of application of substrate
- Produce novel catalysts
- Undertake collaborate projects with pharmaceutical, food development or medicinal intermediate companies while aiming for acquiring sponsored research funds

■ Associated System:
JST A-STEP "High-risk Challenge" type (in 2014 2017)
■ Awards:
The Chemical Society of Japan Award for Creative Work 2013
The Inoue Prize for Science 2014 The Ichimura Prize for Science 2014
The Prize for Science and Technology from the Ministry of Japan 2015
■ Intellectual Property:
Japanese Patent Application No. 2014 018 " Method for Preparing Optically-active Carboxylate Ester"
■Prototype: Present
■Sample: Available

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2022.04

Energy and environment

Technology assessment to create value added for power plant operation and electricity retailing business with the liberalization of electricity sales

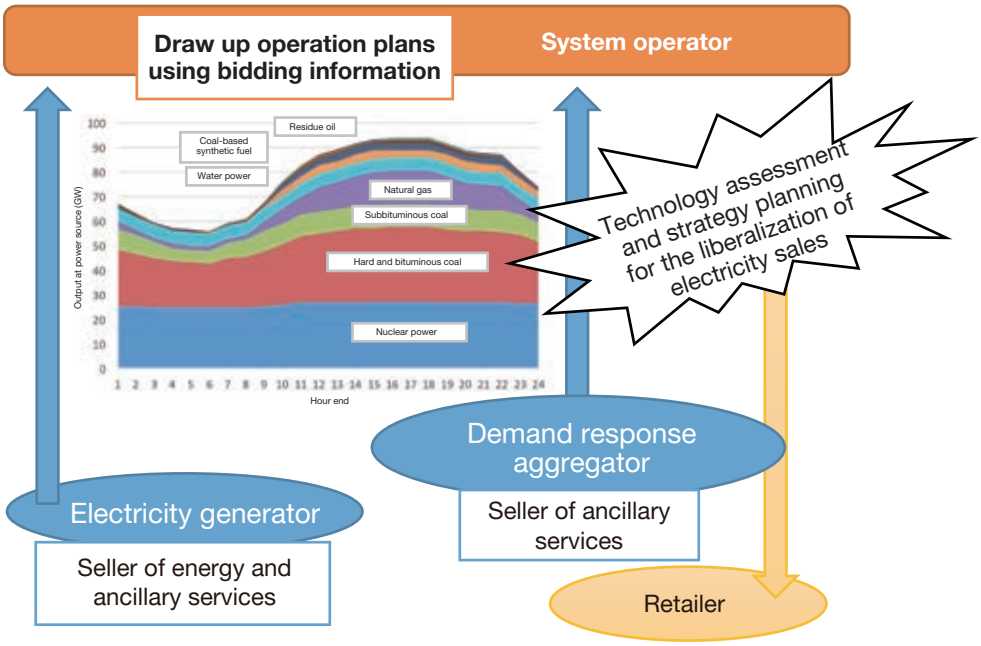
Nobuyuki YAMAGUCHI (Associate Professor, Department of Electrical Engineering, Faculty of Engineering, Tokyo University of Science)

Purpose of Research

In Japan, the phased liberalization of electricity sales (electricity system reform) is under way with its completion scheduled for 2020. As a result, any company will be able to enter power generation, power transmission and distribution, and electricity retailing businesses if it obtains a license. With this deregulation, an electricity market worth ¥5 trillion is expected to emerge according to the Ministry of Economy, Trade and Industry. In Europe and North America, where the electricity market was liberalized earlier, not only electric energy (kWh), but also electric system control called an "ancillary service" is procured or traded openly, and this is attracting public attention as something that suggests how electricity business and technology assessment in Japan should be in the future.

Summary of Research

This research uses mathematical programming to formulate operation plans aimed at cost minimization taking complicated technical restrictions at power plants into consideration and proposes optimal agreements for electricity users using demand response by adjusting power consumption according to wholesale electricity prices. It also assesses the value of ancillary services for electricity system control in order to support interconnected photovoltaic and wind power generation systems whose output fluctuate widely.



