NO. 5

ALCA Breakthrough

E N G

ALCA

Change the game with technologies!

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ALCA Outline

The emission of CO_2 actually accounts for the largest percentage among greenhouse gases (GHG) as a cause of global warming issues. Today, the realization of a low carbon society has become a global challenge. In the context of this international trend, the Japanese government has taken an approach to reduce GHG emissions, launching the Advanced Low Carbon Technology Research and Development Program (ALCA) in 2010 as a research program toward developing low carbon technology for the reduction of GHG emissions.

Management

The Program Director (PD) of ALCA oversees its entire operation and each Program Officer (PO) is responsible for the general management of the technology area. We conduct a "stage-gate evaluation" during the research period to decide on whether to continue the research. By the selection and concentration in such a stage-gate evaluation, we intend to accelerate research and development, focusing on social implementation in 2030.

Technology Areas

There are basically two approaches to solve the global warming issues: the "adaptation option" and "mitigation option." The former is to reduce the global warming effect by adjusting the paradigm for nature and society.

In contrast, the latter is to suppress the GHG emissions themselves, and there are considerable expectations for science and technology to contribute in this area. ALCA intends to build a low carbon society, through game-changing technology, although we hope to find scientific and technological options in various R&D areas.

Program Director (PD) Kazuhito Hashimoto President, NIMS

Program Officer (PO)

Kohei Uosaki Fellow, National Institute for Materials Science Technical area: Next Generation Batteries	Yoshiharu Doi Professor Emeritus, Tokyo Institute of Technology Technical area: White Biotechnology	Atsuhiro Osuka Professor, Kyoto University Technical area: Solar Cell and Solar Energy Systems
Hiroyuki Ohsaki Professor, The University of Tokyo Technical area: Superconducting Systems	Akihiko Kondo Professor, Kobe University Technical area: Biotechnology	Takashi Tatsumi President, National Institute of Technology and Evaluation Technical area: Innovative Energy-Saving and Energy-Producing Chemical Processes
Kenji Taniguchi Specially Appointed Professor, Osaka University Technical area: Innovative Energy-Saving and Energy-Producing Systems and Devices	Shigehito Deki Professor Emeritus, Kobe University Technical area: Next-Generation Smart Community	Kohmei Halada Emeritus Researcher, National Institute for Materials Science Technical area: Ultra Heat-Resistant Materials and High Quality Recyclable Steel

SDGs Sustainable Development Goals

ALCA develops technologies to reduce GHG emissions, which will contribute to the following goals related to environment and energy.

See P. 14 for JST's efforts

Chapter 01 Reducing CO_2 Emissions

Chapter 02 Capture and Utilization of CO_2

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CHANGE THE GAME ALCA WITH TECHNOLOGIES

Next-Generation Lithium-Sulfur Battery Enabled by Ionic Liquid Electrolyte

Masayoshi Watanabe,

Professor, Graduate School of Engineering Sciences, Yokohama National University

Ionic liquid

The non-volatility, flame retardancy, and unusual solubility of ionic liquid are used to resolve the issue of active materials dissolving from the sulfur positive electrode

Lithium-sulfur battery

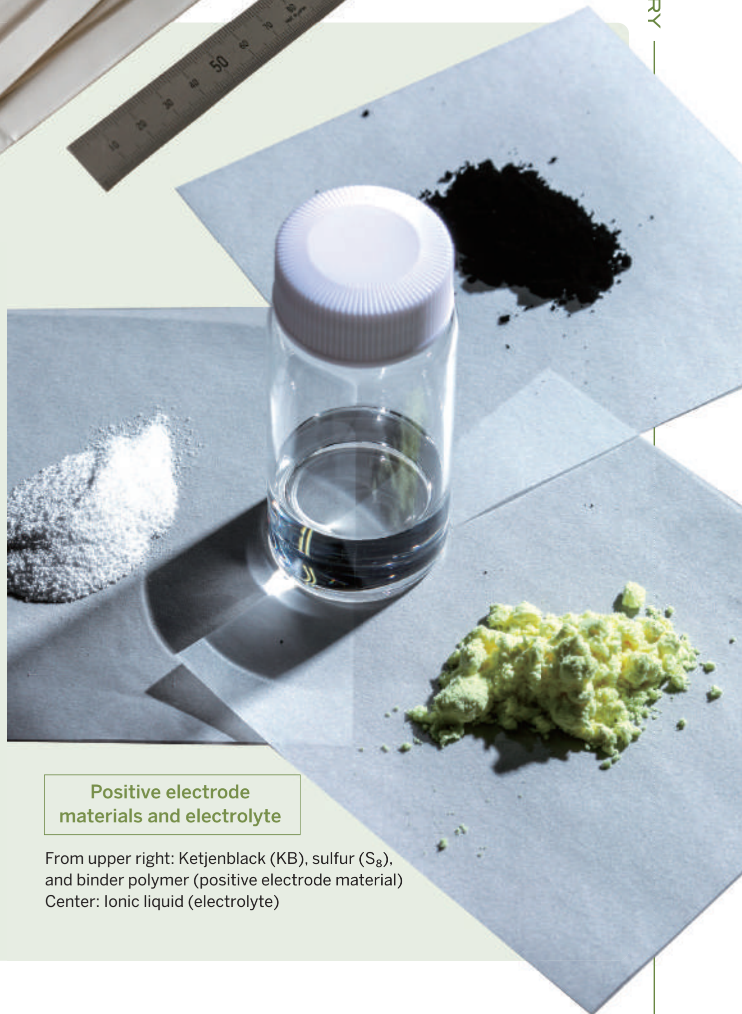
LIBTEC has assembled a prototype of a 10 Ah battery as part of a joint project with ALCA-SPRING and NEDO's SOL-iD-EV

1 Baking a positive electrode material using an electric furnace

2 Lithium polysufides are insoluble (left).

3 Assembly of laminated cells

4 Evaluation of charge and discharge performance



Positive electrode materials and electrolyte

From upper right: Ketjenblack (KB), sulfur (S_8), and binder polymer (positive electrode material)
Center: Ionic liquid (electrolyte)

LITHIUM-SULFUR BATTERY

The development of low-cost and high-performance secondary batteries without resource constraints is a key technology for achieving a low-carbon society. The lithium-sulfur battery is a promising candidate for next-generation secondary batteries that satisfy the requirements above. The ALCA Specially Promoted Research for Innovative Next-Generation Batteries (ALCA-SPRING) is committed to developing this technology. As the ionic liquid electrolyte enables the use of lithium metal, silicon or graphite for the negative electrode, and sulfur or lithium sulfide for the positive electrode, the assembly of a diverse range of lithium-sulfur batteries is made possible. We are committed to developing innovative lithium-sulfur batteries by utilizing the insolubility of ionic liquid electrolyte to positive electrodes, specific ion transport properties and electrode reactions of the ionic liquid electrolyte, and by resolving issues concerning volume change and insulation related to charge and discharge through optimizing the nanostructure of positive and negative electrodes.

