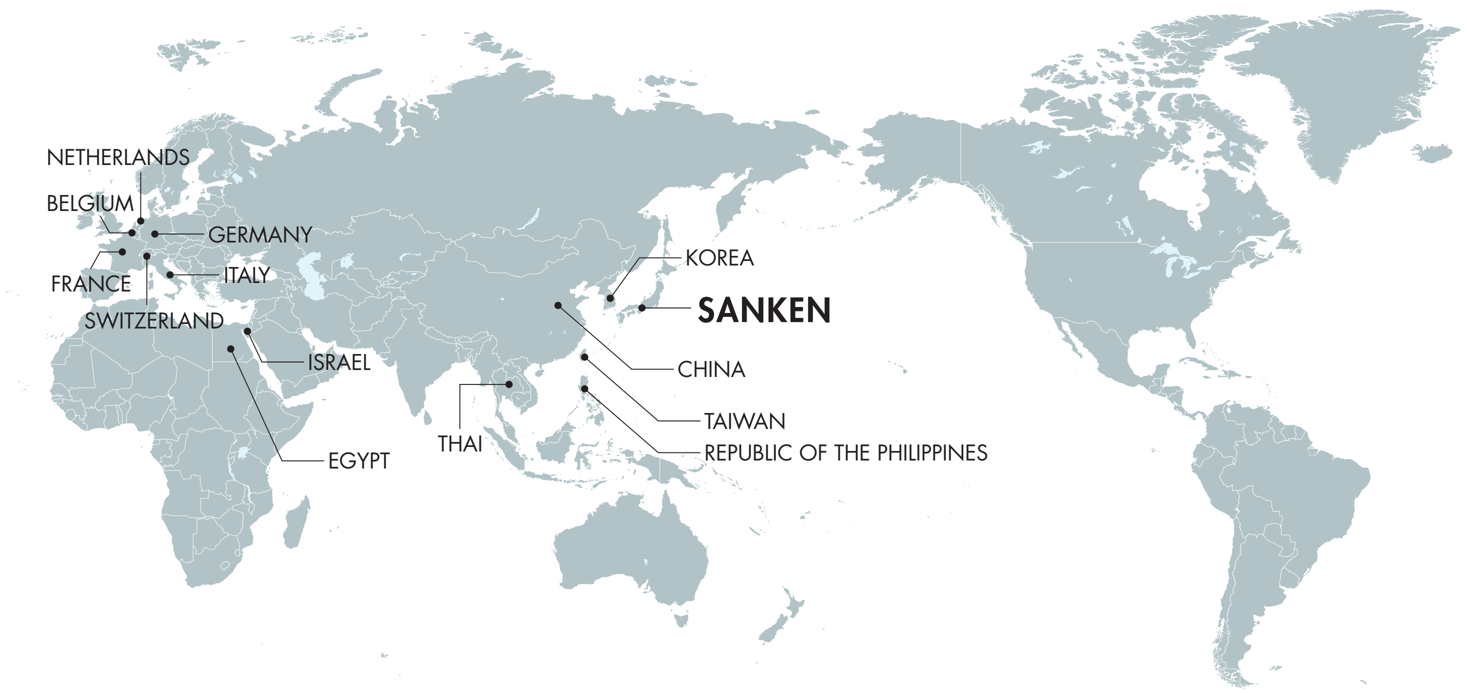
Academic Exchange Agreements of SANKEN with Universities Abroad

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)
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) 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 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) University of Sciece 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)

as of April 2021



SANKEN, Osaka University

https://www.sanken.osaka-u.ac.jp/en/

SANKEN, Osaka University

Annual Report 2021

Year ended March 31, 2021

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.

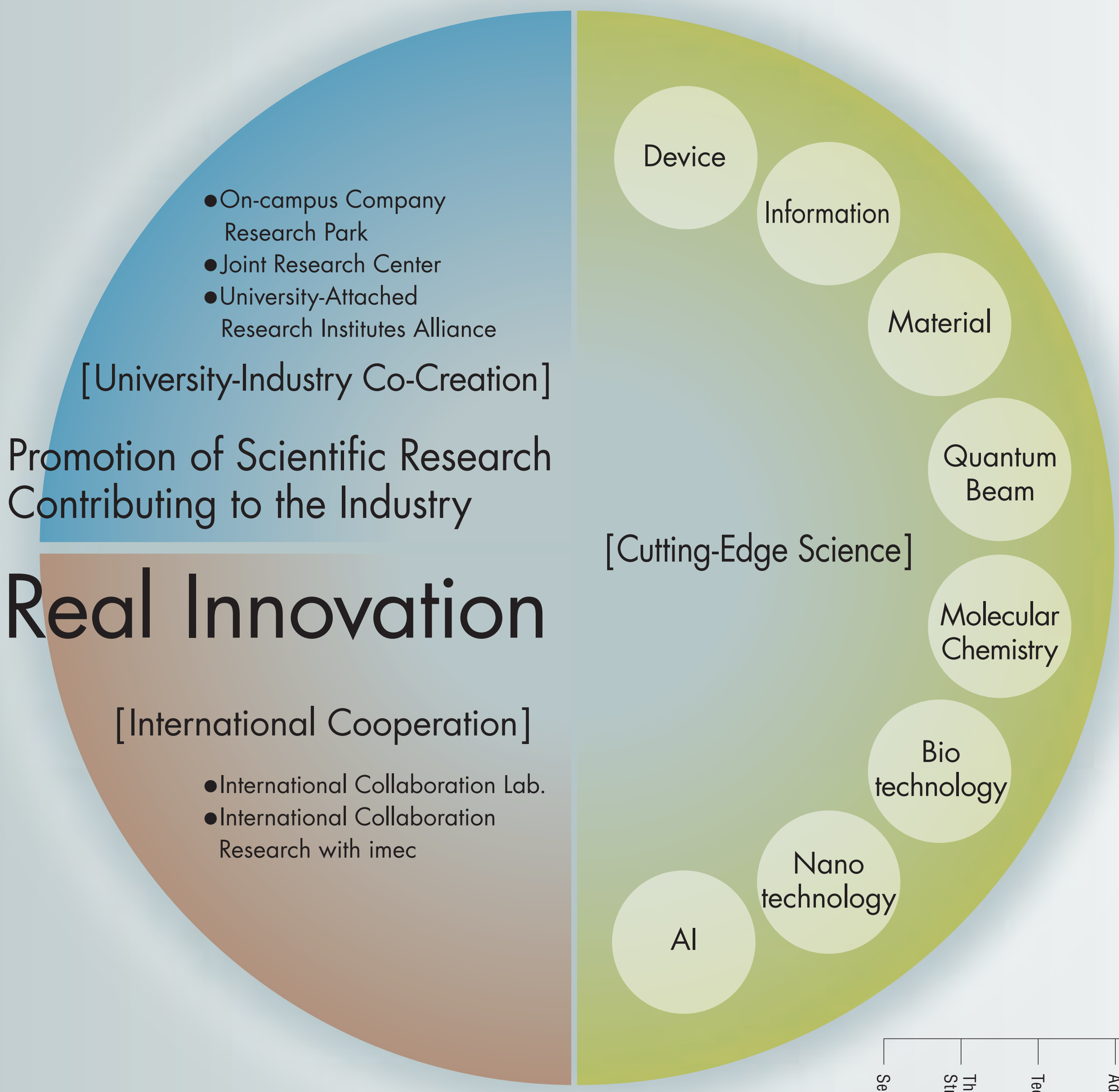
For example, the SANKEN, which has been leading nanotechnology research organization since the 1980s, has established its Nanoscience Nanotechnology Center at the early stages of development of nanoscience and has led the world since. In the field of information and AI, where social implementation is 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 for all over the world, we will strive to provide the highest level of research and education. As one of our actions, we have decided to change 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 with different viewpoints. We sincerely ask for your continued support and encouragement.

