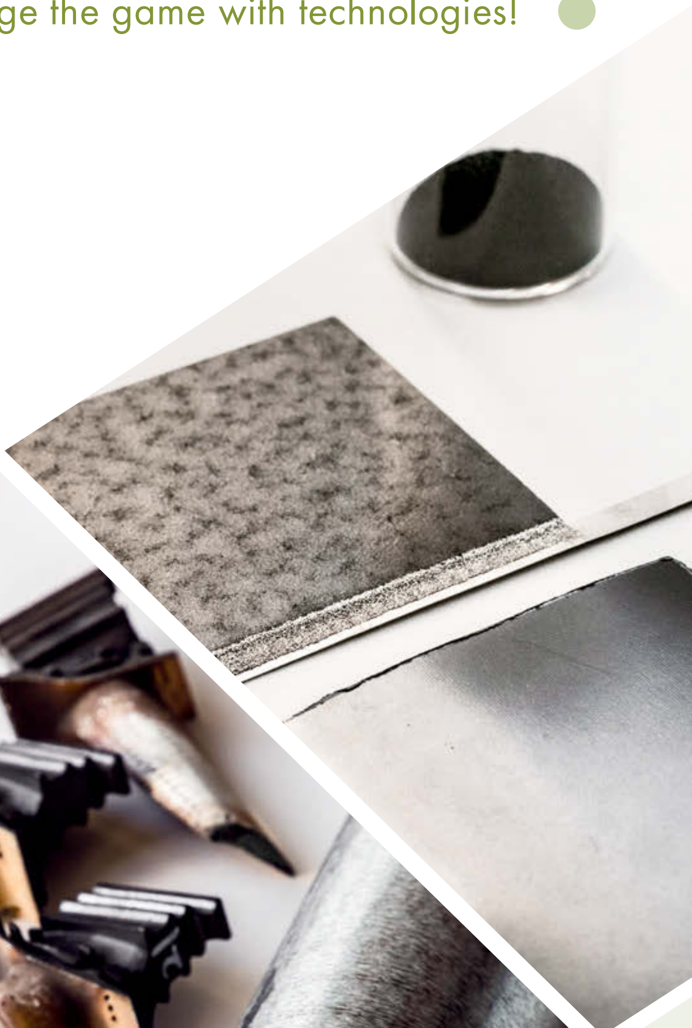
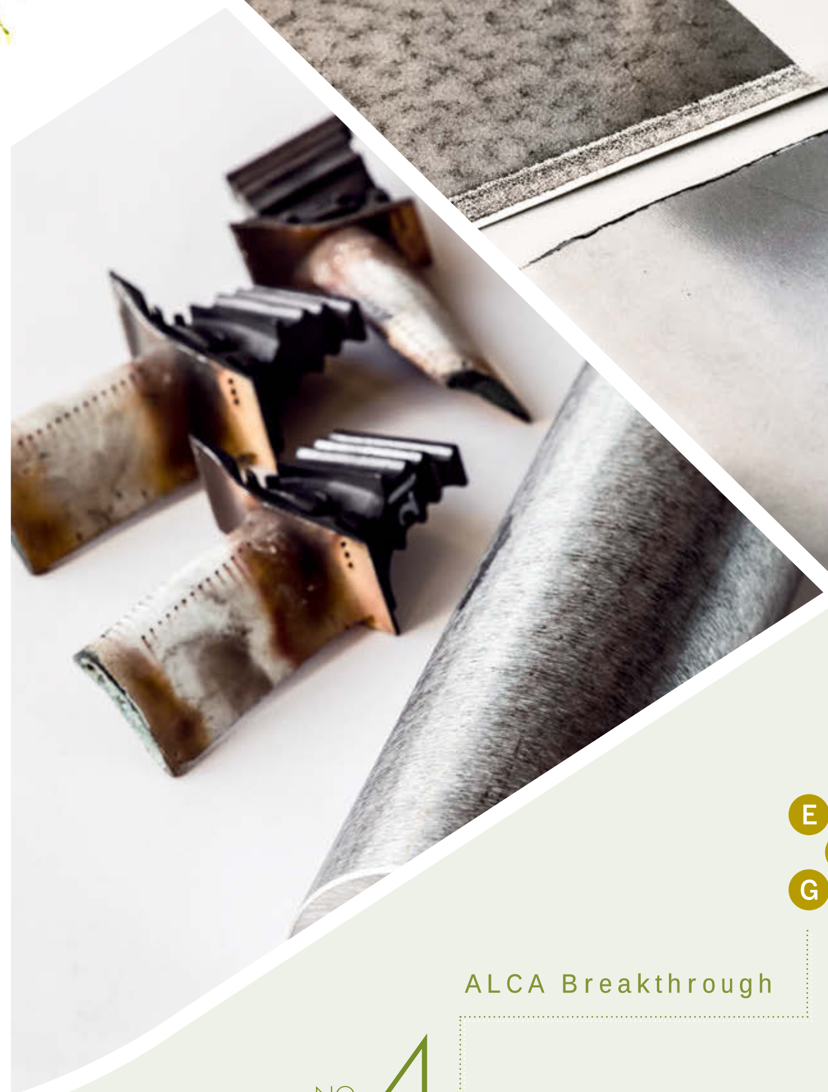
ALCA

Change the game with technologies!





