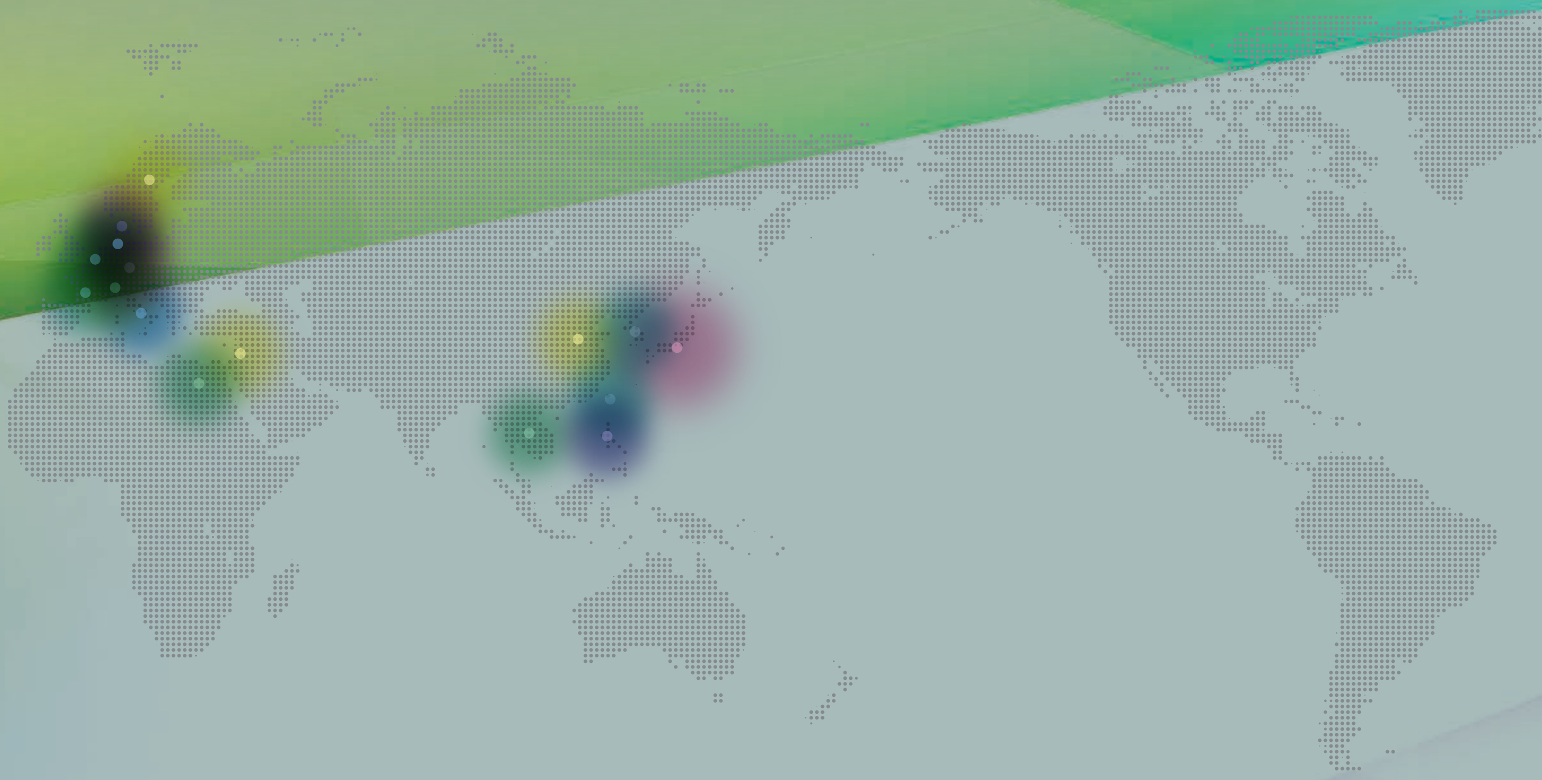
Annual Report 2020

Year ended March 31, 2020

The Institute of Scientific and Industrial Research, Osaka University



The Institute of Scientific and Industrial Research (ISIR: SANKEN) was established at Osaka University in 1939 in response to strong demand from the Kansai business community for a research institute focused on “basics and applications of natural sciences necessary for industry”. From the very beginning, we have been aiming at developing new interdisciplinary research areas, and in response to the needs of society and times, we have been reshaping our organization and broadening our research fields. In 2009, we have expanded to the current four research divisions: Information and Quantum Sciences, Advanced Materials and Beam Science, Biological and Molecular Sciences, and Nanoscience and Nanotechnology.

In 2010, we started Japan's first Network-type Joint Research Center for Materials and Devices, consisting of five research institutes, in collaboration with IMRAM (Tohoku University), RIES (Hokkaido University), CLS (Tokyo Institute of Technology), and IMCE (Kyushu University). We are also carrying out a joint research project “Dynamic Alliance for Open Innovation Bridging Human, Environment and Materials (Five-star Alliance)” involving five research institutes; hence, forming a strong scientific network all over the country and increasing research abilities.

During this period, the social situation and industrial structure of Japan and the rest of the world have been constantly changing. However, even today, 80 years after foundation of the SANKEN, its philosophy has not changed, and we are vigorously promoting our goals - finding the next direction of science and technology and leading advanced scientific and social implementation of world-leading technologies.

For example, the SANKEN, which has been leading nanotechnology research organization since the 1980s, has established its Nanoscience Nanotechnology Center at the early stages of development of nanoscience and has led the world since. In the field of information and AI, where social implementation is currently progressing greatly, we have established cutting-edge research laboratories in the 1970s, that are still functioning and have been contributing greatly to the development of the academic area. Based on extensive history and features of the SANKEN, the Artificial Intelligence Research Center (AIRC) was launched in April 2019 to combine interdisciplinary fields of quantum, materials, beam, biology, molecule, and nanotechnology sciences with information science. Through the activity in AIRC, we aim to bring next-generation industrial innovations to society by building the basis of AI-driven science and its implementation.

For the future, without forgetting SANKEN’s mission - accumulating the knowledge generated from daily research across diverse scientific fields, sublimating it as a technology, and surely transferring it into society for solving social problems and sustainable development, we will strive to provide the highest level of research and education.

To that end, we will strongly promote collaboration and co-creation with a variety of academic communities, universities, research institutes and companies with different viewpoints. We sincerely ask for your continued support and encouragement.

Director
Tohru Sekino

- On-campus Company Research Park
- Joint Research Center
- University-Attached Research Institutes Alliance

[University-Industry Co-Creation]

Promotion of Scientific Research Contributing to the Industry

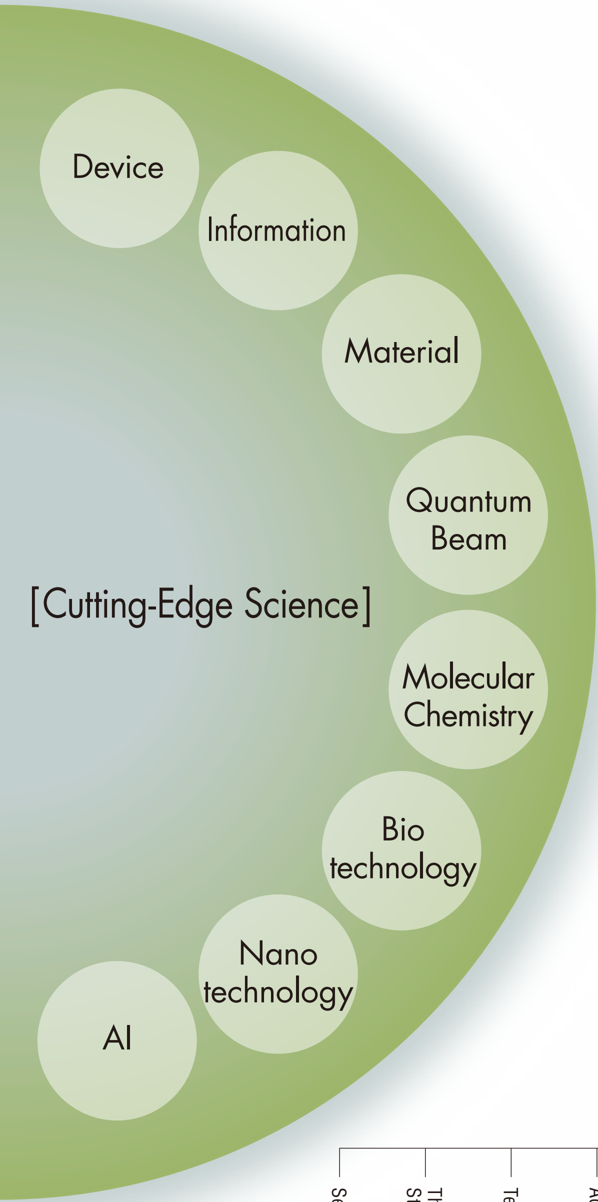
Real Innovation

[International Cooperation]

- International Collaboration Lab.
- International Collaboration Research with imec