Director

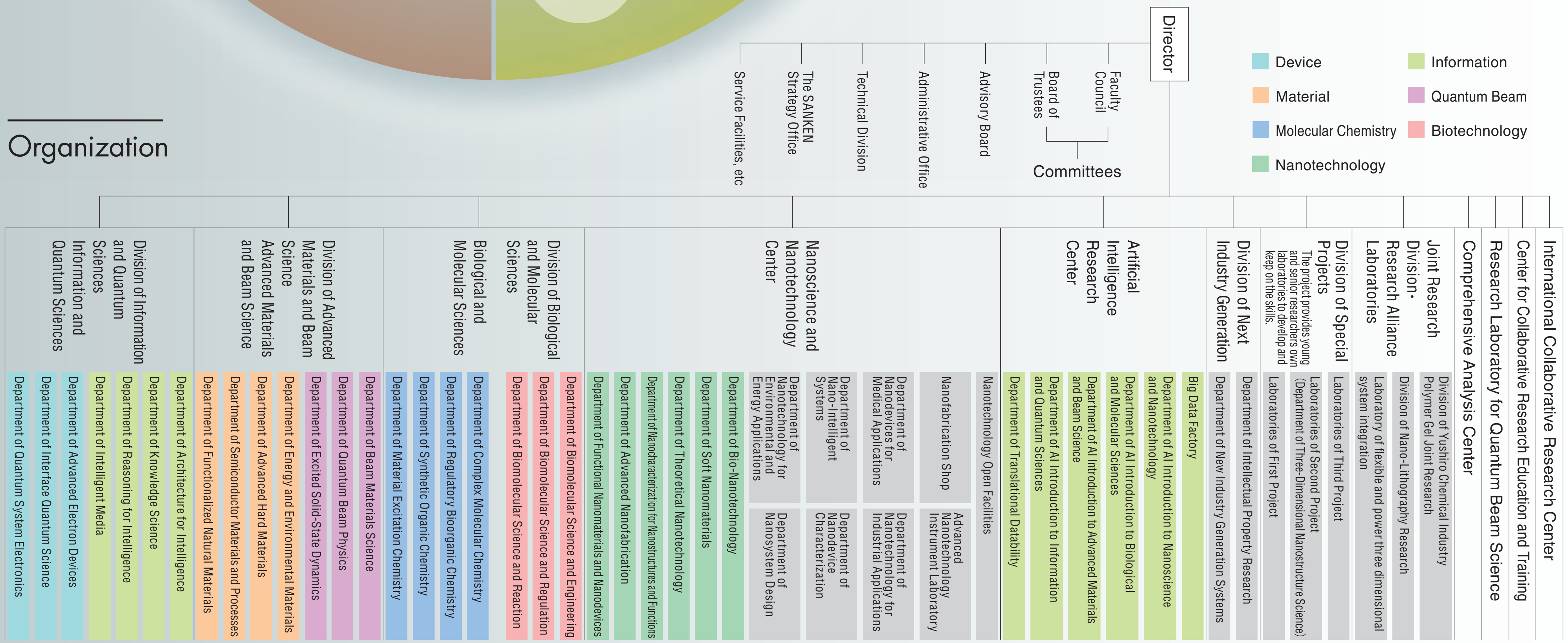
Tohru Sekino

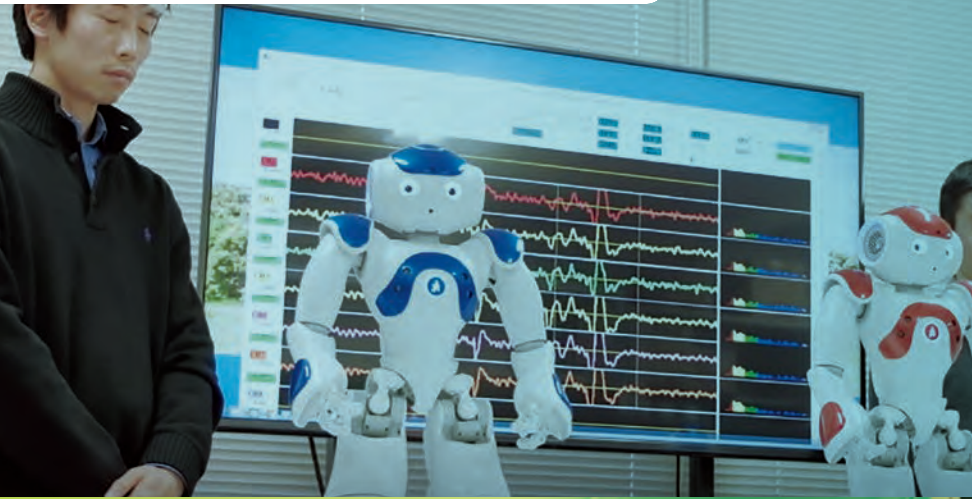


History

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 (Kysuyu 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