ENG

ALCA Breakthrough

NO. 4

ALCA

Change the game with technologies!

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
Tetsuya Osaka	Professor Emeritus / Senior Research Professor, Waseda University Technical area: Electric Storage Devices
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

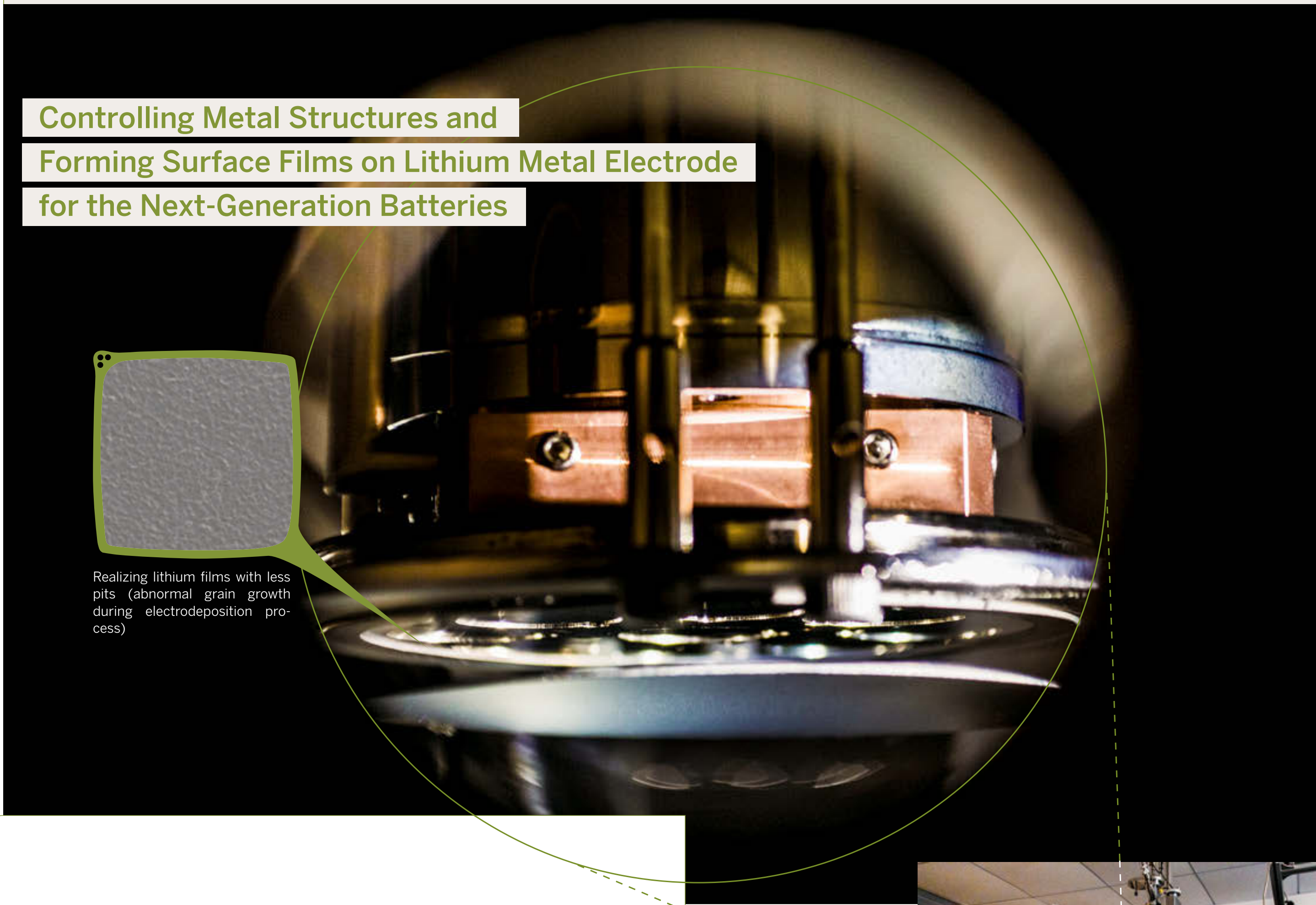
SDGs

Sustainable Development Goals

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

See P. 18 for JST's efforts

Controlling Metal Structures and Forming Surface Films on Lithium Metal Electrode for the Next-Generation Batteries

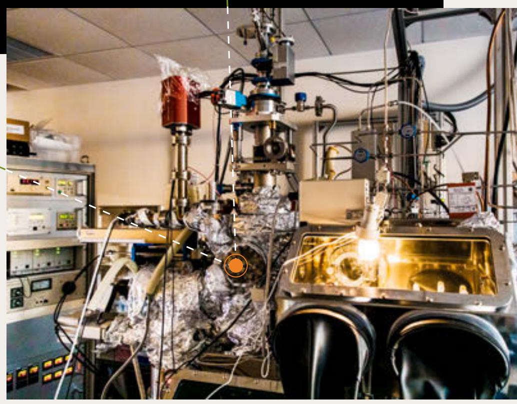


Realizing lithium films with less pits (abnormal grain growth during electrodeposition process)