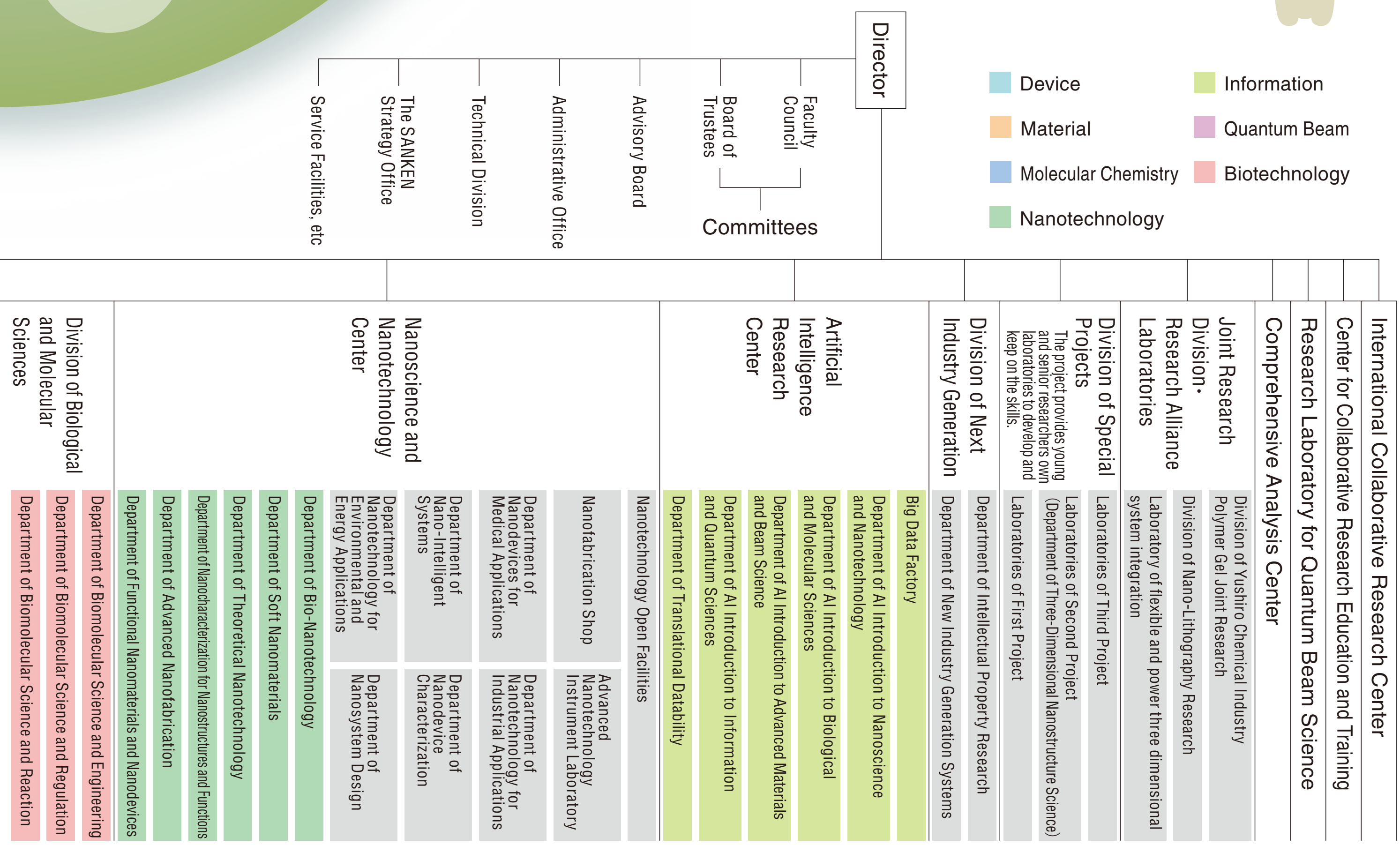
Organization

- Division of Information and Quantum Sciences
  - Information and Quantum Sciences
    - Department of Quantum System Electronics
    - Department of Interface Quantum Science
    - Department of Advanced Electron Devices
    - Department of Intelligent Media
    - Department of Reasoning for Intelligence
    - Department of Knowledge Science
    - Department of Architecture for Intelligence
- Division of Advanced Materials and Beam Science
  - Advanced Materials and Beam Science
    - Department of Functionalized Natural Materials
    - Department of Semiconductor Materials and Processes
    - Department of Advanced Hard Materials
    - Department of Advanced Interconnection Materials
    - Department of Excited Solid-State Dynamics
    - Department of Quantum Beam Physics
    - Department of Beam Materials Science
- Biological and Molecular Sciences
  - Department of Material Excitation Chemistry
  - Department of Synthetic Organic Chemistry
  - Department of Regulatory Bioorganic Chemistry
  - Department of Complex Molecular Chemistry



History

1939	ISIR: SANKEN was established in Sakai City with 3 research departments.
1968	SANKEN has been relocated to Suita City.
1977	Material Analysis Center was established.
1995	Restructured to an Institute composed of 6 divisions with 24 departments for the purpose of promoting sciences on materials, information and biology.
2002	Nanoscience and Nanotechnology Center was founded. The new Center focused its research on nanomaterials and devices, beam science for nanotechnology and industrial nanotechnology. We were awarded the 21 Century COE Program MEXT (the Ministry of Education, Culture, Sports, Science and Technology).
2007	4 institutes' Alliance (4 institutes' network) was started. ISIR-REIS (Hokkaido Univ.) alliance laboratory was set up.
2008	Division of Special Projects was launched.
2009	SANKEN was reorganized to 3 divisions and Nanoscience and Nanotechnology Center. Material Analysis Center was reorganized to Comprehensive Analysis Center. SANKEN Incubation Building was constructed and Company Research Park was started.
2010	The Network Joint Research Center for Materials and Devices and 5 institutes' Alliance (5 institutes' network) were started. SANKEN was the headquarters of this nation-wide 5 institutes network.
2011	We concluded a research-collaboration agreement with Interuniversitair Micro-Electronica Centrum vzw (imec), one of the world's largest nanotechnology research institute and "imec office" was opened at SANKEN.
2013	Osaka University has been selected as one of the core universities of the MEXT program, COI STREAM, and ISIR will play a role of the Osaka Univ.
2016	Dynamic Alliance for Open Innovation Bridging Human, Environment and Materials including ISIR (Osaka Univ.), RIES (Hokkaido Univ.), IMRAM (Tohoku Univ.), CRL (TIT) and IMCE (Kyusyu Univ.) was established. SANKEN is the headquarters of this nation-wide 5 institutes network.
2017	We established "ISIR imec center" in imec of Belgium to promote the global cooperation network.
2019	Artificial Intelligence Research Center was established. ISIR official mascot "SANKEN" was born.



Device

Quantum Technology

Next-generation IoT Sensors

Flexible Intelligent System

Information

Computer Vision

Machine Learning

Spoken Dialogue Systems

Artificial Intelligence

Data Mining

Material

Silicon

Cellulose Nanofiber

Multi-Functional Materials

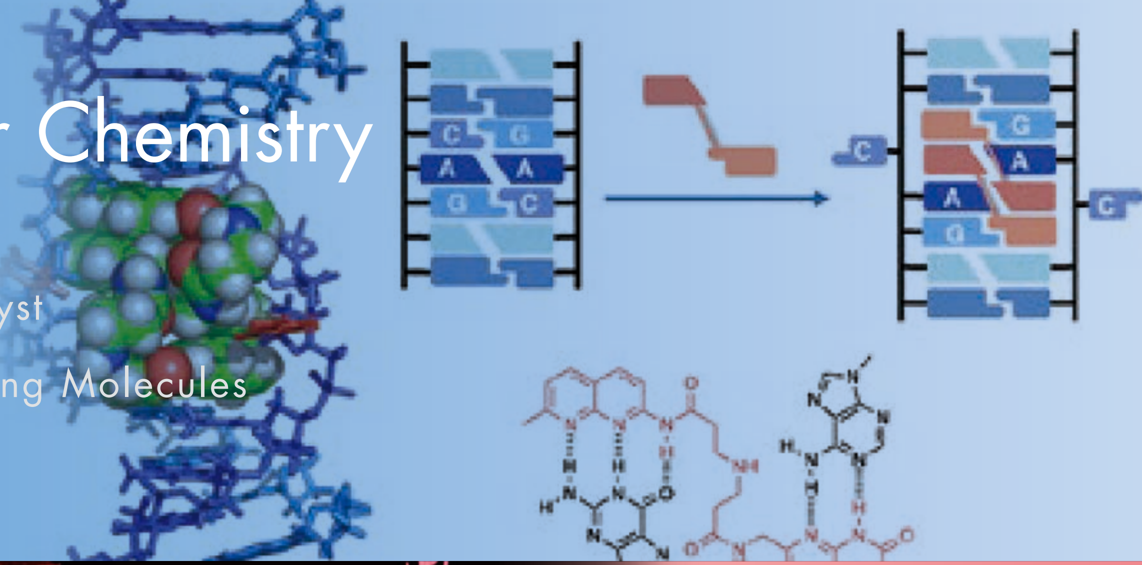
Interfaces and System Integration

Quantum Beam

Physics of the Low-dimensional Material via
The cutting-edge Electron Spectroscopies

