ACCEL
Accelerated Innovation Research Initiative
Turning Top Science and Ideas into High-Impact Values

PROJECTS
What is ACCEL?

ACCEL aims to set a path to the next phase, such as company R&D, venture start-up and other public funding, based on the outputs of the Strategic Basic Research Programs (CREST, PRESTO, ERATO, etc.) that have the potential to be world-leading but cannot be continued by companies and other organizations due to their perceived risks. The Program Manager (PM) leads research and development with the innovation requirements and goals, demonstrating Proof of Concept (POC) and promoting the appropriate rights arrangements.

R&D Period

Up to 5 years*

* However, in the event that POC has been completed and it is regarded that the R&D results can be passed on to companies at an early stage, the R&D project may be brought to completion quickly. Furthermore, in the event that on the other hand it is judged through interim evaluations etc. that there are no prospects of POC being achieved or the results of the R&D are unlikely to be able to be passed on to companies the same measures may be taken and the project halted.

Evaluation Criteria for Selecting Projects

1. Significant and world-leading R&D results must be shown.
2. The results obtained through the Strategic Basic Research Programs must be developed, and a vision described in which the expectations of society are met, and links created that will lead to improved industrial competitiveness and international development, and changes to society itself.
3. When the end of ACCEL is reached there must be prospects for the flow of the R&D to be passed on to companies, ventures and other projects.*
4. The R&D plan must be able to concretely provide POC to companies and investors.
5. It must be demonstrated that even after ACCEL personnel are being fostered to continue the R&D, that there is an exit leading to corporate collaboration and the launch of ventures etc., and that there are prospects for the R&D leading to the securing of global personnel.

* The results of R&D obtained through ACCEL must aim to be high-impact results that both surprise and attract companies and investors.

R&D Budget

10-300 million yen/year and project

PM and Research Director

Under the ACCEL program a PM and Research Director work together on each R&D project, directing the overall R&D team (R&D project) including the joint researchers and participant companies, and taking responsibility for promoting the R&D towards its ultimate POC. The PM and Research Director bring together a team that will be adequate and optimal in order to reach its goal. The PM will at appropriate intervals report to the R&D Management Committee and JST on the progress and results of their projects, and deal with the evaluations and advice provided as a result of their reports.

R&D Management Committee

The screening of matters regarding ACCEL will be conducted by an R&D Management Committee consisting of external experts etc. The specific roles of the Committee are as follows.

- Evaluations of the R&D projects (preliminary, interim and ex post facto)
- Evaluation of the PM
- Improvements to the R&D plans
- Alterations to the R&D plans (including expansion, downscaling or suspension)
- Other decisions, advice or guidance regarding the pursuit of the R&D project

It should be noted that in order to contribute to making judgments regarding the above-mentioned roles the R&D Management Committee may set up other expert evaluation committees consisting of external experts.

Chair
Yoichiro Matsumoto
President, Tokyo University of Science

Members
Masahiko Ichie
President & Representative Director, Skymark Airlines Inc.
Hiroshi Okajima
Principal Fellow, TOYOTA CENTRAL R&D LABS., INC.
Kazuhiko Sumi
Professor, College of Science and Engineering, Aoyama Gakuin University
Kazuhiko Toyama
Managing Partner, Industrial Growth Platform, Inc.
Yoshio Hayashi
Chief Creative Manager, Open Innovation Institute, Kyoto University
Development of thin, soft, human-compatible organic devices

In recent years, the focus of attention in the electronics field has shifted from inorganic materials such as silicon to low-cost, lightweight, soft, and biocompatible organic materials with healthcare applications. We have done extensive research on materials and devices, with the overall goal of developing human-compatible organic devices. In the CREST Project, we developed a process using organic transistors to manufacture large-area, stretchable, sheet-type sensors. And in the ERATO Project, we established a method for manufacturing integrated circuits based on attaching high-performance organic transistors onto the surface of 1-μm thick ultra-thin polymer substrates. This allowed us to develop sheet-type sensors that do not break even when rolled up and can be attached to flexible surfaces such as human skin. We have also succeeded in developing both a device equipped with organic photodetectors and LEDs that can measure the oxygen saturation levels in blood, as well as a device composed of biocompatible material that does not cause skin inflammation even after continuous attachment for a week.

Towards a society where everyone can easily monitor their biological information in order to protect their health

In the ACCEL Project, we plan to develop a stretchable image sensor (Conformal Bioimager) by integrating and further advancing the processes and technologies we have already developed through previous research. The Conformal Bioimager will allow anyone to easily measure their own biological information anytime and anywhere by simply attaching a sheet to their skin. Development of a wearable sensor that can continuously monitor health conditions for 24 hours a day, 7 days a week without causing any stress or discomfort when applied to the skin of the wearer will be helpful for health management and disease prevention, and can contribute towards bringing about a regional comprehensive care system that can maintain the health of people wherever they live.

In developing devices using organic materials, we need to ensure both harmony with the global environment and affinity with the humans who live in it. Wearable devices for monitoring with cameras or similar equipment have already been commercialized. However, the skin-attachable devices we have developed feature the ability to accurately measure biological information such as blood flow, respiration, and movement in real time, all of which normally cannot be measured without attaching equipment to the skin. Such features have never been seen in wearable devices.

The underlying technology for achieving the Conformal Bioimager is just a step away from completion. To overcome the final hurdle, however, we have to develop something that allows us to utilize both the soft parts that attach to the skin and the hard parts where the battery and other components are mounted as a system, and we also have to establish a manufacturing process. In the ACCEL Project, I would like to solve this problem in order to enable the broad use of this technology for the betterment of society.

As leaders in the field of stretchable electronics, we will put our expertise to work to solve these final problems in order to advance this technology towards commercialization and applications for society.

With the Conformal Bioimager, we will realize a secure, safe, and comfortable society where everybody can accurately measure his/her biological information anytime and anywhere.

Research Director

Takao Someya
Professor, School of Engineering, The University of Tokyo

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Program Manager

Yorishige Matsuba
ACCEL Program Manager, Japan Science and Technology Agency

I have known Professor Someya since 2003, and have occasionally helped his research as a materials manufacturer. Since then I have followed his work with much interest. In particular, I feel that the stretchable optical sensor is highly practical and has excellent potential for practical, real world use.

This unprecedented project is unique in the sense that it aims to achieve whole-sale integration of the collection and analysis of various body signals. The method is non-invasive and expandable, and the necessary equipment is already available, so a prototype may well be ready sooner than expected. However, being a system for health management and disease prevention, there are various criteria besides the technical aspects that must be satisfied before it can be brought to completion. We are working to make it a business reality within a short timeframe. In doing so, we are drawing on my experience of developing new business projects, and optimally coordinating the university research that forms the project base with applied research carried out by companies.

I believe there is a lot of potential in this technology. This is my chance to show my skill as the PM on how quickly this technology can be developed for different applications.
Terahertz Optical Science and Technology in Semiconductors

Developing a high-intensity terahertz pulse light source that allows observation of living cells

Terahertz (THz) light is the electromagnetic wave range at the boundary between radio waves and light. It has been called an unexplored electromagnetic region because of the difficulty with which it is generated, controlled, and detected. However, recent technological innovations have triggered higher expectations for its commercialization. In the CREST project, we have developed the world’s highest intensity THz pulse light source, with a peak electric field of 1 MV/cm or more, using 100 femtosecond pulsed lasers and lithium niobate crystals. We are able to amplify the number of free electrons responsible for electrical conduction in the semiconductor some 1000 times by simply irradiating the semiconductor with this THz light for a mere trillionth of a second. In addition, we were able to discover a variety of extremely non-linear optical responses. Moreover, by developing a novel THz near field microscopic apparatus that takes advantage of the characteristics of this light source, we have achieved real-time observation with video rates and spatial resolutions of less than a hundredth of the wavelength limit, succeeding in the observation of living cells as well.

