ANNUAL REPORT 2023

Year ended March 31, 2023

SANKEN
OSAKA UNIVERSITY

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

Quantum Beam

Quantum-beam-induced Nanochemistry

Laser-driven Particle Acceleration

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

Quantum beam-driven drug discovery and medical application

Device

Quantum Technology

Next-generation IoT Sensors

Flexible Intelligent System

flexible spintronics sensors

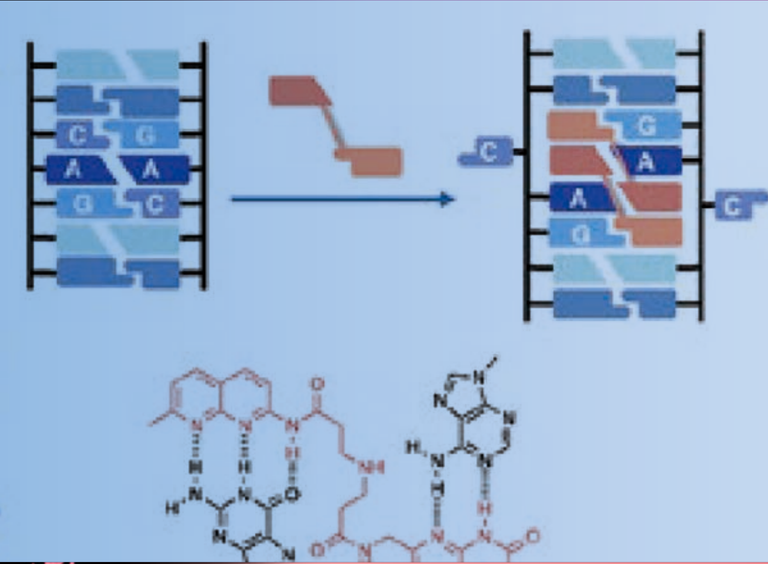
Molecular Chemistry

Photochemistry

Asymmetric Catalyst

DNA/RNA-targeting Molecules

Chemical Biology



Information

Computer Vision

Machine Learning

Spoken Dialogue Systems

Artificial Intelligence

Data Mining

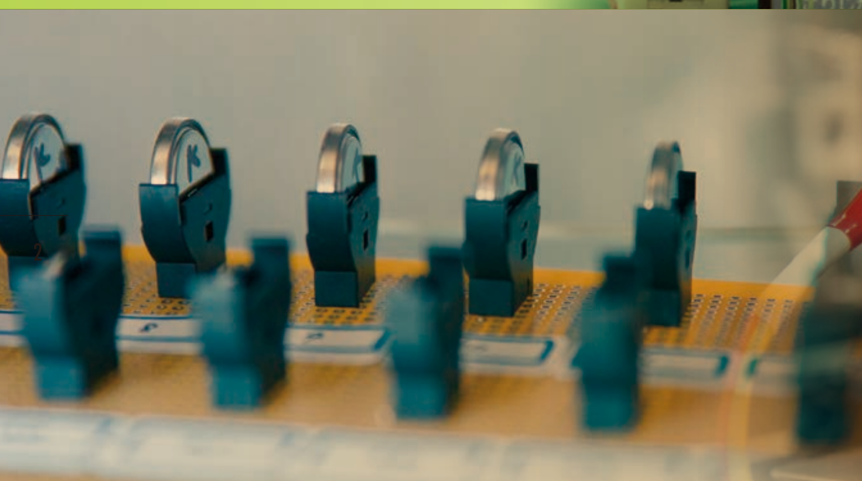
Biotechnology

Bio-inspired Materials

Multidrug Resistant Bacteria

Luminescent Protein

Smell Digitization



Material

Cellulose Nanofiber

Silicon

Multi-Functional Materials

Advanced Batteries

Nanotechnology

Functional Oxide Nanoelectronics

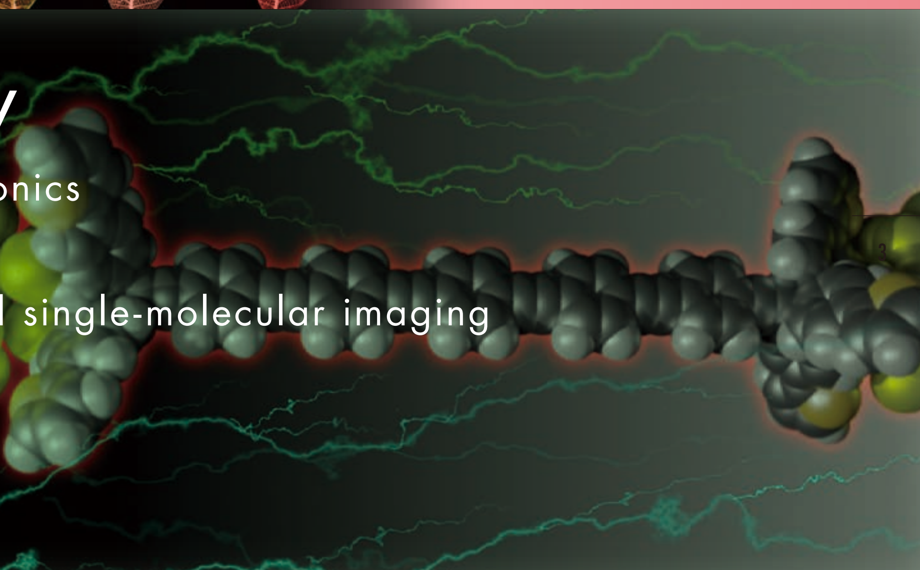
Quantum Beam

Single-atom spectroscopy and single-molecular imaging

Materials Design

Single-molecule Science

Simulation



The Institute of Scientific and Industrial Research (ISIR: SANKEN) was established at Osaka University in 1939 in response to strong demand and support 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. At present, SANKEN is covering wide-variety of research areas including; 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 (NJRC) for Materials and Devices, consisting of five research institutes, in collaboration with RIES (Hokkaido University), IMRAM (Tohoku 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, 84 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.

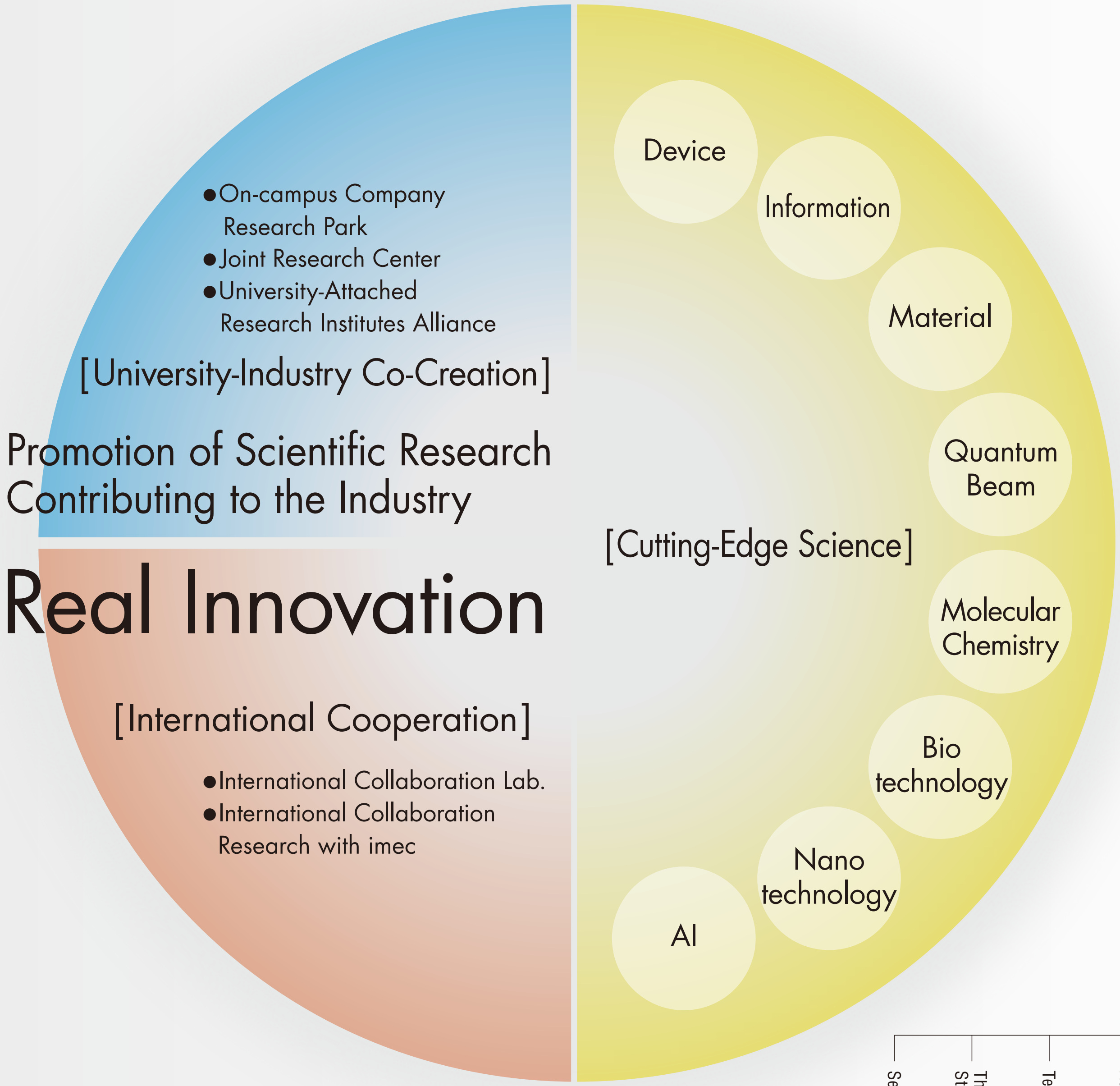
For example, the SANKEN, which has been leading nanotechnology research organization since the 1980s, has established its Nanoscience Nanotechnology Center at the early stages of development of nanoscience and has led the world since. In the field of information and AI, where social implementation is 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 for all over the world, we will strive to provide the highest level of research and education. As one of our actions, we changed our official English name of the Institute to “SANKEN” in June 2021, and to develop into a more globally recognized and familiar research institute.