Laser-driven Particle Acceleration

Quantum-beam-induced
Nanochemistry



Molecular Chemistry

Photochemistry

Asymmetric Catalyst

DNA/RNA-targeting Molecules

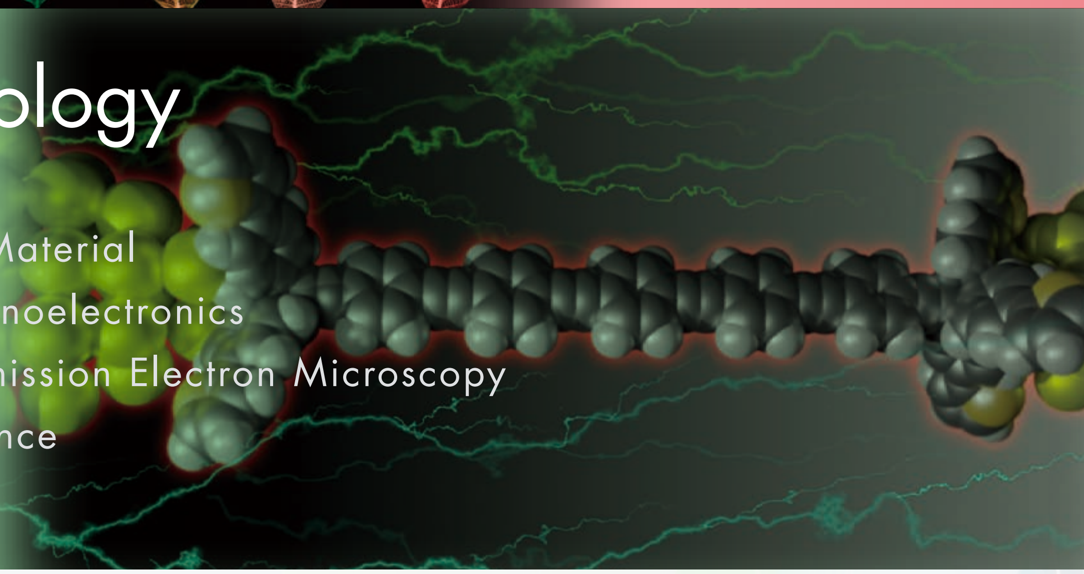
Chemical Biology

Biotechnology

Bio-inspired Materials

Multidrug Resistant Bacteria

Luminescent Protein



Nanotechnology

Quantum Beam

Organic Functional Material

Functional Oxide Nanoelectronics

Environmental Transmission Electron Microscopy

Single-molecule Science

Materials Design

We are aiming to contribute to society
by promoting state-of-the-art research
and solving environmental, energy medical,
safety and security issues.

Company Research Park

We operate a space “Company Research Park.”
This space promotes open innovation by companies in cooperation with our research activities. The users can receive state-of-the-art technical counseling for practical application research and can form and utilize networks as an open innovation base.

Research Alliance and Network-type Joint Research Center

Promote and support wide-range of collaborative research through five university institutes

Dynamic Alliance for Open Innovation Bridging Human, Environment and Materials (Five-star Alliance)

Five-Star

The “Five-star Alliance” is aiming to realize true and clearly-targeted academic and industrial “innovation” through the “covalent” and “dynamic” cooperation researches among the 5 university institutes; ISIR: SANKEN Osaka U, RIES Hokkaido U, IMRAM Tohoku U, CLS Tokyo Institute of Tech., and IMCE Kyushu U. The five-star alliance is strategically operating three research groups across the 5 Institutes and multidisciplinary collaborative researches including of-stay type “CORE Lab” and programs for graduate students.

alliance.tagen.tohoku.ac.jp/english/

Network Joint Research Center for Materials and Devices (NJRC)

NJRC

“Network Joint Research Center for Materials and Devices” (NJRC) is operated by five university institutes (Five-star Alliance) and organizes a network-type joint research system in the wide-variety of academic fields, and forms core research hubs for the promotion of advanced and interdisciplinary researches.
Joint researches in NJRC are operated with application-basis programs open to nation-wide research communities.

five-star.tagen.tohoku.ac.jp/english/

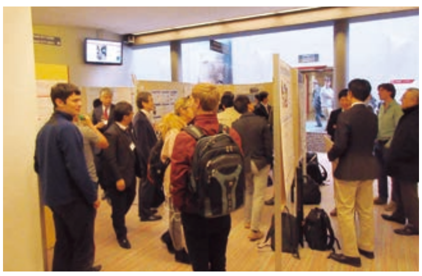
Education

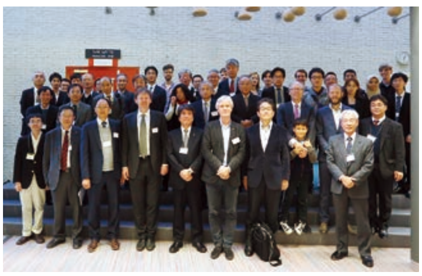
Members of SANKEN participate in graduate education in cooperation with the Graduate School of Science, Engineering, Engineering Science, Pharmaceutical Sciences, Information Science and Technology and Frontier Biosciences. In addition, we provide the lectures in Interdisciplinary Educational Subjects and contribute partly to the advanced human resource development by participating in Institute for Nanoscience Design, Osaka University.

International Cooperation

Academic Exchange Agreements of ISIR with Universities and Research Institutions Abroad (April, 2020)

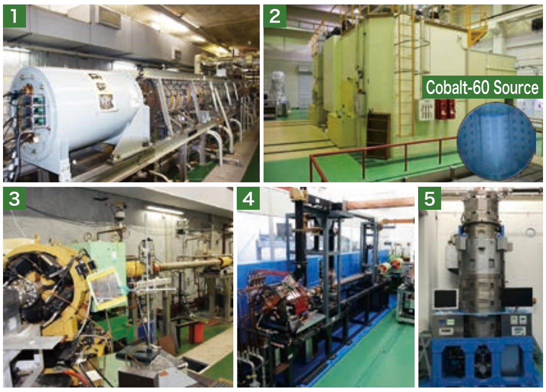
- Inter-University Exchange Agreements: 16
- Faculty-level Exchange Agreements Based on Inter-University Exchange Agreements: 7
- Faculty level Exchange Agreements: 19
- ISIR Overseas Center: 1





Facilities

Research Laboratory for Quantum Beam Science



Developments and applications of ultimate short-pulsed electron beam, high-brightness electron beam, light source base on FEL and positron beam have been promoted together with an intense Co-60 gamma-ray source in this facility.

▶Machine List

1. L-band electron linac
2. Co-60 gamma-ray irradiation facility
3. 150 MeV S-band electron linac
4. RF-Gun equipped S-band electron linac
5. Time-resolved electron microscope

● THz light source based on FEL of L-band linac

www.sanken.osaka-u.ac.jp/labs/rl/English/

Comprehensive Analysis Center

As a common facility for comprehensively performing composition and structural analysis of various materials, Comprehensive Analysis Center has equipment of composition analysis system, spectroscopic analysis system, electron microscope system, state analysis system.

▶Machine List

1. Element analyzer
2. Transmission electron microscope
3. Nuclear magnetic resonance
4. X-ray diffractometer
5. Mass spectrometer

● Scanning electron microscope

www.sanken.osaka-u.ac.jp/labs/cac/

Nanotechnology Open Facilities

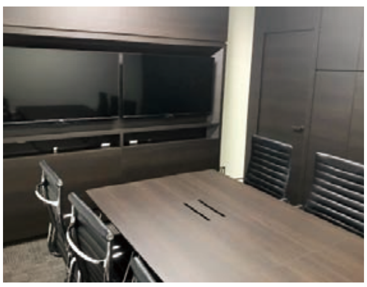
Nanotechnology Open Facilities totally contributes to creations of novel nano-materials and nano-devices for companies / universities / institutes researchers in nanotechnology research fields with the latest equipment and technical support.

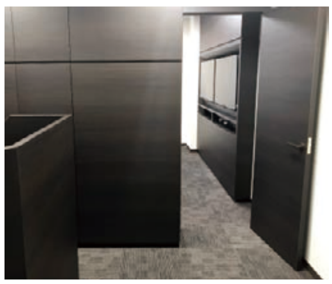
▶Machine List

1. 125keV EB Lithography
2. Helium Ion Microscope
3. Deep Reactive Ion Etching
4. Pulsed Laser Deposition
5. Scanning Electron Microscope
6. Scanning Probe Microscope

nanoplatform.osaka-u.ac.jp

Artificial Intelligence Research Center





The Artificial Intelligence Research Center was established for realizing laboratory-led “bottom-up type AI introduction” at the Institute of Scientific and Industrial Research, which has a wide range of research fields in the under-one-roof. Specifically, the AI center (1) trains young researchers in each research field to be suitable for AI introduction, (2) establishes an AI introduction protocol appropriate for each research field, (3) establishes “AI introduction liaison office” for returning the fruits to each department of Osaka university, and aiming for implementation in industry and transmission to the world, (4) conducts researches to lead the solutions obtained by AI to scientific principles without ending them as a black box.

www.sanken.osaka-u.ac.jp/labs/aic/

Featured Researcher

Touring industrial laboratories and meeting with research groups

SANKEN has engaged in cutting-edge scientific research and development of contemporary academic-industrial collaborations for nearly 80 years, as a leading multidisciplinary laboratory of science and technology in Japan. At present, the Institute has a focus on three research fields, information/quantum science, material/beam science, and biology/molecular science, and has an industrial nanotechnology center. The Institute has expanded its research interests in response to recent developments in scientific technology, and has obtained world-leading research findings in collaboration with various groups. The research scientists who have produced these great achievements are introduced here, with a description of the latest topics.