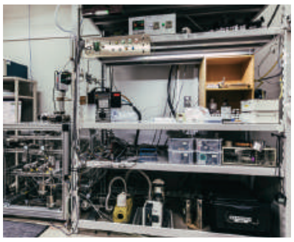
Fuel Cell Driven by a Carbon Catalyst: A Step Toward Achieving a Low-Carbon Society

Jun-ichi Ozaki,
Professor, Graduate School of Science and Technology, Gunma University

CHANGE THE GAME ALCA WITH TECHNOLOGIES

A carbon alloy catalyst

Temperature Programmed Desorption (TPD) device



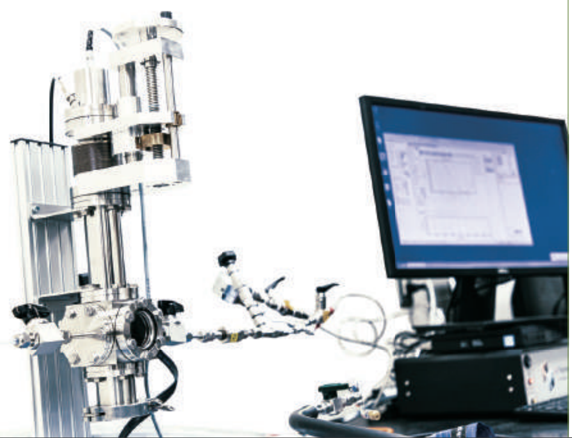
The functional group on the carbon surface is measured

The temperature may be increased up to 2,000°C

In this R&D project, we developed a carbon alloy catalyst for fuel cells that boasts a similar performance to platinum, a high-cost precious metal. A carbon alloy catalyst is a carbon material with a catalytic function added through the control of its structure and composition. By engaging in a study centered around understanding the operating principle of this catalyst, we have devised a policy for designing carbon catalysts. We also confirmed that this policy can be applied effectively to the world's first non-platinum cathode catalyst for fuel cells, commercialized by Nisshinbo Holdings. We are planning to further expand the applications of the carbon alloy catalyst to include high-power density, stationary fuel cells for backup power supply, and then those for home use and automobile use.

Work function evaluation device
A joint study was performed with Nisshinbo Holdings' resident researchers at Gunma University

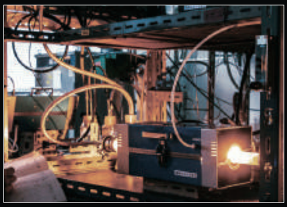
Work function evaluation device

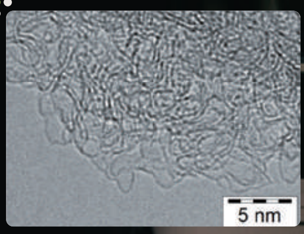


CARBON ALLOY CATALYST

Oxygen reduction performance evaluation device: Evaluation of electrode performance

Electric furnace: Baking catalysts





Transmission electron microscopy image of carbon alloy catalyst

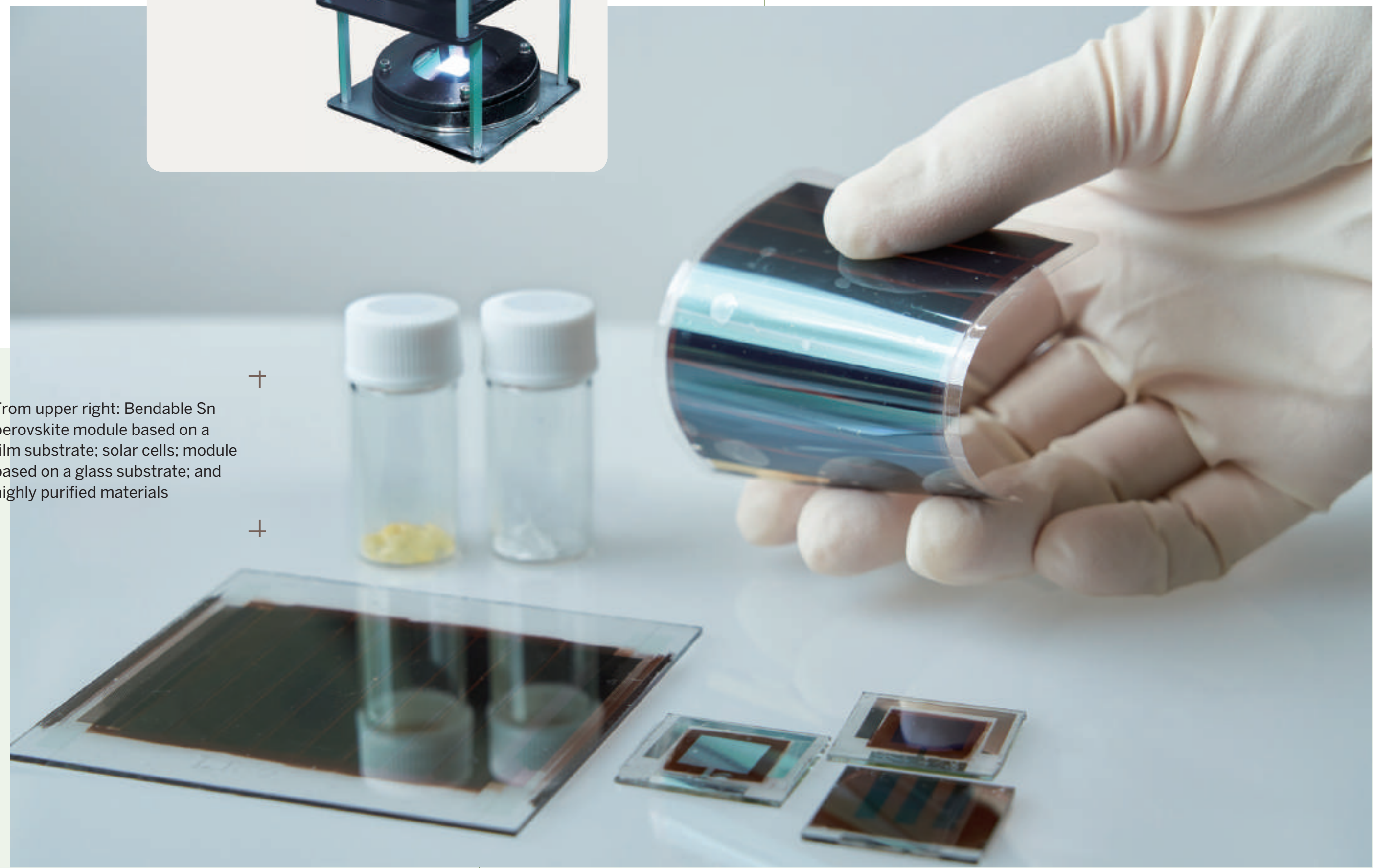
ZOOM

Development of an Eco-Friendly Lead-Free Perovskite Solar Cell as a Power Supply for Anywhere Use