KEI NISHIKAWA / KIMIHIKO ITO

"Next Generation Batteries" are a technical area on which ALCA places special emphasis. Our team is actively working on issues common to each battery system in order to accelerate the practical application of the "next generation batteries" (ALCA-SPRING) in a cross-sectoral manner. A major issue when lithium metal is used as the anode is the formation of non-uniform deposits of lithium metal, known as dendrites, on the anode surface, which may compromise battery safety. In order to inhibit dendrites formation and ensure safety in the use of high capacity lithium-metal anodes, we at National Institute for Materials Science are conducting research studies on the control of the metal structures of the lithium foil and the technology for forming surface films. These studies have resulted in the building of a system that tailors lithium foil under an inert gas atmosphere such as argon, to control various parameters including casting, extrusion, and rolling, and is an uncommon process around the world. We are also working on the creation of lithium foils that can be handled stably in dry air by adding trace amounts of oxygen and carbon dioxide in the inert gas atmosphere to form artificial films on the reactive lithium surface. In addition, we have succeeded in building a system for depositing lithium under an ultra-high vacuum environment, thus forming metal structures different from those of the lithium foils mentioned above. These results have made it possible to explore the details of metal structures that are more suitable for extending the life of storage batteries.

Kei Nishikawa, Senior Researcher
Kimihiko Ito, Principal Researcher
Center for Green Research on Energy and Environmental Materials
National Institute for Materials Science



Ultra-high vacuum lithium vapor deposit system for controlling the crystalline orientation of lithium foils.

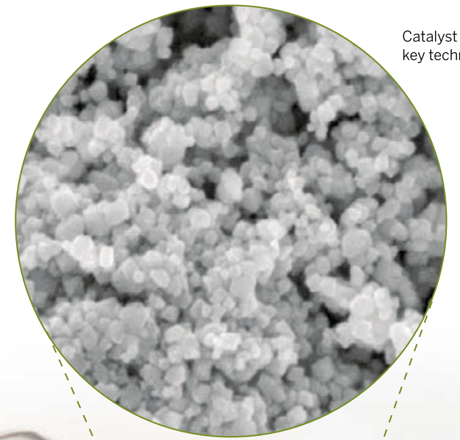
1 Lithium vacuum casting apparatus 2 Lithium extruder 3 Lithium rolling mill 4 Extruded lithium metal foils

Recent Development of Metal Hydride/Air Secondary Battery (HAB) Toward the First World's Practical Application

A metal hydride/air secondary battery (HAB) is an aqueous secondary battery that operates with water decomposition during charge and water generation during discharge. HABs make it possible to achieve both high energy density and safety at the same time. This unique property is useful to realize a novel energy storage system enabling to charge from renewable electric energy generated by solar and wind power, and supplying according to electricity demand. The materials of HAB are appropriate to recycling and are possible to solve the resource shortage and cost increase. We have already demonstrated that HAB has an energy density of 900 Wh/L, beyond the other secondary batteries, and a good cyclability more than 500 cycles and have been developing the cell units for commercialization of HAB.

Masatsugu Morimitsu, Professor

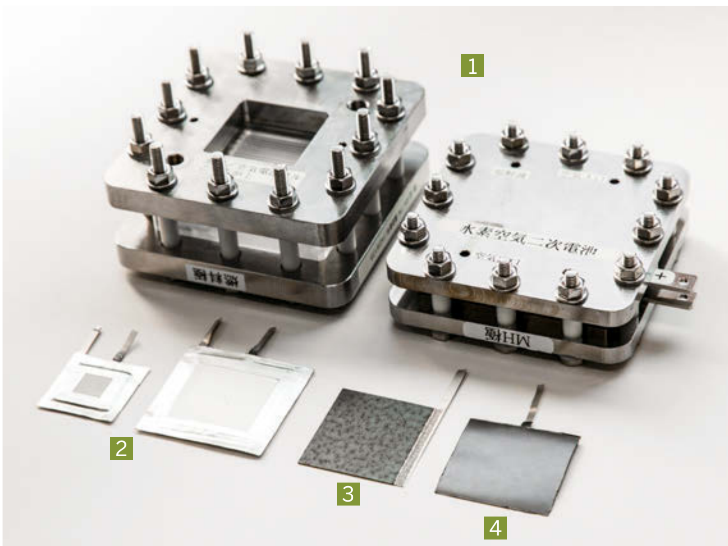
Graduate School of Science and Engineering,
Doshisha University



Catalyst nano-particles, key technologies for HAB

Titanium disks covered with (left) and without (right) catalyst nano-particles.
A novel method to evaluate catalytic activity, Titanium Disk Method (TDM), has been developed.

Roller heat press machine: air electrode manufacturing equipment

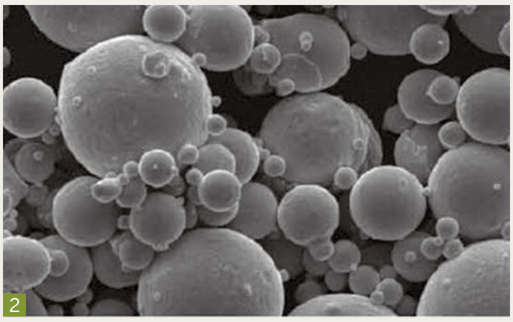


1 MH/Air cell with air circulation
2 MH/Air type cells
Left: 0.5Ah / Right: 2.5Ah
3 Hydrogen storage alloy negative electrode
4 Air electrode