Overcoming the limit of computer processing with use of high-performance materials

Marked change of resistance

In the information society, which has ballooned in an almost uncontrolled way, development of technologies that improve the ability of computers to process enormous amounts of data is an urgent issue. To date, the number of transistors (semiconductors) incorporated in large-scale integration (LSI) circuits of computers has been increased for densification to improve computing power. However, miniaturization technology for such high computing power is reaching a limit; that is, a minimal line width of 10 nanometers (one-billionth of a meter). This predicted technology wall has become a reality, and this has led to research and development of technological innovations. For example, a device is being developed using sophisticated new materials to change the LSI from a planar to a 3D structure to use space more efficiently.

Dr. Hattori's research focuses on "strongly electron correlated metallic oxides," which are expected to be major candidates as next-generation computer device materials. These metallic oxides include manganese (Mn), nickel (Ni), and vanadium (V), and can undergo instant phase transitions to insulant or metal upon a slight change in temperature, as well as a marked change in electric resistance. These features are of considerable interest for new materials for electronics, including as transistors with a major role as switches in energy saving. However, since hyperfine processing of the materials is difficult due to their hard and fragile properties, it was difficult to obtain nanosized material, the smallest unit that maintains the original features of the materials, and this caused a bottleneck in the research.

Accumulation of molecules

Based on the reverse thinking that, "molecules can be accumulated from scratch because it is difficult to extract molecules from a thin film as a nanostructure assembly", Dr. Hattori developed the "three-dimensional nanoplate pulsed laser deposition (PLD) method." A convex base is prepared to form a 3D pattern. First, using chipmaking technology, epitaxially grown crystals are developed in the direction of the longitudinal axis on the base. Next, the base is tilted at an angle of 60-90° to extend the crystals on the lateral side (lateral direction), which had previously been considered to be impossible. Using this method, the smallest nano 3D conformation was developed successfully for the first time worldwide.

This nanostructure can be developed into a 10- to 100-nanometer section with a high degree of accuracy, and also into part of a transistor. It has been found to be an excellent material, as shown by the resistance change rate at extremely low temperatures of one nanostructure of 8000 times that of a thin film with an assembly of nanostructures, which has more sluggish features.

Dr. Hattori also works on technology to check the condition of the lateral sides of a 3-dimensional silicon substrate, which is required for 3D LSI. Her method of microscope observation has a high degree of accuracy of 0.1 nanometers for one atom, which was previously thought to be impossible. This method can improve performance by careful evaluation of the flatness of the lateral sides.

Breaking the conventional rules

After experiencing building of experimental equipment in a surface science laboratory when she was a student at the Nara Institute of Science and Technology, Dr. Hattori has performed fundamental research in solid state science, such as phase transitions, at the Institute of Scientific and Industrial Research at Osaka University. She looks back on the earlier time, saying that it allowed her "to bring non-conventional thinking to problems after learning various fields and asking honest questions about these fields." She hopes to fulfill her dream of using her research results for development of ultrafast computers or computers that mimic activities of nerve cells.

Dr. Hattori is also raising two junior high school students, together with her husband and research partner, Assistant Professor Ken Hattori, Nara Institute of Science and Technology. She is good at cooking, but places a focus on nutrition, taste, and short cooking time, rather than good looking dishes. She feels that cooking is similar to experimental science, and she has good ideas for her research while cooking. She believes that people who are happier have greater creativity. She is also committed to gender-neutral activities to support the development of female researchers and create a bright future for all women.

Associate Professor

Azusa N. HATTORI

Three-dimensional nanostructure research

Written by Yoshinori Sakaguchi, former editorialist and former reporter for Sankei Shimbun, and current Adjunct Professor at Nara Institute of Science and Technology. Covers general science fields, mainly medical science, as a science journalist.

Department of Quantum System Electronics

Travelling Towards a Quan at Light Speed

A research team led by Osaka University demonstrated how information encoded in the circular polarization of a laser beam can be translated into the spin state of an electron in a quantum dot, each being a quantum bit and a quantum computer candidate. The achievement represents a major step towards a “quantum internet,” in which future computers can rapidly and securely send and receive quantum information.

Elemental conversion of light

Quantum computers have the potential to vastly outperform current systems because they work in a fundamentally different way. Instead of processing discrete ones and zeros, quantum information, whether stored in electron spins or transmitted by laser photons, can be in a superposition of multiple states simultaneously. Moreover, the states of two or more objects can become entangled, so that the status of one cannot be completely described without this other. Handling entangled states allow quantum computers to evaluate many possibilities simultaneously, as well as transmit information from place to place immune from eavesdropping.

木山 治樹

Haruki KIYAMA

However, these photons carrying quantum information decays within less than 100 km in conventional optical fiber networks. To realize the goal of a quantum internet, over which coherent light signals can relay quantum information, these signals must be able to interact with electron spins inside distant computers.

Researchers led by Osaka University used laser light to send quantum information to a quantum dot by altering the spin state of a single electron trapped there. While electrons don't spin in the usual sense, they do have angular momentum, which can be flipped when absorbing circularly polarized laser light.

tum Internet

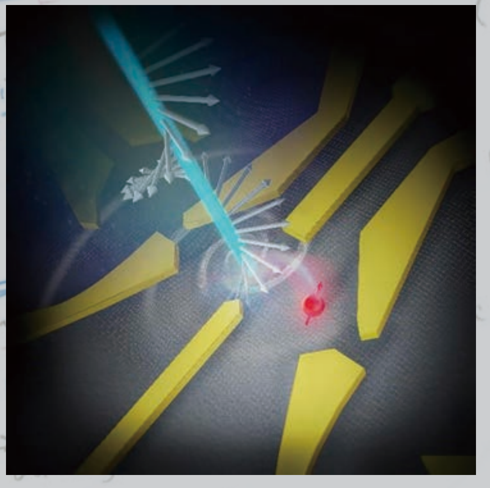


Figure. Schematic image of the spin detection of a circularly polarized photon exciting an electron spin. The yellow nano-fabricated metal electrodes form the pockets required to trap the electrons, move them, and sense them.

“Importantly, this action allowed us to read the state of the electron after applying the laser light to confirm that it was in the correct spin state,” says first author Takafumi Fujita. “Our readout method used the Pauli exclusion principle, which prohibits two electrons from occupying the exact same state. On the tiny quantum dot, there is only enough space for the electron to pass the so-called Pauli spin blockade if it has the correct spin.”

Expanding quantum equipment

Quantum information transfer has already been used for cryptographic purposes. “The transfer of superposition states or entangled states allows for completely secure quantum key distribution,” senior author Akira Oiwa says. “This is because any attempt to intercept the signal automatically destroys the superposition, making it impossible to listen in without being detected.”

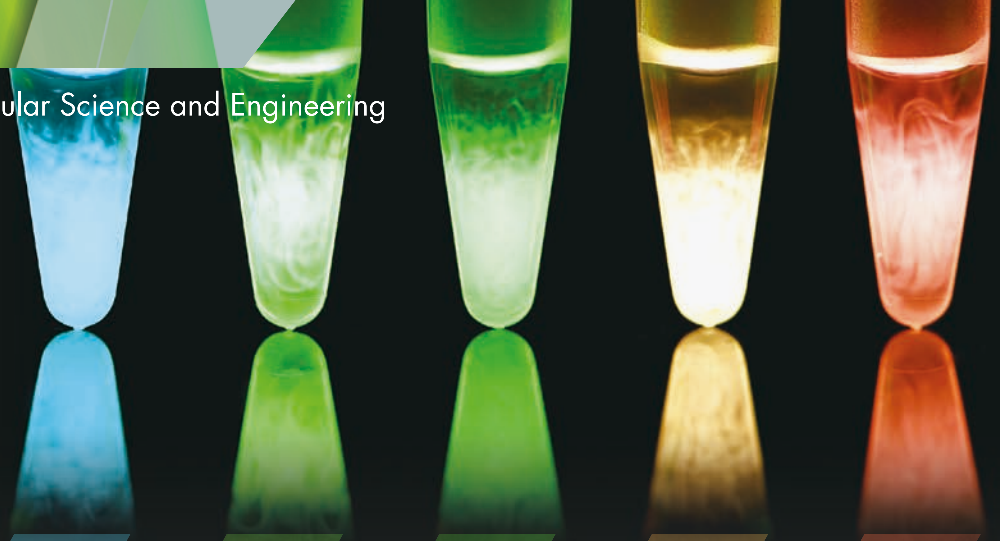
The rapid optical manipulation of individual spins is a promising method for producing a quantum nano-scale general computing platform. An exciting possibility is that future computers may be able to leverage this method for many other applications, including optimization and chemical simulations.