Comparison with Conventional or Competitive Technologies

Setting questions in a way that is consistent with the technical restrictions of power plants, power transmission networks, distribution networks, etc. and with electric business policy in Japan and abroad and enabling strategy planning transcending the boundaries between engineering and policy-making

Expected Applications

- Formulating a wholesale electricity trading strategy with ancillary services in mind
- Examining power source investment strategies taking future policy risks into account
- Lowering wholesale electricity procurement costs utilizing demand response

Challenges in Implementation

Verifying the effectiveness and refining models based on not only sample data but also actual data

What We Expect from Companies

Considering corroborative joint research using field data

Points

- **Enabling reviews focusing on technical restrictions and policy/market risks to which analyzers pay attention**
- **Analyzing power generation,p ower transmission and distribution, and electricity retailing businesses in an integrated manner**
- **Examining suggestions to ap an through research and analysis of overseas electricity business**

Future Developments

- Sophistication of analysis according to the progress in electricity system reform
- Establishment of a body to promote wide-area electricity use
- Creation of an hour-ahead market and full liberalization of electricity sales
- Creation of a real-time market and removal of pricing regulations

■ Associated System:
Participating in the research project in the JST-CREST EMS area, named "Building System Theory for Harmonized Power System Control based on Photovoltaic Power Prediction" as its principal joint researcher
(From April 1, 2015 o March 31, 2017)

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2022.04

Communication and information processing

Secure, fast, light encryption based on non-commutative algebra

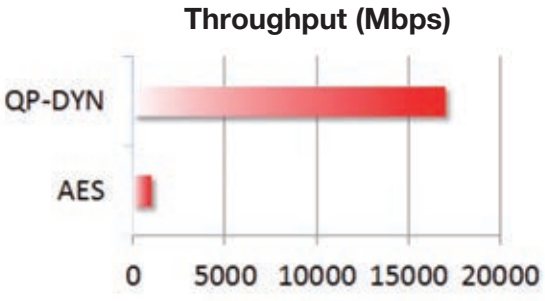
Satoshi IRIYAMA (Associate Professor, Department of Information Sciences, Faculty of Science and Technology, Tokyo University of Science)

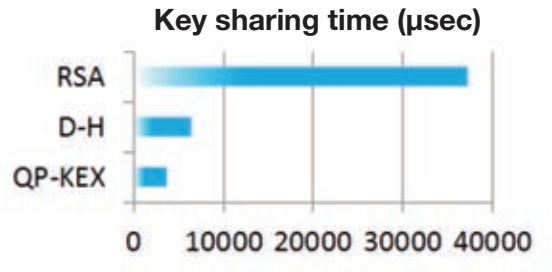
Purpose of Research

Prof. Emeritus Ohya (TUS) and Prof. Accardi (University of Rome II) have developed a novel encryption method as a result of their more than 20 years of study on mathematics (noncommutative algebra and noncommutative probability theories). We are studying a cipher based on noncommutative algebra and an encryption method based on a new principle.

Summary of Research

The shared key stream cipher (QP-DYN), based on a unique mathematical theory, can generate high-quality random numbers. The public key exchange (QP-KEX) is based on mathematics that can be reduced to a matrix type discrete logarithm problem and is safe. It does vector calculation and allows parallel processing for fast encryption.





Cryptobox
(8 cm x 8 cm, 500 g)

Comparison with Conventional or Competitive Technology

Throughput more than 10 times faster than AES was achieved. Key generation and key exchange was about 10 times faster than RSA. When implemented on FPGA, the circuit size was about 7% that of AES.

Expected Applications

- High-speed processing by a cloud server, etc.
- Higher safety in a mobile environment
- Real-time processing for 4K /8K video distribution

Challenges in Implementation

- Development of attractive services
- Registration as an encryption standard
- Standardization of specifications

Points

- **Safer One-Time-Pad cipher**
- **Faster key generation,k ey exchange,an d encryption**
- **Smaller and lighter circuit**

What We Expect from Companies

Collaboration on the installation on a smaller chip and the product/service/ application development of the new encryption method.

Future Developments

Many pilot products are being developed. These will be broadly publicized both in Japan and overseas.

■Prototype:
Portable encryption device “Cryptobox,” Email encryption (compatible with Outlook and Google), and mobile App.

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2022.04

Medical

Pinpoint electrolysis unit with conductive diamond ink electrode for dental treatment

Takeshi KONDO (Associate Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science), etc.

Purpose of Research

Conductive diamond electrodes are generally made by the CVD method, but with this method, the types of substrate materials are limited and manufacturing is expensive. In this research, we have developed an ink that contains conductive boron doped diamond powder. By coating various substrate materials with this ink, we have succeeded in simply manufacturing diamond ink electrodes in a wide range of shapes.