Developing New Ultra-Heat-Resistant Ferritic Steels for Realizing Higher Efficiency Thermal Power Generation

New austenitic heat-resistant steel for 800°C class advanced ultra-supercritical thermal plant

TCP phases (Fe_2Nb Laves phases) and GCP phases (Ni_3Nb-γ'' phases)



1 Powder preparation by the atomization method

2 Powder for HIP (≤ 50μm)

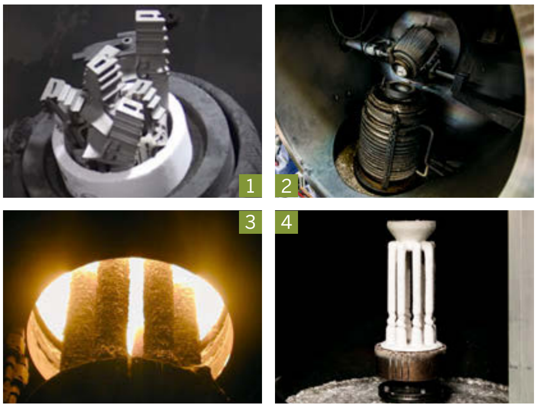
MASAO TAKEYAMA

In order to improve the power generation efficiency of a thermal power plant, it is necessary to raise the temperature of the steam sent into the turbines. A material that maintains its strength for a longer period is also indispensable. In this study, we are developing the world's first iron-based austenitic heat-resistant steels, aiming at an 800°C class thermal power plant that significantly improves power generation efficiency. The developed heat-resistant steel shows higher creep rupture strength and higher oxidation resistance against high-temperature steam, due to TCP phases (Fe_2Nb Laves Phase) formed within the crystal grain boundaries and GCP phases within the grains. In the light of its high rupture strength and ductility even in the powder molding process, we are applying the power HIP (Hot Isostatic Pressing) process to turbine parts as well.

Masao Takeyama, Professor
School of Materials and Chemical Technology
Tokyo Institute of Technology

A capsule for simulation HIP turbine valve

Below: Vacuum melting/unidirectional solidification furnace for items 1 to 4 below



1 Used turbine blades are put into melting crucible made with CaO 2 Melted and forged within the melting/forging room (poured into casts after melted) 3 Moved to cooling room for slow cooling (crystal growth) 4 Resulting monocrystal bar (the cast is seen on the surface)

Reducing the Material Costs of High-Performance Superalloys for Turbine Blades to 1/4* — made possible by a Direct and Complete Recycling Method

*According to the estimates by NIMS

A creep test, applying a constant tension load to the materials at a high temperature.

Used turbine blades
Turbine blades of jet engines actually used in airplanes

HIROSHI HARADA

We have developed a recycling technique that significantly reduces the cost of the base material of nickel-based superalloys for turbine blades. After a small-scale experiment in the laboratory, we dissolved 3 tons of simulant used turbine blade material (with sulfur added) in a commercial furnace of an ingot manufacturer. We added calcium oxide (CaO) while predicting the properties using our alloy design program, adjusted the main components and removed the impurities (sulfur). As a result, we found that an alloy with high-temperature properties equivalent or superior to the superalloy before use can be obtained. Using this "direct and complete recycling method," the material cost of high-performance superalloys for turbine blades can be reduced to one fourth. The turbine manufacturing and recycling processes can also be shortened significantly, which will reduce energy consumption accordingly.

Hiroshi Harada, Research Adviser
National Institute for Materials Science

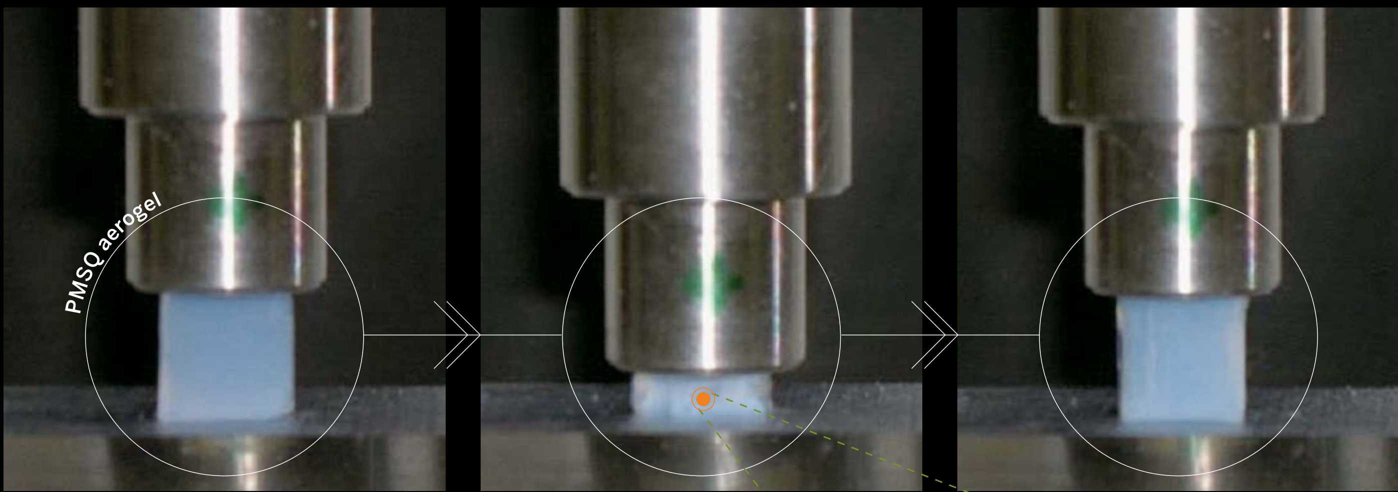
Melting pot made with CaO

Ingot acquired after melting test
Ingot acquired after melting and forging simulant material equivalent to used turbine blades (3 tons) in a large-scale commercial furnace (5.4 tons)