Construction of a high-resolution, high-speed, safe terahertz imaging system

In addition to the development of the THz light source and detector, issues to be addressed in the ACCEL project include systemization. While the THz light source has seen rapid development, the output levels are still insufficient. We will expand light-laser-excitation terahertz technology into terahertz-semiconductor technology, constructing a basic imaging system using semiconductor sources and detectors. With the increases in output power and imaging speed gained by making arrays and modules of semiconductor light sources and with the sensitivity improvement gained by adding phase detection technology to detectors, we will use conversion to arrays and modules for high-speed imaging and construct a basic terahertz imaging system composed of a light source, detector, optimized low-loss optical system, control system, and analysis software to make possible equipment such as body scanners and non-destructive inspection systems that are even higher-resolution, faster, and safer than the existing technologies. This will enhance the security of public places such as transport facilities and improve the safety of products non-destructive inspection systems that are even higher-resolution, faster, and safer than the existing technologies.

I am convinced I can succeed in paving the way to a new phase by going back to the first principles of physics, thinking independently, and reconstructing them from scratch.

Out of an interest in fundamental physics, I previously conducted research using THz light as a tool to investigate the excitation mode of electrons and molecules in semiconductors. I started out by using existing equipment for measurement, but the light source intensity was weak, and I became unsatisfied with the measurement method as well. This motivated me to continue pursuing world-leading research, with the goal of developing a light source and creating a measurement apparatus. Now I have succeeded in developing the underlying technology necessary to apply imaging technology using THz light to society.

In this ACCEL project, we will drastically improve the performance of individual elements based on semiconductors, reconstructing the THz light system in order to satisfy every one of those long-unmet industrial expectations, bringing about a real-time, reliable, and safe imaging system.

I have already drawn multiple road maps to success. My aim is the creation of innovations that will allow this technology to become common and contribute to society as soon as possible.

I am engaged in this project with the conviction that this is a once-in-a-lifetime opportunity, fulfilling the dreams of many researchers and others who have been involved with this THz technology.

Technology development towards industrial application of terahertz light aimed at helping achieving a safe and secure society.

- Realization of a Safe & Secure Society
  - Body scanner
  - Non-destructive inspection

- Terahertz optical science
  - Construction of a factorable imaging system
  - Rapid improvement of universal semiconductor devices
  - Molecular interaction
  - Molecular vibration of solids

- THz light
  - Terahertz (THz) light
  - This is a special light/electromagnetic wave that falls in the region between millimeter waves and infrared light, with the characteristics of both radio waves and light. It passes through media such as cloth, paper, plastics, and wood, but not water or metal. It generally has an oscillation frequency of 300 GHz to 10 THz, which is the region that provides much information about molecular structures and kinetic states, including molecular vibration and rotation, molecular interaction, and the lattice vibration of solids.

- Actual imaging of a knife hidden in a parka
  - Vertical scale (mm)
  - Horizontal scale (mm)
  - The imaged knife
  - Placing a knife in a parka

KOICHIRO TANAKA
Research Director
Professor, Graduate School of Science, Kyoto University

KOICHIRO TANAKA
1999: Ph.D. (Science), Kyoto University; after working at the Institute for Solid State Physics at The University of Tokyo and other institutes, started work at Kyoto University in 1997; 2004: Professor, Kyoto University; 2006: Adjunct PI, Professor, iCeMS, Kyoto University; 2014: Professor in Graduate School of Science and concurrently appointed to iCeMS. Field of expertise: Optical physics.

RYOICHI FUKASAWA
Program Manager
ACCEL Program Manager, Japan Science and Technology Agency

When I was carrying out corporate research on THz technology, Professor Tanaka and I succeeded in developing a compact THz sensing system that was revolutionary at that time. Later, I founded an R&D-type venture company and continued development towards putting THz light technology to practical use, such as establishing non-destructive inspection equipment utilizing THz light. These days, the industry is increasing and varying demands for the ability to image objects more precisely and more finely, so I am constantly strongly reminded of the need for a THz light technology that allows us visualize objects that were invisible using existing light technology. THz light technology has made some impressive advances in recent years, but there are still obstacles preventing the wide adoption of this technology in society. To solve these problems, we need to accomplish breakthroughs such as downsizing and reducing costs by carrying out semiconductor-focused research in this ACCEL project. To open up the path towards full-scale application of THz light technology, we shall move this project ahead with the goal of promoting participation from industry and expanding applications.
Application Field Development of Dynamic Intelligent Systems by Using High-Speed Vision

From the speed of the human eye to the speed that machines can capture

The conventional image processing speed is around 30 frames per second, which is a frame rate chosen to suit the speed of the human eye. To operate cars or robots more quickly and accurately, image processing speeds need to be increased to machine-capturable levels. However, this was difficult due to limitations in data readout circuits and processing speeds in scanning, which transforms images into electrical signals.

To solve these problems, we succeeded in developing an image processing technology that boasts incredibly high speeds. Based on this technology, we have both proposed and demonstrated intelligent systems such as a high-speed tracking device that can capture a flying object as if it were a stationary image, and a dynamic projection mapping system that tracks a moving three-dimensional object and projects video onto it.

Broad application potentiality, from high-speed interfaces to traffic

The objective in this ACCEL project is to develop this technology further and establish a common basis for high-speed image processing technology for a range of uses. It can also be used to construct optimal and unique systems in each field, including automobiles/transport and high-speed human interfaces. In addition, we hope to present a proof-of-concept demonstration of intelligent systems that complement and expand the capabilities of the human eye.

This research will advance intelligent systems that use visual senses far beyond human capability, integrating information and the real world and drastically changing the information environment surrounding us.

While many people associate photos or video with how beautifully the images can be shot, I focus on how quickly it can be shot and processed. So I have been researching ways to instantaneously provide feedback on shooting information and improve mechanical performance to unprecedentedly high levels. In this research, eliminating bottlenecks in the image processing speed will allow us to achieve high-speed imaging, transfer, and processing systems in a number of different forms, offering true real-time image processing in perfect step with subject movements.

In collaboration with Dr. Kishi, the program manager and a professional in the practical application of image processing technology, with whom I conducted joint research before this ACCEL project, I will further develop this high-speed image processing technology, demonstrate the functions and performance that make the impossible possible, and apply them to society.

I will construct an entirely new intelligent system by recognizing and controlling the real world in real time.

This intelligent system, which goes far beyond human capabilities and makes full use of high-speed image processing technology, will bring innovation to the world.

Research Director
Masatoshi Ishikawa
Professor, Graduate School of Information Science and Technology, The University of Tokyo

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Program Manager
Norimasa Kishi
ACCEL Program Manager, Japan Science and Technology Agency

When I first learned of this research, I was stunned by being able to see things that could never be captured before. As the program manager, I am very keen to spread this world-leading technology, these ideas, from Japan to the world.

In this ACCEL project, I will work on the practical applications of high-speed image processing technology, based on the hands-on experience I gained assisting with research on practical applications for the bird’s-eye view/around view monitors currently used in car navigation systems. Specifically, I will set the target values and provide smooth execution management for the POC of the intelligent system so as to reflect the demands of people in each of the various fields of application. In addition, I will promote strategies for practical use and open up application fields so that the technology can be used by as many people as possible in different fields.

An intelligent system that uses high-speed image processing technology can be expected to be deployed in business in multiple ways, making it the focus of much attention from a range of business fields.

Norimasa Kishi
Program Manager

Profile

Building next-generation media content ecosystem technologies

Offering active music experiences by analyzing music content automatically

Digitization of music dramatically improves the enjoyment of music. We have been carrying out R&D on information technology as a way to bring out the true value of digital music and allow people to actively enjoy it, thanks to state-of-the-art music-understanding technologies that can estimate musical elements from audio signals.