The work is published in Nature Communications as “Angular momentum transfer from photon polarization to an electron spin in a gate-defined quantum dot.” (DOI: https://doi.org/10.1038/s41467-019-10939-x)

Akira OIWA

Takafumi FUJITA

Department of Biomolecular Science and Engineering



New cable-free brain i may take social neuros

Limitation of conventional methods for brain activity imaging

Existing electrophysiological and fluorescence-based brain imaging techniques in mice are generally invasive, require head fixes or cables, and are not suitable for long-term recordings. While there have been recent advances in imaging methods in freely moving animals, these are major limitations for researchers that are interested in the correlation of brain activity and social behaviors.

LOTUS-V, a bioluminescent protein-based membrane voltage indicator

Researchers at Osaka University have developed a new method to record brain activity simultaneously in multiple, freely moving mice. The method is based on a recent bioluminescence-based indicator of membrane voltage called “LOTUS-V”. The LOTUS-V bioluminescent probe is genetically encoded, which means that it is delivered to target cells non-invasively via a common gene expression system (the adeno-associated virus). Its signal is derived from cell membrane voltage changes, which reflects brain activity.

“The LOTUS-V method reported brain activity in freely moving mice with a good sensitivity and without motion artifacts,” says corresponding author Takeharu Nagai. “More importantly, it could measure dynamically changing brain activity in the primary visual cortex during social interactions.”

Cable-free LOTUS-V imaging can report brain activity in freely moving mice

LOTUS-V was applied to cells in the primary visual cortex; this area was targeted because it is known to respond to locomotor activity and visual stimulation. LOTUS-V signal changes reflected neural activity in response to visual stimuli and locomotor activity, as well as during interactions with other mice; neural activity was

永井 健治
Takeharu NAGAI

maging method ciience to the next level

significantly higher when the mouse approached others. Furthermore, the LOTUS-V signal was not affected by leaky signals emitted from other, nearby mice, which means that it faithfully reflected in vivo brain activity.

"Our method successfully detected activity of the superficial layer of the primary visual cortex-this is about 300 μm deep," says Shigenori Inagaki, first author of the study. "It will be important to test its applicability to recording in deeper brain regions."

Perspective of cable-free bioluminescence imaging method

While the temporal resolution of the LOTUS-V method was sufficient to investigate the dynamics of brain activity triggered by specific events, it is not yet superior to that of the fiber-based method.

"These results could be really exciting for social neurobiologists," Nagai says. "It is minimally invasive, doesn't require cables or head fixes, and is suitable for long-term recordings in freely moving animals, meaning it could be useful in a broad range of other research fields, too."

The article, "Imaging local brain activity of multiple freely moving mice sharing the same environment", was published in Scientific Reports at DOI: https://doi.org/10.1038/s41598-019-43897-x.

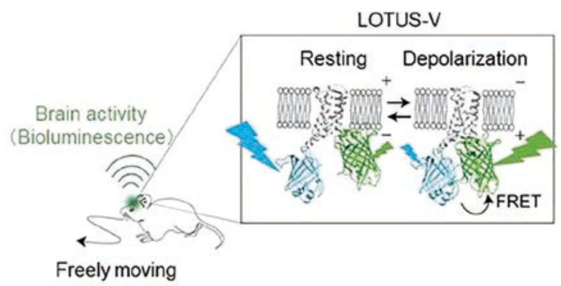


Figure 1. Schematic illustration of the wireless brain activity recording

The color of LOTUS-V bioluminescence changed from cyan to green when neurons in the brain were activated. LOTUS-V is a chimeric protein composed of a bioluminescent protein (cyan), fluorescent protein (lime green), and a voltage-sensitive domain (gray). Membrane depolarization induces conformational changes in the voltage-sensitive domain and shortens the distance between the bioluminescent and fluorescent proteins. Eventually, the efficiency of energy transfer (i.e. FRET) increased and the intensity of lime green was enhanced (conversely, the intensity of cyan decreased). All rights reserved by Professor Takeharu Nagai.

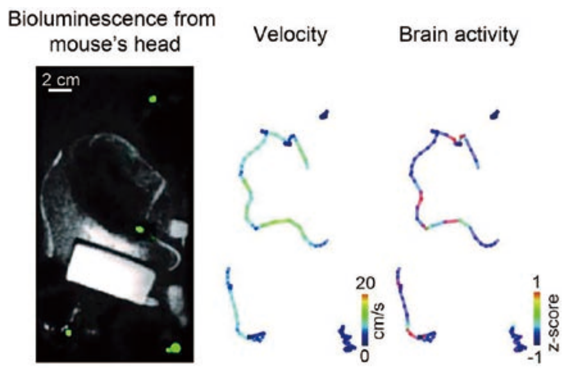


Figure 2. Local brain activity of multiple freely-moving mice in the same cage was visualized.

Left: In four mice, bioluminescence from the primary visual cortex (green) was observed at the same time. Center and Right: Pseudo-colored locomotion trajectories, indicating velocity (center) and brain activity (right) of four mice freely interacting with each other in the same cage.

Wareble Biomonitoring with Flexible Electronics

A research group led by Professor Tsuyoshi Sekitani and Associate Professor Takafumi Uemura of The Institute of Scientific and Industrial Research, Osaka University, succeeded in developing the world's thinnest and lightest differential amplifier for bioinstrumentation.

Conventionally, bioinstrumentation circuits for health care and medical use have consisted of hard electronic devices, such as silicon transistors. However, when soft biological tissues, such as skin, come into contact with hard electronic devices, they tend to become inflamed. Therefore, monitoring of biosignals in everyday life over a long period of time proved difficult. The research group developed a flexible bioinstrumentation circuit that eliminates the discomfort caused by the device attached to the body of the user by integrating flexible electronic devices called organic transistors on a thin and flexible plastic film with a thickness of 1μm (1μm is 1 one-millionth of 1m). The developed circuit is a signal-processing circuit called a differential amplifier.

Compared with conventional single-ended amplifiers, the flexible differential amplifier developed in this study can not only amplify very weak biopotential but also reduce disturbance noise. This group demonstrated that the differential amplifier can be applied to human instrumentation and realize real-time monitoring of electrocardiac signals, which are important biosignals, with reduced noise levels.

This achievement is expected to lead to the monitoring of various weak biosignals (e.g. brain waves and cardiac sounds of a fetus) in everyday life in addition to electrocardiac signals without subjecting users to the discomfort caused by devices attached to the body.

Motivation for Research and Achievements

In Japan, with its declining birthrate and aging population, the application of flexible electronics such as organic transistors in the medical and health care fields has been actively promoted. Sensors and electronic circuits with a high compatibility with biological tissues such as skin and organs are realized by using soft organic materials.

Among these sensors and electronic circuits, flexible amplifiers with organic transistors integrated into them eliminate the discomfort felt by users caused by the devices

World's thinnest, lightes enables bioinstrumentat

Takafumi UEMURA

Masahiro SUGIYAMA

attached to the body. The research and development of such amplifiers as sensors to continuously monitor very weak biosignals is currently ongoing. However, conventional organic amplifiers mainly have a single-ended structure that cannot distinguish the target biosignals from disturbance noise, making it difficult to monitor biosignals with a low noise level (Figure 1). A differential amplifier is a circuit that can measure signals with the noise components removed. However, the variation in the quality of manufactured organic transistors is large compared with that of silicon transistors; thus, there have been no reports on flexible differential amplifiers that realize precise noise reduction.

The research group succeeded in developing a flexible organic differential amplifier with a noise reduction function by developing a compensation technique that can reduce the dispersion of current flowing in organic transistors inside

situations through the use of the high-precision flexible bioinstrumentation circuits without subjecting users to any discomfort caused by the devices attached to their body. For example, bioinstrumentation of people who are performing physically strenuous exercise, such as during sports, becomes possible owing to the improved wearability and adhesion between the device and skin. The real-time long-time bioinstrumentation data thus obtained will promote early detection of diseases and improve the efficiency of treatment, monitoring of the elderly and patients, and monitoring of exercise load. These achievements will further lead to the solution of various problems in Japan's aging society by way of reduced medical expenses and improved quality of life (QOL).

t signal amplifier
ion with reduced noise

the amplifier to as small as 2% or less. The amplifier was fabricated on a parylene film with a thickness of 1 μm. The amplifier does not break when the film is bent and can be attached to human skin without causing any discomfort. Electrocardiac signals were amplified 25-fold and the noise was reduced to one-seventh or less by using this flexible differential amplifier for monitoring the signals. The group demonstrated that the noise caused by external power sources as well as large body-motion noise caused by walking are removed during the monitoring of electrocardiac signals (Figure 1).