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

Director

Tohru Sekino



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 central 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.
2021	In June 1st 2021, the official English abbreviated name of our institute was changed from “ISIR” to “SANKEN”.

Organization

Director
- Faculty Council
- Board of Trustees
- Committees
- Advisory Board
- Administrative Office
- Technical Division
- The SANKEN Strategy Office
- Service Facilities, etc

Device / Information / Material / Quantum Beam / Molecular Chemistry / Biotechnology / Nanotechnology

Division of Information and Quantum Sciences
- Information and Quantum Sciences
  - Department of Architecture for Intelligence
  - Department of Knowledge Science
  - Department of Reasoning for Intelligence
  - Department of Intelligent Media
  - Department of Advanced Electron Devices
  - Department of Interface Quantum Science
  - Department of Quantum System Electronics

Division of Advanced Materials and Beam Science
- Advanced Materials and Beam Science
  - Department of Beam Materials Science
  - Department of Quantum Beam Physics
  - Department of Excited Solid-State Dynamics
  - Department of Energy and Environmental Materials
  - Department of Advanced Hard Materials
  - Department of Semiconductor Materials and Processes
  - Department of Functionalized Natural Materials

Division of Biological and Molecular Sciences
- Biological and Molecular Sciences
  - Department of Complex Molecular Chemistry
  - Department of Regulatory Bioorganic Chemistry
  - Department of Synthetic Organic Chemistry
  - Department of Material Excitation Chemistry
  - Department of Biomolecular Science and Engineering
  - Department of Biomolecular Science and Regulation
  - Department of Biomolecular Science and Reaction

Nanoscience and Nanotechnology Center
- Nanotechnology Open Facilities
- Nanofabrication Shop
- Advanced Nanotechnology Instrument Laboratory
- Department of Nanodevices for Medical Applications
- Department of Nanotechnology for Industrial Applications
- Department of Nano-Intelligent Systems
- Department of Nanodevice Characterization
- Department of Nanotechnology for Environmental and Energy Applications
- Department of Nanosystem Design
- Department of Bio-Nanotechnology
- Department of Soft Nanomaterials
- Department of Theoretical Nanotechnology
- Department of Nanocharacterization for Nanostructures and Functions
- Department of Advanced Nanofabrication
- Department of Functional Nanomaterials and Nanodevices

Artificial Intelligence Research Center
- Big Data Factory
- Department of AI Introduction to Nanoscience and Nanotechnology
- Department of AI Introduction to Biological and Molecular Sciences
- Department of AI Introduction to Advanced Materials and Beam Science
- Department of AI Introduction to Information and Quantum Sciences
- Department of Translational Datability

Division of Next Industry Generation
- Department of Intellectual Property Research
- Department of New Industry Generation Systems

Division of Special Projects

The project provides young and senior researchers own laboratories to develop and keep on the skills.
- Laboratories of First Project
- Laboratories of Second Project (Department of Three-Dimensional Nanostructure Science)
- Laboratories of Second Project (Department of Advanced Materials and Implementations)
- Laboratories of Third Project

Joint Research Division・Research Alliance Laboratories
- Laboratory of flexible and power three dimensional system integration
- KOBELCO Future Pioneering Co-Creation Research Center
- Division of Nano-Lithography Research
- Division of Material Science of Si-based Agent

Comprehensive Analysis Center

Research Laboratory for Quantum Beam Science

Center for Collaborative Research Education and Training

Network Joint Research Center for Materials and Devices

International Collaborative Research Center

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.

Alliances among Research Institutes and Network Joint Research Center

Crossover Alliance to Create the Future with People, Intelligence and Materials (Five-star Alliance)

Five-Star

Five university research institutes across Japan Archipelago (Research Institute of Electronic Science at Hokkaido University; Institute of Multidisciplinary Research for Advanced Materials at Tohoku University; the Laboratory for Chemistry and Life Sciences, Institute of Innovative Research at Tokyo Institute of Technology; Institute of Scientific and Industrial Research at Osaka University; Institute for Materials Chemistry and Engineering at Kyushu University) cooperate with each other to organically cross-over rich research resources including human resources, knowledge, technology, and facilities, and promote research aimed at solving social issues and the development of young researchers.

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

Network Joint Research Center for Materials and Devices (NJRC)

NJRC

The Network Joint Research Center for Materials and Devices (NJRC) has been established in FY2011 as a first network of such centers in Japan (a project approved by the Ministry of Education, Culture, Sports, Science and Technology). The five research institutes that make up the center work together to invite researchers from a wide range of research institutions for joint research thorough open recruitment. Taking advantage of the characteristics of the network of centers, we promote joint research with universities, public research institutes, and private companies in Japan and overseas, and strengthen research capabilities and develop human resources in the fields of materials and devices and their related fields.

five-star.sanken.osaka-u.ac.jp/en/

KOBELCO Future Pioneering Co-Creation Research Center

As the labor force continues to shrink due to the declining birthrate and aging population, the manufacturing industry needs to respond to rapid changes in the business environment including decarbonization. In particular, there are urgent needs to evolve the workplace so that workers can demonstrate their ability through operations that generate higher added value.

Therefore, by combining KOBELCO's diverse and realistic manufacturing experience and technology with Osaka University's AI and other cutting-edge science, the research center will develop solutions that enable workers to grow with digital systems and be more creative.

KOBELCO 未来協働研究所 KOBELCO Future Pioneering Co-Creation Research Center

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 R^3 Institute for Newly-Emerging Science Design, Osaka University.

International Cooperation

Academic Exchange Agreements of ISIR with Universities and Research Institutions Abroad (April, 2023)

- Inter-University Exchange Agreements: 14
- Faculty-level Exchange Agreements Based on Inter-University Exchange Agreements: 6
- Faculty level Exchange Agreements: 15
- 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 (AIRC)

産業科学AIセンター

The Artificial Intelligence Research Center was established for realizing laboratory-led "bottom-up type AI introduction" at SANKEN, 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/

Professor Emi Minamitani
Department of Theoretical Nanotechnology

SANKEN Visit 01

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.

Interpretation of microstructure using mathematics and physics and identification of next-generation materials with improved characteristics

Successful high-precision prediction of thermal conductivity

Crystals of silicon (Si), a semiconductor material, have a regular atomic structure like diamond. However, when silicon is quenched from liquid conditions, the structure changes to an amorphous (non-crystalline) solid in which the silicon atoms bond to each other irregularly, leading to materials with strong light absorption and less thermal conductivity. Amorphous silicon is already in practical use in solar power systems, but identification of improved functions and utilization of amorphous materials as a next-generation material requires understanding of the local regularity of the latent microstructure in the amotphous structure and investigation of the details of the relationship of this structure with various physical phenomena.

Professor Minamitani has made a breakthrough in the theoretical simulation that is directly linked to the reliability and performance of materials. This work has involved development of a high-precision prediction technique for thermal conductivity of amorphous silicon, and elucidation of the cause of variation using a new topological data analysis method.