Summary of Research

Conductive boron doped diamond is a functional electrode material with excellent chemical stability and bioaffinity. Using this technology, by combining conductive diamond power with a polymer material, we developed a conductive diamond ink which can be used to coat various substrate materials to create electrodes. The conductive diamond ink was applied to the tip of a metallic needle, and an electrode unit was created by then wrapping the tip with an ion exchange membrane and aluminum ribbon cathode. By applying voltage to this electrode unit in water, it is possible to efficiently generate electrolytic ozone, and it has been shown that this unit can be used as a dental treatment instrument for localized disinfection.

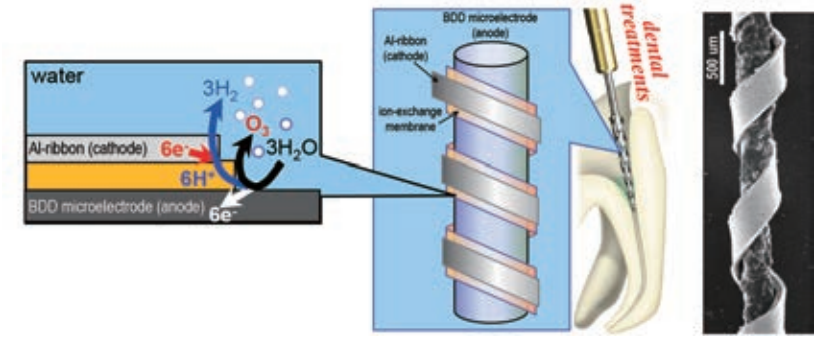


Fig. 1 Structure of the electrolysis unit and principle of electrolytic ozone generation

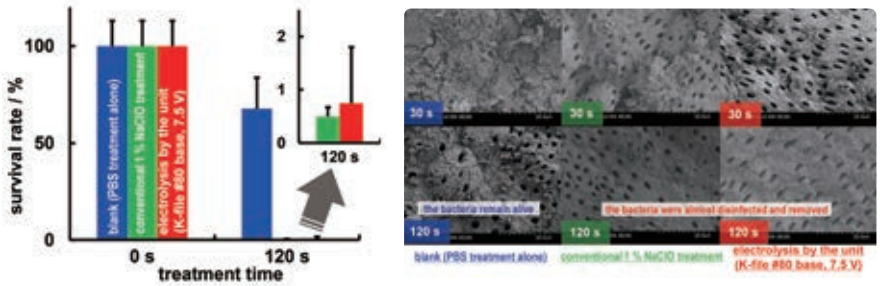


Fig. 2 Survival rate and SEM image of *P. gingivalis* in the root of a cow tooth after treatment

Comparison with Conventional or Competitive Technology

- By applying the conductive diamond ink to substrate materials with a wide range of types and shapes, it is easy to manufacture electrodes.
- Compared to other materials, it is possible to efficiently generate electrolytic ozone, thereby enabling disinfection treatments.

Expected Applications

- Dental treatment instruments (root treatments, gingivitis treatments)
- Electrochemical sensors for medical use (electrocardiogram, electromyogram, blood sugar level, measuring uric acid levels)
- Electrolytic water treatments (sterilization, produce drinking water, generate water with electrolytic function)

Challenges in Implementation

Collaboration with a company that creates prototype dental treatment instruments

What We Expect from Companies

- Create a prototype dental treatment instrument (prototyping).
- Develop new applications for the conductive diamond ink other than dental treatment instruments.

Points

- **Disinfection through the localized generation of electrolytic ozone**
- **Uses diamond with excellent bioaffinity**
- **Can be used with a wide range of materials, shapes and sizes**

Future Developments

- Manufacture of electrodes with an even smaller tip
- Trials using human teeth
- Study with the aim of commercialization and pharmaceutical approval
- Development of sensors and electrodes for electrolysis

- Research System: Photocatalyst Group at the Kanagawa Academy of Science and Technology, Tsurumi University School of Dental Medicine, Healthcare Oral Instruments and Materials Research Center
- Associated System: Grants-in-Aid for Scientific Research, Young Researcher (B)
- Intellectual Property: International patent application filed
- Prototype: Available
- Sample: Provision of conductive diamond power samples is subject to prior consultation