Future Prospects

Smart watches and other wearable devices for monitoring biosignals, such as electrocardiac signals, in everyday life are already on the market. Bioinstrumentation is expected to become easier and more comfortable in various

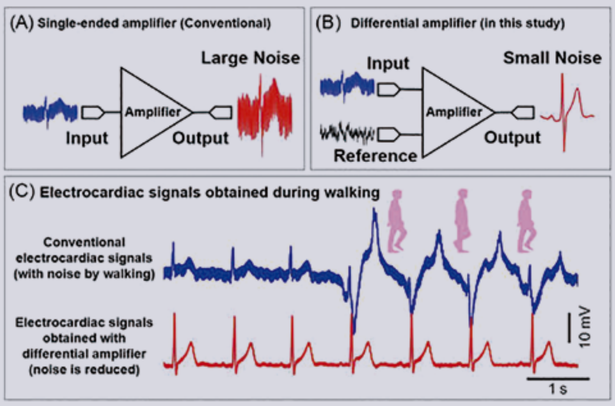


Figure 1. Electrocardiac signals obtained using flexible organic differential amplifier
(A) Conventional single-ended amplifier
(B) Differential amplifier developed in this study
Electrocardiac signals obtained from a walking subject. In the electrocardiac signals obtained using a conventional single-ended amplifier, large noise caused by walking is included in the waveform. In contrast, such noise is removed from the waveform obtained using the developed flexible organic differential amplifier.

https://doi.org/10.1038/s41928-019-0283-5

Department of Advanced Interconnection Materials

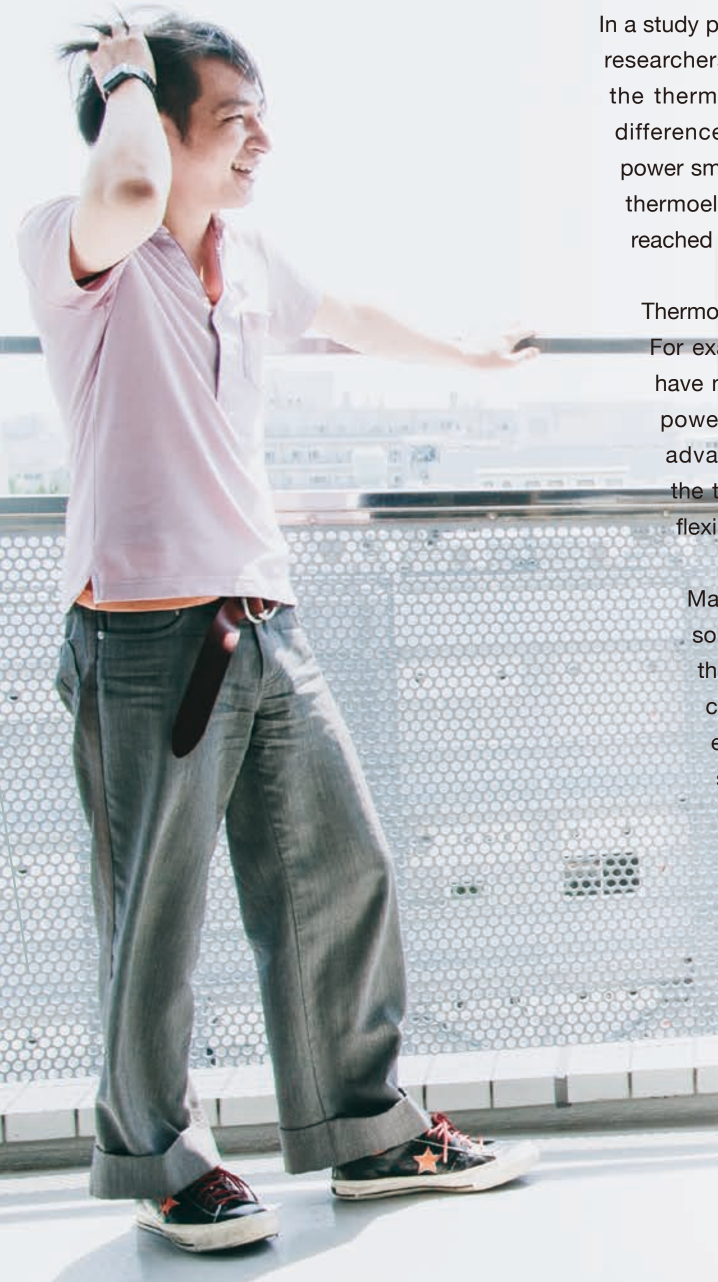
How do

Interconnected healthcare and many other future applications will require internet connectivity between billions of sensors. The devices that will enable these applications must be small, flexible, reliable, and environmentally sustainable. Researchers must develop new tools beyond batteries to power these devices, because continually replacing batteries is difficult and expensive.

In a study published in Advanced Materials Technologies, researchers from Osaka University have revealed how the thermoelectric effect, or converting temperature differences into electricity, can be optimally used to power small, flexible devices. Their study has shown why thermoelectric device performance to date has not yet reached its full potential.

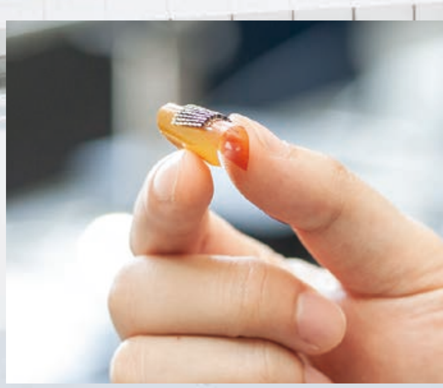
Thermoelectric power generators have many advantages. For example, they are self-sustaining and self-powered, have no moving parts, and are stable and reliable. Solar power and vibrational power do not have all of these advantages. Aviation and many other industries use the thermoelectric effect. However, applications to thin, flexible displays are in their infancy.

Many researchers have optimized device performance solely from the standpoint of the thermoelectric materials themselves. “Our approach is to also study the electrical contact, or the switch that turns the device on and off,” explains Tohru Sugahara, corresponding author of the study. “The efficiency of any device critically depends on the contact resistance.”



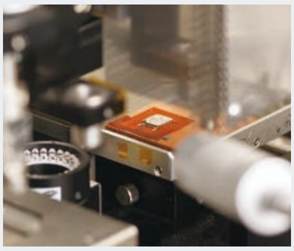
菅原 徹

Tohru SUGAHARA



you power billions of sensors?

By converting waste heat into electicity



In their study, the researchers used advanced engineering to make a bismuth telluride semiconductor on a 0.4-gram, 100-square-millimeter flexible, thin polymer film. This device weighs less than a paperclip, and is smaller than the size of an adult fingernail. The researchers obtained a maximum output power density of 185 milliwatts per square centimeter. “The output power meets standard specifications for portable and wearable sensors,” says Sugahara.

However, approximately 40% of the possible output power from the device was lost because of contact resistance. In the words of Sugahara: “Clearly, researchers should focus on improving the thermal and electrical contact resistance to improve power output even further.”

Japan’s Society 5.0 initiative, aimed at helping everyone live and work together, proposes that the entirety of society will become digitalized. Such a future requires efficient ways to interconnect our devices. Technological insights, such as those by Ekubaru, co-lead author, and Sugahara, are necessary to make this dream a reality.

The article, “Fabrication and characterization of ultra-lightweight, compact, and flexible thermoelectric device based on highly refined chip mounting” was published in Advanced Materials Technologies at DOI: https://doi.org/10.1002/admt.201901128.

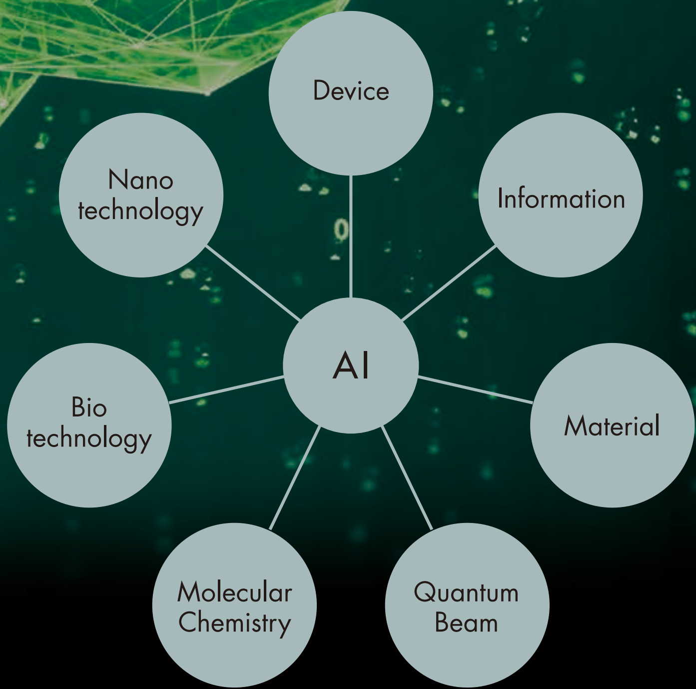
Kenzo IBANO

AI Creates Next Generation

Artificial Intelligence Research Center-ISIR (AIRC-ISIR) was established in April, 2019. AIRC-ISIR objectives are to nurture AI researchers specialized in each of the research divisions of ISIR, which brings a broad range of research fields under-one-roof, and to put “bottom-up AI implementation”, which involves the development of AI implementation protocols, into practice. AIRC-ISIR aims to develop protocols for research-site-driven AI implementation by setting up AI implementation research divisions that correspond to the 3 research divisions (Division of Information and Quantum Sciences / Advanced Materials and Beam Science / Biological and Molecular Sciences) and the Nanoscience and Nanotechnology Center that comprise ISIR, educating young researchers in each division about AI, and connecting with existing AI research institutions. In addition, there are plans to use this center as an “AI implementation liaison office” to share the research results not only within the Osaka University but with research institutions and companies in Japan and overseas for utilization.

In the past, AI research institutions that are driven by AI researchers have been set up, but the establishment of a research center that carries out bottom-up AI implementation, in which those who are not AI researchers are the focus and grow to become AI researchers who are specialized in each research division through the help of AI researchers, is also a unique aspect from a global perspective.