Identification of the characteristics of amorphous structure by data analysis

Amorphous structure is not completely chaotic, but rather exhibits medium-range order on the scale of micrometers (10^{-8} m). Professor Minamitani first performed a simulation using various cooling conditions to produce amorphous silicon, derived many model structure patterns, and calculated their respective thermal conductivities. In particular, she revealed the structural characteristics using topological data analysis based on persistent homology. She also developed a model to show how silicon atoms bond to each other in a ring and visualized the distribution of the size and shape of the rings.

By quantifying these data and using them as input into a machine learning model, precise prediction of thermal conductivity from the structure information has been achieved. Second, an analysis of the microstructure showed that atoms bonding in pentagonal patterns were strongly related to variation of thermal conductivity as the minimal unit for medium-range order. If the pattern is distorted to a rectangular shape, the balance of interatomic forces is lost, resulting in reduced thermal conductivity.

Professor Minamitani said ambitiously, "Application of mathematical and physical sciences unveiled complicated structures that could not be understood using current experimental techniques. This approach can also be applied to other disordered structures including alloys, so I intend to use it for a general purpose".

Exploration of new many-body effects

Professor Minamitani started her study with the theme of many-body physics. Many electrons and atoms interact with each other within a substance, leading to the appearance of a function based on the properties of the respective electrons and atoms. For example, electrons can undergo condensation as a pair (known as a Cooper pair) that leads to zero electrical resistance; i.e., superconductivity. Professor Minamitani has aspirations in this area and explains, "Many theoretical studies of many-body effects use models with simplified properties of substances because of the need to deal with complicated interactions. My aim is to pursue the process underlying the macroscopic physical properties by examining the microscopic interactions that are present in realistic materials".

Another theme Professor Minamitani is currently studying is the phenomenon of electron scattering due to interaction with phonon (lattice vibration) energy. This phenomenon is strongly associated with thermogenesis and thermal conductivity. She collaborates with experimental researchers targeting layered materials including graphene, for which the surface is easy to control and interactions can be observed. Precise analysis is conducted with a combination of experimental data and first-principles calculations for electron movement in substances simulated by Professor Minamitani to find new many-body effects. One target is a solution to energy conservation, such as cooling of semiconductor overheating in personal computers.

Enjoy physics without overworking

Professor Minamitani is continuing her physics-based studies and is also currently pursuing theoretical work using applied mathematics. She recalls, "I was interested in mathematics, but not good with it, before entering Osaka University. It was not in my nature to calculate and solve differential calculus by hand. Automatic processing for complex calculations due to enhanced computer software is providing the opportunity to start a study using mathematics".

She made some unexpected discoveries as she changed study sites from RIKEN to the University of Tokyo to the Institute for Molecular Science. Scanning tunneling microscopy (STM) uses spectral analysis to examine a current flowing through a sharp metal probe close to the surface of a sample. STM can also detect a phonon from a current change. Her collaborator on an experiment mentioned to her, "Strange peaks appear at specific bias voltage in the data". Professor Minamitani found a strong interaction between electrons and phonons based on a theoretical study, and developed a new method to improve the accuracy of observation. She says, "The stranger the phenomena compared to common knowledge, the more interesting the study".

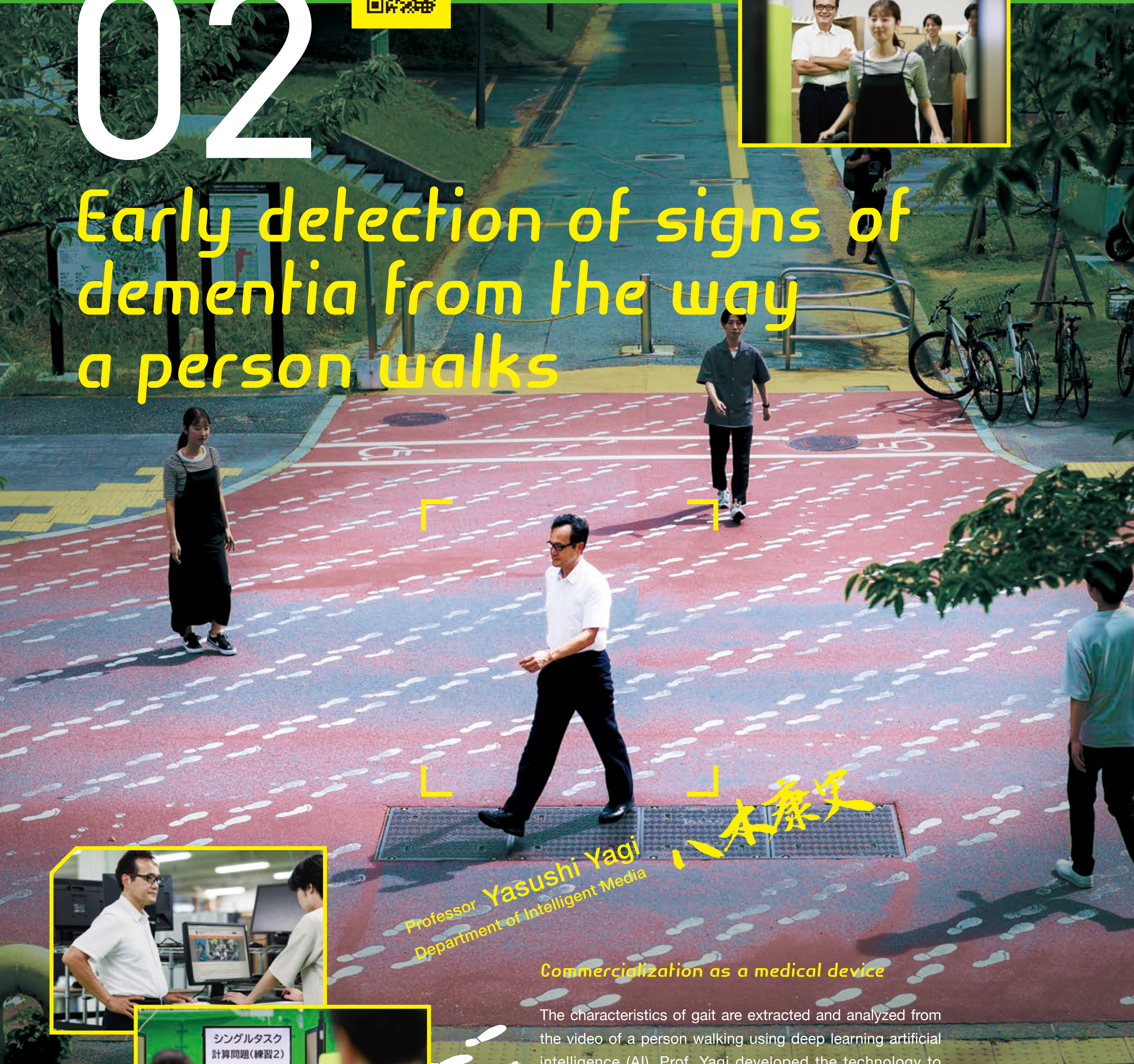
Professor Minamitani decided to be a researcher as she grew up watching her relatives, who were researchers in arts and sciences who were happily working on self-chosen themes. She says, "I think a researcher is a self-employed worker who can study an area of interest and work on their own time". However, young would-be researchers are decreasing in number due to the perception that research requires a lot of effort. Professor Minamitani says, "We need to show that research is rewarding to attract young people to science and to make them understand that research is not merely tough, but is fascinating work".

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.

SANKEN Visit

02

Early detection of signs of dementia from the way a person walks



Professor Yasushi Yagi
Department of Intelligent Media

Commercialization as a medical device

The characteristics of gait are extracted and analyzed from the video of a person walking using deep learning artificial intelligence (AI). Prof. Yagi developed the technology to estimate biometric information from a person's gait. Criminal investigations now use this technology to identify a person based on their gait. The technology is also of practical use in the medical field and is likely to be used as a diagnostic aid (programmed medical device) for early detection of mild cognitive impairment (MCI). This is a preclinical stage of dementia that is difficult to diagnose.

"Gait analysis is the only technology that can remotely evaluate a variety of biological information via video images, making it highly valuable for use in healthcare fields. Its accuracy has improved due to advances in deep learning technology, and it is now used as circumstantial evidence for gait recognition in criminal investigations, similarly to facial recognition and fingerprints," said Prof. Yagi.

Determination by calculation and stepping

The system to diagnose MCI asks subjects to perform two types of tasks simultaneously (dual tasks): "calculation", which uses brain cognitive function, and "stepping", which uses physical function, to examine how smoothly the brain can switch between tasks. Characteristics of subjects, such as the speed of their answers to calculation questions and the way they move their feet are analyzed by AI by combining a database containing more than 70,000 gait videos and biometric data collected by Prof. Yagi's team at facilities for elderly people. The performance of this method in MCI screening (identification) exceeds the results of standard brain cognitive function screening tests conducted at medical centers through interviews.