Atsushi Wakamiya,
Professor, Institute for Chemical Research,
Kyoto University

Produce high-quality Pb-free semiconductor films and solar cells by capturing images using a high-speed camera while optimizing our spin coating film formation method

Evaluate the performance by exposing the cell to light

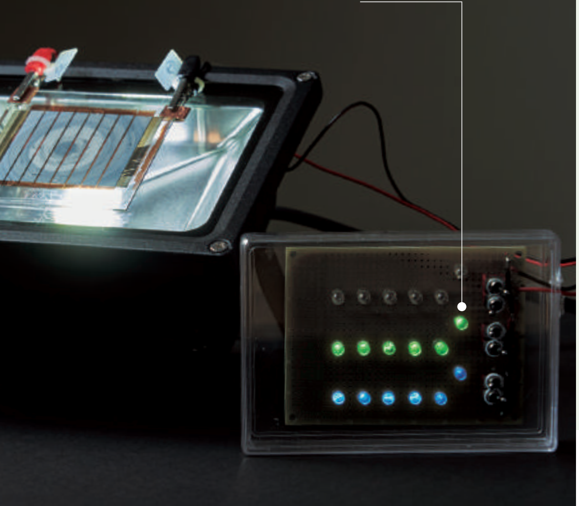


From upper right: Bendable Sn perovskite module based on a film substrate; solar cells; module based on a glass substrate; and highly purified materials

Pb-FREE PEROVSKITE

We have improved the performance of solar cells using lead-free perovskite material, based on our innovative material-purification technology and the development of a technology to produce high-quality semiconductor films. These solar cells display a high power generation efficiency in both outdoor and indoor environments, and can be used as a power supply for anywhere use because the utilization of a film substrate allows for a lightweight, thin, and bendable property. These cells contribute to achieving a low-carbon society with a stable energy supply as they can be used as a power supply for IoT sensors, wearable devices, vehicles, and emergency tents in case of a disaster.

The developed Sn perovskite module using solar cells to illuminate LEDs



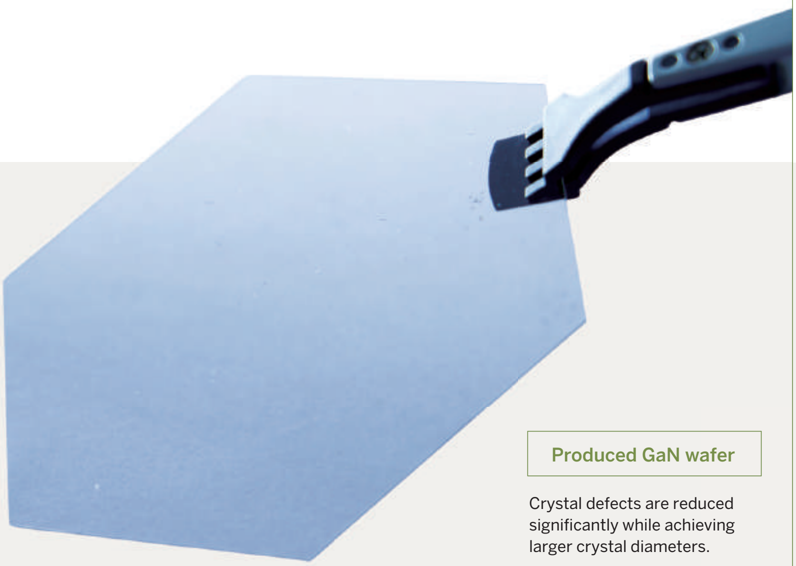
Aim to expand ALCA's findings and introduce them to society via a start-up we founded

Development of GaN crystal that does not show leak current during power conversion

Yusuke Mori,
Professor, Graduate School of Engineering, Osaka University

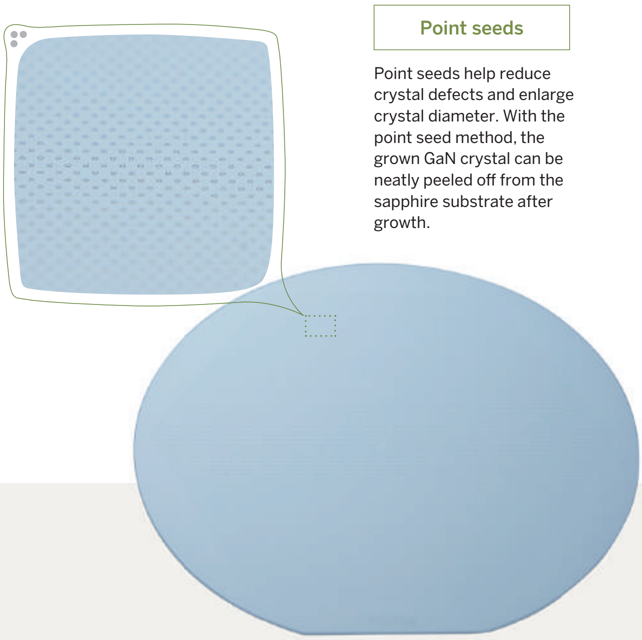
GaN is expected to be used as a power device for power conversion, but its crystal quality and size had been insufficient, making it impossible to be put into practical use. In this research, we succeeded in improving the quality of the GaN crystal by growing it with the Na flux method and point seeds. The result showed the ideal characteristics that current does not leak during power conversion. We could also achieve the 6-inch size required for practical use. Various power devices using this GaN crystal can be realized. Examples of its applications include those related to driving motors such as electric vehicles, power infrastructure such as power conditioners and transformers, and microwave generation such as microwave heating devices and communication equipment. High-quality GaN crystals contribute greatly to energy saving and increased efficiency of these devices.

Crystal growing device



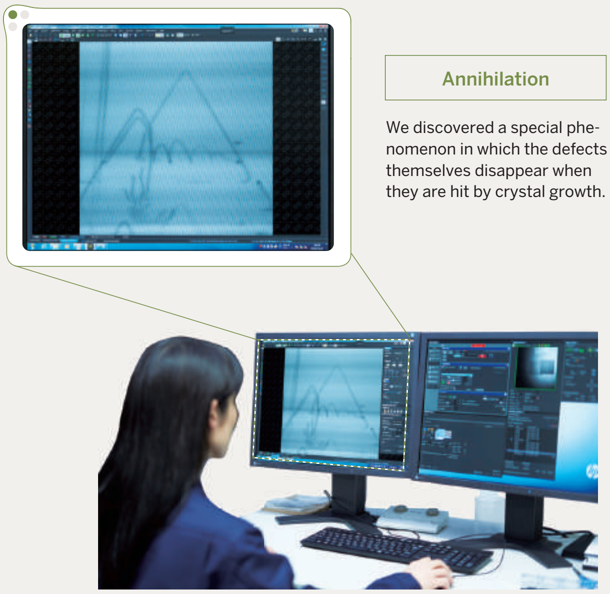
Produced GaN wafer

Crystal defects are reduced significantly while achieving larger crystal diameters.