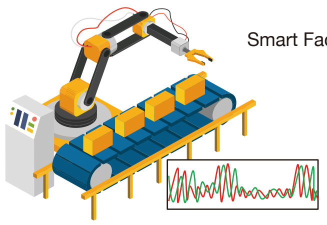
Artificial Intelligence Research Center



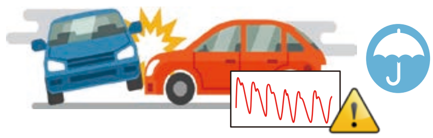
Changing society by Dynamic Modeling and Forecasting of Time-evolving Data Streams

Given a large, semi-infinite collection of co-evolving data sequences (e.g., IoT / sensor streams), which contains multiple distinct dynamic time-series patterns, our aim is to incrementally monitor current dynamic patterns and forecast future behavior.

IoT Big Data / Real-time AI technology



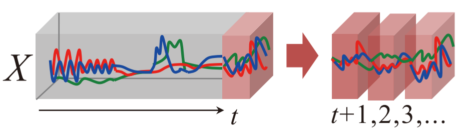
Smart Factories



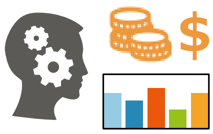
Self-Driving

Real-time Dynamic Data Analysis and Forecasting Technology

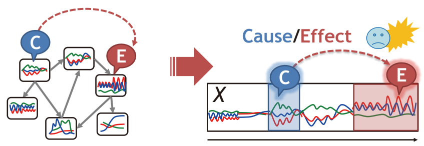
Real-time Automatic Extraction of Dynamic Consequences from Big Data



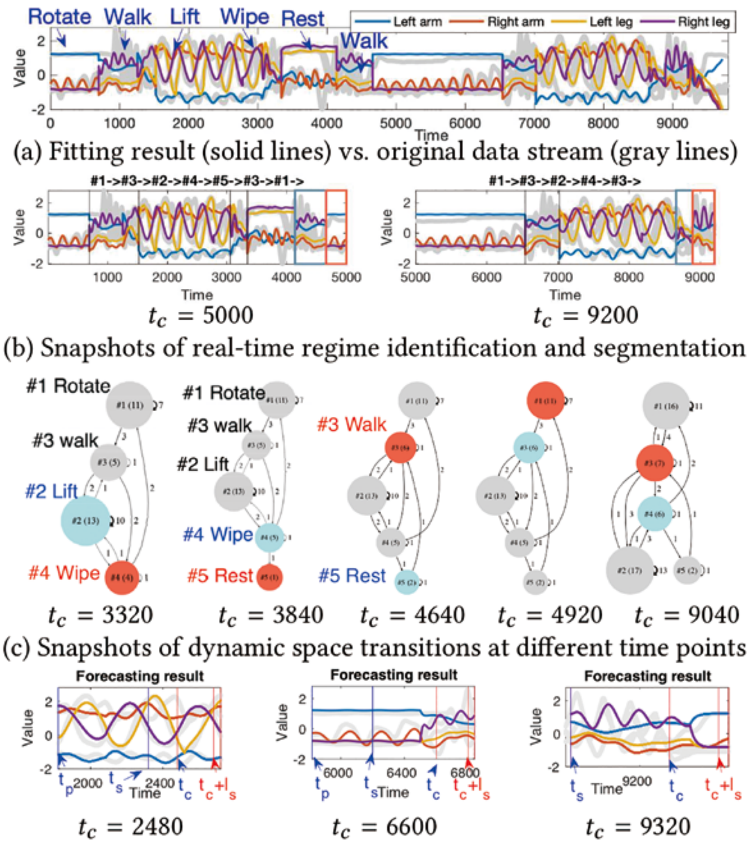
Tensor analysis, Real-time forecasting



Automatic Data Extraction



Dynamic data analysis and forecasting of Data Streams



(a) Fitting result (solid lines) vs. original data stream (gray lines)

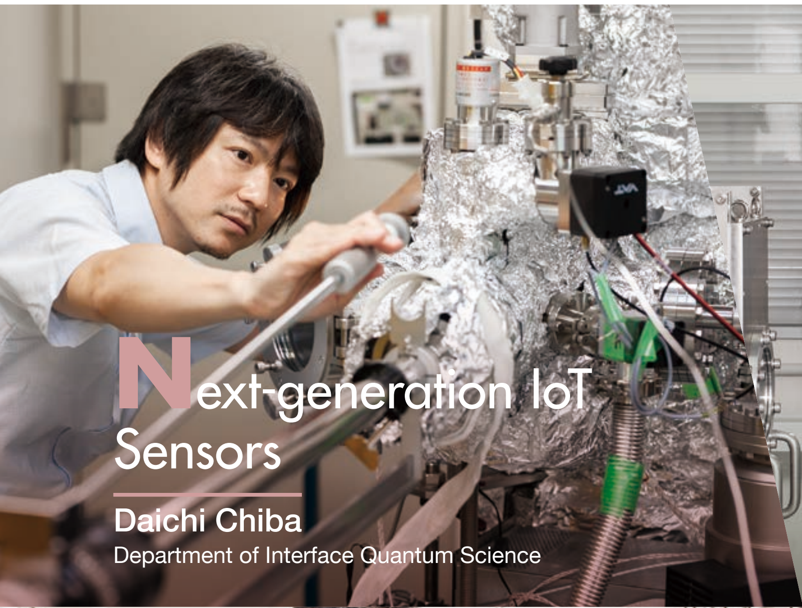
(b) Snapshots of real-time regime identification and segmentation

(c) Snapshots of dynamic space transitions at different time points

(d) Snapshots of l_s = 200-steps-ahead future value forecasting

Data Analysis using Motion Sensor Stream

New Research Groups



Next-generation IoT Sensors

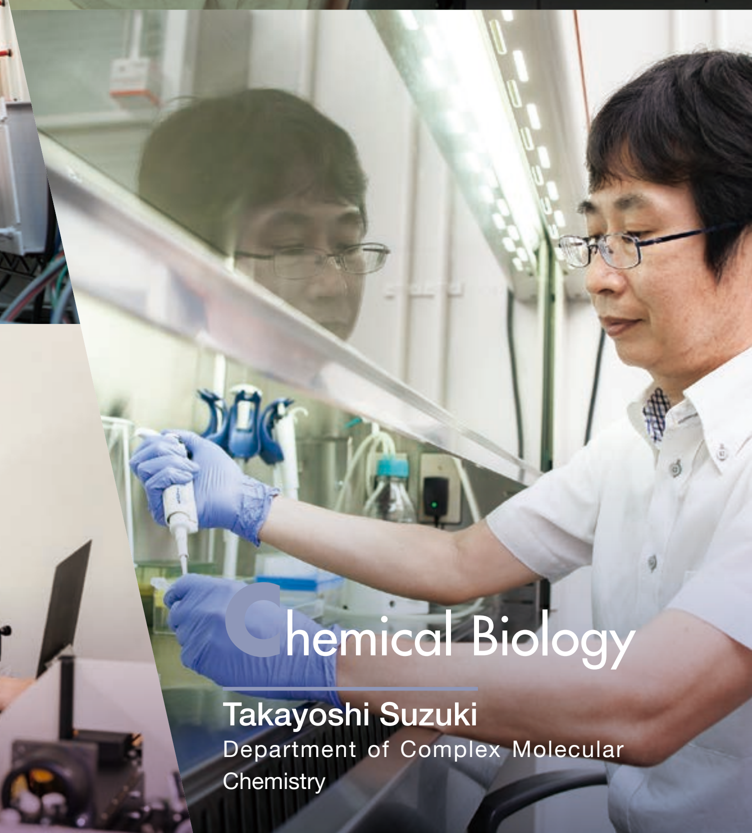
Daichi Chiba
Department of Interface Quantum Science

Laser-driven Particle Acceleration

Tomonao Hosokai
Department of Quantum Beam Physics

Organic Functional Material

Yutaka Ie
Department of Soft Nanomaterials



Chemical Biology

Takayoshi Suzuki
Department of Complex Molecular Chemistry

Photochemistry

Mamoru Fujitsuka
Department of Material Excitation Chemistry

The Young Scientists' Prize, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology

Renovation of Paper for Emergence of Catalytic and Electronic Functions

I was very honored to receive the award for my research to pioneer the new possibility of "Paper" towards green chemistry and electronics. I would like to thank the professors who have mentored and collaborated with me, the students, technical assistants, the secretaries and university administration who supported me, and my family. I will be more diligent in the future.