Applied research for approval of the medical device is in progress, as one of the medical device development projects of the Japan Agency for Medical Research and Development (AMED). Prof. Yagi says, "The device is inexpensive and can be used to test patients easily in a short time without the presence of a specialist. Therefore, it is probable that the device can be installed in general practice clinics and a patient can be referred to a neuropsychiatrist based on the test results. I think the device will be effective for early detection of dementia including Alzheimer's disease, which is predicted to increase with aging of the population".

Challenge of avatar identification

Prof. Yagi is also participating in the Cabinet Office's "Moonshot Research & Development Program" project, which aims to create a society free from various restraints in the real society, such as body, space and time, by the year 2050. He is working on the development of technology for identification of a person to ensure the safety and reliability of a "cybernetic avatar (CA)," which is remotely operated by users in place of themselves at sites such as the "Metaverse", where interaction and business is conducted in virtual spaces on the Internet. "For example, a CA might be involved in a crime without the user's knowledge, and consequently, the user could suffer damage. We are examining robust safety measures such as a method to always identify the CA with the user".

Utilization of personal data

Prof. Yagi is also the general manager of the "Initiative for Life Design Innovation (iLDi)" of Osaka University, a research support project for the Society 5.0 Realization Research Support Project commissioned by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The iLDi Headquarters aims to build a society that enriches human life (Society 5.0) through scientific and technological innovation that utilizes various data, including AI and big data analysis. As an attempt to achieve this goal, the headquarters will provide private companies with data containing personal information used for academic research at universities, clearing regulations under the Act on Protection of Personal Information, to activate industry-academia collaborative research, including product development.

Under the Act on Protection of Personal Information, data containing personally identifiable information obtained through academic research at universities cannot be used as is by private companies for secondary use for product development. Companies must again explain the details of the change in the purpose of use to the individual and obtain his/her consent. Therefore, a "dynamic consent" mechanism was introduced at the headquarters, whereby each time a company uses personal data provided by the university, the name of the user and the purpose of use are communicated to the university laboratory and the subject, and permission is given by the user. The headquarters started trial operations of this method of data exchange and is validating its effectiveness.

Prof. Yagi expressed his aspirations, "High-value-added personal data is considered an important asset that, depending on how it is used, can generate significant innovation for daily life and industry. We would like to provide valuable personal data obtained from academic research to private companies and further expand the data distribution system to enable active utilization of the data".

Challenge of satisfying intellectual curiosity

After completing his graduate studies at Osaka University Graduate School of Engineering Science, Prof. Yagi worked at a research laboratory of Mitsubishi Electric Corporation. He then returned to Osaka University and became Professor at the Institute of Scientific and Industrial Research (ISIR: SANKEN) in 2003. He also served as Director of SANKEN and as Director and Vice President of Osaka University. His basic research theme is computer vision to play the role of robot's eyes, but he has achieved a wide range of results. This includes his development of the world's first sensor for a mobile robot with a 360-degree view, as an elemental technology to compile a video database of gait.

Prof. Yagi says, "We have chosen interesting themes that satisfy our intellectual curiosity and we have rushed headlong into these studies. I hope that young researchers will also rethink their safety-oriented attitudes and take on these challenges".

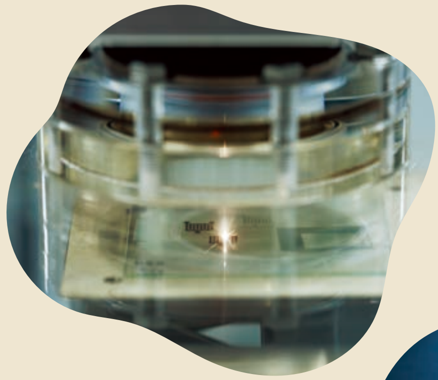
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

15 LIFE ON LAND

Electronics can grow on trees thanks to nanocellulose paper semiconductors

A team including Associate Professor Koga from SANKEN (The Institute of Scientific and Industrial Research), at Osaka University reports wood-derived semiconductors that can be tuned for use in a range of sustainable electronic devices



古賀 大尚

Hirotaka Koga

Semiconducting nanomaterials with 3D network structures have high surface areas and lots of pores that make them excellent for applications involving adsorbing, separating, and sensing. However, simultaneously controlling the electrical properties and creating useful micro- and macro-scale structures, while achieving excellent functionality and end-use versatility, remains challenging. Now, Osaka University researchers, in collaboration with The University of Tokyo, Kyushu University, and Okayama University, have developed a nanocellulose paper semiconductor that provides both nano–micro–macro trans-scale designability of the 3D structures and wide tunability of the electrical properties. Their findings are published in *ACS Nano*.

Cellulose is a natural and easy to source material derived from wood. Cellulose nanofibers (nanocellulose) can be made into sheets of flexible nanocellulose paper (nanopaper) with dimensions like those of standard A4. Nanopaper does not conduct an electric current; however, heating can introduce conducting properties. Unfortunately, this exposure to heat can also disrupt the nanostructure.

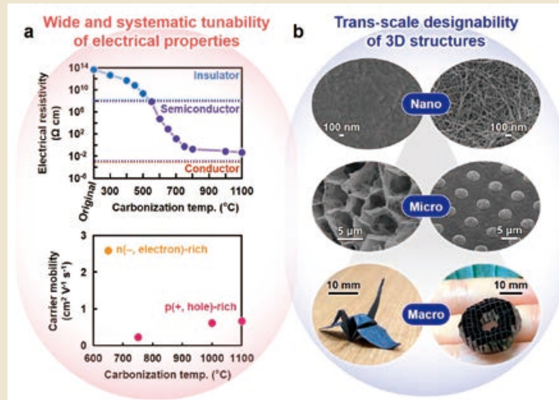
The researchers have therefore devised a treatment process that allows them to heat the nanopaper without damaging the structures of the paper from the nanoscale up to the macroscale.

“An important property for the nanopaper semiconductor is tunability because this allows devices to be designed for specific applications,” explains study author Hirotaka Koga. “We applied an iodine treatment that was very effective for protecting the nanostructure of the nanopaper. Combining this with spatially controlled drying meant that the pyrolysis treatment did not substantially alter the designed structures and the selected temperature could be used to control the electrical properties.”

The researchers used origami (paper folding) and kirigami (paper cutting) techniques to provide playful examples of the flexibility of the nanopaper at the macrolevel. A bird and box were folded, shapes including an apple and snowflake were punched out, and more intricate structures were produced by laser cutting. This demonstrated the level of detail possible, as well as the lack of damage caused by the heat treatment.

Examples of successful applications showed nanopaper semiconductor sensors incorporated into wearable devices to detect exhaled moisture breaking through facemasks and moisture on the skin. The nanopaper semiconductor was also used as an electrode in a glucose biofuel cell and the energy generated lit a small bulb.

“The structure maintenance and tunability that we have been able to show is very encouraging for the translation of nanomaterials into practical devices,” says Associate Professor Koga. “We believe that our approach will underpin the next steps in sustainable electronics made entirely from plant materials.”



(a) Wide and systematic tunability of the electrical properties and (b) nano-micro-macro trans-scale designability of 3D structures of the as-prepared semiconductor (denoted the nanopaper semiconductor)
(CC BY, credit: 2022 Koga et al. Nanocellulose paper semiconductor with a 3D network structure and its nano–micro–macro trans-scale design. ACS Nano)

The article, “Nanocellulose paper semiconductor with a 3D network structure and its nano–micro–macro trans-scale design,” was published in *ACS Nano* at DOI: https://doi.org/10.1021/acsnano.1c10728

Makusu Tsutsui

Blue Energy

A team including Associate Professor Tsutsui from SANKEN (The Institute of Scientific and Industrial Research), at Osaka University create an ultrathin silicon membrane with arrays of nanopores to permit osmotic flow to generate electricity, which may provide a previously untapped source of renewable energy from the oceans

Devising renewable sources of energy is a key concern for scientists, political leaders and communities as the world comes to terms with the realities of climate change and the limits of the earth's natural resources. In an exciting new development, scientists from the Institute of Scientific and Industrial Research at Osaka University have demonstrated that electricity may be obtainable from water with a high salt concentration, such as seawater.