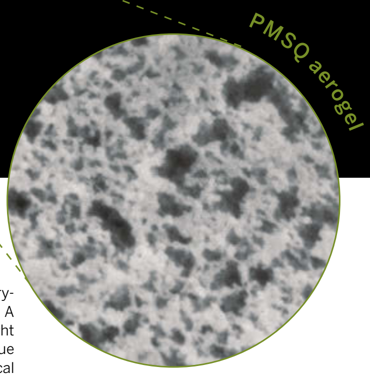
The aerogel we developed can be formed into desired shapes, and applied to transparent insulated windows and thermal insulating material for walls and piping.

Sheet shaped | Granular | Blanket

Development of Transparent Aerogel Superinsulators with Improved Mechanical Strength



It shows a uniaxial compressive flexibility of approximately 80% linear strain and springs back almost completely when the load is removed.



Aerogel manufactured by drying under normal pressure. A promising ultra-light weight thermal insulator material due to the high porosity and optical transparency (>90%)

KAZUKI NAKANISHI

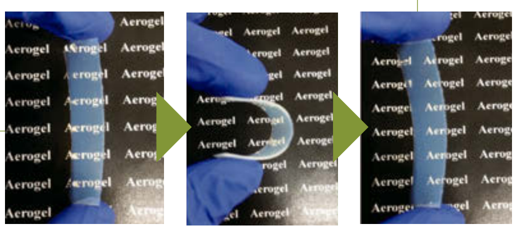
Aerogels are known as a low-density solid material with the lowest thermal conductivity. However, extended applications of aerogels have been difficult due to their low mechanical strength. In this research, we have designed new organic-inorganic hybrid networks to improve strength and flexibility of the aerogels, and established an ambient-pressure drying process, without relying on high-pressure supercritical drying. These results promise a low-cost production of aerogels with improved handling and forming abilities, which increases the possibility of extended applications such as transparent superinsulating windows. With this new technology, contributions to low carbon society are expected through improving efficiencies of various thermal processes.

The R&D process of this technology for practical implementation has been ongoing under NEDO's strategic innovation program for energy conservation technologies since financial year 2018.