So far, we have created services such as Songle, which visualizes the elements of music, Songrium, which visualizes and provides a bird’s eye view of a huge amount of musical content, and TextAlive, which generates lyrics animations, and which have been released on the Internet. These services offer active experiences for music appreciation and creation as a way to deepen people’s understanding of music, and can add new value to the huge amount of media content that has been accumulated so far.

Building a platform that creates value from a huge amount of media content

In the ACCEL project, our aim is to contribute to the development of the next-generation media content industry by establishing a technology that helps people to both appreciate and create music, and by building a service platform for music content ecosystems.

Specifically, we will enhance music-understanding technologies to analyze large amounts of music in more diverse ways, and develop Content Appreciation Support Technologies that can allow people to enjoy their favorite pieces of music more actively. We will also advance R&D for Content Creation Support Technologies that allow people to freely create music content to reflect themselves and their tastes. In addition, we will support co-creation actions that convey the appeal of content to others, and further amplify the value of music content.

Contribute to development of the next-generation media content industry

I would like to tackle the challenge of creating new academic, industrial, social, and cultural value; a challenge that will have a considerable impact on the world.

I would like to carry out R&D with him so that we can change the world together.

As music can be easily combined with other content, I will establish new business models through far-ranging collaboration with related industries.

The accumulation of large-scale media content such as music and video will generate new value for music appreciation and creation.
Development of High-Resolution LIDAR System Based on Slow-Light Structures

Slowing the speed of light brings innovation to conventional technology

Light travels so fast that it goes around the Earth some 7.5 times per second. Being able to make full use of “slow light” technology that significantly lowers the speed of light allows different light-related functions, such as modulation, switching, wavelength conversion, detection, dispersion compensation, correlation, and beam scans, to become increasingly sophisticated.

We are working on R&D for this slow light technology using photonic crystals,* and so far have established its fundamental theory and demonstrated its basic operation. Under special environments, such as extremely low temperatures, it is known that the speed of light can be reduced down to the speed of a bicycle. Instead of employing such extreme deceleration, our slow light technology has succeeded at room temperature, or under similar easily usable environments, in lowering light speed by around one-tenth to one-hundredth on a small semiconductor chip. As a result, we are producing world-leading results on research to improve the sophistication of the functions described above.

Towards the realization of LIDAR (Light Detection and Ranging) that can recognize surroundings in three dimensions and at high resolution

In the ACCEL project, as an application of slow light technology, we will develop and realize LIDAR that can recognize an object in three dimensions by precisely measuring the distance and direction of the object using reflected light. The project will develop a high-resolution, non-mechanical optical beam steering device,* and we intend to build and demonstrate a compact and low-cost LIDAR system incorporating this scanner. The design and fabrication techniques developed during the project are expected to bring about a significant evolution in optoelectronics and related fields.

* A mosaic structure with period of around half a light wavelength. This freely controls the behavior of light by fully exploiting light’s wave-like property.

Research Director
Toshihiko Baba
Professor, Graduate School of Engineering, Yokohama National University

If the speed of light slows down to one-tenth, its interactions with the environment become ten times larger. If this property is applied to an optical device, its performance will be improved ten-fold. While it also becomes ten times harder to handle, however, this has been mitigated by recent technological advancement, and slow light devices are now ready for practical use. This is why this ACCEL project has chosen slow light and LIDAR as themes. I am engaged in the research while consulting with Dr. Kobayashi about his wealth of experience with commercialization. He has been active at the forefront of optical device development since I was a student.

The ACCEL project experimentally produces LIDAR chips incorporating optical beam scanners at an LSI factory. Through multiple discussions in parallel with the prototype production, we will determine the properties necessary for commercialization. Our ultimate goal is to achieve LIDAR chips that stand out for being ultra-compact, high-resolution, vibration-resistant, and low-cost productivity.

Using the intriguing phenomenon of “light slowing down” that I have long studied, I will develop LIDAR chips that can recognize the entire environment as three-dimensional images, thus making a contribution to our society.

Program Manager
Kohroh Kobayashi
ACCEL Program Manager, Japan Science and Technology Agency

The application of developed technologies to society requires three important elements: technology, people, and hardware. “Technology” means world-leading original technology such as slow light. “People” are the basis for the relationship of trust needed for successful technology transfer. “Hardware” means that the technology to be transferred will be passed along not only as written documents but also as tangible objects.

In this ACCEL project, as Program Manager I will support the research team led by the research director, Professor Baba, in the promotion of commercialization through linking research and industry. I visited several dozen Japanese and American companies to hold hearings and make proposals right back at the program preparation stage. I will also hold conferences with the industrial sector on LIDAR as needed. LIDAR is a field where there is a lot of expectations for technological advances and market expansion. I would like to participate in the project not only for the joy of being part of the commercialization of this world-leading fundamental research but also to enjoy it as a difficult challenge.

As a sensor indispensable for automated driving technology and high-performance robots with artificial intelligence, LIDAR has the possibility to become the most powerful technology for future industry.

Light traveling at lower speeds will create highly-controlled automated driving technology and precisely-moving robots, overturning long-held beliefs.

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**FY2015**

**Creation of the Functional Materials on the Basis of the Inter-Element-Fusion Strategy and Their Innovative Applications**

What is inter-element-fusion, this innovative idea that overturns the conventional wisdom for metallurgy?

Humankind has combined elements with different characteristics to develop materials with excellent properties. We are advancing research on inter-element-fusion that creates new materials by mixing immiscible metallic elements in the bulk state, at the atomic level. Focusing on the element rhodium,* an expensive element used as a catalyst, we have succeeded in mixing at the atomic level palladium and ruthenium, which are on either side of rhodium on the periodic table, to develop a novel alloy (nano-alloy material) that can replace rhodium at about a third of the cost. We also found that this novel alloy offers a superior property; namely how its catalytic activity is higher than natural rhodium, resulting in its reaction proceeding at temperatures lower than previously. Although its durability still needs to be investigated, its current performance is expected to be good enough to be used for exhaust gas purification.

* A type of rare metal. It is widely used as industrial catalyst, for decomposition of nitrogen oxide in exhaust gases and for conversion of hazardous carbon monoxide to carbon dioxide.

**Building a mass production system for this novel nano-alloys and making them available to industry**

In the ACCEL project, we will be able to use previous research to theoretically predict physical and chemical properties of the new materials that are made through inter-element-fusion, enhancing the accuracy of its structural design with this new concept. In addition, we will demonstrate that it is possible to create new materials with desired properties. Moreover, by establishing the technology for the mass production of these new materials and providing prototype samples to industry in a range of fields, we shall seek out the path to commercialization, aiming to contribute to the development of society and industry.

The real value of a scientist is tested by whether something new can be created. The application of inter-element-fusion will maximize the potential capacity of every element on Earth.

**Inter-element-fusion technology, a sort of “modern-day alchemy” that creates new materials and achieves the stable supply replacing rare materials, will act to support future chemical industries.**

Inter-element-fusion technology, a sort of “modern-day alchemy” that creates new materials and achieves the stable supply replacing rare materials, will act to support future chemical industries.
Realization and Development of Innovative Information Processing System and Application

Using Near-Field Coupling Integration Technology

"3D Integrated Chip" reduces power consumption to 1/1000

Recent years have seen dramatic increases in the information processing speed of computers and the amount of data being exchanged among them. Power consumption has also increased, however, leading to serious issues with equipment overheating and failing.

This is why our research, which permits drastic reductions in power consumption to prevent heat generation, is under the spotlight. By stacking chips three-dimensionally, or vertically, within an LSI (Large Scale Integration) and making the wireless communication between chips, we have succeeded in developing a technology that dramatically reduces power consumption to just one thousandth of conventional chips. This TCI (ThruChip Interface) technology enables data equivalent to six million two-hour movies (corresponding to 1400 years’ worth of video recordings) to be transmitted using just the power equivalent to a single button battery. The TLC (Transmission Line Coupler) we have developed together with the TCI is a technology that allows non-contact connections between circuit boards and modules. This technology will cause fewer communication failures compared to wired connections, and offers advantages in terms of speed, size, weight, energy use, and cost, allowing this technology to be used in smartphones and artificial satellites.