Some people think about "osmosis" as just a science term they were forced to learn in elementary school biology class. However, the spontaneous motion of dissolved ions or molecules through a semi-permeable membrane when there is a concentration difference between the two sides can be harnessed to generate electricity. And luckily for us, the oceans are filled with salty water, which may be used to help alleviate humanity's ever-growing demand for energy. However, in order to be practical, this membrane needs to be very thin and highly selective to allow ions—but not water molecules—to pass through.

Now, a research team led by Osaka University has used conventional semiconductor processing technology to precisely control the structure and arrangement of nanopores in an ultrathin silicon membrane. Because these fabrication methods have been around for decades, the costs and design complexities were minimized. Moreover, the size and location of the pores could be precisely controlled. "Whenever there is a non-equilibrium situation, such as two water tanks with different salt concentrations, there is often an opportunity to covert this thermodynamic energy into electricity," says first author Makusu Tsutsui.

Using a single 20-nm-sized nanopore, the device reached a peak power efficiency of 400 kW/m^2. However, the researchers found that adding too many nanopores to the membrane actually reduced the power that could be extracted. The optimal configuration of pores, 100-nm-sized nanopores arranged in a grid with a spacing of one micrometer, yielded an osmotic power density of 100 W/m^2. This was an important step in understanding how to design nanopore devices for best power generation. "Many other research groups are promising environmentally friendly 'green' energy, but we go one step further and propose 'blue' energy based on oceanwater that can be applied on an industrial scale," senior author Tomoji Kawai says. Future projects may include ways to scale up the devices for real world testing.

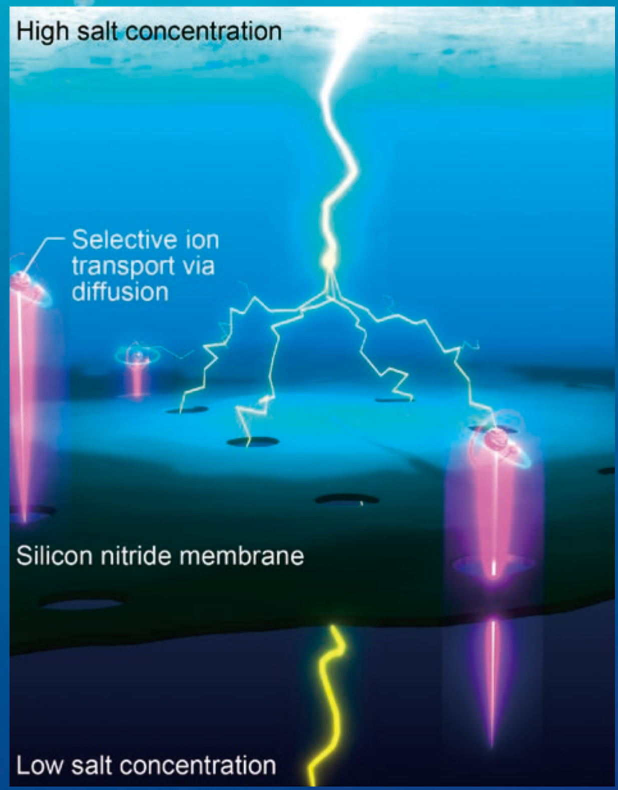


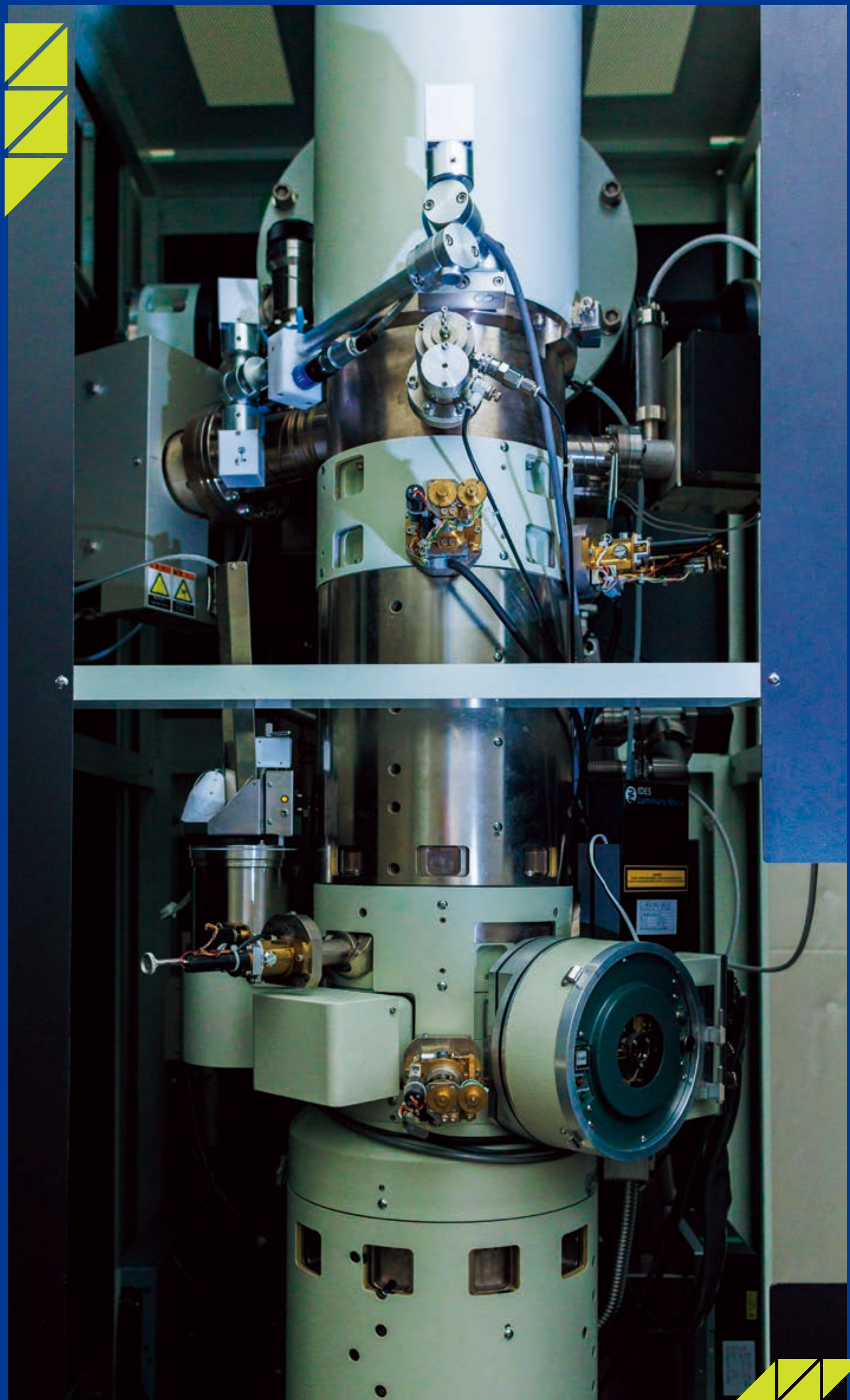
Fig. 1
Osmotic power generation using size- and position-controlled solid-state multi-nanopores.

The article, "Sparse multi-nanopore osmotic power generators" was published in *Cell reports Physical Science* at DOI: https://doi.org/10.1016/j.xcrp.2022.101065

3 GOOD HEALTH AND WELL-BEING

6 CLEAN WATER AND SANITATION

Simple Technique Ushers in Long-Sought Class of Semiconductors



A team including Professor Suenaga from SANKEN (The Institute of Scientific and Industrial Research), at Osaka University and collaborating partners use routine nanofabrication procedures to prepare a revolutionary metal superlattice. This development will enhance the utility of microelectronics in common technologies

Breakthroughs in modern microelectronics depend on understanding and manipulating the movement of electrons in metal. Reducing the thickness of metal sheets to the order of nanometers can enable exquisite control over how the metal's electrons move. In so doing, one can impart properties that aren't seen in bulk metals, such as ultrafast conduction of electricity. Now, researchers from Osaka University and collaborating partners have synthesized a novel class of nanostructured superlattices. This study enables an unusually high degree of control over the movement of electrons within metal semiconductors, which promises to enhance the functionality of everyday technologies.

Precisely tuning the architecture of metal nanosheets, and thus facilitating advanced microelectronics functionalities, remains an ongoing line of work worldwide. In fact, several Nobel prizes have been awarded on this topic. Researchers conventionally synthesize nanostructured superlattices—regularly alternating layers of metals, sandwiched together—from materials of the same dimension; for example, sandwiched 2D sheets. A key aspect of the present researchers' work is its facile fabrication of hetero-dimensional superlattices; for example, 1D nanoparticle chains sandwiched within 2D nanosheets.