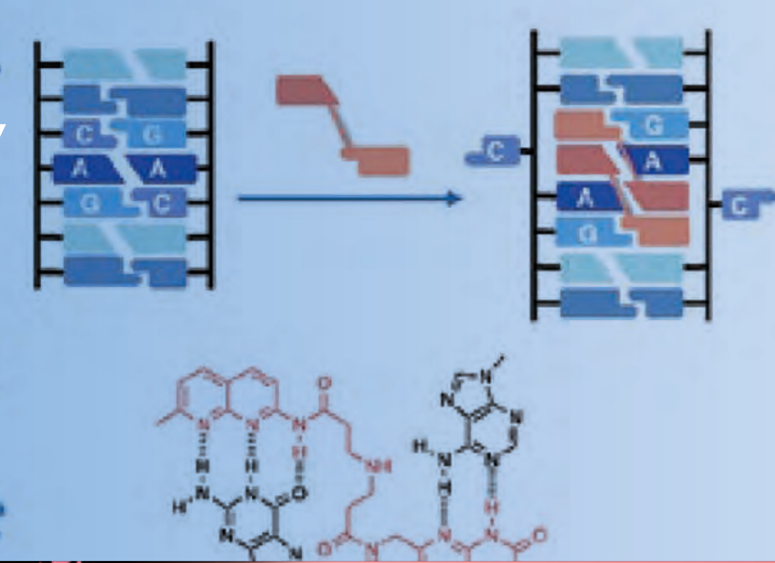
Device

Quantum Technology

Next-generation IoT Sensors

Flexible Intelligent System

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

Material

Cellulose Nanofiber

Silicon

Multi-Functional Materials

Advanced Batteries

Nanotechnology

Functional Oxide Nanoelectronics

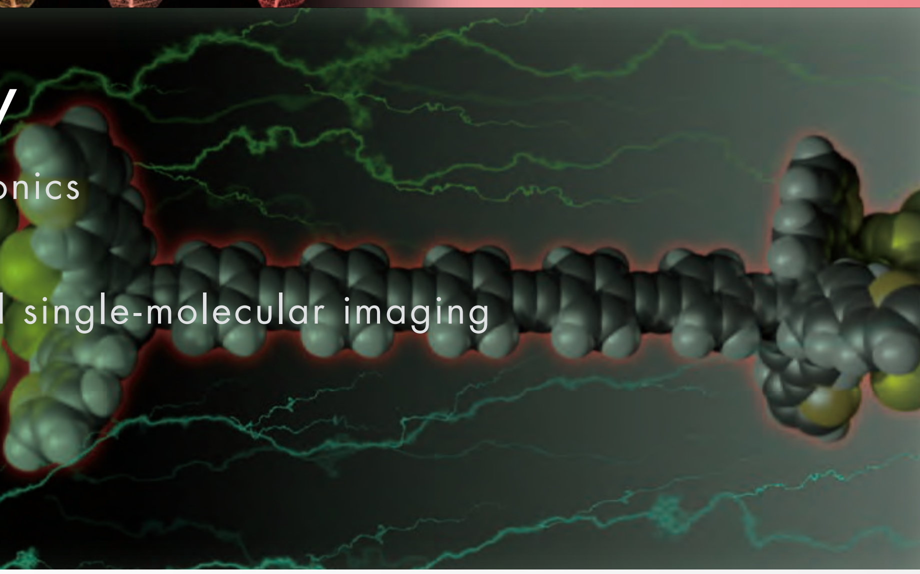
Quantum Beam

Single-atom spectroscopy and single-molecular imaging

Materials Design

Organic Functional Material

Single-molecule Science



Quantum Beam

Quantum-beam-induced Nanochemistry

Laser-driven Particle Acceleration

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

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/

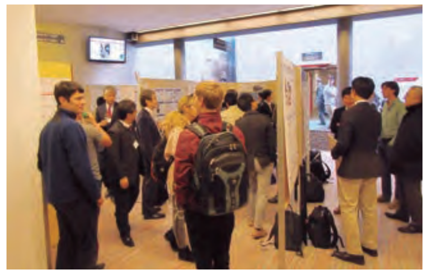
Education

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

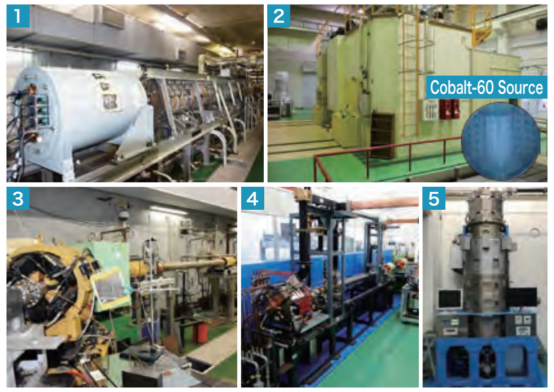
Academic Exchange Agreements of ISIR with Universities and Research Institutions Abroad (April, 2021)

- Inter-University Exchange Agreements: 15
- 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/

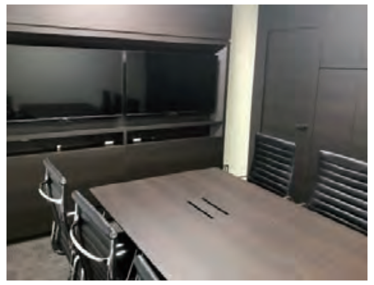
Nanotechnology Open Facilities

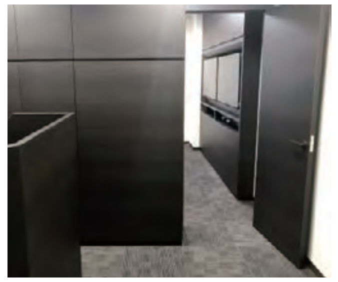
Nanotechnology Open Facilities totally contributes to creations of novel nano-materials and nano-devices for companies / universities / institutes researchers in nanotechnology research fields with the latest equipment and technical support.

▶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





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.

Detection of body movement by a flexible magnetic sensor

Spintronics

"Spintronics" is a technology that has been widely used to improve the performance of information devices, such as computer hard discs, sensors, and memory. Conventional "electronics" uses electrons to transfer information using electricity. In addition, spintronics uses nanotechnology so that an electron can maintain information in its own spin. This approach has been used to produce highly sensitive magnetic heads (writing and read-out devices) in most hard discs. In the future, the same technology will be applied in many unexplored fields, and this will result in major changes in the era of the Internet of Things (IoT).

Prof. Chiba has conducted studies on control of the magnetic nature of spintronics materials, and is now developing an entirely new application, as the first of its type worldwide. He has prepared a material that can detect the direction and level of pull power on a flexible plastic substrate to enable highly accurate wearable measurements. This technology is likely to be used in "vital motion sensors" to detect body movements.

Prof. Chiba said, "Basic research in spintronics may easily be used for development of applications, as seen in the use of giant magnetic resistance (GMR) in hard discs about 10 years after its Nobel Prize-winning development. Our sensor may have the highest sensitivity performance to date."

Detection of pull power

The sensor is a material in which tunnel magnetoresistance (TMR) of magnetic memory is used to record information with no electric power source. Nanometer-size (one billionth) electrons pass through an insulant sandwiched by two thin magnetic films. Electric resistance is low when the magnetic poles (north and south poles) of the two magnetic films are placed in the same direction, and high when the poles are placed in opposite directions. As a magnet is pulled, the magnet becomes magnetized in the direction of pull. Therefore, when the direction of magnetization is fixed, there is an angle between the directions of the two magnets, which changes the electric resistance. Using this change, it becomes possible to detect the direction and level of strain of an object. The accuracy of detection is hundreds of times higher than that of conventional strain measuring devices.

It has been shown that movements of five fingers can be detected when a sensor material is laid on the back of the hand. Prof. Chiba envisions the potential of the technology, saying, "It is important to improve the performance of the material and to enable measurement over a wide range using multiple kinds of materials. For example, such materials placed on the chest will be able to detect heartbeats continuously and will be useful as a future home health care system."

Extracting latent potential

As a student at Tohoku University, Prof. Chiba worked in the laboratory of Prof. Hideo Ohno (current President of Tohoku University), who developed a magnetic semiconductor with characteristics of both a semiconductor and a magnet. Thus, Prof. Chiba became interested in changing the magnetism of materials using an electrical method. Since then, he has been dedicated to the study of the practical use of spintronics at Kyoto University and Tokyo University.

As one of his achievements, Prof. Chiba provided the first evidence worldwide that the magnetism of ultra-thin magnets can be electrically switched in a reversible way. This material then shows a ferromagnetic property (ON) and no such property (OFF) without application of voltage, and could be used as a binary switch of "0" and "1" for writing of information. His many achievements also include speeding up of information writing using less electricity.

Prof. Chiba reviewed his achievements, saying "I sometimes found a superior function in a familiar material by examining the material to the utmost limit in experiments, based on the principle of creating new value by extracting the latent potential of a material."

Last April, Prof. Chiba began work as an honorary professor at SANKEN (The Institute of Scientific and Industrial Research). He said, "SANKEN provides many opportunities for communication among researchers in various fields, and thus I am able to perform collaborative studies on soft materials." It is the first time Prof. Chiba has lived in the north area of Osaka, but he is happy with his life here because his elder son, an elementary school student, can play with frogs in a leafy area. This was not possible in urban Tokyo. He likes seasonal sports from his youth, such as skiing in winter and swimming in summer, and his family are also very happy in their new environment.

Professor **Daichi Chiba**
Department of Interface Quantum Science
千葉大地

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.

Cohesive circuit protection by nanocellulose

Researchers from Osaka University developed a cellulose nanofiber coating that counters bending damage, retains electrode function underwater, and thus offers unparalled circuit protection for next-generation electronic devices.