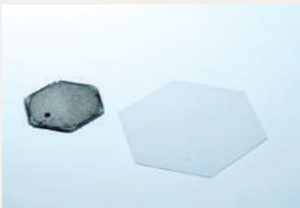
Point seeds

Point seeds help reduce crystal defects and enlarge crystal diameter. With the point seed method, the grown GaN crystal can be neatly peeled off from the sapphire substrate after growth.



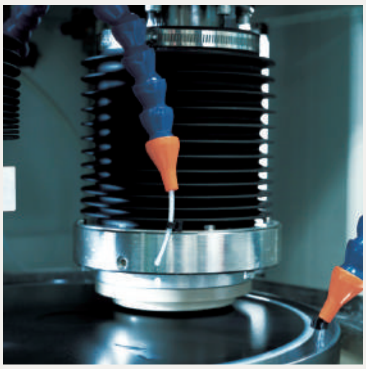
Annihilation

We discovered a special phenomenon in which the defects themselves disappear when they are hit by crystal growth.



The transparency of wafers has improved dramatically (right) compared to the start of the ALCA project (left)

Crystal surface polishing device



Polishing agent is dripped onto the surface

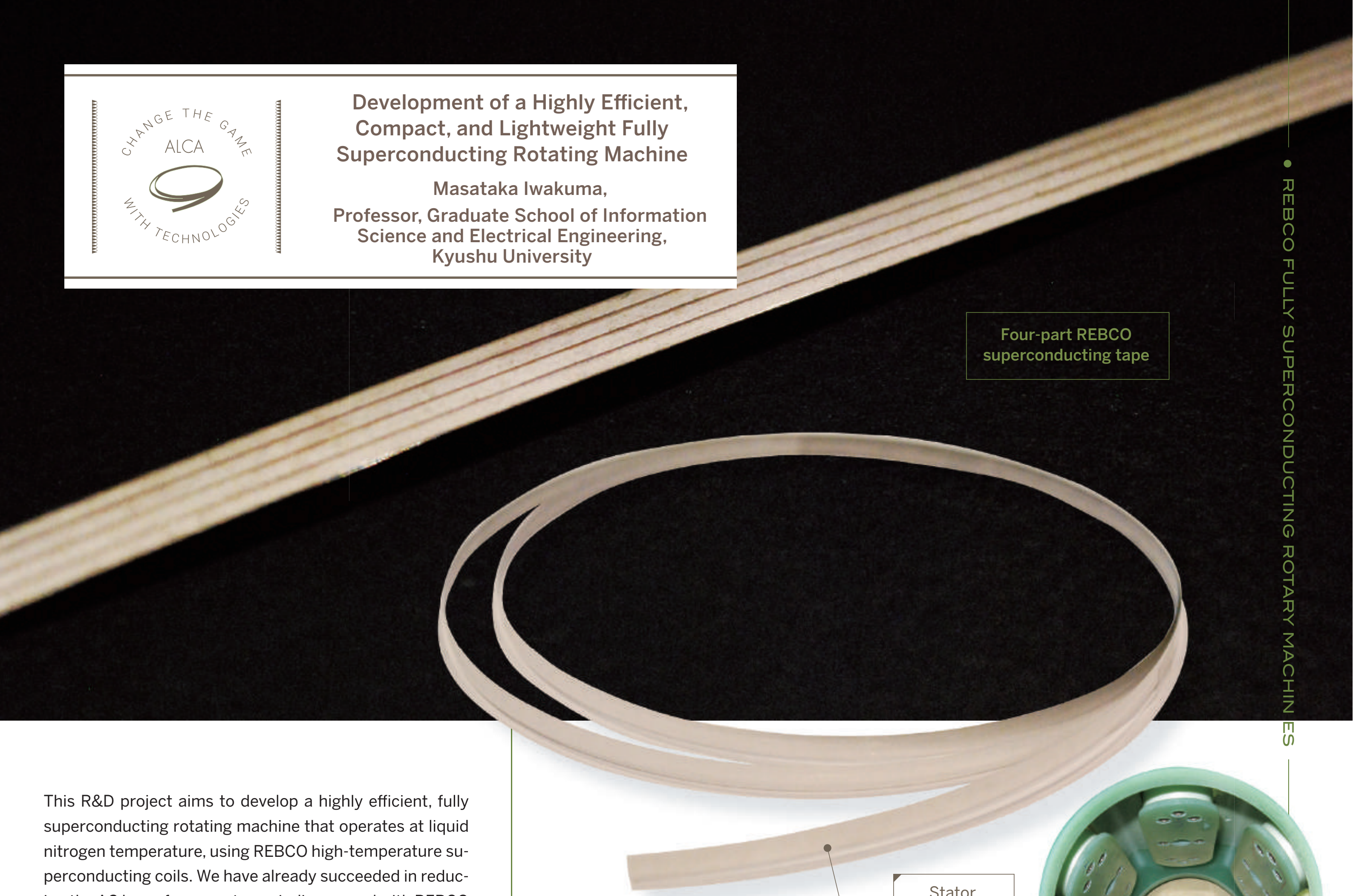
Panasonic Corporation

Osaka University

Joint study with Panasonic's resident researchers at the university

Development of a Highly Efficient, Compact, and Lightweight Fully Superconducting Rotating Machine

Masataka Iwakuma,
Professor, Graduate School of Information Science and Electrical Engineering, Kyushu University