Handling large volumes of data at high speed with ultra-low power consumption

In the ACCEL project, we plan to construct a system to handle large volumes of data at high speeds with ultra-low power consumption levels by stacking LSIs using TCI technology and connecting them wirelessly with peripheral devices such as sensors using TLC technology. This technology will result in significant advances in a range of fields that include supercomputers, robots, ultra-resolution microscopes, and automated driving.

Furthermore, we are advancing the development of the eBrains palm-sized artificial intelligence. This is the 3D integration of both a computer that has 1/5000th the processing performance of the "K" supercomputer, and an artificial intelligence that has a degree of integration 1/500th of the human brain. This incorporates the world’s first system to carry out both logical/computational and intuitive/spatial information processing in combination.

Our proposal is to switch the connection of chips or circuit boards from a mechanical type using soldering or connectors to an electronic type such as near-field coupling.

The TCI and TLC technologies accelerate cutting-edge technologies such as supercomputers, artificial intelligence, and robots, making them a familiar part of our lives.

The core idea of the TCI and TLC is how signals can be effectively sent back and forth between near-fields. The TCI employs a mechanism whereby the magnetic field coupling of coils on chips effectively allows data communication. The TLC enables wireless communication through the deformation of a part of the transmission line and the coupling of the electric and magnetic fields.
Reinforcement of Resiliency of Concentrated Polymer Brushes and Its Tribological Applications - Development of Novel "Soft and Resilient Tribology (SRT)" System

Surface-coating of materials drastically improves performance

The giant molecule that is formed by the combination (polymerization) of many sets of small molecules (monomers) is called a polymer. The thin layer created by growing polymers on a material surface is a polymer brush. This will add new functions to the material surface.

We have previously developed the Concentrated Polymer Brush (CPB) that provides completely new characteristics such as ultra-low friction, good lubrication, high elasticity, and excellent bio-compatibility, and further improved these characteristics by multi-layering and hierarchizing the CPBs. In addition, we have successfully and dramatically thickened the CPB layer through innovative surface formation technology and verified its superior tribological properties, including low friction, good lubrication and high wear resistance at not only the micro but also the macro levels, demonstrating the possibility of its application to practical machinery systems.

Reducing friction using CPBs and hence making daily-life electric appliances more durable and higher in performance

In the ACCEL project, we aim to apply CPBs on sliding parts of mechanical elements such as sliding bearings and seals. This allows us to attain high levels of both resilience and low friction that were hard to achieve with previous technology. Finally, we will establish a new concept, Soft and Resilient Tribology (SRT), realizing long-lasting, low power-consumption machinery products.

The CPB has the potential to inspire further innovation even in machinery products based on mature technologies, such as, compressors, automotive equipment, audio equipment, home electronics like refrigerators, and transport equipment. We have previously developed the Concentrated Polymer Brush. This will add new functions to the material surface.

The CPB of special interfacial functions was first fabricated using precise polymerization allowing uniform growth of polymers, and hence accurate control of the brush structure and increased density. This research successfully created a micrometer-sized CPB ten times thicker than conventional ones, drastically reducing its friction resistance.

Concentrated Polymer Brush

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Through my research on concentrated polymer brushes, I would like to develop new aspects of broad material science fields in terms of function and application, laying the foundations of a safe and secure society.

My aim is that contributing to energy-saving and reducing environmental load through the reduction of friction and wear can become one of the pillars supporting the science and technology of the 21st century.
Development of Key Chemical Processes of Extremely High Efficiency with Super-Performance Heterogeneous Catalysts

Developing catalysts that achieve effective chemical synthesis in water

The 20th century brought many different chemical products to enrich our lives. Their manufacture is intimately connected with chemical synthesis. Many chemical syntheses are conducted using catalysts in organic solvents that can dissolve insoluble materials. However, we have succeeded in carrying out synthesis in water.

In our previous research, we developed many high-performance heterogeneous catalysts combining amphiphilic polymers that can disperse in both water and organic solvents with ligands* and special metals such as palladium that show high catalytic activity in water. These catalysts are supported on polymers and so will virtually never be mixed into the products. This permits separation, recovery, and reuse of the catalyst through filtration, resulting in a reduction in the use of rare metals that are often used in catalysts.

Radically streamlining different chemical processes

The ACCEL project aims to develop safe and clean chemical reactions carried out in water with a minute level of catalyst. We will find out how much the use of rare precious metal catalysts can be reduced, and bring this to fruit through fundamental research. In addition, taking advantage of the catalyst being supported on polymers, we will develop methods to supply very pure products, and to recover and reuse the catalyst. This will allow world-wide sales of the catalyst, leading to the dissemination of the new era’s energy-saving, extremely high-efficiency, and environment-friendly chemical processes.

* Molecules that attach to a metal atoms to alter their properties or functions.

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* Molecules that attach to a metal atoms to alter their properties or functions.

In the ACCEL project, our goal is to achieve chemical synthesis with a reduced amount of catalyst, a millififth, or even a billionth. The ideal goal of our research is the development of a thoroughly streamlined processes where, when the raw materials are injected from the inlet, the products will flow out from the outlet after passing through the cartridge filled with the catalyst.

Having organic molecules, which are oil-based react in water is theoretically impossible. However, the umbrella effect makes it possible.

We will establish these processes not only in the laboratory flask but as a technology that is actually useful to mankind, spreading it to the world.

Establishing key chemical processes with extremely high efficiency will defy conventional wisdom and create a new standard for chemistry.

**Umbrella effect**

When water-insoluble organic molecules are added into water containing amphiphilic polymers, they will spontaneously concentrate around the amphiphilic polymers. As it is almost like hiding from the rain under an umbrella, this behavior is called the “umbrella effect.” If we load catalysts in advance around the places where these organic molecules gather, chemical reactions can proceed effectively.

**Research Director**

Yasuhiro Uozumi
Professor, Institute for Molecular Science, National Institutes of Natural Sciences

For some hundred years, it has been commonsense in modern organic synthesis to use organic solvent to dissolve organic molecules that are not easily water soluble. The most popular, safe, and harmless media, however, is water, and all chemical reactions in life forms occur in water. Curious as to whether this could be done artificially, I discovered this umbrella effect, and eventually succeeded in achieving organic synthesis in water.

In the ACCEL project, our goal is to achieve chemical synthesis with a reduced amount of catalyst, a millififth, or even a billionth. The ideal goal of our research is the development of a thoroughly streamlined processes where, when the raw materials are injected from the inlet, the products will flow out from the outlet after passing through the cartridge filled with the catalyst.

**Program Manager**

Toshiaki Mase
ACCEL Program Manager, Japan Science and Technology Agency

Prof. Uozumi uses his very unique ideas to advance research that opens up new fields of chemical synthesis. We need this because of the growing call for green chemistry, which means reducing risks and minimizing environmental loads in R&D, and so super-performance heterogeneous catalysis technology will play an important role in industry. My role is to draw up a business design for this super-performance heterogeneous catalyst technology.

In the ACCEL project, we will consider what needs to be demonstrated for research that helps the world, and continue discussions and FS with companies. Currently, we are proposing raising the performance of the catalyst we developed to practical levels, which will allow the results to be applied to manufacturing processes not only for pharmaceuticals for human or animals, and for agrochemicals, but also for organic electronic materials.

The development of key chemical processes with extremely high efficiency has the potential to greatly advance the world’s chemical technology.