Water is detrimental to electronic devices

Most electronic devices aren't waterproof, much to your irritation if a sprinkler suddenly sprays you while you're talking outside on your cellphone. Some electronics can be made at least water-resistant by, for example, using hydrophobic polymers to coat the electronic circuit. Next generation electronic devices such as flexible devices and degradable sensor devices are another story. Their sealant materials must be able to bend and degradable, yet with current technology it's inevitable that eventually such a sealant will crack or separate from the device—and there goes your water-resistant coating.

Researchers are determined to come up with a solution. Cellulose nanofibers are a proposed polymer coating for flexible electronics. These fibers are made from renewable resources and are environmentally friendly. However, they usually absorb water—commonly thought to be a fatal limitation for imparting water resistance.

Nanocellulose, a hydrophilic material, inhibits water-induced short circuit failures

In a study recently published in *ACS Applied Nanomaterials*, researchers from Osaka University developed self-healing cellulose nanofibers that slightly disperse in water and act to protect a copper electrode, enabling the electrode to function for an extended period. The researchers' flexible circuit protection mechanism retains electrode function underwater and can undergo hundreds of bending cycles. In addition, nanocellulose is biodegradable, making the technology applicable to degradable sensor devices that have less impact on the environment.

"In our initial work, an unprotected copper electrode failed after 5 minutes of dripping water onto it," says Takaaki Kasuga, lead author. "Remarkably, a cellulose nanofiber coating prevented failure over at least a day of the same water challenge."

Electronic circuits are cohesively protected by nanocellulose

Why is this? Remember that cellulose nanofibers don't repel water. Instead, this coating migrates in the electrode by the electric field between the electrodes. The cohesive cellulose nanofiber layer formed on the circuits prevents formation of conductive dendrites that cause short-circuits. The electrodes even maintained their function after the cellulose nanofiber coating was scratched to simulate bending damage.

"Our results aren't attributable to simple ion-exchange or nanofiber length," explains Masaya Nogi, senior author. "The nanofibers aggregate in water into a protective layer made cohesive by locally acidic conditions and polymer cross-linking."

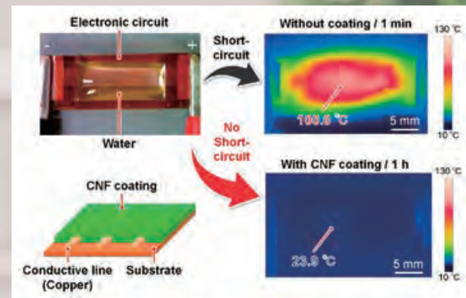


Figure 1. Water is detrimental to electronic devices because it easily causes short circuits and accidents, such as overheating/ignition. By coating electronic circuits with cellulose nanofibers (CNFs), it is possible to prevent water-induced short circuits in a completely different approach compared with conventional waterproofing coatings. (credit: Osaka University)

Novel circuit protection technology creates new applications that enrich our lives

A more rigorous test of the cellulose nanofiber coating was its performance after 300 cycles of bending underwater over the course of an hour. A conventional polymer coating usually failed, but the cellulose nanofiber coating continued to power LEDs.

"You'll be able to stretch, bend, and fold electronics with our coating, and they'll still retain their water resistance," says Kasuga. "This is critical for use in applications under extreme conditions where device failure is unacceptable—for example, medical devices used in emergency disaster response."

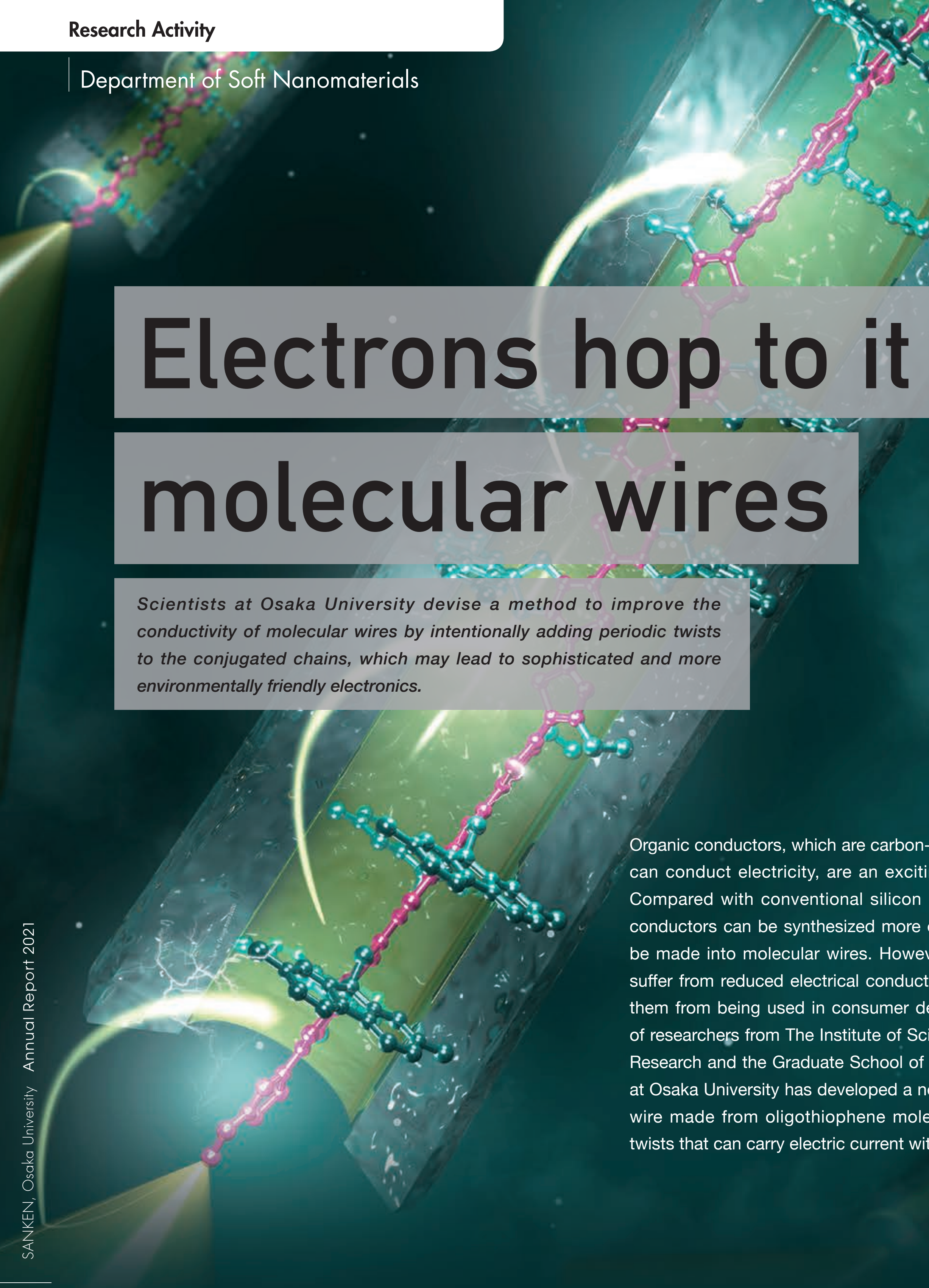
The technology can be used not only for flexible devices but also for eco-friendly degradable sensor devices which will contribute to reduce environmental pollution and management and decrease the disposal costs of sensor devices. It is expected to be a novel technology that is environmentally friendly and enriches our lives.