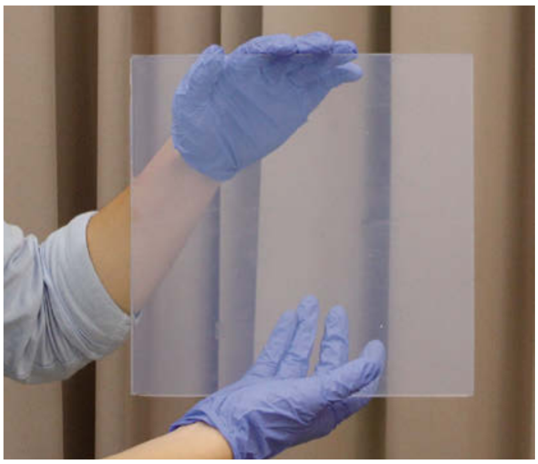
Kazuki Nakanishi, Associate Professor*

Graduate School of Science,
Kyoto University

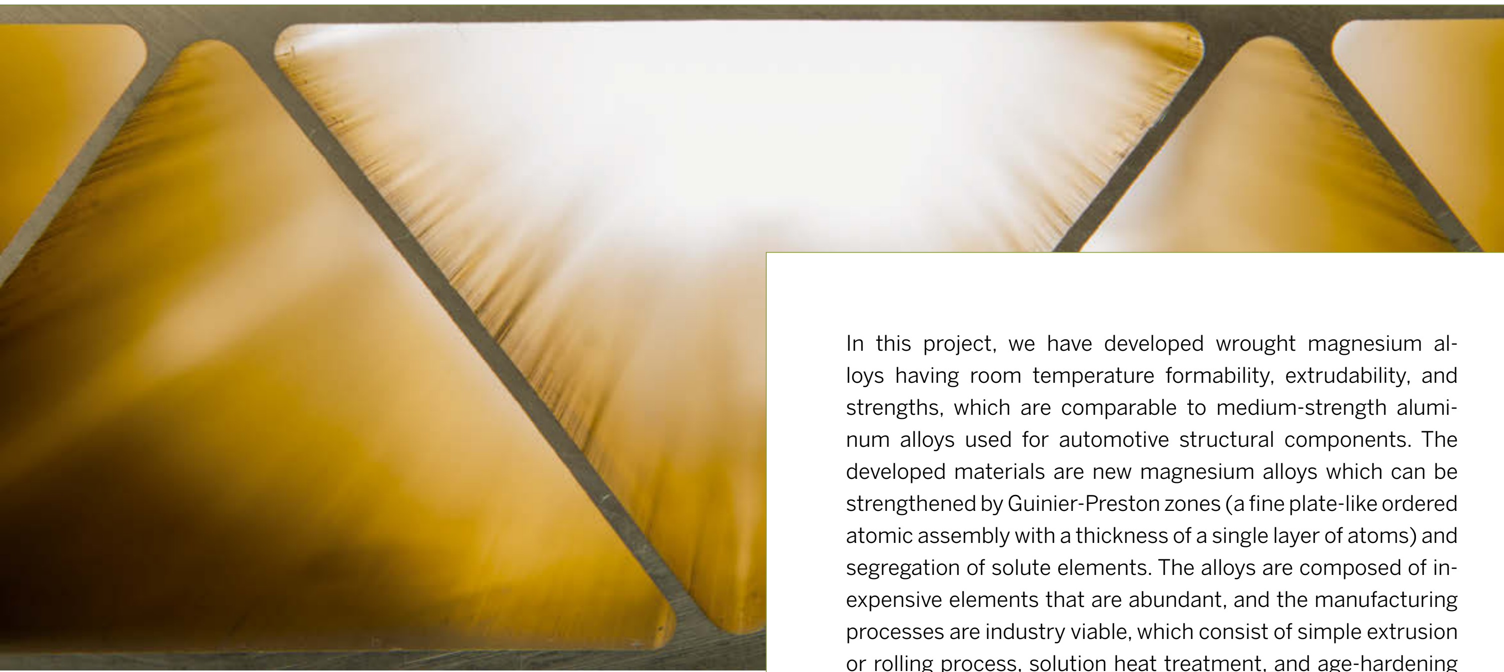
* At the end of contract research at ALCA



The aerogel shows high flexibility against bending deformation. It remains stable after several hundred bends.



Large tiles of about 250x250x10mm^3 can be produced by drying at normal pressures.



In this project, we have developed wrought magnesium alloys having room temperature formability, extrudability, and strengths, which are comparable to medium-strength aluminum alloys used for automotive structural components. The developed materials are new magnesium alloys which can be strengthened by Guinier-Preston zones (a fine plate-like ordered atomic assembly with a thickness of a single layer of atoms) and segregation of solute elements. The alloys are composed of inexpensive elements that are abundant, and the manufacturing processes are industry viable, which consist of simple extrusion or rolling process, solution heat treatment, and age-hardening (bake-hardening) process. Also, low-cost casting methods such as semi-continuous casting and twin-roll casting can be applied. Therefore, the alloys will solve a problem of high production cost that hinders practical applications of wrought magnesium alloys. The new alloys are expected to be used for automotive roofs, doors and bumper reinforcement.

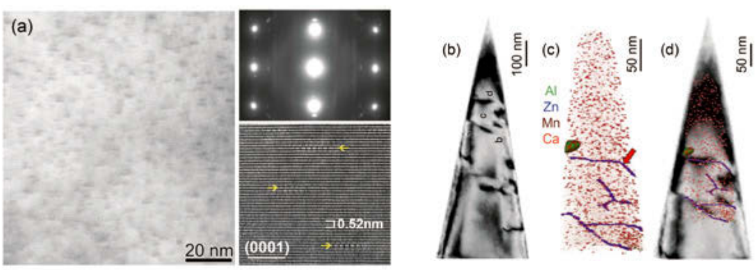
Shigeharu Kamado, Professor
Graduate School of Engineering,
Nagaoka University of Technology

SHIGEHARU KAMADO

Expectations for Vehicle Weight Reduction
Heat-treatable Wrought Magnesium Alloys with Excellent Formability

Excellent room temperature formability could be achieved by grain refinement and zinc addition