"Nanoscale hetero-dimensional superlattices are typically challenging to prepare, but can exhibit valuable physical properties, such as anisotropic electrical conductivity," explains Yung-Chang Lin, senior author. "We developed a versatile means of preparing such structures, and in so doing we will inspire synthesis of a wide range of custom superstructures."

The researchers used chemical vapor deposition—a common nanofabrication technique in industry—to prepare vanadium-based superlattices. These magnetic semiconductors exhibit what is known as an anisotropic anomalous Hall effect (AHE): meaning directionally focused charge accumulation under in-plane magnetic field conditions (in which the conventional Hall effect isn't observed). Usually, the AHE is observed only at ultra-low temperatures. In the present research, the AHE was observed at room temperature and higher, up to around at least the boiling point of water. Generation of the AHE at practical temperatures will facilitate its use in everyday technologies.

"A key promise of nanotechnology is its provision of functionalities that you can't get from bulk materials," states Lin. "Our demonstration of an unconventional anomalous Hall effect at room temperature and above opens up a wealth of possibilities for future semiconductor technology, all accessible by conventional nanofabrication processes."

The present work will help improve the density of data storage, the efficiency of lighting, and the speed of electronic devices. By precisely controlling the nanoscale architecture of metals that are commonly used in industry, researchers will fabricate uniquely versatile technology that surpasses the functionality of natural materials.

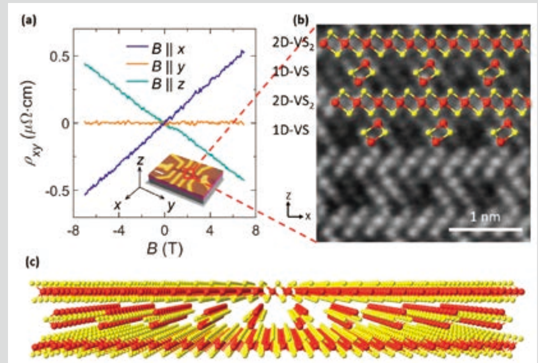


Fig. 1. Discovery of a new superlattice structure exhibiting the anisotropic Hall effect. (a) Anisotropic Hall effect. (b) Scanning transmission electron microscopy (STEM) cross sectional image of 2D-VS2/1D-VS superlattice structure. (c) Schematic model of the 2D/1D hybrid superlattice.

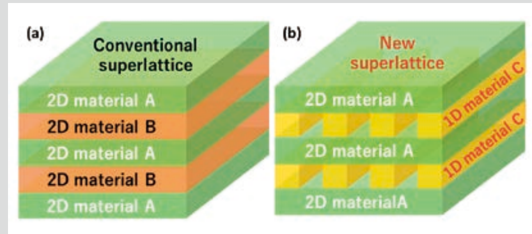


Fig. 2. (a) Conventional superlattice structure model consisting of different 2D materials. (b) Newly discovered superlattice structure model consisting of two-dimensional (film-like) and one-dimensional (chain-like) materials.

4 QUALITY EDUCATION 8 DECENT WORK AND ECONOMIC GROWTH 9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

The article, "Heterodimensional superlattice with room-temperature anomalous Hall effect," was published in Nature at DOI: https://doi.org/10.1038/s41586-022-05031-2

Research Reports

2022.4.8 New quantum dots for quantum networks
Department of Quantum System Electronics/
Akira Oiwa

2022.4.22 Electronics can grow on trees thanks to nanocellulose paper semiconductors
Department of Functionalized Natural Materials/
Hirotaka Koga

2022.5.12 Staying flexible
Department of Advanced Electron Devices/
Teppei Araki

2022.6.20 A golden ticket to smaller electronics
Flexible 3D System Integration Laboratory

2022.7.13 New research furthers understanding of the electronic structure of graphite
Department of Functional Nanomaterials and Nanodevices/Shigemasa Suga

2022.7.21 Hydrogen generated by Si-based agent attenuates inflammation in ulcerative colitis mouse model
Division of Material Science of Si-based Agent/
Hikaru Kobayashi, Yuki Kobayashi

2022.8.2 Blink and you miss it: Intracellular nanothermometer has unprecedented versatility
Department of Biomolecular Science and Engineering/Takeharu Nagai

2022.8.23 Current events: Improved reliability of printed circuit boards
Flexible 3D System Integration Laboratory

2022.8.26 Simple Technique Ushers in Long-Sought Class of Semiconductors
Department of Nanocharacterization for Nanostructures and Functions/Kazu Suenaga

2022.8.26 Untangled blinking: Fluorescence patterns aid medical diagnostics
Department of Material Excitation Chemistry/
Kiyohiko Kawai

2022.10.5 Chiplet integration technology with simplest scheme
Flexible 3D System Integration Laboratory

2022.10.5 Will silicon nitride and common chemistry help revolutionize genomic sequencing?
Department of Bio-Nanotechnology/
Makusu Tsutsui

2022.10.13 Blue energy
Department of Bio-Nanotechnology/
Makusu Tsutsui

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Department of Advanced Materials and Implementations/Teppei Araki

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Department of Biomolecular Science and Regulation/Seiji Yamasaki

2022.10.27 These cellulose nanofibers might be an alternative to petroleum-based plastics
Department of Functionalized Natural Materials/
Takaaki Kasuga

2022.11.24 Imaging the dynamic cellular zoo made easier
Department of Biomolecular Science and Engineering/Takeharu Nagai

2022.12.15 INCIDER fluorescent sensors visualize sticky situations
Department of Biomolecular Science and Engineering/Tomoki Matsuda

2023.3.16 The devil is in the details: Re-imagining fertilizer precursor synthesis
Department of Energy and Environmental Materials/Yu Katayama

Click here for the list

Si-based Agent Fabrication and Properties Endowed Research Department

Division of Material Science of Si-based Agent was established in April, 2021 as the first endowed research division in SANKEN. The department develops Si-based agent which continuously generates a high amount of hydrogen in bowels. Hydrogen generated in bowels can suppress oxidative stress by elimination of hydroxyl radicals. From animal experiments in the cooperative research with Graduate School of Medicine, Osaka University, Si-based agent has been found to have high effects to prevent and/or cure oxidative-stress induced diseases such as chronic kidney disease, Parkinson disease, atopic dermatitis, ulcerative colitis, diabetes, etc. SI-based agent is not absorbed and therefore, no side-effect is reported up to now. We aim to develop safe and effective medicine widely used in various oxidative stress-induced diseases.

Awards

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

Department of Translational Datability associate professor,
Yasuko Matsubara

Research on Modeling and Forecasting of Big Time-series Data

I would like to express my sincere gratitude for receiving this prestigious academic award. I am sincerely grateful to my co-researchers, mentors, members of our research lab, and all Sanken members. Our research team has developed real-time and nonlinear mining and forecasting techniques for large-scale time series data. We will continue to work hard in our research activities to help develop new technologies and industries that will drive the IoT/AI fields in the future.

Department of Quantum System Electronics guest associate professor,
Haruki Kiyama

Study on single-electron spin measurement in semiconductor quantum dots

I am very honored to receive this prestigious award for my research on single-electron-spin measurement in semiconductor nanostructures. I would like to express my sincere gratitude to my supervisors, collaborators, students, and staffs for their support and encouragement.
Our group has developed a novel measurement scheme of electron spins in semiconductor quantum dots. The new scheme has enabled for the first time to discriminate three types of two-electron spins in a single-shot measurement. This scheme may pave the way for realizing multi-valued spin qubits with increased information capabilities in spin-based quantum information processing. I would like to continue my efforts to make further development of quantum technology.

Introduction of Flexible 3D System Integration Laboratory

Members: K. Suganuma, M. Hikita, T. Yamaha, C. Chen, K. Nakayama, M. Nishijima, Z. Zhang, M.-C. Hseih, A. Suetake, H. Yoshida, Y. Liu, S. Zhao, F. Huo, W. Li, R. Liu, S. Moribe

Post 5G and beyond 5G technologies will open a new world in near future. Not only mobile communications, but also autonomous driving, distant doctoral diagnostic, instant security/ natural hazard surveillance, Industry 4.0 manufacturing, and many other new social systems and services will be realized soon or later. Flexible 3D System Integration Laboratory (F3D) has been established in 2020 to explore open innovation of advanced packaging technology for new era. The current main topics are the electric power conversion with wide band gap semiconductors such as SiC and GaN and the post 5G communication systems, which require excellent high functions as well as high reliability. We have developed numbers of essential interconnection materials from lead-free soldering, soft interconnections to heat-resistant sinter joining.