The article, "Cellulose nanofiber coatings on Cu electrodes for cohesive protection against water-induced short-circuit failures," was published in *ACS Applied Nanomaterials* at DOI: https://doi.org/10.1021/acsanm.1c00267

"Return to the Soil" Nanopaper Sensor Device for Hyperdense Sensor Networks" was published in ACS Applied Materials & Interfaces at DOI:https://doi.org/10.1021/acsami.9b13886

春日貴章
Takaaki Kasuga

http://tkasuga.com/



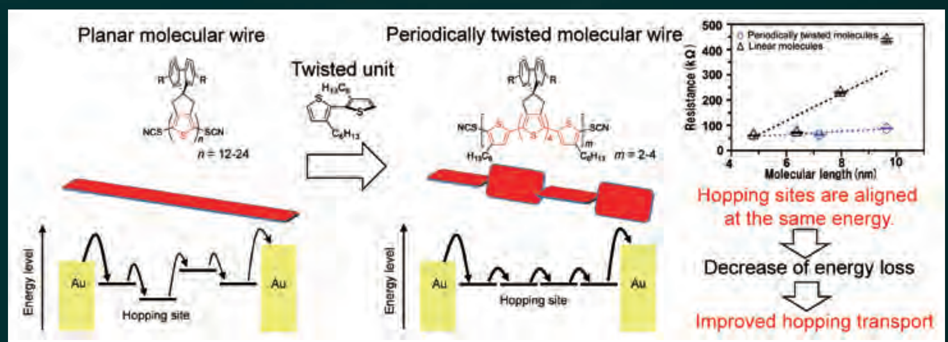
Electrons hop to it on twisted molecular wires

Scientists at Osaka University devise a method to improve the conductivity of molecular wires by intentionally adding periodic twists to the conjugated chains, which may lead to sophisticated and more environmentally friendly electronics.

Yutaka Ie

IE group
Youtube: https://www.youtube.com/watch?v=PKgKbrNHOo4&feature=youtu.be

Organic conductors, which are carbon-based materials that can conduct electricity, are an exciting new technology. Compared with conventional silicon electronics, organic conductors can be synthesized more easily, and can even be made into molecular wires. However, these structures suffer from reduced electrical conductivity, which prevents them from being used in consumer devices. Now, a team of researchers from The Institute of Scientific and Industrial Research and the Graduate School of Engineering Science at Osaka University has developed a new kind of molecular wire made from oligothiophene molecules with periodic twists that can carry electric current with less resistance.



Concept and chemical structure of periodically twisted molecular wires. (credit: Osaka University)

Ultimately small organic conductors

Molecular wires are composed by several-nanometer-scale long molecules that have alternating single and double chemical bonds. Orbitals, which are states that electrons can occupy around an atom or molecule, can be localized or extended in space. In this case, the π orbitals from individual atoms overlap to form large "islands" that electrons can hop between. Because electrons can hop most efficiently between levels that are close in energy, fluctuations in the polymer chain can create energy barriers. "The mobility of charges, and thus the overall conductivity of the molecular wire, can be improved if the charge mobility can be improved by suppressing such fluctuations," corresponding author Yutaka Ie says.

Precise molecular design

The overlap of π orbitals is very sensitive to the rotation of the molecule. Adjacent segments of the molecule that are aligned in the same plane form one large hopping site. By purposely adding twists to the chain, the molecule is broken into nanometer-sized sites, but because they are close in energy, the electrons can hop easily between them. This was accomplished by inserting a 3,3'-dihexyl-2,2'-bithiophene unit after every stretch of 6 or 8 oligothiophene units.

We found that, overall, creating smaller islands that are closer in energy maximized the conductivity. We also measured how temperature affects the conductivity, and showed that it was indeed based on electron hopping. "Our work is applicable to single-molecule wires, as well as organic electronics in general", co-lead author Yoshikazu Tada says. This research may lead to improvements in conductivity that will allow nanowires to become incorporated into a wide array of electronics, such as tablets or computers.

The article, "Improving intramolecular hopping charge transport via periodical segmentation of π-conjugation in a molecule," was published in *Journal of the American Chemical Society* at DOI: https://doi.org/10.1021/jacs.0c10560

7 AFFORDABLE AND CLEAN ENERGY
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

From trash to treasure:
silicon waste finds new use in Li-ion batteries

Fabrication of Li-ion battery electrodes with Si swarf/graphite sheet composites, achieving high performance, reduced cost, and environmental friendliness.

Li-ion batteries (LIBs) are widely used in various mobile electronics. Concerns of global warming and climate change have recently boosted the demand for LIBs in electric vehicles and solar photovoltaic output smoothing. Si has been studied as an active material with a high theoretical capacity of 3578 mAh/g, which is around ten times higher than that of graphite (372 mAh/g).

Now, a team of researchers at Osaka University has used flake-shaped Si nanopowder wrapped by ultrathin graphite sheets (GSs) to fabricate LIB electrodes with high areal capacity and current density.

Generally treated as industrial waste, Si swarf is generated at a rate of 100,000 tons per year globally from Si ingots that are produced from silica through processes at 1000~1800°C. Water-based coolants and fixed abrasive grain wire saws are paving the way to the use of Si swarf as an anode active material with a high capacity at a reduced cost.

Nano carbon materials have been applied to Si electrodes to improve electrical conductivity and cyclability. Many strategies for dealing with large volume change of Si electrodes at relatively high costs have been demonstrated. However, the Si electrodes do not combine all the requirements for high electrode performance, namely reduced cost, environmental friendliness of materials and processes, and circular economy.

"In this study, Si/graphite sheet composites from Si swarf and expanded graphite are used as the active material with reduced cost and thermal budget (Fig. 1). Si nanopowder is dispersed and wrapped between GSs fabricated from expanded graphite," explains first author Jaeyoung Choi. "GS bridges are formed across cracks and suppress cracking and peeling-off of Si. Agglomerated GSs wrap Si/GS composites, and work as stable frameworks that secure electrolyte paths and buffer spaces for Si volume change."

The Si/GS composite structure and the delithiation limitation improve the cyclability up to 901 cycles at 1200 mAh/g (Fig. 2). The areal delithiation capacity and current density of the Si/GS electrodes linearly increase to 4 mAh/cm^2 and 5 mA/cm^2, respectively, with the mass loading for more than 75 cycles (Fig. 3), while thick electrodes with C-coated Si fabricated in C_2H_4 are not competitive.

Perspective of Li-ion battery electrodes with silicon waste

"Si anode batteries with high capacity and high current density have the potential to be used in electric vehicles. This potential, combined with increasing generation of Si swarf as industrial waste, will allow our work to contribute to reduced greenhouse gas emissions and the achievement of SDGs," says corresponding author Taketoshi Matsumoto.

Finding value in waste is an important strategy to address social problems. The enhanced performance of both state of the art Si devices and devices that use Si waste can reduce environmental load. In the near future, a huge number of solar panels will be replaced after reaching the end of their life. Demand is increasing for recycling crushed Si wafers from solar panel waste into Si electrodes in Li ion batteries.