Device

Multi-in-situ electrochemical impedance monitoring system for healthcare of lithium battery

Isao SHITANDA (Associate Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science)

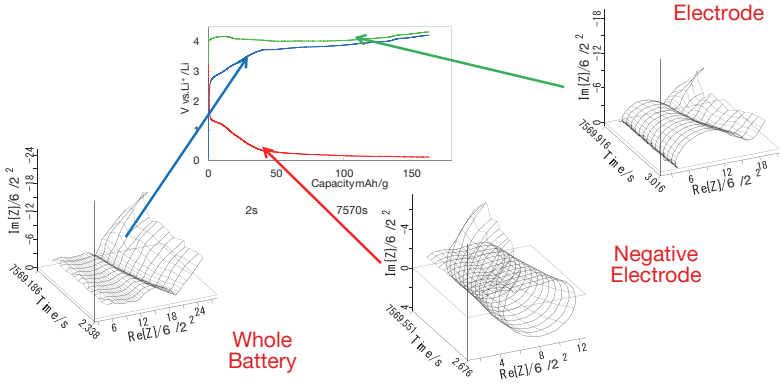
Purpose of Research

The method for determining replacement timing or reusability of built-in batteries is demanded along with the popularization of a hybrid car. In this study, we propose a multi-in-situ electrochemical impedance monitoring system which is able to diagnose deterioration without breaking a secondary battery.

Summary of Research

We have developed a measurement system which can measure quantitative internal deterioration parameters of a lithium ion battery in a charge/discharge cycle using an electrochemical impedance measurement without disassembling the battery. This system separately measures interfacial resistance of each of positive and negative electrodes within the lithium ion battery when internal deterioration evaluation for the battery is performed by multi-in-situ electrochemical impedance method.

We have developed a novel and revolutionary method for evaluating positive and negative electrodes individually while charging or discharging.



Comparison with Conventional or Competitive Technology

- The battery state can be evaluated in real-time while charging and discharging the battery.
- The positive and negative electrodes, components of the battery, can be evaluated status quo.

Expected Applications

- State evaluation for battery installed in an electric car or an aircraft
- Deterioration diagnosis for a big-scale lithium battery module

Challenges in Implementation

It is necessary to figure out the individual features of positive and negative electrodes in the lithium battery during charging/discharging cycle in situ, and to collect the data on quantitative evaluation, with the developed product.

What We Expect from Companies

We are finding a collaborative project partner for evaluating a correlation between a secondary battery states and a measuring result obtained by the developed product.

Points

- **This technology enables to evaluate a natural state of the battery**
- **The information on positive and negative electrode can be obtained individually without breaking the battery**
- **Since various equivalent circuit models are provided,b attery performance parameters can be evaluated in detail by automatic fitting**

Future Developments

- Establish deterioration diagnosis algorithm through evaluation of actual batteries mounted on the hybrid car or the electric car.
- Utilize this theory to development a battery with functions of high-speed charging and discharging.

■ Intellectual Property:
Japanese Patent Application No. 2014 1736
"Method and Device for Evaluating Battery Features"

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2022.04

Device

High-throughput screening of multicomponent functional materials using combinatorial technology based on the electrostatic spray deposition

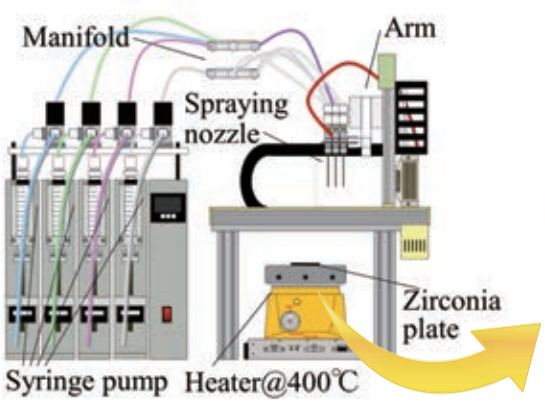
Kenjiro FUJIMOTO (Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