Large size hollow material prototype of mock car bumper reinforcement component



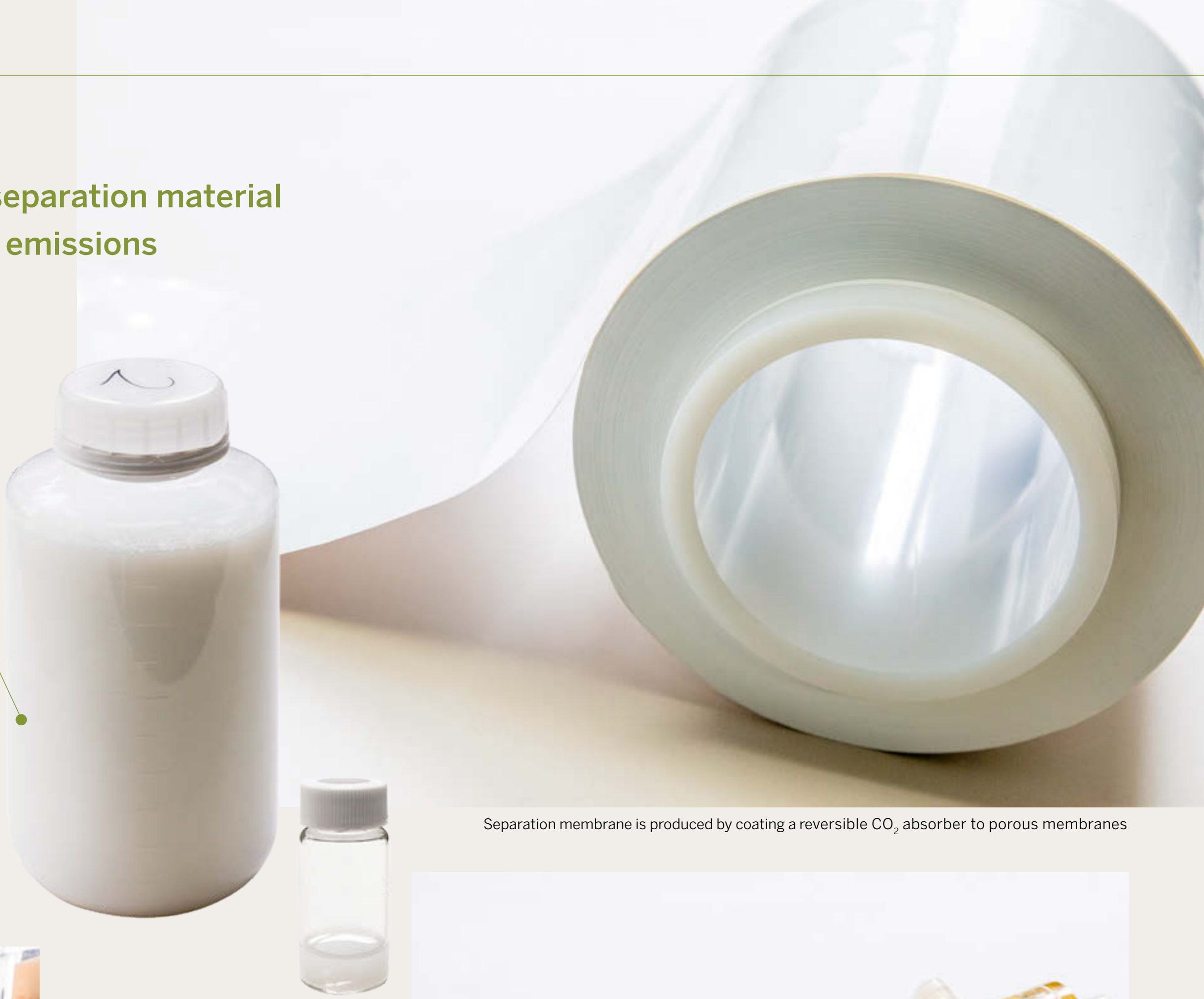
Strengthened by atomic arrangement of aluminum and calcium elements.

Conventional Material | Newly developed alloy

Extruded material: extruded at a temperature of 500°C. High-speed extrusion at the outlet velocity of 60 m/min is possible.

Rolled material: remarkably excellent room temperature formability compared to conventional magnesium alloys.

Economical CO_2 separation material that reduces CO_2 emissions



The developed reversible CO_2 absorber

Separation membrane is produced by coating a reversible CO_2 absorber to porous membranes

1

2

3

1 Coating CO_2 absorber on porous membranes 2 The separation membrane on an evaluation module 3 Evaluation system for the separation membrane

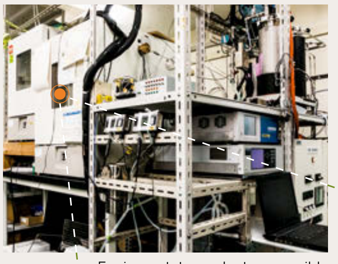
Separation membrane for a hollow type module mold.

We have developed materials that separate and concentrate CO_2 efficiently from exhausted gases of thermal power plants and boilers. Since the materials such as reversible CO_2 absorber, CO_2 selective permeable membrane and separation module can be mass manufactured from low cost material, they enable low cost CO_2 separation process. Moreover, since the materials can directly process the wet gases, it can be used to process post combustion gases without pre-drying process. The concentrated CO_2 will then be chemically converted, utilized and stored.

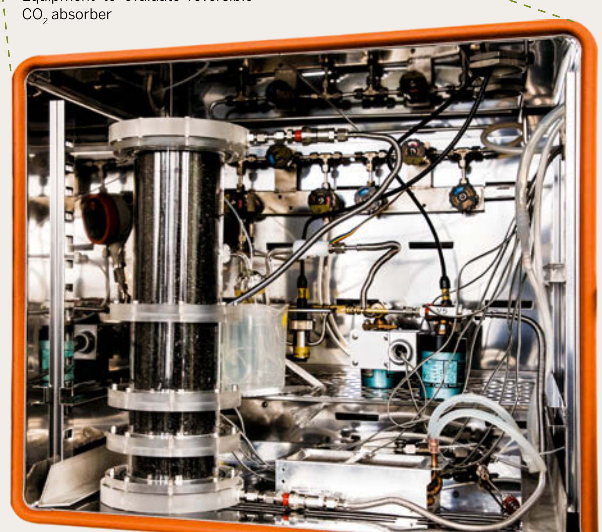
Yu Hoshino, Associate Professor

Graduate School of Engineering,
Kyushu University

YU HOSHINO



Equipment to evaluate reversible CO_2 absorber



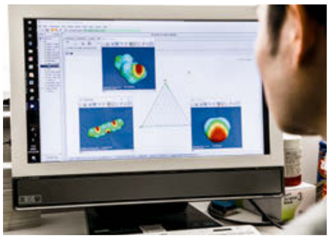
Reversible CO_2 absorbing device

Innovative CO_2 capture technology using phase-separation solvent

Carbon Capture and Storage (CCS), which separates and recovers CO_2 in exhausted gases from power plants and stores them underground, and Carbon Capture and Utilization (CCU), which recycles the captured CO_2, have gathered attention as possible countermeasures to global warming. The key to practical application of such processes is to develop the low cost and low energy process. In this project, we have developed a phase-separation solvent that separates into two-liquid phases upon absorption of CO_2. This solvent has the feature that it can separate and recover CO_2 at lower temperatures than conventional solvent, which can lead to significant energy savings in CO_2 capture. We are also proposing integrated processes in anticipation of CO_2 recycling.