Si swarf wrapped by graphite sheets for Li-ion battery electrodes with improved overvoltage and cyclability,
Journal of The Electrochemical Society.
https://doi.org/10.1149/1945-7111/abdd7e

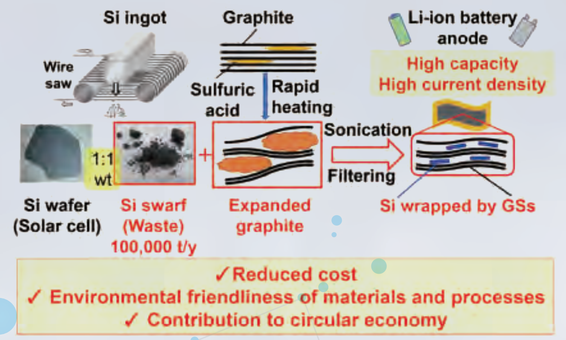


Fig. 1 Fabrication of electrode with Si swarf/graphite sheet (GS) composites. (© Osaka University)

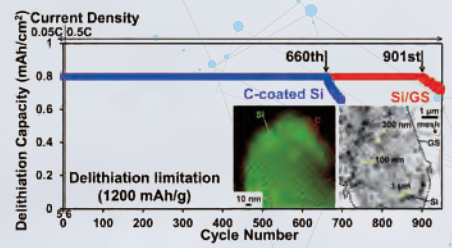


Fig. 2 Cycle performance of Si/GS composite and C-coated Si electrodes. Inserted images are a transmission electron microscope image of a Si/GS composite and an elemental mapping of C-coated Si. C-coated Si was fabricated in C_2H_4 at 1000°C. (© Changed partly from the article. CC BY 4.0.)

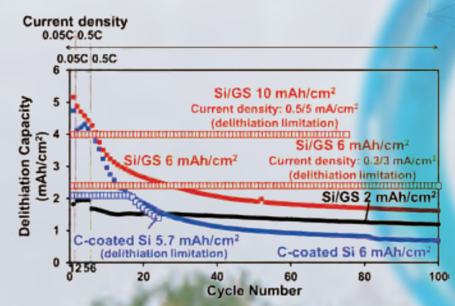


Fig. 3 Cycle performance of thick electrode with Si/GS composites and C-coated Si. (© Changed partly from the article. CC BY 4.0.)

Taketoshi Matsumoto

Taketoshi Matsumoto

7 AFFORDABLE AND CLEAN ENERGY
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION

ResOU
From trash to treasure: Silicon waste finds new use in Li-ion batteries
https://resou.osaka-u.ac.jp/en/research/20210210_3

Key Scientific Article. Renewable Energy Global Innovations
Improvement of Cyclability of Li-Ion Batteries Using C-Coated Si Nanopowder Electrode Fabricated from Si Swarf with Limitation of Delithiation Capacity
https://renewableenergyglobalinnovations.blogspot.com/2017/09/renewable-energy-global-innovations_85.html

Long-term storage memory - digital Rosetta Stone (dRS)
https://www.youtube.com/watch?v=7KJT12P91wg

Key Scientific Article. Advances in Engineering
Photoluminescence from vibrational excited-states for organic molecules adsorbed on Si nanoparticles
https://advanceseng.com/photoluminescence-vibrational-excited-states-organic-molecules-adsorbed-si-nanoparticles/

ResOU
High-performance anode material for lithium-ion batteries (LIBs) produced from waste Si sawdust
https://resou.osaka-u.ac.jp/en/research/2017/20170220_1

Elsevier's Catalysis Journals Top Cited Authors 2004-2008
Efficient usage of highly dispersed Pt on carbon nanotubes for electrode catalysts of polymer electrolyte fuel cells
https://www.sciencedirect.com/science/article/abs/pii/S0920586104001592?via%3Dihub

Department of Bio-Nanotechnology
Department of Reasoning for Intelligence
Department of Biomolecular Science and Reaction

Sorting out viruses with machine learning

Scientists at Osaka University develop a label-free method for identifying respiratory viruses based on changes in electrical current when they pass through silicon nanopores, which may lead to new rapid COVID-19 tests.

Makusu Tsutsui
Nanoscale Biophysics

Tomoji Kawai
Nanoscience and Nanotechnology

Takashi Washio
Machine learning

Shun'ichi Kuroda
Biomolecular Science

The article, "Digital pathology platform for respiratory tract infection diagnosis via multiplex single-particle detections," is published in *ACS Sensors* at DOI: https://doi.org/10.1021/acssensors.0c01564

Overview

The ongoing global pandemic has created an urgent need for rapid tests that can diagnose the presence of the SARS-CoV-2 virus, the pathogen that causes COVID-19, and distinguish it from other respiratory viruses. Now, researchers from Japan have demonstrated a new system for single-virion identification of common respiratory pathogens using a machine learning algorithm trained on changes in current across silicon nanopores. This work may lead to fast and accurate screening tests for diseases like COVID-19 and influenza.

The tiny sensor to detect single virus

In a study published this month in *ACS Sensors* scientists at Osaka University have introduced a new system using silicon nanopores sensitive enough to detect even a single virus particle when coupled with a machine learning algorithm.

In this method, a silicon nitride layer just 50 nm thick suspended on a silicon wafer has tiny nanopores added, which are themselves only 300 nm in diameter. When a voltage difference is applied to the solution on either side of the wafer, ions travel through the nanopores in a process called electrophoresis.

The motion of the ions can be monitored by the current they generate, and when a viral particle enters a nanopore, it blocks some of the ions from passing through, leading to a transient dip in current. Each dip reflects the physical properties of the particle, such as volume, surface charge, and shape, so they can be used to identify the kind of virus.

Machine learning to identify viral species

The natural variation in the physical properties of virus particles had previously hindered implementation of this approach, however, using machine learning, the team built a classification algorithm trained with signals from known viruses to determine the identity of new samples. "By combining single-particle nanopore sensing with artificial intelligence, we were able to achieve highly accurate identification of multiple viral species," explains senior author Makusu Tsutsui.

The computer can discriminate the differences in electrical current waveforms that cannot be identified by human eyes, which enables highly accurate virus classification. In addition to coronavirus, the system was tested with similar pathogens - respiratory syncytial virus, adenovirus, influenza A, and influenza B.

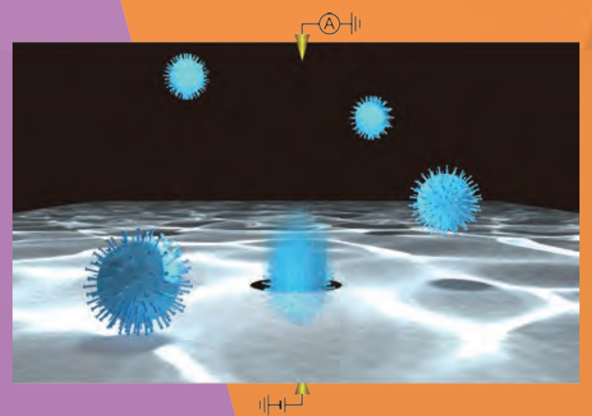


Fig. Single virus particle detections using a solid-state nanopore (credit: Osaka University)

Future perspectives

The team believes that coronaviruses are especially well suited for this technique since their spiky outer proteins may even allow different strains to be classified separately. "This work will help with the development of a virus test kit that outperforms conventional viral inspection methods," says last author Tomoji Kawai.

Compared with other rapid viral tests like polymerase chain reaction or antibody-based screens, the new method is much faster and does not require costly reagents, which may lead to improved diagnostic tests for emerging viral particles that cause infectious diseases such as COVID-19.