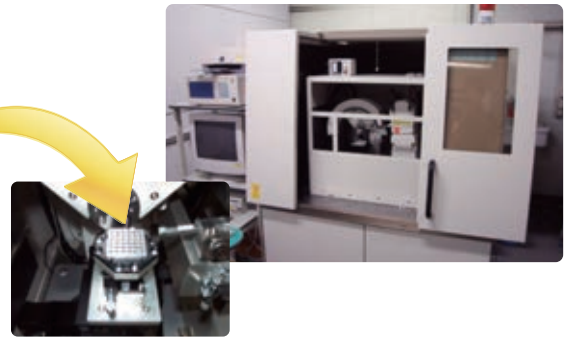
A broad range of multicomponent functional materials are a subject of extensive study and screening. However, as more components are included in a material, the combinations of parameters to be screened (component ratio, temperature, atmosphere, pressure, etc. in the case of composite materials) exponentially increase. In 1θs , peptide synthesis by Dr. Merrifield led to the rise of combinatorial technologies. In the late 1θs , automated synthesizers using multiple inorganic/metal material components were developed, allowing the use of thin films and bulk samples for high-speed material screening. We have developed the electrostatic atomization-type high-speed material screening system "M-ist Combi," which allows screening of liquid, film, or bulk samples of materials. Using this system, we are investigating novel multicomponent functional materials and obtaining findings that may provide clues for next-generation materials.

Summary of Research

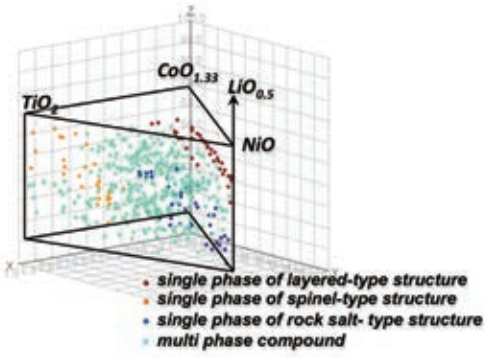
Combinatorial material screening system based on electrostatic atomization: M-ist Combi



Combinatorial high speed X ray powder diffraction



Example: Screening for lithium secondary battery cathode material
Reaction of quasi-quaternary Li-Ni-Co-Ti oxide (@ 700ºC)



Our system can achieve ● fold faster material synthesis,● fold lower reagent cost.B ecause its core technology, electrostatic atomizer,h as a simple configuration,p ost-screening larger scale synthesis of candidate materials is easy

Future Developments

Not only lithium secondary battery cathode materials and oxide thermoelectric materials, but also environmental cleanup materials will be studied. Because our system is compatible with various sample forms (powder, thin film, liquid), screening for optimal paint and building materials (plaster, etc.), plating solutions, conductive paste compositions, and polymers will be possible.

- Awards: Intl. Solid Reactivity Assoc. Best Poster Award, etc., invitation lectures at conferences, companies
- Intellectual Property: Japanese Patent No. 5016960 "Electrostatic atomizer and method of producing samples from main agents"
- Prototype: made
- System demonstration: can be viewed

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2022.04

Safety

Safety performance measures for railway stations

Shintaro TERABE (Professor, Department of Civil Engineering, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

The railway system in Japan is generally safer than that in other countries. However, falling and from the platform of the passengers, the contact accident between train is generated not a little, it is necessary to establish safety strategy. The purpose of this study, station structures and equipment, and its usage is, is to establish a quantitative evaluation methods the impact of the passengers safety and trusty.

Summary of Research

In order to improve the pleasantness and safety of public transport services, We developed ICE (Index of Comfortable and Easeful Public Transportation)[1] along with the Ministry of Land, Infrastructure and Transport (MLIT). In the present study, the safety level of railway platforms, which was not included in ICE, is evaluated based on four major indices: structure, passenger flow, train movements, and passenger characteristics. From these indices, sub-indices were set which can be quantitatively evaluated.

Index	Sub-index
Platform structure factor	①~⑤
Passenger flow factor	⑥~⑨
Train movement factor	⑩~⑬
Passenger characteristics	⑭~⑯

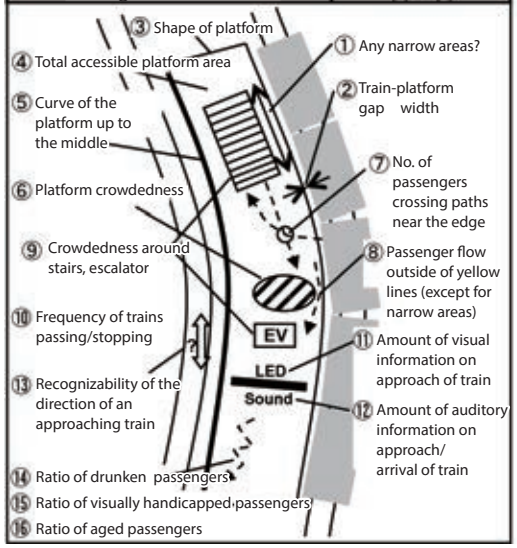


Fig. 1. Platform safety indices.