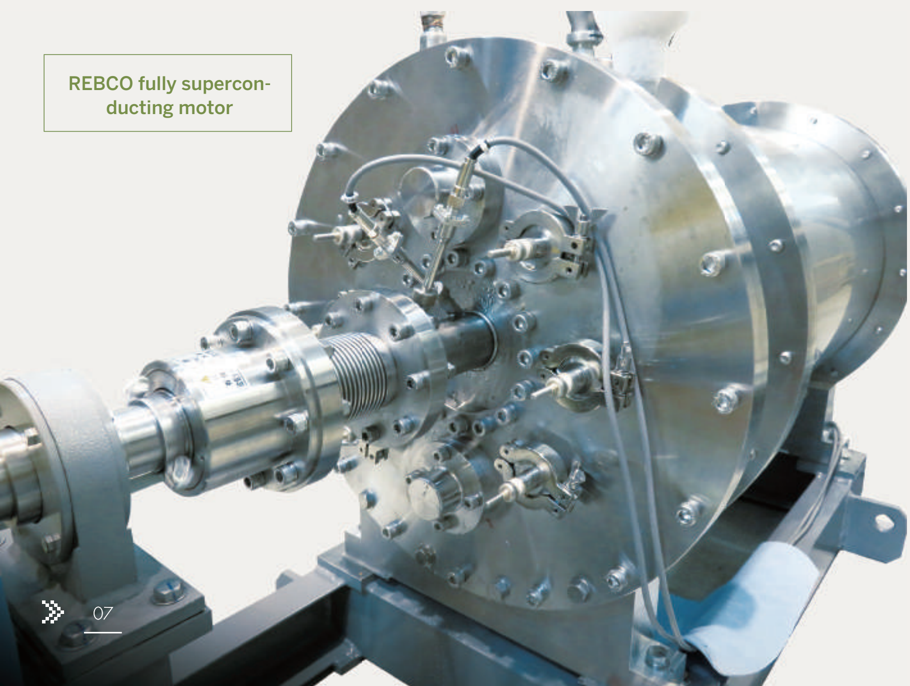
Four-part REBCO superconducting tape

This R&D project aims to develop a highly efficient, fully superconducting rotating machine that operates at liquid nitrogen temperature, using REBCO high-temperature superconducting coils. We have already succeeded in reducing the AC loss of an armature winding wound with REBCO superconducting tapes, the prototyping of a casing for housing the armature winding (which has a vacuum structure for thermal insulation), and its commissioning as a synchronous motor and generator. This fully superconductingsynchronous machine has proved itself capable of achieving greater efficiency due to its superconducting nature, and a smaller and lighter rotating machine as a result of not using ferrous metals. Fully superconducting rotating machines can be used not only for general industrial use, but also for electric propulsion of aircraft that require lightweight solutions.

Stator

REBCO coil

Rotor



REBCO fully superconducting motor

Cooling with liquid helium's cold heat

Temperature controller

REBCO fully superconducting motor (full view)

CHANGE THE GAME ALCA WITH TECHNOLOGIES

Development of a Device That Removes Iron Oxide Scale from Water Feeding Pipes

Shigehiro Nishijima

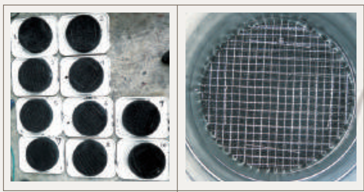
Professor, Department of Applied Nuclear Technology, Faculty of Engineering, Fukui University of Technologyy

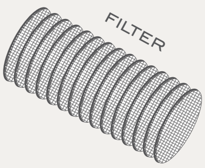
Experimenting device at the university

Scaleup (demo conducted at an actual thermal power plant)

Sampling before and after use of the filter to ascertain the effectiveness of scale removal

Water fed through the power plant's filter

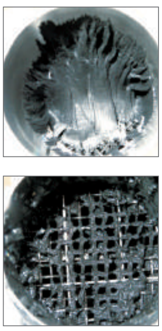




Main unit of superconducting magnet

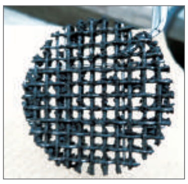
A filter is installed at the center of the magnet

The developed device removes scale (limescale) from water feeding pipes by using a strong magnetic field generated by a superconducting magnet. The device can deliver full performance even when the amount of water supply or scale is massive, or in high-temperature and high-pressure environments. The performance of the device was verified by installing it on a heater boiler. We also confirmed that the device can be used in the chemical cleansing of water feeding pipes at thermal power plants. Thermal power plants carry out chemical cleansing on a regular basis to prevent a reduction in performance caused by scale accumulated in water feeding pipes. By installing this device on the water feeding pipes, thermal power plants can prevent the reduction in performance as well as power generation efficiency, which will suppress the increase of CO_2 emissions.



Above: Filter inlet
Below: Filter within the pipe

Scale is captured



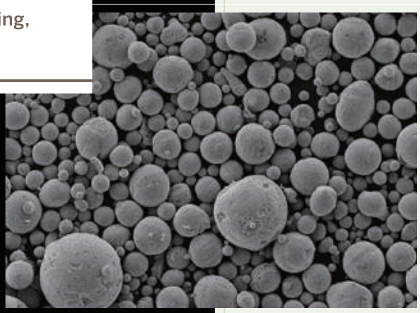
Filter with captured scale

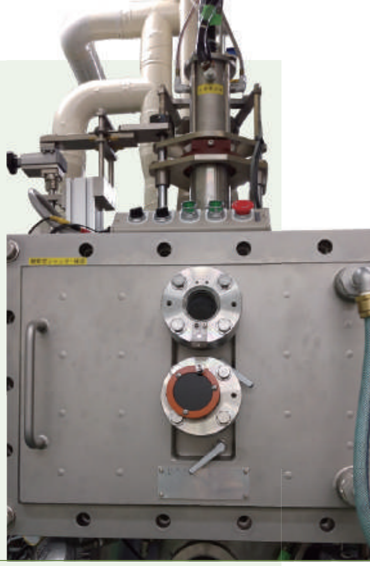
Discharged water

CHANGE THE GAME WITH TECHNOLOGIES ALCA

Development of a New Super-Heat-Resistant Material to Enable Gas Turbine Operation at Very High Temperatures

Haruyuki Inui,
Professor, Graduate School of Engineering, Kyoto University

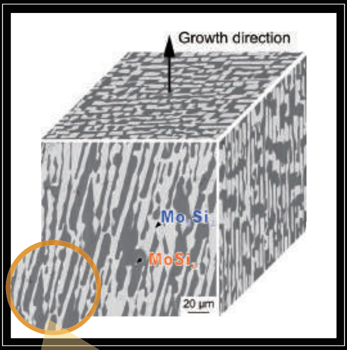




Atomization device

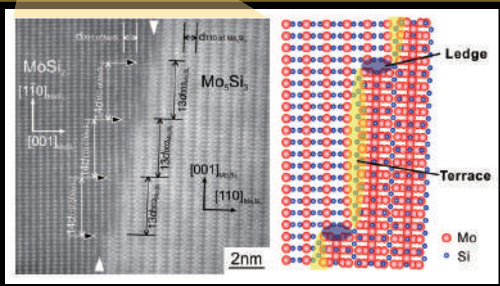
Labyrinth alloy powder

Labyrinth alloy powder (right) for use with additive manufacturing (3D printing) is produced by utilizing the newly developed atomization device for super high melting point materials (far right) to heat, dissolve, and atomize the $MoSi_2$ alloy ingot.



A monocrystal structure that consists of two phases (labyrinth structure) is formed through unidirectional solidification. This improves the functionality of the interface (greater thermal stability, toughness, and creep strength).