**PROFIE**

YASUHIRO UOZUMI

1966: M.S. (Pharmacology), Graduate School of Pharmacy-Science, Tokyo University. 1997: Professor, Nagoya City University after Hokkaido University, Columbia University, and Kyoto University; in current post since 2000. Research into catalytic organic transformation in water, nano-metal catalyst, highly performance transition metal complex catalysts, etc. Ph.D. (Pharmacology)

**PROFILE**

TOSHIKAI MASE

1983: M.S. (Pharmacology), Graduate School of Pharma-Science, Tokyo University. Joined Sagami Chemical Research Institute; University of Michigan, Banyu Pharmaceutical Co., Ltd., and Meiji Seika Kaisha, Ltd. Has created a track record as the person responsible for pharmaceutical research and development of manufacture processes. Ph.D. (Pharmacology)
Fundamentals and Applications of Diamond Electrodes

Using familiar diamonds as electrodes

Everyone knows what diamonds are, but this time we found a new use for them other than jewelry or industrial uses. Diamond is an insulator. However, when doped with boron, it turns into a conductive material. And so we are developing diamonds with high boron content and their use as electrodes. These diamond electrodes are noted for not using rare metals and for being able to be manufactured relatively easily.

Our previous research has revealed the fundamental characteristics and functions of diamond electrodes used as electrochemical electrodes. It also showed their utility in a range of different applications, including successfully developing high-performance sensors, achieving organic synthesis, and producing useful materials using carbon dioxide (CO₂).

Improving electrode performance and finding ways to expand applications

This ACCEL project aims to establish design guidelines for diamond electrodes and to search out applications to maximally utilize their performance. Market and competition research will be conducted in CO₂ reduction they can effectively produce formaldehyde, which is used as a raw material for chemical products, at room temperatures and under ambient pressures. There was a huge reaction to this research, and I feel a great sense of responsibility, but also a sense of satisfaction. The electrodes produce extremely small noise currents, so can become excellent high-accuracy sensors. We succeeded in accurately monitoring neurotransmitters in the brain and stomach pH in mice.

In the ACCEL project, we will use our research results to clarify the mechanism in terms of material science and develop large-area, high-performance electrodes. Along with Mr. Tsukahara, our program manager, who will provide the path to the commercialization, I would like to contribute to a way of manufacturing that benefits society while being attuned to the needs of our society.

Yasuaki Einaga
Professor, Faculty of Science and Technology, Keio University

Diamond, a material everyone has heard of, is fascinating thanks to the successive discoveries that are being made of its many exciting characteristics.

Diamond electrodes have a wide range of applications. For example, in CO₂ reduction they can effectively produce formaldehyde, which is used as a raw material for chemical products, at room temperatures and under ambient pressures. There was a huge reaction to this research, and I feel a great sense of responsibility, but also a sense of satisfaction. The electrodes produce extremely small noise currents, so can become excellent high-accuracy sensors. We succeeded in accurately monitoring neurotransmitters in the brain and stomach pH in mice.

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As research on diamond electrodes has a short history and many unknowns remain in the field, there is a huge amount of excitement and joy in discovering new phenomena.

Nobuhiko Tsukahara
Program Manager

This technology is expected to be useful in all aspects as a base technology for society that will greatly contribute to solving issues of the global environment and energy.

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Molecular Basis of Symbiotic Networks and Its Application

Exploring the possibility of arbuscular mycorrhizal (AM) fungi as a substitute for finite fertilizer

Agriculture supports our daily life, and one of the fertilizers used for agriculture is phosphorous fertilizer. The phosphate rock that is the raw material of phosphorous fertilizer is a limited resource. As Japan is 100% dependent on imports to meet its domestic demand, reducing its use is a major issue in consideration of future agriculture and the supply and demand of food. As a clue that might solve this issue, the focus is on arbuscular mycorrhizal (AM) fungi, which establish symbiotic relationships with 70 to 80% of vascular plants on their roots. We are trying to clarify the mechanism of the symbiosis between AM fungi and plants based on the idea that we can reduce phosphorous fertilizer use by making use of the characteristics of AM fungi. Previous CREST research has provided insights into the molecular infrastructure that clarifies the symbiosis mechanism. For example, a group at Osaka Prefecture University found that the factor activating AM fungi is strigolactones, a substance produced by plants.

Developing technology to utilize AM fungi to bring revolutionary changes to agriculture

In the ACCEL project, we aim to develop the most suitable technology for utilizing AM fungi by bringing these findings to field-based research. We will sequence the genome of mycorrhizal fungi and perform field inoculation experiments to evaluate the efficacy of arbuscular mycorrhizal fungi in terms of the reduction of phosphorous fertilizer use. Based on these findings, we will develop a diagnostic technology for effective use of arbuscular mycorrhizal fungi. The utilization of arbuscular mycorrhizal fungi and reduction of phosphorous fertilizer use will drastically change agriculture, contributing to solving the problems of food supply and demand which we must deal with on a global basis.

Arbuscular mycorrhizal fungi

These are AM fungi that establish a symbiotic relationship with plants on their roots. The fungi receive photosynthetic products such as sugars from plants in exchange for nutrients such as phosphate and water, which the fungi extract from the soil through their hyphae. The arbuscular mycorrhizal fungus present research deals with is an obligate symbiotic fungus that cannot live alone, and is useful, for example, in improving the disease resistance of plants.

Arbuscular mycorrhizal fungi are the most common symbiotic microorganism of land plants. I hope to reveal the mechanism of spore formation and growth that depend on symbiosis.

Research Director
Masayoshi Kawaguchi
Professor, National Institute for Basic Biology, National Institutes of Natural Sciences

Arbuscular mycorrhizal fungi are ancient organisms that have even been found in fossils more than 400 million years old. Their biology is shrouded in mystery. My goal is to make the symbiosis mechanism clear, thus establish this as an effective culture technology and make both plant production and environmental preservation possible. So far, using Lotus japonicus, a model of legumes, we have isolated many mutants of arbuscular mycorrhizal fungi that are poor at symbiosis and identified the genes responsible, allowing us to clarify the mechanism.

Arbuscular mycorrhizal fungi are the most common symbiotic microorganism of land plants. I hope to reveal the mechanism of spore formation and growth that depend on symbiosis.

In this ACCEL project, I am moving ahead with research in collaboration with many research institutions, including experts on soybeans and corns on various kinds of soil from all over Japan that have different environmental factors, and diagnosing the effective use of arbuscular mycorrhizal fungi. Based on the analytical results, I would like to build a system that can offer the most suitable “prescription” for arbuscular mycorrhizal fungi for different locations. In the future, I would like to propose a new sustainable agriculture that utilizes the functions of various soil ecosystems in each location, and expand this new agriculture overseas.

My research focus is in agriculture and soil science, and, as the Program Manager, I hope to play the role of applying the laboratory results to the field, or in other words, applying fundamental research results to agricultural fields.

In the ACCEL project, I am connecting state-of-the-art genome research with field-based research as well as organizing cultivation tests. Working with many other members, I am growing beans and corns on various kinds of soil from all over Japan that have different environmental factors, and diagnosing the effective use of arbuscular mycorrhizal fungi. Based on the analytical results, I would like to build a system that can offer the most suitable “prescription” for arbuscular mycorrhizal fungi for different locations. In the future, I would like to propose a new sustainable agriculture that utilizes the functions of various soil ecosystems in each location, and expand this new agriculture overseas.

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Masanori Saito
ACCEL Program Manager, Japan Science and Technology Agency

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Presenting the world with “embodied media”

Researching into technology to transmit haptic as well as visual and auditory sensations

In terms of human visual and auditory senses, the spread of transmission technologies such as television has already allowed us to experience sensations through images and sounds, just as if the real thing were in front of us. In addition to visual and auditory sensations, we have newly developed a technology to record, transmit, and reproduce haptic sensations based on the principle of haptic primary colors. We have constructed the fundamental technology of haptic sensation transmission by developing technology such as a display apparatus by which 3D objects projected in the air can be directly touched, and teleexistence technology in which a robot installed in a remote location transmits visual, audio, and tactile information to the user, giving them the sensation of being inside the robot.