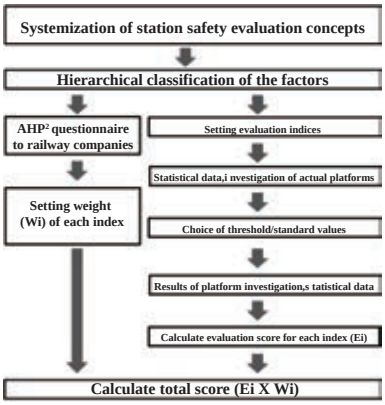


Fig. 2. Flow of safety evaluation score calculation steps

Comparison with Conventional or Competitive Technology

In a previous attempt to evaluate the safety of a railway system, statistical data on actual railway accidents were used to calculate their probability distribution, and causes of and countermeasures against serious accidents (crash, derailment, etc.) were investigated. However, human injury or death in a station, though more frequent, was not investigated. Another study set up a method to comprehensively evaluate the convenience, pleasantness, and execution certainty of train change in a Shinkansen station that was the same as the present study except that it did not include safety evaluation. The present study is the first to quantitatively evaluate the safety level of a railway station from the viewpoint of passengers.

Expected Applications

Can evaluate the relative safety level before and after a safety measure by the railway company or the relative safety of each platform side to decide the order in which new measures are executed.

Challenges in Implementation

Use actual data to make this quantitative safety evaluation method more useful and convenient.

What We Expect from Companies

Collaboration with a railway company or safety management firm to apply the present method to an actual platform.

Points

- **Indices weighted in accordance with multivariate analysis of actual data.G ood reproducibility**

Future Developments

June 2015 Started further study to improve usefulness of the present system based on actual data.

1) MLIT Transport Consumer Policy Division: Investigation into improved “pleasantness and safety” of public transport services, 2004
2) AHP: Analytic Hierarchy Process

Disaster prevention

Development and installation of new type of river and tsunami embankment that withstands various forces, and evaluation of evacuation action under actual flood conditions

Yasuo NIHEI (Professor, Department of Civil Engineering, Faculty of Science and Technology, Tokyo University of Science)

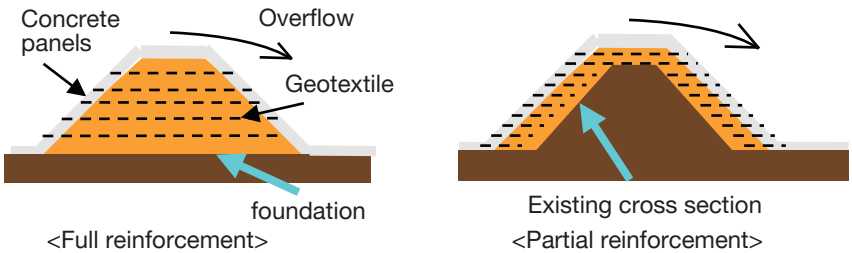
Purpose of Research

There is great concern about huge damage due to flood and debris flow caused by storms and tsunami compounded with earthquakes, all over the world. It is necessary to replace disaster prevention measures with disaster mitigation measures, but fundamental technology for disaster mitigation has not been sufficiently established. The present study aims to develop hardware and software measures of disaster mitigation which can deal with huge floods and compound disasters, and minimize the risks to life and property caused by flood and tsunami.

Summary of Research

One of the world's largest flow flumes

A new type (GRS) of river levee



<Full reinforcement> <Partial reinforcement>

Hardware Measures

Development and installation of new type of river and tsunami embankment that withstands overflow erosion of huge floods

Connecting many geotextile layers to concrete panels covering the embankment increases resistance against overflow erosion and earthquakes. A new type low-cost embankment effectively blocks huge floods with a steep slope and a small cross-section. Our laboratory recently built one of the world's largest wave testing channels (left photograph) in addition to a large wave maker for tsunami testing. Using this and a small flume, we conduct model tests to develop new types of levees that will actually protect against disasters.