3 GOOD HEALTH AND WELL-BEING

Research Reports

2020.04.28
It takes a neutron beam to find a proton Natural Sciences
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20200428/
Department of Biomolecular Science and Reaction / Toshihide Okajima

2020.05.20
Three-dimensional chessboards
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20200520/
Department of Functionalized Natural Materials / Kojiro Uetani

2020.06.01
Lighting the way to porous electronics and sensors
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20200601/
Department of Energy and Environmental Materials / Tohru Sugahara

2020.09.11
New on/off functionality for fast, sensitive, ultra-small technologies
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20200911/
Department of Functional Nanomaterials and Nanodevices / Teruo Kanki

2020.10.15
Detecting early-stage failure in electric power conversion devices
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20201015/
Flexible 3D / Chuantong Chen, Katsuaki Suganuma

2020.10.20
Hazumi datasets for dialogue systems that recognize human sentiment released
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20201020/
Department of Knowledge Science / Kazunori Komatani

2020.11.26
A filter for environmental remediation
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20201126/
Department of Advanced Hard Materials / Yoshifumi Kondo, Tomoyo Goto, Tohru Sekino

2020.12.11
Toward imperceptible electronics that you cannot see or feel
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20201211_2/
Department of Advanced Electron Devices / Ashuya Takemoto, Teppei Araki, Tsuyoshi Sekitani

2020.12.15
A colossal step for electronics
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20201215/
Department of Functional Nanomaterials and Nanodevices / Umar Sidik, Azusa N. Hattori, Hidekazu Tanaka

2020.12.17
Pulp succeeded in diet? Determining the slenderization of wood pulp
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20201217/
Department of Functionalized Natural Materials / Kojiro Uetani

2021.02.10
The chemistry lab inside cells
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20210210-1/
Department of Biomolecular Science and Reaction / Toshihide Okajima

2021.03.18
Shutting the nano-gate
https://www.sanken.osaka-u.ac.jp/en/hot_topics/topics_20210312/
Department of Bio-Nanotechnology / Makusu Tsutsui
Department of Reasoning for Intelligence / Takashi Washio, Tomoji Kawai

New Research Groups

Single-atom spectroscopy and single-molecular imaging

Professor, **Kazutomo Suenaga**
Department of Nanocharacterization for Nanostructures and Functions

Advanced Batteries

Professor, **Yuki Yamada**
Department of Energy and Environmental Materials

Awards

The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology (Awards for Science and Technology)

Department of Interface Quantum Science
Professor, Daichi Chiba

Pioneering research on novel control methods for nanomagnets

Our research group has developed a novel method to manipulate the properties of nanomagnets by using voltage, current, and mechanical stress. For example, we succeeded for the first time that a magnetic force of a magnetic material can be switched on and off by voltage, and also showed that the direction of magnetization can be electrically or mechanically controlled without applying a magnetic field. This result is expected not only to make contributions to further advancement of spintronics, but also to open up a future that is not an extension of it.

Shimadzu Research Promotion Award

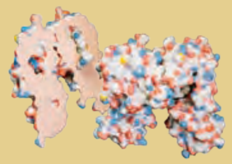
Department of Advanced Electron Devices
Professor, Tsuyoshi Sekitani

Development of ultra-thin and ultra-light biopotential measurement systems and sheet-type medical devices

I would like to express my sincere gratitude to my laboratory members, collaborators, many professors, PGV Inc. (a venture company originated from Osaka University), and the wonderful research environment and support system of SANKEN and Osaka University for making it possible for me to receive this very prestigious award. Our laboratory is engaged in research on basic materials, physical properties, and applications of flexible and stretchable electronics using organic materials. By improving the reliability of soft electronics and establishing a technological basis for accurate measurement, we have been able to realize devices that can be certified as medical devices. We will continue our efforts to contribute to new medical treatments through this technology.

17th JSPS (Japan Society for the Promotion of Science) Prize

Department of Biomolecular Science and Regulation
Professor, Kunihiko Nishino



Studies on the Function and Regulatory Mechanism of Bacterial Drug Efflux Pumps

I am very honored to receive the 17th JSPS Prize. This prize was established in 2004 to recognize and support outstanding young researchers in order to raise the level of scientific research in Japan to the world's highest standard. With this award, I also received the title of Distinguished Professor of Osaka University. I would like to express my heartfelt gratitude to all the laboratory members, collaborators, and members of SANKEN. With this encouragement, we will continue to push forward with our research so that we can create a world without the threats of infectious diseases.

FOREST (Fusion Oriented REsearch for disruptive Science and Technology)

FOREST (Fusion Oriented REsearch for disruptive Science and Technology) is a brand-new funding program by Japan Science and Technology Agency. The FOREST program promotes out-of-the-box thinking and ambitious transdisciplinary research that requires long term endeavor without fear of failures, targeting research fields related to science and technology (excluding those related to the humanities alone) with the potential to create seeds that will lead to disruptive innovation. In order to promote "emergent research", which aims to create seeds that will lead to disruptive innovation through diversity and fusion without setting specific issues or short-term goals, this program will provide long-term support for free, challenging, and fusion-oriented research that is not bound by existing frameworks for a period of seven years in principle, while ensuring an environment where researchers can devote themselves to their research.

Hirotaka Koga
Department of Functionalized Natural Materials

Creation of Bioresource-Based Sustainable Electronics

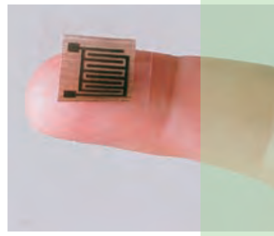
Research Outline

In recent years, there has been a rapid increase in the production of electronic devices, which has accelerated the consumption of depletable resources such as metals and petroleum. In addition, a large amount of electronic waste is generated, causing adverse effects on the human body and environmental destruction.

This research aims to create all components required for electronic devices, i.e., insulators, semiconductors, and conductors, from bioresources to realize environmentally friendly and sustainable electronics. This research will be a pioneering work towards the construction of a resource-recycling society, where people can live affluently with highly functional electronic devices made from bioresources and return them to nature after use.

Thoughts on Research

There are many attractive biological materials in the earth, including wood-derived "nanocellulose". However, human beings have not yet been able to fully utilize the excellent functions of biological materials. In this project, I will explore the electronic functions of biological materials and aim to innovate eco-friendly and high-performance green electronics.



Studies on Integration of Ultra-Flexible and High-Transparence Devices and Processing of Minute Signals

Research Outline

Conventional electronic devices comprising electrodes and semiconductors have been made of hard and opaque inorganic materials, increasing the presence of electronics. This study examines a fundamental technology for next-generation personal sensors established through research and development of electronic devices expressing softness of human skin does and expressing transparency of water. The devices conform to human skin, increasing their imperceptibility. Device integration and processing of minute signals are promoted to contribute to optimization of on-site estimation for scenarios such as early detection of diseases.

Thoughts on Research

The researcher attempts to open a novel field of research exploring the expression of new material properties and their hidden mechanisms, with a broad perspective of scientific and technological benefits to society. Particularly, flexible and transparent device characteristics will be maximized by nanomaterial design and nanonetwork control, eventually creating "imperceptible electronics" and thereby creating new value in this field.

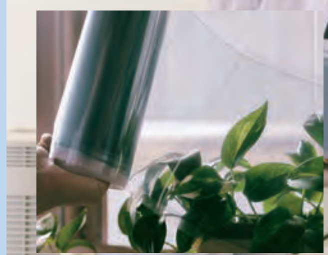


Fig.1 Concept of the proposed technology.

Teppei Araki
Department of Advanced Electron Devices

Development of a lens-less gigapixel camera using multi-stage optical encoding

Research Outline

Ultra-high-resolution gigapixel cameras, which faithfully record the light of the real world using the pixel count of "giga" units, are expected to play an important role as the next image-information input device in the future society. However, such cameras are currently large and have limited applications. In this research, we aim to realize a compact gigapixel camera that can capture ultra-high resolution images on mobile devices by designing a fusion of coding optics and information processing.

Thoughts on Research

When I was a student, I was involved in the research of a large, high-resolution camera called a gigapixel camera, and ever since then, I have been thinking that the concept of "camera" in the world and the related industries will definitely change if this camera becomes much smaller. At this project, I aim to achieve this goal using the completely new imaging concept.