Haptic Primary Colors

Human haptic sensation is a perception based on several types of sensor information. We came up with the idea that this haptic sensation could be broken down into three elements: vibration, force, and temperature; and proposed to call it the “principle of haptic primary colors” after the three primary colors of light. Like reproducing color on a display resolved into three primary colors, digitizing each element of haptic sensation enables it to be recorded, transmitted, and reproduced.

Embodied Media Technology Based on Haptic Primary Colors

Research Director

Susumu Tachi
Professor Emeritus, The University of Tokyo

I specialize in robotics and virtual reality (VR), and have made contributions to the creation of each of these disciplines and academic fields of study.

My research came from an idea that the power of science and technology could be used to augment human functions we lose and to further empower our inherent abilities. In 1980, I came up with the idea of telexistence, a technology that allows humans to transcend time and space. Ever since, I have conducted research with the goal of realizing telexistence, which evolved from visual and auditory sensations into tactile sensations and then into full embodiment.

In the ACCEL project, I would like to build groundwork to commercialize embodied media technology as a compilation of my long-lasting research. I will create a new industrial field by developing a compact, integrated tactile sensation transmission module and realizing virtual reality and telexistence as embodied media that incorporate visual and auditory sensations as well as tactile sensations of presence.

Telexistence is a technology that can expand human existence by making users feel as if they exist in other locations without actually being there.

Telexistence will solve problems such as labor shortages and night work, helping provide better ways of life. In addition, as one of the open innovation strategies, I will organize a consortium on embodied media to apply it to society by disseminating research outcomes and bringing together a great range of knowledge and wisdom.

Giving back research results to society will allow the birth of completely new media, which will lead to the realization of a society where you can feel the sensation and warmth of the skin when you shake hands with a person who lives overseas, or that you can take care of your parents living far away from you, and where you can manufacture precision parts effectively by reproducing a craftsman’s delicate touch.

Program Manager

Junji Nomura
ACCEL Program Manager, Japan Science and Technology Agency

My role in the ACCEL project is to commercialize technology that universities have developed in concert with companies. I will provide a path for the use of embodied media in the broadcasting, entertainment, and other fields. I will also pave the way to the industrial world by introducing telexistence. Telework using telexistence will solve problems such as labor shortages and night work, helping provide better ways of life. In addition, as one of the open innovation strategies, I will organize a consortium on embodied media to apply it to society by disseminating research outcomes and bringing together a great range of knowledge and wisdom.

I feel that haptic sensation is the ultimate element of manufacturing. Turning it into technology is a great challenge for the industrial world.

Susumu Tachi

Professor Emeritus, The University of Tokyo

1973: Ph.D. (Engineering), The University of Tokyo; Visiting Scientist at Massachusetts Institute of Technology; Professor, Graduate School of Information Science and Technology, The University of Tokyo; Professor, Graduate School of Medical Design, Keio University. Research into guide dog robots, teleexistence, retroreflective projection technology, autostereoscopic VR, and haptic primary colors.

Junji Nomura

Development of Flexible Nitride Semiconductor Devices with PSD

Making it possible to manufacture low-cost and high-quality LEDs and transistors

The electronic equipment we use in our daily lives is composed of core devices such as integrated circuits on wafers* made from single crystal semiconductor materials. This single crystal wafer, however, is stiff and brittle, which means it can easily crack even with minor impacts. Furthermore, there are many issues with manufacturing high-quality devices, as they require extremely high temperatures of at least 1000 degrees Celsius, expensive materials that can withstand high temperatures, and it is difficult to make large-area devices.

A method that can solve all these problems at once is our unique PSD method, which can provide high-quality crystals at low temperatures. This enables the manufacturing of large-area devices at a much lower cost, and we have already succeeded in the trial production of full color LEDs using low-cost glass substrates.

The ACCEL project attempts to make single crystals by using the PSD method on large-area and low-cost substrates such as glass or flexible substrates that can be easily bent. By combining devices thus made such as LEDs and transistors, the project aims to develop new electronic devices that have unprecedented characteristics such as light weight and flexibility. In the future, it may be possible to have computers or displays that can be rolled up and carried like paper by integrating functions such as computation, memory, display, and sensors on a sheet of paper.

Bringing technological innovation to electronic devices

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PSD method (Pulsed Sputtering Deposition)

PSD (Pulsed Sputtering Deposition) is a type of sputtering deposition method that grows high-quality crystals on a substrate by supplying the source material in pulses. Using this method, we have developed a thin film deposition technology for gallium nitride (GaN), which offers superior qualities as a semiconductor material.

Hiroyuki Fujimaki

Professor, Institute of Industrial Science, The University of Tokyo

Having been involved in research on semiconductors for 30 years, I would like to bring about another "new revolution" that will completely change our lives in the same way the internet has. The PSD method is a way to cover material surfaces with a thin film made of a semiconductor. Previously, it was considered impossible to use this method to generate high-quality crystals. However, by improving the conditions and procedures of crystal growth and transcribing a carbon sheet called graphene on a substrate, we succeeded in creating a high-quality crystal layer on it.

Our current task in the ACCEL project is to generate high-quality crystals on flexible substrates. In addition, I am improving the performance of the LEDs and transistors made by the PSD method. I am working towards making electronics even more free with the help of a program manager who provides a bridge to society.

Program Manager

Akira Usui

ACCEL Program Manager, Japan Science and Technology Agency

To create a new thing, a new method is required. I feel fascination and a sense of accomplishment when undertaking missions to carry out research from practical standpoints and apply the results to society.

In the ACCEL project, it is my task to plan a strategy to realize the PSD devices and disseminate them to society. At this stage, I am contacting companies and attempting to match them with the university. Once low-cost devices can be manufactured stably, the PSD method will become a key technology to incorporate LEDs and transistors into products or systems that semiconductors have never been used in, and these products could spread into the fields of electronics and medicine, or potentially even into our daily lives. Technology that enriches our lives and contributes to society’s prosperity. This is truly innovative technology.
Three-Dimensional Integrated Circuits Technology
Based on Vertical BC-MOSFETs
and Its Advanced Application Exploration

From planar to vertical – Create innovation through transistor evolution

As functions of electronic devices such as smartphones become increasingly sophisticated, short battery lifetimes are becoming a problem. Transistors are the key technology to drastically reducing power consumption. However, improvements in the commercialized planar type transistors are approaching their performance limit. With planar transistors, as the transistors become smaller, current control between electrodes becomes harder, and induces current leakage.

Hence, we have developed a totally new vertical transistor, a Vertical Body-Channel MOSFET, achieving a 1/100 to 1/1000 reduction in current leakage compared to standard planar transistors and a reduction in chip size at the same time. In addition, we succeeded in operating a 1-MBit memory based on vertical transistors for the first time in the world.

Accelerate the development of both integrated circuits and a range of electronic devices through the use of vertical transistors

In the ACCEL project, we are developing a high-speed, large-capacity, and low-power-consumption working memory* by optimal utilization of vertical transistors. Fundamental common technologies will be strategically built to allow applications that can cover various integrated circuits.

And, by promoting the development and construction of the technology, we will create a new technological platform for semiconductor integrated circuits and lead the way for innovative power-saving integrated circuits. This will create new electronics systems that, for example, will improve smartphone performance 100 times over conventional ones and eliminate the need of charging for up to as long as a month or more, contributing to an information-oriented, energy-saving, and ubiquitous society.

Diameter = 40 nm
Generation Over the technology gap

* A memory system that temporarily stores all system data from smartphones to supercomputers.

Innovative Brain

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Innovative Brain
The Nanospace Science of PCP
for Molecular Control

Efficient separation and reuse of a target gas substance

Various gases are spread widely throughout nature. Porous materials such as activated carbons and zeolites have been utilized for their separation. However, it is difficult to isolate a single target gas from a mixture without a large expenditure of energy. To solve this problem, we have successfully synthesized Porous Coordination Polymer (PCP), a new material that can selectively and efficiently adsorb and separate specific gas substances from a gas mixture.