Software Measures

Evaluation of evacuation action under actual flood conditions

To evaluate property of evacuation activities after floods and landslides, we conducted tests of flood evacuation, recreating flood conditions using the large-scale channel. Based on these experimental results, we developed models of flood evacuation that will save lives in an actual flood disaster.

Points

- **Embankments made with very earthquake-proof geosynthetic reinforced soil (GRS) and integrated with concrete covering the embankment, greatly increases resistance to flow erosion**
- **Embankments reinforced and made erosion resistant with a small cross-section at low cost**
- **Structure adapted to specific conditions (partial reinforcement, etc.)**

■Laboratory Apparatus:
Large-scale open channel
(length: 20 m, width: 10 m, height: 1.8m)
Small open channel
(length: 40 m , width: 0.2 m, height: 0.4m)
Two-dimensional wave flume with tsunami maker
(length: 36m , width: 1.0 m, height: 1.2 m)

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2022.04

Colloid and interface chemistry

Developments of functionalized amphiphilic molecules and active control of interfacial properties

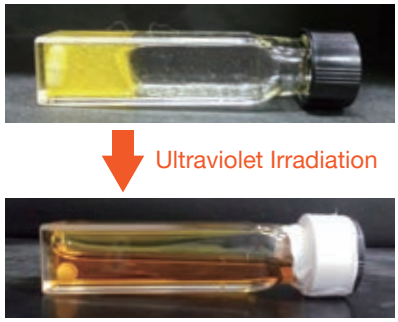
Kenichi SAKAI (Associate Professor, Department of Pure and Applied Chemistry, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

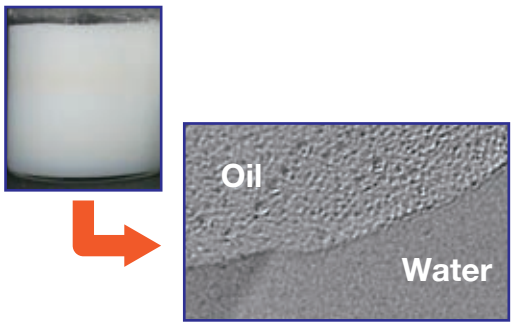
Every material has an "interface." The key point of the "interface chemistry" is to freely control the interfacial properties by selectively using (or molecularly designing) suitable amphiphilic material. Our laboratory aims at developing functionalized amphiphilic material (surfactant) and achieving precise control of various interfaces with such material.

Summary of Research

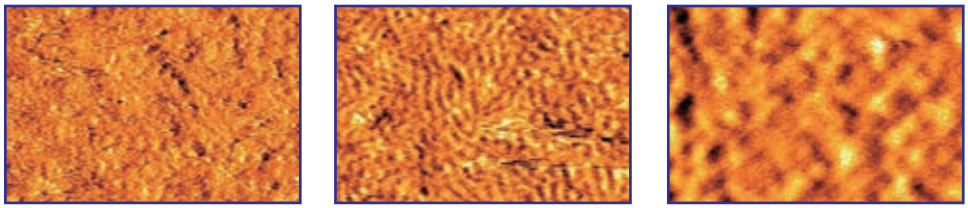
1) Developing novel amphiphilic materials (Gemini type, amino acid-based, stimulus-responsive, or polymerizable surfactant)
2) Preparing emulsion focused on saving resources and energy
3) Analyzing adsorption of amphiphilic material at a solid-liquid interface (experimental analysis using atomic force microscope, quartz crystal microbalance and friction force measurements)



Photoviscosity Control of Stimulus-responsive Surfactant Solution



TEM Image of Emulsion Sample



AFM Images of Surfactant Adsorption Layer Formed at Solid-liquid Interface

Points

- **We have developed the amphiphilic material which is eco-friendly or has distinctive additional values**
- **Correct understanding of properties of the amphiphilic material leads to appropriate formulations in product development**
- **We expect to assist to solve the problems occurred during development works by evaluating or analyzing interfacial phenomenon**

Comparison with Conventional or Competitive Technology

Out laboratory has advanced research on interfacial phenomenon in order to take advantage of obtained information in manufacturing. We also willingly accept the collaborative project with private companies to share the research results for the common good, while emphasizing basic research.