Department of Functionalized Natural Materials
Associate Professor, Hirotaka Koga

Projects 5

- Develop Super Japanese by Human Power Activation/Enhancement of Industrial
- Creation of a novel approach for drug development by elucidation of the regulation mechanism of cell migration with S1P transporters
- Development of a microscopy system for bioluminescence imaging
- Development and demonstration of laser-driven quantum beam accelerators
- Construction of two dimensional biological model platform using sugar chain modified graphen

Dynamic Alliance for Open Innovation Bridging Human, Environment and Materials

Develop and deepen the scientific outcomes of collaboration among 5 Institutes※1 of Alliance "Five-star Alliance", Promote dense-covalent joint research, Aiming to realize innovation with a clear target

CORE Lab (Collaboration Research Lab)

The aim of CORE Lab is to have young researchers mid-to-long term stay in the alliance's member institutions (5 Core Institutes) as PIs (Principal Investigators) for more intensive joint research.
FY2020: 15 programs

Expanded Collaborative Research Program A/B

The aim of this program is to develop the publicly-offered "Cooperative Research※2" in the Joint Research Center (NJRC) for Materials and Devices, and aim to achieve excellence in interdisciplinary research.
※2 Exploratory Basic Research Project by NJRC
(A) FY2020: 36 programs
(B) FY2020: 40 programs

Young Scientists Research Program

Graduate students and other type of students from outside institutions are appointed as PIs, aiming to foster researchers and strengthen research capabilities for the next generation.
FY2020: 22 programs

※1 5 institutes: Research Institute for Electronic Science (RIES), Hokkaido University; Institute of Multidisciplinary Research for Advanced Materials (IMRAM), Tohoku University; Laboratory for Chemistry and Life Science (CLS), Tokyo Institute of Technology; The Institute of Scientific and Industrial Research (ISIR), Osaka University; and Institute for Materials Chemistry and Engineering (IMCE), Kyushu University

Five-Star Dynamic Alliance

RIES Hokkaido University Research Institute for Electronic Science

IMRAM

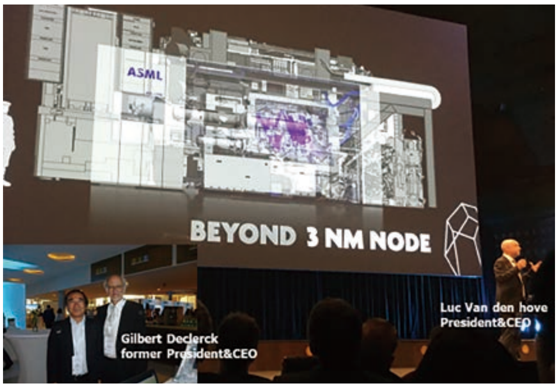
Chem. Res. Lab. since 1939

ISIR OSAKA UNIVERSITY

IMCE

NJRC Network Joint Research Center for Materials and Devices

"Five-star Alliance" is complementary to the "Network Joint Research Center (NJRC) for Materials and Devices", which is operated by the 5 institutes.



ITF2019 @Antwerp, Belgium

imec

In May, 2019, ITF (imec Technology Forum) 2019/Future Summit 2019 was held at Antwerp, Belgium. Luc Van den hove, president & CEO, gave key note speech about our future with technology and choice. In September, under the leading graduate schools program, Max Planck Mainz laboratory and One Planet Center imec were visited at Mainz, Germany and Wageningen, The Netherlands, respectively.

Max Planck @Mainz, Germany

One Planet Center @Wageningen, The Netherlands

SANKEN International Symposium

SANKEN International Symposium aims to discuss and exchange ideas with prominent researchers working on the cutting-edge research field to seek the new scientific areas that SANKEN should contribute to in future. The symposium also exhibits the presence of SANKEN in the specific area and strengthens the international network of the researchers.

The SANKEN International Symposium which focuses on a scientific topic has been held once every year outside or within Osaka City since 1998. The symposium has been jointly held with the SANKEN International Nanotechnology Symposium since 2004. Many world-leading scientists in academic and industry are invited from overseas as well as domestic. Almost all the researchers and students of ISIR participate in the symposium and the number of the participants including the invited speakers exceeds 100 for every symposium.

The 23rd SANKEN International Symposium and the 18th SANKEN Nanotechnology International Symposium were held from 9th to 10th January in 2020 at the Awaji Yumebutai International Conference Center. Setting the symposium title “Scientific and Industrial Research for Space Age”, which is a quite new field for SANKEN, we have discussed possibility for us to contribute the future space developments by utilizing our knowledges of devices, informatic, materials, quantum beam, chemistry, biology and nanotechnology throughout the symposium.

SANKEN International Symposium

Groningen University

Research Activity with Groningen University

The Third Data Workshop was organized by Artificial Intelligence Research Center (AIRC), Institute of Scientific and Industrial Research (ISIR: SANKEN), Osaka University (OU) and CogniGron (Groningen Cognitive Systems and Materials Center), Groningen University (RuG), in Zernike Campus, Groningen University on March 2nd and 3rd, 2020. This Data Workshop was initiated by an informal talk between Rector Magnificus Elmer Sterken, RuG and President Shojiro Nishio, OU in 2017 about continuing collaborative relations between both universities especially in Information and Data Sciences. At the same time, some collaborative projects based on the JSPS Bilateral Program and Core-to-Core Program were being carried out in a two-university-four-institute base including Zernike Institute for Advanced Materials (ZIAM), Groningen Biomolecular Sciences and Biotechnology Institute (GBB), SANKEN, and Institute for Protein Research (IPR). To enhance the activities between two universities, RuG Office at OU was established in March, 2018, located in the First Research Building of SANKEN. Summer/winter schools will be planed as further activities for faculty and student research/education exchanges.

Overseas Study Report

Masaru Kondo

Gröger lab, Bielefeld University, Germany

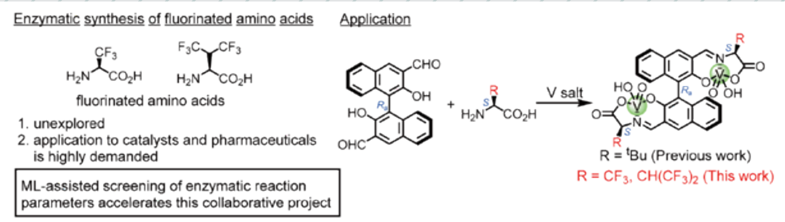
11/30-12/7/2019

Gröger group has focused on development of unique enzymatic reactions. While biocatalytic reactions often affords products in much higher selectivity under mild reaction conditions over chemocatalysis, many reaction parameters (pH, temperature, concentration etc.) significantly affect the results. To realize efficient and strict parameter setting of enzymatic reactions, I suggested machine learning (ML) assisted parameter screening as a collaborative project. Sasai and Washio groups successfully applied ML to development of the new chemical reaction through efficient exploration of reaction conditions (*Chem. Commun.* **2020**, *56*, 1259).

I joined 13th International CeBiTec Symposium (12/2-12/4, 2019) and had oral presentation on ML-assisted efficient exploration of flow reaction conditions. I learned a variety of biocatalytic reactions through this symposium.

On the next day, I visited Gröger laboratory to learn the know-how of enzymatic reactions (e.g. apparatus and preparation of enzyme). After the lab-tour and discussion with Prof. Gröger, I decided to apply ML-assisted parameter screening to enzymatic synthesis of fluorinated amino acids, which enhance metabolic stability and hydrophobicity of molecules. If we can prepare pharmaceuticals and catalysts using fluorinated amino acids instead of natural ones, their activities can be dramatically changed. In the future work, optimal reaction conditions will be efficiently explored using ML. As a synthetic application, preparation and evaluation of fluorinated amino acid derived chiral vanadium catalysts will be performed.


My presentation in the symposium




Christmas market in Bielefeld

SWEDEN	Uppsala University (Department of Physics and Astronomy)
GERMANY	Forschungszentrum Julich RWTH Aachen University University of Augsburg RWTH Aachen University (Institute of Organic Chemistry) Bielefeld University (Faculty of Chemistry) University of Cologne (Faculty of Mathematics and Natural Science) Fraunhofer Institute for Integrated Systems and Device Technology IISB
BELGIUM	Interuniversitair Micro-Electronica Centrum vzw (imec)
NETHERLANDS	Eindhoven University of Technology (Department of Mechanical Engineering)
SWITZERLAND	University of Geneva (Faculty of Science)
DENMARK	Aalborg University
FRANCE	The National Center for Scientific Research University of Bordeaux Ecole polytechnique Université Paris-Saclay
ITALY	The University of Genoa
ISRAEL	The Hebrew University of Jerusalem
EGYPT	Assiut University (Faculty of Science)
KOREA	Pusan National University Chonnam National University Pukyong National University (Basic Science Research Institute) Pusan National University (College of Natural Sciences) Chungnam National University (College of Natural Sciences) Chungnam National University Hanyang University Korea Institute of Ceramic Engineering and Technology Advanced Radiation Technology Institute / Korea Atomic Energy Research Institute Sun Moon University (Collage of Engineering) Duksung Innovative Drug Center (DiDC), Duksung Women's University
CHINA	Peking University Peking University (The School of Electronics Enginering and Computer Science) Inner Mongolia Normal University (School of Chemistry and Environment Science) University of Scièce and Technology Beijing (School of Materials Science and Engeneering) Shenzhen University The University of Hong Kong (School of Biological Sciences)
TAIWAN	National Taiwan University National Chiao Tung University (Collage of Science)
THAI	Thammasat University Chulalongkorn University (Department of Computer Engineering, Faculty of Engineering) King Mongkut's University of Technology North Bangkok (Faculty of Applied Science)
REPUBLIC OF THE PHILIPPINES	De La Salle University (College of Computer Studies)

OSAKA UNIVERSITY

ISIR OSAKA UNIVERSITY

The Institute of Scientific and Industrial Research, Osaka University