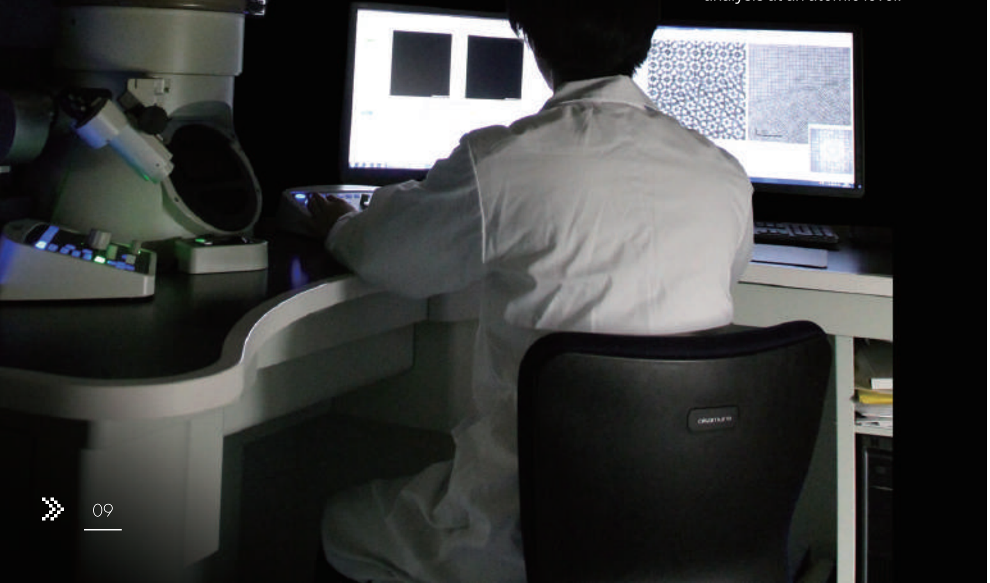
Enlarged view of the boundary between white and gray sections



STEM image

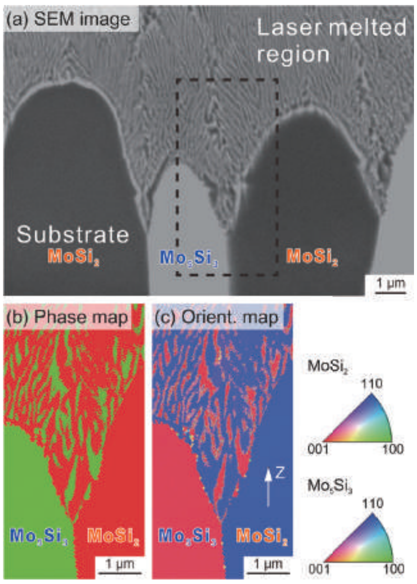
We discovered that the formation of the ledge-terrace structure partially mitigates interface misfits, and that the interface inclined from the growth direction becomes stable macroscopically.
We also improved the mechanical property (fracture toughness) by designing the interface structure based on the results of analysis at an atomic level.

We also improved the mechanical property (fracture toughness) by designing the interface structure based on the results of analysis at an atomic level.

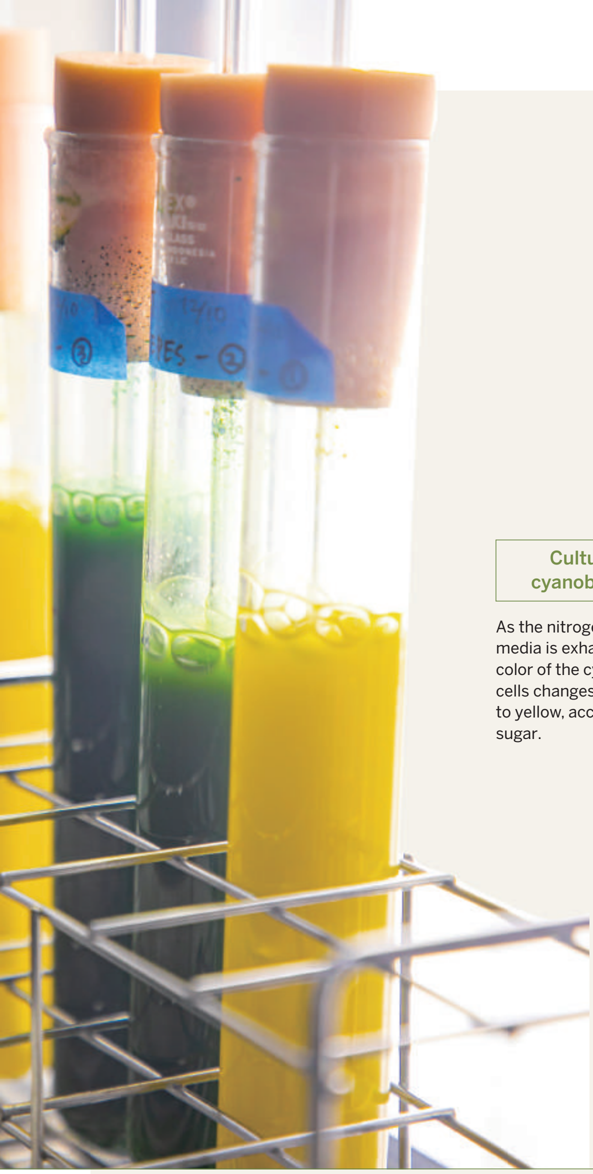


● $MoSi_2$-BASED MULTI-PHASE SINGLE-CRYSTAL ALLOYS

Based on an entirely new concept of a brittle/brittle multi-phase material that combines transition metal silicides with high melting point and high-temperature strength properties, we controlled the atomic structure of the interface between different phases as well as element partition and interface element segregation in an effort to improve the structure's thermal stability, strength, and toughness. As a result, we developed a $MoSi_2$-based super high-temperature heat-resistant material with a much greater mechanical property compared to conventional materials. In addition, we have focused on the additive manufacturing (3D printing) method as a means to produce the components for this alloy to be developed. To develop this method, we have created a new powder production process and additive manufacturing process. Our study is expected to help reduce the emissions of greenhouse gases significantly through the use of a newly developed alloy with a much higher heat-resistant temperature to increase power generation efficiency by enabling gas turbines at thermal power plants to operate at very high combustion temperatures.



We conducted a laser melting and coagulation test of the surface of the labyrinth monocrystal alloy intended for additive manufacturing. We confirmed the formation of a labyrinth structure that is much finer than the structure of a monocrystal substrate, as well as the retention of the monocrystal substrate's crystal orientation. The results indicate that we are able to produce monocrystal structures using seed crystals, and further improve the mechanical properties.



Production of a Bioplastic Material Using Cyanobacterial Fermentation

Takashi Osanai,
Associate Professor, Graduate School of Engineering, Kyoto University

METABOLIC ENGINEERING OF CYANOBACTERIA

Culture of cyanobacteria

As the nitrogen in the media is exhausted, the color of the cyanobacterial cells changes from green to yellow, accumulating sugar.

We also started the production of useful metabolites using Euglena.

As a by-product, we extracted phycocyanin, a blue pigment that plants and moss cannot produce (it can be used in foods).

Analysis of products generated from the fermentation of cyanobacteria (succinic acids and lactic acids)

In this study, we developed new methods to produce succinic acids and lactic acids using cyanobacteria (blue-green algae), which perform photosynthesis. Succinic acids and lactic acids are the compounds of bioplastics. Our group discovered that the cyanobacteria release succinic acids and lactic acids outside the cells during fermentation. We also discovered various genes that increase the production of succinic acids and lactic acids such as metabolic enzymes, transcriptional regulators, and clock proteins. These new methods of bioplastic production are expected to produce plastic materials that are not derived from petroleum, while creating a new chemical industry that uses carbon dioxide as carbon sources.