Expected Applications

- Developing surfactants (detergent, emulsifier, dispersant, thickening agent, lubricant additive, etc.)
- Developing formulations using the surfactants (cosmetics, foods, medicaments, paint, ink, etc.)
- Developing particle dispersion system (emulsion or suspension)

What We Expect from Companies

We are finding the company as a collaborative project partner. We are also willing to offer tech support if you want more information on interface chemistry.

Future Developments

We want to approach complicated boundary study fields (e.g. tribology) from the aspect of interface chemistry.

■ Awards:
Innovation Award (2012) in Oil Technology of Japan Oil Chemist's Society
Best Paper Awards (2010)
CSI Medallion of Japan Society of Colour Material (2007)

■ Intellectual Property:
Japanese Unexamined Patent Application Publication No. 2011-131137
"Cationic Surfactant, Blend Composition of Anionic/Cationic Surfactants and Hair Cosmetics"

Energy and environment

Material design for novel-concept-based solar cells —Sulfurization or oxidization of “cheap” metals

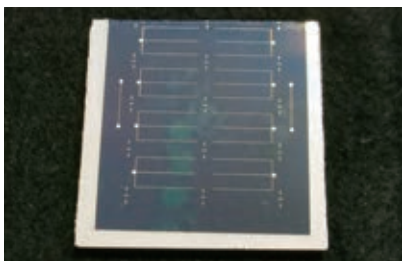
Mutsumi SUGIYAMA (Professor, Department of Electrical Engineering, Faculty of Science and Technology, Tokyo University of Science)

Purpose of Research

- We have developed a novel method for fabricating a solar cell, which is safe and stable from manufacturing point of view as well as environmental friendly while disposing. The materials used for fabricating the solar cell are available at general hard-ware store that are inexpensive and harmless.
- We have proposed new ways to use the solar cell of oxide semiconductor (not limited to nickel oxide) as a transparent energy harvesting device.

Summary of Research

- We have considered an entire process (bottom to top approach) to develop novel concept-based solar cell. It includes searching a proper semiconductor material, investigating its electronic properties and engineering the materials for device fabrication. For example, SnS and Cu_2SnS_3 solar cells were fabricated by subjecting a copper (Cu) or tin (Sn) film or both to a heat process under a sulfur atmosphere.
- The solar cell fabricated using nickel oxide (NiO) is a transparent solar cell, which absorb only ultraviolet rays that is harmful to humans, and generate electricity. This type of solar cells can be installed even at location where the conventional solar cell cannot be used, for example windows or plastic greenhouses. Furthermore, they can also be used for preparing an invisible camera or sensor by combining with a transparent diode or transistor.



Points

- **We have proposed a solar cell whose transparency gradually changed (NiO-based solar cell, photo on the left) and "a transparent intelligent glass" with high added value, which is made by combining transparent transistors (p-type TFT, photo on the upper right) and sensors**
- **We have managed the entire process from material development to device design e.g. fabricating solar cell with a safe and inexpensive materials like SnS (photo on lower right)**

Comparison with Conventional or Competitive Technology

Since the silicon semiconductor, which constitutes approximately 90% of the solar cells currently produced requires highly pure silicon, hence the manufacturing cost increases. In a contrast, we have developed a next-generation solar cell which is safe, risk-free and has excellent performances that can be manufactured at a low cost.

Expected Applications

- Transparent window glass which generates electricity using ultraviolet rays
- Shade-type power generation window glass
- Employ such solar cell in the energy harvesting device (for example, a sensor which doesn’t need electricity or an invisible security camera)

Challenges in Implementation

- Need to improve power generation efficiency and develop a way to use in new fields (proposals).
- Selection of safe and eco-friendly materials is important to develop environment-friendly, low cost, next-generation solar cell.

What We Expect from Companies

We are looking for collaborative project work with companies to develop safe, risk-free and inexpensive next-generation solar cell in not only field stated above but also in other various fields.

Future Developments

The currently available solar cells have several “economic” problems such as use of harmful materials, dangerous production processes, which result high manufacturing/materials costs. This study has a purpose to realize an inexpensive “next-generation solar cell” which can be safely manufactured and used with no risk.

- Intellectual Property:
  Japanese Unexamined Patent Application Publication No. 2013-109766 “ Photovoltaic Light Control Element and Method for Manufacture the Same”
- Prototype: Present
- Sample: May be provided. Decision on this made after discussion with requester.

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