For example, Ag sinter joining has been first established before 2010 and has been world widely expanding for power semiconductor assembly. The basic mechanism, why one can sinter affordable Ag flakes at so low temperature below 200°C, was understood by the nano-structure observation with thermodynamic simulation. Recently, the thermal characteristic for the four kinds of SiC power module structures constructed by SiC-heater chip, DBA (Direct Bonded Aluminum) substrate and Al (Aluminum) heatsink were measured as shown in Figure.1. Two kinds of die-attach materials including SAC solder and Ag paste sinter were applied to bonding the SiC to the DBA substrate, and three kinds of thermal interface material (TIM) layer including SAC solder and Ag paste sinter and Si grease were applied for the DBA substrate to Al heatsink bonding. Ag paste was used to direct bonding on a bare DBA substrate and Al heatsink without any metallization layer sintering at 250°C pressure less air conditions. The large area bonding from DBA (30x30mm^2) to Al heatsink was achieved with a interface bonding rate larger than 90% by the Ag paste sinter with an optimized sintering process. Compare with the tradition power module structure bonding by SAC solder die attach and Si grease TIM, the SiC chip temperatreu decreased from 270°C to 175°C for the All-Ag sinter paste joining structure, and the total thermal resistance of the joint structure (SiC/DBA/Al heatsink) decreased from 1.58 K/W to 0.85 K/W. The heat dissipation has been improved by 1.8 times. The results were also confirmed and fit well by a 3D finite element analysis.

Figure. 2 shows our activity and collaboration structures. F3D has four active consortiums, WBG system integration, Advanced electronics adhesives, Weak-micro via prevention, and Printed electronics. Not only inside Osaka University, F3D has excellent academic partners outside, sharing deep knowledge and analytical skills for developing new materials. F3D and the partners initiate national project both for technology developments and for international standardization if required under the strong support of industries with METI/NEDO and MEXT. F3D is organizing many open seminars as well as consortium close meetings. You can find the information at our website (https://www.f3d.sanken.osaka-u.ac.jp/). Laboratory facilities are open for industrial members. If you have any questions, please reach us at F3D (F3D@sanken.osaka-u.ac.jp).

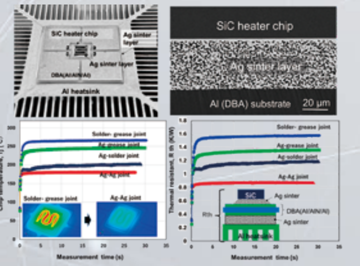


Fig.1 Low thermal resistance power module design by Ag sinter paste interconnects

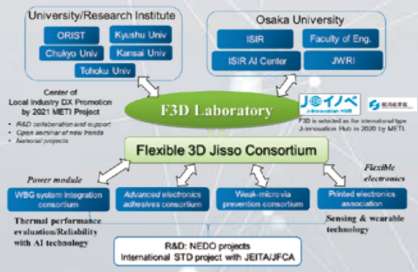
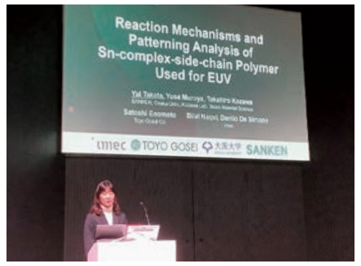


Fig.2 F3D's collaboration and industrial consortium activity.

11th imec Handai International Symposium held at imec, and both imec NL and OnePlanet Research Center visits December 8 – December 12, 2022

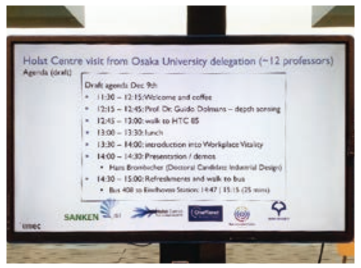
The 11th imec Handai International symposium was held in person on December 8, for the first time since three years, at imec, Leuven, Belgium, where prof. Tohru Sekino, director SANKEN, prof. Jo De Boeck, executive vice president & CSO, imec joined. After giving keynote speech of profs. Tohru Sekino and Chris Van Hoof, imec fellow, there were 20 oral presentations with research activities of next generation computing, information processing, flexible, wearable electronics, nano, and bio electronics. There were about 50 participants in total. In next year, we decided 12th symposium is held at Osaka University on November. We will be able to develop stronger cooperation by holding an in person event.

Our delegation also visited imec NL/Holst Centre at High Tech Campus Eindhoven and OnePlanet Research Center at Wageningen University, as imec subsidiary companies in The Netherlands, where they are aiming at various application systems, and advanced agriculture and foods, respectively, in order to discuss our next collaboration topics.



Presentation by Ms. Yui Takata


12th imec Handai International Symposium



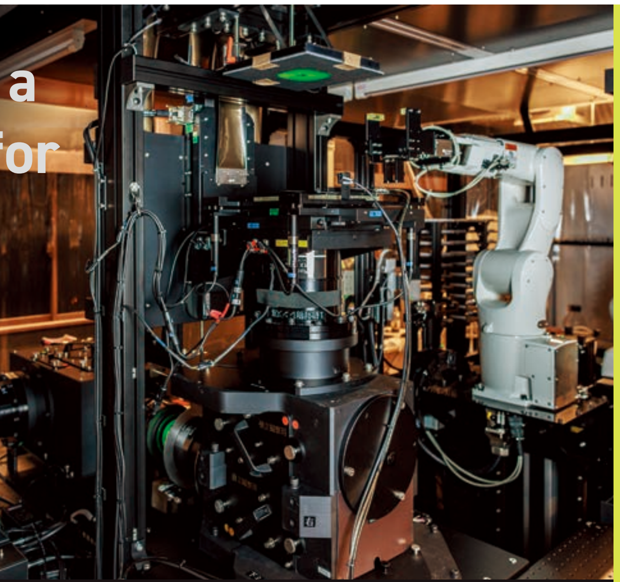
imec NL visit

OnePlanet Research Center visit

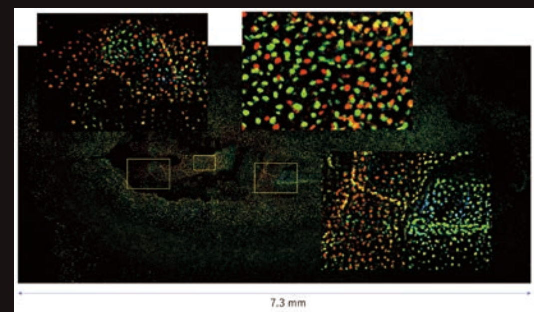
The 26th SANKEN International Symposium

The 26th SANKEN International Symposium on "Green Transformation For a Sustainable Society" was held on January 11th and 12th, 2023, at the Lecture Hall in SANKEN, and also off-line (hybrid style) concurrently with The 21st SANKEN Nanotechnology International Symposium, The 10th Kansai Nanoscience and nanotechnology International Symposium, The 18th Handai Nanoscience and nanotechnology International Symposium, and The 4th AIRC-SANKEN International Symposium. This symposium focused on the latest developments enforced towards realizing an Efficient Society. The topics covered the recent advances in the research for clean energy, IoT, AI, DX and others. Prof. Ifan Stephens (Imperial College of London) provided a plenary lecture, and Prof. Xiaodong Chen (NTU, Singapore), Prof. Hitoshi Wakabayashi (Tokyo Institute of Technology), Prof. Hironao Sajiki (Gifu Pharmaceutical University), Prof. Yoshiyuki Shimoda (Osaka University), Prof. Nobuhiro Yanai (Kyushu University), Dr. Arkady Krasheninnikov (Aalto University, Finland) and Prof. Jianyu Huang (Yanshan University, China) provided keynote lectures, along with 3 other invited speakers. In addition, 40 poster presentations were made at the SANKEN CReA by students and young researchers. Heated and active discussions were seen at the poster session venue, which was crowded with people until late at night. 8 poster presentations of young researchers were selected and awarded the Outstanding Poster Awards. All presentations covered timely topics which will contribute to scientific and technological developments of Green Transformation.

Automated trans-scale scope as a flagship bioimaging instrument for BioDX research



A team of scientists led by Prof. Takeharu Nagai has developed an amazing bioimaging system called "AMATERAS", which automates cell culture and image acquisition with remote-controlled robotic arms. AMATERAS uses a 250-megapixel CMOS sensor and a one and only giant lens to realize single cell dynamics observation in an extraordinary large field-of-view. AMATERAS can simultaneously observe more than one million cells in just one second. The number of cells that can be observed is far greater than that of conventional microscope. It is also possible to analyze cells in tissues and perform time-lapse observation. The data size of a single image taken with this system can be as large as 250 megabytes, and for time-lapse and 3D observation, as large as gigabyte or terabyte. Such ultra-large image data cannot be managed by individual researchers. The data is sent over a high-speed network to RIKEN's SSBD database, where it is stored and managed. RIKEN SSBD will standardize the format of image data used in biological and medical research, and create a platform for sharing data, which will lead to open science and further development of life sciences. In collaboration with RIKEN, Nagai's team is now working to form a center for international collaborative research to realize Bio DX. AMATERAS will be made available to the outside researchers as a flagship shared facility in the near future. Please look forward to it!