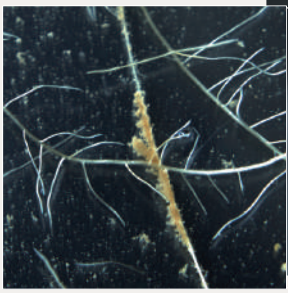
Reconstructing Nitrifying Microbial Consortium in Artificial Soil

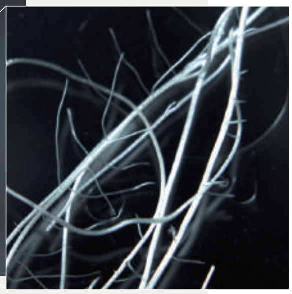
Akinori Ando,
Assistant Professor, Graduate School of Agriculture, Kyoto University

Cultivation with hydroponics

Plants are grown with organic nitrogen mineralized (nitrified) using the microbial consortium we developed. Formation of a biofilm can be observed around the roots of a plant cultivated using an organic fertilizer (left).

Cultivation with organic fertilizer





Cultivation with mineral fertilizer

Organic matter is collaboratively broken down by soil microbial consortia and taken up by plants for growth. Up to the present, it has been difficult to recreate this organic-to-mineral nutrient conversion in a non-soil environment. In an attempt to achieve this, we first established a technology to produce mineral nutrients from soil microorganisms in a non-soil environment. Next, we constructed an artificial nitrifying microbial consortium that can dissolve organic matter using only three bacterial species. We have also succeeded in creating artificial soil and utilizing it to cultivate crops. In the future, we are planning to incorporate microorganisms involved in the promotion of plant growth and the suppression of diseases into the design of nitrifying microbial consortia. As part of our efforts to achieve a low-carbon society, we will apply this design to a changeover from chemical fertilizers to organic fertilizers, the modification of non-arable land, and large-scale soil creation.

When rice husk charcoalis used, plants (komatsuna) grown using artificial soil containing only five types of designed microbial agents (right) displayed a growth similar to that of the plants cultivated using normal soil containing various microbes (left).

Aquaponics technology was developed to nitrify the feed and feces of farmed fish and remove nitrate ions from plant cultivation via a nitrifying microbial consortium.

Strawberries are cultivated using an artificial soil (rice husk charcoal) containing the designed microbial agents.

Plants (komatsuna) are grown using an artificial soil with immobilized microbial consortium.

Designed microbial agent

Development of a Microbial Strain Producing Polymer Materials from Lignin, a Major Component of Wood

Tomonori Sonoki,

Associate Professor, Faculty of Agriculture and Life Science, Hirosaki University

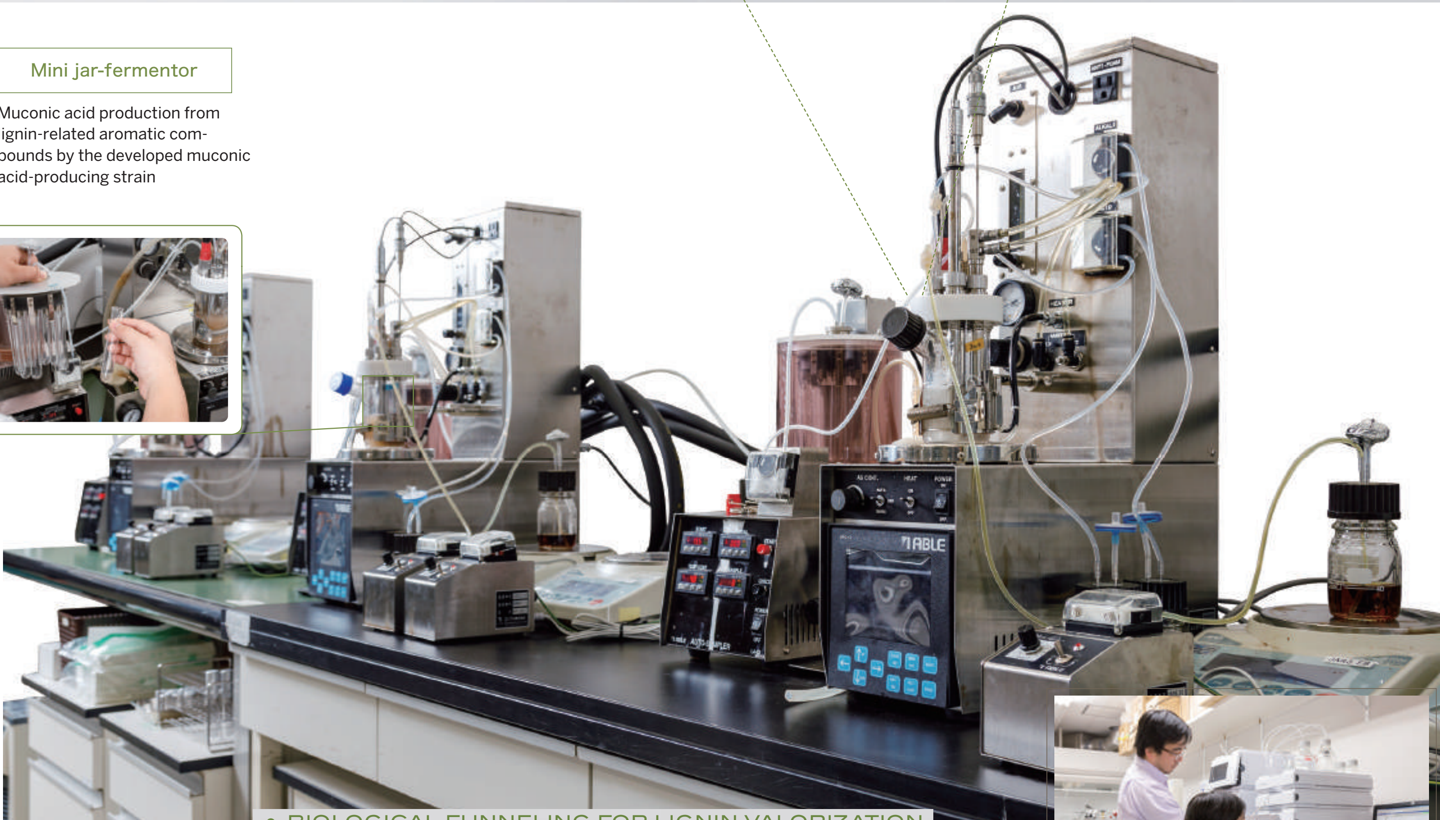
A microbial strain used in this study

Lignin extracts via chemical decomposition (containing heterogeneous aromatic compounds)

Wood chips

Mini jar-fermentor

Muconic acid production from lignin-related aromatic compounds by the developed muconic acid-producing strain