PCP is a crystalline compound (a metal complex) having a network structure in which metal ions and organic molecules are alternately bonded together, and containing countless uniform pores on the molecular level. It can achieve various kinds of gas separation and other functions by changing the combination of the two component substances. So far, we have successfully developed PCPs that can adsorb and separate specific gases such as carbon monoxide (CO) and oxygen.

Investigating technologies to separate gases useful for industry highly efficiently and easily

In the ACCEL project, we are conducting R&D to achieve highly efficient gas separation technology by taking advantage of the characteristics of PCPs. First, we will work on efficient gas separation, using CO as the target gas, which is high in demand for industrial use. Then, we will apply the findings obtained here to the separation of oxygen/argon, hydrogen and other gases. PCP is a revolutionary material with the potential to bring about a breakthrough in the chemical industry, energy conservation and other areas such as health care and environmental problems. Its use will lead to the development of innovative technologies. It also has promise as a material able to store hydrogen, methane and other gases.

Gas adsorption mechanism of a Porous Coordination Polymer

A PCP has a flexible structure, the framework of which expands and shrinks, responding to external stimuli. Porous structures are produced in the framework when it expands. When a specific gas, such as CO, is bonded to a metal ion, the bonding serves as a trigger to open a gate for more CO inclusion. Nitrogen gas, which has a similar structure to CO, cannot work as a “key,” therefore separation with high purity is achieved.

Profile

Susumu Kitagawa
Director of Institute for Integrated Cell-Material Sciences (iCeMS), and Distinguished Professor of Institute for Advanced Study, Kyoto University

My research focuses on metal complexes, which are synthesized from metal ions and organic molecules. More than twenty years ago, I came up with the idea that nanospace surrounded by metal complex molecules is another functional entity. I then focused on porous structures of metal-ligand coordination frameworks, which are currently called PCP or MOF. In particular, I thought that these pores would be useful to accommodate and confine gas molecules. In the early stage of this research, I was faced with its weakness of being structurally unstable and easy to break but finally succeeded in synthesizing robust PCPs having stable structures.

In the ACCEL project, we have developed PCPs that exhibit selective carbon monoxide adsorption ability over nitrogen at ambient temperatures. Having a program manager (PM) who conducts the process for practical application, I can focus on the research.

Takaiku Yamamoto
ACCEL Program Manager, Japan Science and Technology Agency

To make research and development a success, it is very important to form a technology group with skills in different fields. In this project, I am lucky to have highly skilled team members and am proud to have created a good team.

One of the outstanding abilities of PCPs is their ability to adsorb CO. A large amount of CO is produced along with CO2 and N2 in chemical industry processes and the ironmaking process. Generally, CO, which is highly toxic, is burned and used as a heat source. When it is burned, a large amount of CO2 is produced, which is a global-warming gas. There is therefore a strong need for a low-cost separation technology.

In the ACCEL project, we perform small-scale evaluation tests to evaluate the durability and robustness of PCPs and collect the necessary data to perform tests on a larger scale. We are searching for an applicable business model, while keeping a close eye on our competitors.
"Photonic Crystal Laser" - Towards Realization of High Power and High Brightness Operation

Molding light with photonic crystals for high-power lasers

Lasers are used in manufacturing in areas such as optical recording for DVDs and metal processing. While compact semiconductor lasers are low in cost, high in energy efficiency, and easy to control and handle, their maximum output power, beyond which their beam quality is seriously degraded, is extremely small compared to the gas lasers that are common in industry. Consequently, they have not been used in manufacturing with heavy demands, such as metal or material processing that requires high power.

We have invented an artificial optical nano-structure called a photonic crystal, and are trying to use it to realize a photonic crystal laser that provides high power and high functionality while still enjoying the advantages of semiconductor lasers. Our previous research has demonstrated the possibility of achieving a high powered laser by making the light on the entire emitting surface be in phase.

Combining high-power lasers to achieve even more power

In the ACCEL project, we aim to increase the output power of the photonic crystal laser, which currently is just one watt per element, to up to ten watts per element. We will also develop a high-power module that produces 100 watts by combining modules of 10-watt lasers. Recently, we have discovered that the element created a high power laser beam of around one watt.

Using these methods, we aim to come up with a compact, high-performance, and high-output laser processing technology, one that has been difficult to achieve using existing semiconductor laser technology.

In a semiconductor laser, enlarging the light emission area increases power, but drastically impairs the beam quality, distorting its wavelength, phase, and travel direction. We found out that light is kept in phase over a very broad area using the unique resonance function of photonic crystals called “band-edge resonance.” Installing this in the proper position in the laser element created a high power laser beam of around one watt.

In the ACCEL project, we aim to increase the power, with 10 watts as our target, by solving and verifying the problems we face one by one. Specifically, we will research designs with refined photonic crystal structures, as well as the nanotechnologies required to implement these designs. Through this research, we would like to increase the competitive strength of Japanese laser technology internationally. In addition, we will train researchers through the innovation of new technology.

If this laser from Japan achieves 100 or 1000 watts of output power as a single device in the future, I expect that it will revolutionize laser technology.

The photonic crystal laser is a prime example of Japan's original innovating technology. I shall communicate its original/innovating technology. I shall communicate its practical achievements to ensure it becomes a major technology worldwide.

This photonic crystal laser, a venture into a new field, will brighten the future of Japan and semiconductor lasers.

Susumu Noda
Professor, Graduate School of Engineering, Kyoto University

In the ACCEL project, I will collaborate with three companies to promote R&D, discover potential needs through market research and hearings with users, and develop this technology so that it can be used for processing, as well as for medical and measurement uses. In addition, with a help of a think tank, I will look for ways in which less than 10 watts of power can deliver sufficient performance, and promote its commercialization. The real power of a technology is only truly demonstrated when it replaces the existing universally used technology. The photonic crystal laser has ample potential for this.

Susumu Noda
Professor, Graduate School of Engineering, Kyoto University

Program Manager
Shigenori Yagi
ACCEL Program Manager, Japan Science and Technology Agency

I have noted this research as one of the frontiers of physics from the time when I was developing a CO₂ laser at a company, and have been impressed with their progress and results. As the Program Manager, I would like to verify and present the technical feasibility of the photonic crystal laser and promote application-oriented strategic research management.

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Shigenori Yagi
ACCEL Program Manager, Japan Science and Technology Agency

PROFILE

Susumu Noda
1984: M.S. (Engineering), Kyoto University. Joined Mitsubishi Electric Corporation; R&D and commercialization for discharge application devices and laser processing machines. Ph.D. (Engineering)

Profile

1972: M.S. (Engineering), The University of Tokyo. Joined Mitsubishi Electric Corporation; R&D and commercialization for discharge application devices and laser processing machines. Ph.D. (Engineering)
Innovative Molecular Structure Analysis Based on Self-Assembly Technology

A once-in-a-century revolution — resolving the bottleneck of X-ray structural analysis

The creation of new materials has made our lives more convenient. Identifying a new material requires an analysis of its molecular structure. X-ray diffraction technique* is a reliable analytical method for determining molecular structure, but is required crystallization of the sample, which takes a large amount of both the sample and time.

Hence we developed a crystalline sponge method that does not need sample crystallization, solving a long-standing problem. The crystalline sponge method allows a chemical compound to be structurally analyzed even if it is a liquid at room temperature, as well as allowing analysis with a sample of around five micrograms, or roughly a thousandth of the previous amount. To date, we have developed the epoch-making LC-SCD method, used to analyze the molecular structure of a trace of some constituent material extracted from an animal or a plant, and succeeded in identifying the structure of more than a hundred different chemicals.

* A method of analyzing structures where molecules are aligned in an orderly fashion (periodic sequence) by using the characteristics of X-ray transmission that bends around the molecules. Even gigantic molecules can be observed and their 3D structure visually imaged.