Tomoya Nakamura
Department of Intelligent Media

Asako Murata
Department of Regulatory Bioorganic Chemistry

Chemoinformatic analysis of small molecules targeting RNAs

Research Outline

RNA has become an attractive target for drug development. However, due to the limited number of examples of known RNA-small molecule pairs, there are few reliable design strategies for small molecules targeting RNAs. I have recently developed a high-throughput method for analyzing the interaction between various RNA sequences and a given small molecule. With a large data set of RNA-small molecule interactions obtained by the method, data mining of small molecules will be carried out to obtain the chemical structures of small molecules important for binding to the target RNAs.

Thoughts on Research

I would like to apply data mining and machine learning techniques to a large and homogeneous data set of RNA-small molecule interaction in order to develop a model for predicting an RNA-small molecule pair in the future. I believe that this interdisciplinary approach can accelerate drug discovery and development for targeting RNAs.

Takafumi Uemura
Department of Advanced Electron Devices

Metabolites Measurements with a Sheet-type Biomonitoring System

Research Outline

This study develops a sheet-type biomonitoring system by combining ultra-lightweight and flexible electronic circuit technology with biotechnology. This system will enable the minimally invasive and continuous measurement of various biochemical indicators, such as metabolites, including it's circadian variations. This technology will enable the prevention of lifestyle diseases and unknown infectious diseases, thus creating disruptive innovations in the technology fields of preventive medicine and telemedicine in the future.

Thoughts on Research

Electronics is an essential science and technology in modern society, and will continue to evolve as a valuable tool for enriching human lives. To build a better future where everyone can live safely and comfortably, I will be taking on challenging research to integrate the different technologies of life science and electronics.

Introduction of Flexible 3D System Integration Laboratory

Members: K. Suganuma, C. Chen, Z. Zhang, M.-C. Hseih, A. Suetake, H. Yoshida, K. Takahashi, Y. Liu, S. Zhao, S. Moribe

Scope:

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. Like this approach, F3D is performing basic research and finding new materials towards new system integration technology for the next generation electronics manufacturing.

Collaboration structure:

Fig.1 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.

Introduction of new activities in 2021:

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 as illustrated in Fig.2. Worldwide R&D have already begun in order to achieve this world.

There are so many technology issues including materials and processing to support this evolution.

1) Cu interconnection:

Now, semiconductor manufacturing is facing to the lithography limit around 2 nm resulting in 3D chip let integration with ultra-fine pitch closing to 1 μm. For this fine pitch interconnection, no more soldering is available. Cu-to-Cu direct interconnection is one of the promising methods. After long period of R&D of Ag sinter joining, we have developed several affordable Cu sinter materials without any high pressure and reduction atmosphere. 200 °C joining process can make a strong Cu-Cu bond with an optimized solvent.

2) Thermal management:

Thermal management and dissipation technology are the other critical issue. Semiconductors have been denser and more compact endlessly resulting in much heat is generated inside Si or wide band gap semiconductors. F3D has been developing new thermal evaluation systems and damage sensing systems with the aid of AI technology. Fig.3 shows the system developed and an example of the thermal distribution image of SiC die-attached substrate.

Others and Contact information:

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).

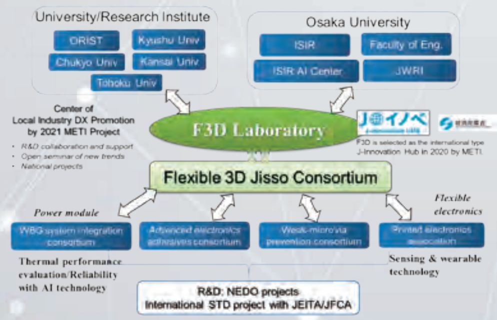


Fig.1 F3D's collaboration and industrial consortium activity.

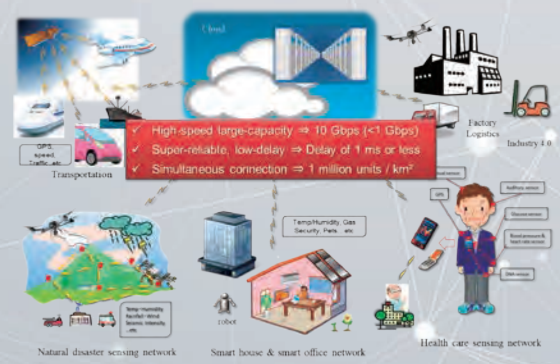


Fig.2 Coming post/beyond 5G era.

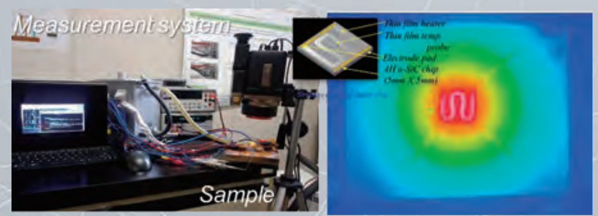


Fig.3 Thermal measurement system and SiC device image

imec

9th imec Handai International Symposium November 30th, 2020

This year it is 10th anniversary symposium.

We strongly expect real symposium at imec or Osaka University after stopping the spreading of Covid 19 infection in Europe as well as in Japan.

9th imec Handai international symposium composed of real time online and web hybrid system was held during November 30 to December 7, where prof.Tohru Sekino,director SANKEN, prof. Jo De Boeck, Executive vice president&CSO, imec joined.

After giving keynote speech of prof. Tohru Sekino and prof. Chris Van Hoof, imec fellow, 18 papers were given on the imec home page. Presentation fields were of next generation computing, information processing, flexible, wearable electronics, and nano-bio electronics. After one week, on December 7, real time on-line closed meeting was held where prof. Jo De Boeck and prof. Hidekazu Tanaka gave concluding remarks, respectively. There were total 105 participants where 38 from imec, and 39 from Osaka University.

Under strong friendship collaboration, (Collaborative framework Agreement contracted on 2011), especially in COI(center of innovation) project, we continued to develop bio-medical devices such as EEG, ECG, GSR and others for these 6 years. On 2020 fiscal year, updated new type EEG for female and also used for Brain Melody application, GSR(Chill+) for measuring skin resistivity, and updated ECG(Nightingale v2) where sampling frequency up to 256Hz, with bio-impedance and with 7 nights long battery life.

These device are applied to social implementation at Crimson Technology and GOGAKUDO.



Female EEG (Brain Melody)	GSR (Chill+)	ECG (Nightingale V2)
8ch EEG Fp1, Fp2, F3, F4, F7, F8, T3, T4 Reference Fz, Bias F2	3-axis accelerometer skin temperature 10-50°C GSR 0.01-20uS PPG	1ch ECG 256Hz 1ch bio-impedance accelerometer 7nights battery

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 SANKEN participate in the symposium and the number of the participants including the invited speakers exceeds 100 for every symposium.

The 24th SANKEN International Symposium and the 19th SANKEN Nanotechnology International Symposium were held from 8th to 9th January in 2021 using a digital platform. This symposium was one of Osaka University's 90th and Osaka University of Foreign Studies' 100th Anniversary Commemoration Projects. In this symposium, Professor Bernard L. Feringa, a Nobel Prize winner in 2016 and Distinguished Professor of Molecular Sciences at the University of Groningen, one of our important Global Knowledge Partners, gave a special lecture entitled "The Art of Building Small". Setting the symposium title "Life and Environmental Sciences", which is a quite important field for SANKEN, we have discussed possibility for us to contribute the future developments by utilizing our knowledges of devices, informatic, materials, quantum beam, chemistry, biology and nanotechnology throughout the symposium.