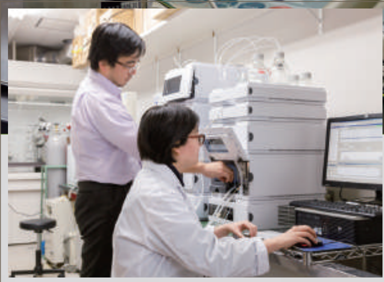


● BIOLOGICAL FUNNELING FOR LIGNIN VALORIZATION

In this study, we developed a microbial strain that efficiently produces muconic acid, a platform chemical in the use of various polymer syntheses such as nylon and polyester that are currently made from petroleum, from lignin, a major component of inedible biomass such as wood. The heterogeneous structure of lignin has been a hurdle to convert it into useful materials. The concept of biological funneling of various structures into a particular compound proved in this study can be applied to the production of other useful aliphatic and aromatic compounds as well. And, from our results, the production of biomass-based and highly functional polymers from lignin as an alternative to petroleum-based ones is expected (this work was jointly conducted with a research group led by Prof. Eiji Masai, Nagaoka University of Technology).

Analysis

Analyzing the metabolites produced in the culture



Muconic acid purified from a fermentation broth

Advanced Low Carbon Technology Research and Development Program (ALCA) collaborates with the "Realization of a low carbon society, a global issue" area of JST-Mirai Research & Development Program.

The "Realization of a low carbon society, a global issue" area of the JST-Mirai Research & Development Program at ALCA will promote innovative research and development that contributes to the realization of a future low carbon society based on top-down management, the small start system, and the stage gate evaluation system, as a way to take advantage of underlying basic research rooted in science. In particular, in the area bottleneck solution, which is a necessary technical theme for the realization of a low carbon society, the technologies that are necessary for a substantial reduction of greenhouse gases by 2050 will be developed around the technology areas specified in "Energy and Environment Innovation Strategies" of the government.
ALCA will also collaborate with programs of other offices and ministries to transfer results for implementation in society. These approaches will create "Game Changing Technologies" to radically decrease carbon dioxide, which is hoped to be achieved by 2050. Through the implementation of these technologies in society, we aim to contribute to the realization of a low carbon society.

See the web page on the right for the outline of study domain and approved topics: https://www.jst.go.jp/mirai/jp/program/lowcarbon/index.html

Special thanks to

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Jun-ichi Ozaki

Kyoto University
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Tomoya Nakamura
Yasuko Iwasaki
Yuko Matsushige

Osaka University
Yusuke Mori
Masayuki Imanishi

Kyushu University
Masataka Iwakuma

Fukui University of Technology
Shigehiro Nishijima

Kyoto University
Haruyuki Inui
Kyosuke Kishida

Meiji University
Takashi Osanai

Kyoto University
Akinori Ando
National Agriculture and Food Research Organization
Makoto Shinohara

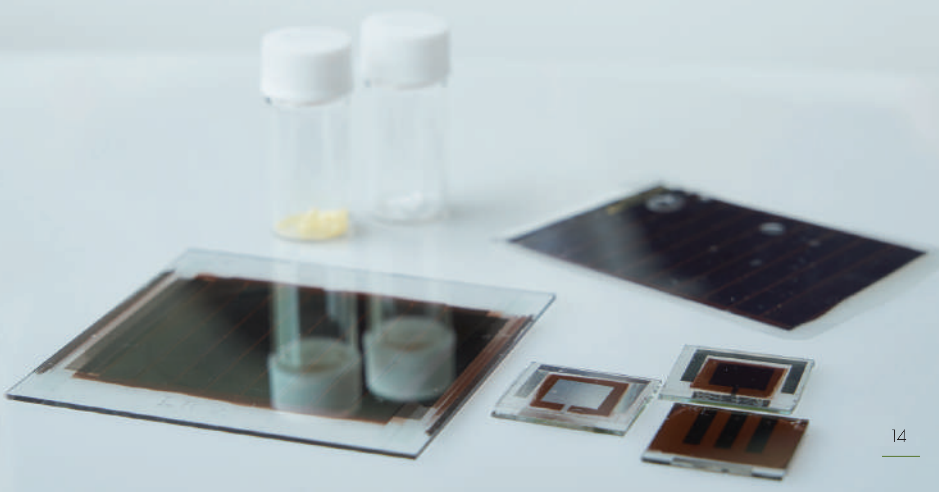
Hirosaki University
Tomonori Sonoki
Applied Microbiology Research Group

Japan Science and Technology Agency and Sustainable Development Goals

In September, 2015, the United Nations General Assembly unanimously adopted the 2030 Agenda for Sustainable Development that comprise of 17 Sustainable Development Goals (SDGs) and 169 targets. The SDGs provide the universal goals to the issues the world including Japan and the humanity faces. The goals and targets of the SDGs are relevant to the implementation of Super Smart Society, "Society 5.0" (Forth Industrial Revolution), set by the 5th Science and Technology Basic Plan as a major pillar of the Japan's Plan for Dynamic Engagement of All Citizens for the strategic growth as well as to the basic principle of our international cooperation.

The First annual Multi-stakeholder Forum on Science, Technology and Innovation for the SDGs (STI Forum) was held on 6–7 June 2016, at the UN Headquarters in New York, aiming to address how the Science, Technology and Innovation (STI) could contribute to the implementation of the SDGs ("STI for SDGs"). It is highly expected that, to achieve the SDGs, the STI play an indispensable role by resolving various emerging issues we face and by providing scientific data and analysis for better political decision.

It is indeed crucial that all stakeholders from government, universities, research agencies and institutes, NGOs and private sectors, etc., take transformative steps in a holistic manner toward STI for SDGs. As Japan Science and Technology Agency (JST) promotes not only the research and development (R&D) but also plans R&D strategies as well as enhance science communication, science education and open data, we are taking inclusive initiatives nationally and internationally for achieving the SDGs.



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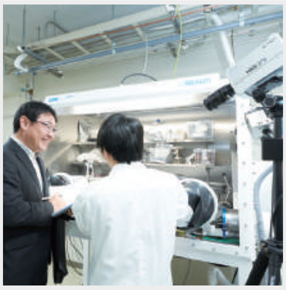
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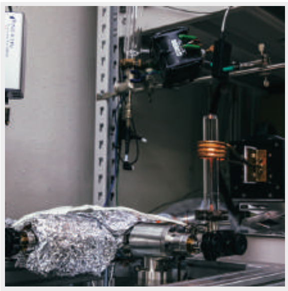
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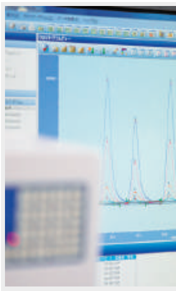


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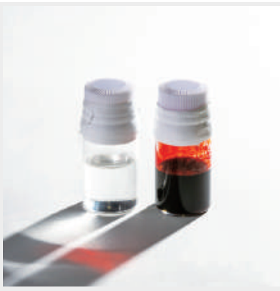
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