Research to analyze more diverse materials is in progress

In the ACCEL project, we seek a way to commercialize the crystalline sponge method based on our previous research results. We are developing several types of crystalline sponge, which we estimate can handle 20 to 30 % of all organic molecules. From now on, we would like to expand the applicable range of molecules and also develop crystalline sponges focused on capturing specific rare molecules.

Widespread use of our crystalline sponge will contribute to fostering innovation in many fields: from drug discovery, where the period of new drug development can be shortened, to chemicals and foods. With help of those engaged in commercialization, we shall contribute to society.

Research Director

Makoto Fujita

Distinguished Professor, The University of Tokyo, and Distinguished Professor, Institute for Molecular Science, National Institutes of Natural Sciences

I majored in organic synthesis as a young man, and then gained experience on briefly working on inorganic materials, allowing me to acquire a cross-sector, comprehensive way of thinking which brought me to my current research. What triggered me to study X-ray structural analysis was the discovery of self-assembly, the spontaneous construction of unprecedented structures by mixing organic molecules and metallic ions. My inspiration that these structures could perhaps be used to analyze molecular structures turned out to be the solution for a long-standing problem.

In the ACCEL project, the researchers are trying to find what sorts of application frameworks should be offered to society, with Dr. Ezaki, the Program Manager, teaching them about commercialization, not a field they have much expertise in. Our short-term task is to develop various types of crystalline sponges and increase the number of analyzable molecules. We are currently preparing types for hydrophilic and acidic molecules as well as for the current type for analysis of molecules which are reluctant to mix with water.

The fundamental research is a challenging task. After a half-century since I started, my research is about to be ready for applications, and so I am eager to make this happen.

Program Manager

Atsuo Ezaki

ACCEL Program Manager, Japan Science and Technology Agency

I have experience in being the person responsible for product development and commercialization, and have always wished to commercialize superior research in the academic sector for use in industry; making my contribution to society. The fundamental research has high purity as science, but has a long way to go to achieve commercialization. That requires hard effort, but solving daily problems is rewarding as well as fascinating.

I have talked with many from industry who are interested in this research, and also asked them what sort of social contribution their companies each wish to make. Through this program, I will polish this technology to make it into "technology that can contribute to social value," within the overall ecosystem composed of industry, academia, and other related organizations. Working in concert with the stakeholders, I would like to transform this innovative fundamental research outcome into socially-applicable products.

The crystalline sponge that solved the “100-year-problem” of X-ray structural analysis will bring about innovative research styles in the organic-synthesis-related industry.

Crystalline sponge method

The crystalline sponge is a hollow chemical with a structure similar to a basket made up of numerous micropores between 0.5 and 1 nanometers in diameter. Soaking a liquid sample into the crystalline sponge permits the molecules to be introduced in the basket and be automatically aligned in an orderly fashion, stabilizing them and allowing X-ray analysis without crystallizing samples.

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Profile

Makoto Fujita

1982: M.S. (Engineering), Chiba University. Joined Sagami Chemical Research Institute; 2002: Professor, School of Engineering, The University of Tokyo after successively Chiba University, the Institute for Molecular Science and Nagoya University. 2018: appointed concurrently to Distinguished Professor, Institute for Molecular Science, National Institutes of Natural Sciences. Field of expertise: Self-assembly of molecules. Ph.D. (Engineering)

Profile

Atsuo Ezaki

ACCEL Program Manager, Japan Science and Technology Agency

1989: M.S. (Engineering), Tokyo Metropolitan University. Joined Konishiroku Photo Industry Ltd. (currently Konica Minolta, Inc.). Engaged in product R&D, business start-up, and technical strategy promotion through the development of photographic material and launching businesses for inkjet printer systems and Organic LEDs.
Materials Science and Application of Electrides

Creating a stable material with anionic electrons for industry use

“Electride” is the general term for a chemical compound in which electrons serve as anions. Electrides are a new concept, and as such, are expected to show intriguing physical properties. In previous studies, electrides have been chemically and thermally unstable and even the best-quality electrides are only stable at -40 degrees Celsius or less, and in a no-air environment, they have been hard to handle and so very little was known about their physical properties.

We have succeeded in synthesizing a new material, “C12A7 Electride,” which is composed of aluminum oxide and calcium oxide (used in cement) by replacing its oxygen ions with electrons. This gives us what we could call “electrically conductive cement,” a material that is stable both in air and at room temperature. We can expect breakthrough applied research for the material such as high-performance catalysts or electronic materials.

Developing electrides as high-performance catalysts and electronic materials

In the ACCEL project, we aim to develop electrides that include not only the C12A7 electrode but also a two-dimensional electrode, for industrial use as catalysts or electronic materials.

In applications as catalysts, we are aiming to synthesize ammonia at lower pressures and lower temperatures than conventional. We aim to commercialize manufacturing ammonia synthesis that uses less energy and is environmentally friendly.

Ammonia is a raw material for nitrogen-based fertilizers and a common chemical intermediate, and has recently attracted attention as a hydrogen carrier for renewable energy. For electronic material use, we are developing materials with superior properties to use for electron injection layers and transport layers that will allow us to achieve a low electric voltage drive for and increase the life of large OLED displays.

The C12A7 electride has a skeletal structure that looks like a cage some 0.5 nanometers in diameter, and was originally an insulator with cages filled with oxygen ions. The C12A7 which replaces the oxygen ions with anionic electrons becomes very electrically conductive and readily releases electrons. Although it readily releases electrons like alkali metals, it has the unique characteristics of being both chemically and thermally stable.

The variety of possibilities the electride provides, such as food production, renewable energy, and large televisions, will encourage technological innovation.

To succeed in research that can be linked to actual applications, it is important to understand the true nature of the material and to create a bird’s-eye view in your mind. A catalyst and a semiconductor may seem to be two completely different subjects, but are similar in terms of the control of electrons in a solid.

Forerunners who put innovative research outcomes into practical use always feel anxious. However, I will make my way towards our great goal with convictions based on my experiences.

Research Director

Hideo Hosono
Professor of Laboratory for Materials and Structures, Institute of Innovative Research, and Director of Materials Research Center for Element Strategy, Tokyo Institute of Technology

My research theme has mainly covered the creation of new materials for transparent oxide semiconductors. “IGZO” is a typical example, used in thin-film transistors to drive high-definition liquid crystal displays and large organic EL television screens. This helped create “Better Life,” but I didn’t want to stop there. I really wanted to create something “Essential for Life”. On the assumption that I would be able to make good use of the unique properties of the C12A7 electrode discussed above, I began researching the synthesis of ammonia, which is necessary for food production, under mild conditions.

In the ACCEL project, we have succeeded in conducting ammonia synthesis at under 400 degrees Celsius, at atmospheric pressures, and in just a short time. This process used to require high temperatures, between 400 and 500 degrees Celsius, and high pressures, between 100 to 300 atmospheres. If this synthesis process is achieved at lower energy levels, ammonia will be able to be manufactured in small batches and in a variety of locations, contributing to solve the food problem.

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Program Manager

Toshiharu Yokoyama
ACCEL Program Manager, Japan Science and Technology Agency

Electride is a new material that has great potential for industry. The issue how its superior functions and properties should be brought out and put into practical use.

In the ACCEL project, we are advancing research integrally, from the fundamental to the application study phases, supporting it as we pave the way to commercialization. For catalyst use, we will study the issues, expecting further developments, after aiming for the construction of a compact ammonia manufacture plant. For electronic material use, we are developing materials with superior properties to use for electron injection layers and transport layers that will allow us to achieve a low electric voltage drive for and increase the life of large OLED displays. In addition, we are working to expand applications, considering a variety of possibilities such as recycling and chemical synthesis using low temperature decomposition of carbon dioxide, which has provided interesting results. Through this research, we would like to train researchers who will be responsible for the next generation.

To succeed in research that can be linked to actual applications, it is important to understand the true nature of the material and to create a bird’s-eye view in your mind. A catalyst and a semiconductor may seem to be two completely different subjects, but are similar in terms of the control of electrons in a solid.

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