Takeharu Nagai
Department of Biomolecular Science and Engineering, SANKEN, Osaka University

SANKEN
OSAKA UNIVERSITY

The SANKEN logo has been renewed.

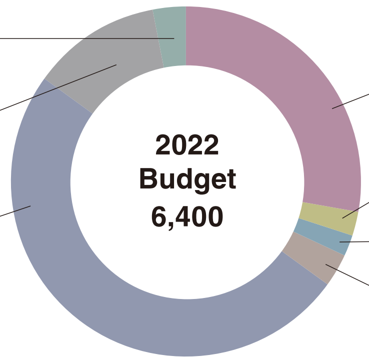
In June 2021, the Institute of Scientific and Industrial Research changed its name from "The Institute of Scientific and Industrial Research" to "SANKEN," a Japanese abbreviation that is easy to remember and reflects the philosophy of the institute. SANKEN's philosophy of pioneering research in "the fundamentals and applications of natural science for industry" has never changed and will never change. On the other hand, many changes have taken place around us in the past few years. AIST will take actions to continue to be a leader in cutting-edge research in the midst of these changes toward the middle of the 21st century. One of these actions is to strengthen public relations and change the English name of AIST so that more people will know about AIST. The basic philosophy of the three divisions and one center developing in harmony, as expressed in the previous logo (established in 2006), will be retained, while indicating development through co-creation and circulation. We hope that many people will become familiar with AIST and SANKEN so that the ideas expressed in the new logo will continue to grow.

Fact Sheet

Sample (2022)

Publications	Application for Patent
379	59

Subsidies etc.	150 (53)
Joint Research with Private Sector	730 (163)
Contract Research	3,140 (108)
Management Expenses Grants	1,720
Charge for Facilities Use etc.	80
Grants-in-Aid for Scientific Research	480 (102)
Donation for Research	100 (52)



(in unit of million yen, ( ) number of funds)

Constituent Member

Graduate Students 210

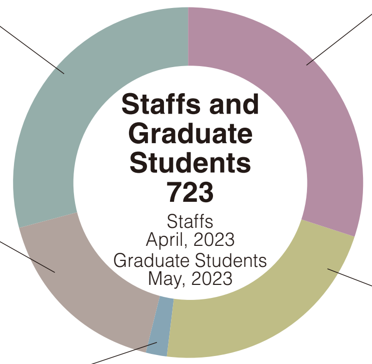
School of Science	30 / 21
School of Engineering	63 / 31
School of Engineering Science	7 / 4
School of Pharmaceutical Sciences	2 / 1
School of Information Science & Technology	28 / 13
	Master / Doctor
School of Frontier Biosciences	10 Doctors

Visiting Researchers 126

Visiting Professor	1
Visiting Associate Professor	0
Guest Professor	66
Guest Associate Professor	21
Guest Academic Staff	5
Guest Researcher	33

Postdoctoral Fellows 9

JSPS Postdoctoral Fellowship	9



Full-time Employees 219

Professor	24
Associate Professor	29
Assistant Professor	37
Endowed Research Department professor	1
Specially Appointed Professor(Full-time)	6
Specially Appointed Associate Professor(Full-time)	10
Specially Appointed Lecturer(Full-time)	3
Specially Appointed Assistant Professor(Full-time)	19
Specially Appointed Researcher(Full-time)	39
Administrative Officer	15
Technical Staff	12
Specially Appointed Administrative Officer	19
Specially Appointed Technical Staff	5

Part-time Employees 159

Specially Appointed Professor	11
Specially Appointed Associate Professor	3
Specially Appointed Assistant Professor	0
Specially Appointed Researcher	52
Support Staff	33
Technical Assistant	60

Osaka University Foundation for the Future

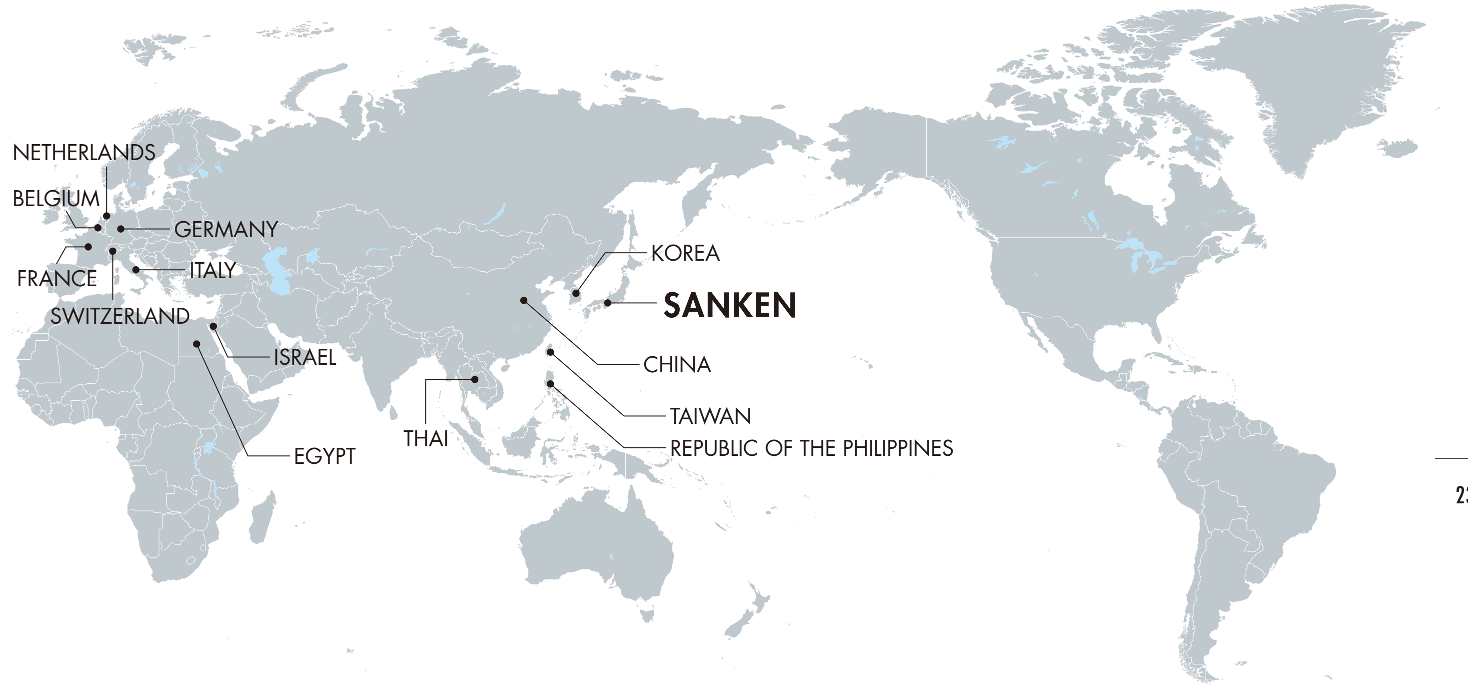
We aim to be a university that offers education and research that responds to the challenges of the new era and meets the needs of society by inheriting the knowledge and individual skills gained through our 90 years of history for the next 50 years, 100 years, and beyond.

When considering the future of Osaka University, it is essential to strengthen a long-term, stable financial foundation and enhance its funds. Our alumni, as well as Osaka University Staff, individuals, corporations, and organizations, we look forward to your warm support and contributions to Osaka University Foundation for the Future.

Academic Exchange Agreements of SANKEN with Universities Abroad

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)
BELGIUM	Interuniversitair Micro-Electronica Centrum vzw (imec)
NETHERLANDS	Eindhoven University of Technology (Department of Mechanical Engineering) Delft University of Technology
SWITZERLAND	University of Geneva (Faculty of Science)
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	Chonnam National University Pukyong National University (Basic Science Research Institute) Hanyang University Sun Moon University (Collage of Engineering) Duksung Innovative Drug Center (DiDC), Duksung Women's University
CHINA	Peking University University of Sciece and Technology Beijing (School of Materials Science and Engeneering) Peking University (School of Intelligence Science and Technology) Dalian Jiaotong University 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) University of the Philippines

as of April 2023



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