Hiroshi Machida, Assistant Professor
Graduate School of Engineering, Nagoya University

Evaluating chemical properties of the CO_2 absorbent



Screening the optimum composition using quantum chemical calculation

CO_2 absorption and desorption laboratory plant

The phase-separation solvent returns to a homogeneous phase (left) upon heating regeneration.

Suppressing leaf wilt by spraying chemical compounds that inhibit stomatal opening

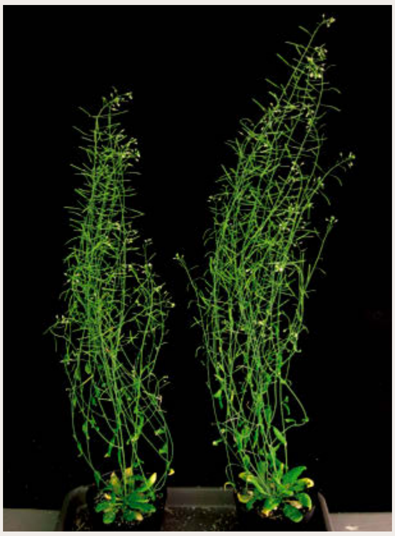
1 Peeling the epidermis of a broad bean leaf
2 3 Incubating and observing epidermal cells under a light source of specific wavelength
4 Measuring photosynthetic speed using a photosynthetic moisture transpiration determining device

Developing technologies to promote growth and improve desiccation tolerance by controlling stomatal aperture

TOSHINORI KINOSHITA

The stomata in plant epidermis are the only inlets of CO_2, which is essential to photosynthesis. The resistance that occurs when taking CO_2 in through the stomata (stomatal resistance) is known to be one of the major rate-determining steps of photosynthesis. In this study, we have clarified that the productivity of the plants whose stomatal apertures are facilitated using light improves and we are demonstrating its usefulness using practical plants such as rice plants and poplars. Our research has also identified a certain chemical that restrains stomatal aperture, and demonstrated that leaf wilt is suppressed by spraying the plants with the compounds identified to inhibit stomatal opening. This finding is expected to contribute to the development of agrochemicals that may be useful for maintaining freshness of cut flowers and for reducing the drought stress of crops in dry areas.

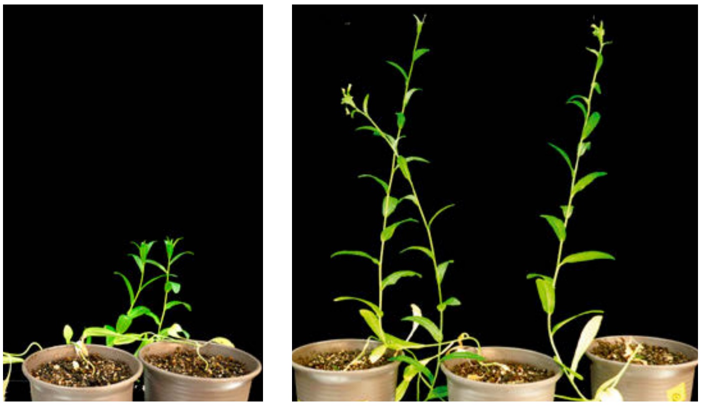
Toshinori Kinoshita, Professor
Institute of Transformative Bio-Molecules, Nagoya University



A strain with overexpressing proton pump (right) has improved production compared to a wild strain (left)

Camelina seeds

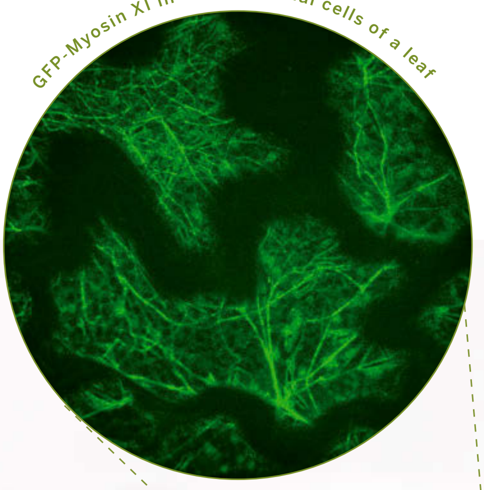
Oil produced from Camelina seeds is used as alternative jet fuel



Camelina with high-speed myosin XI. The plant size of the Camelina with high-speed myosin XI (right) is significantly larger than the one without (left).

Innovative and generic technology for plant biomass enhancement
Artificial acceleration of cytoplasmic streaming

GFP-Myosin XI in the epidermal cells of a leaf

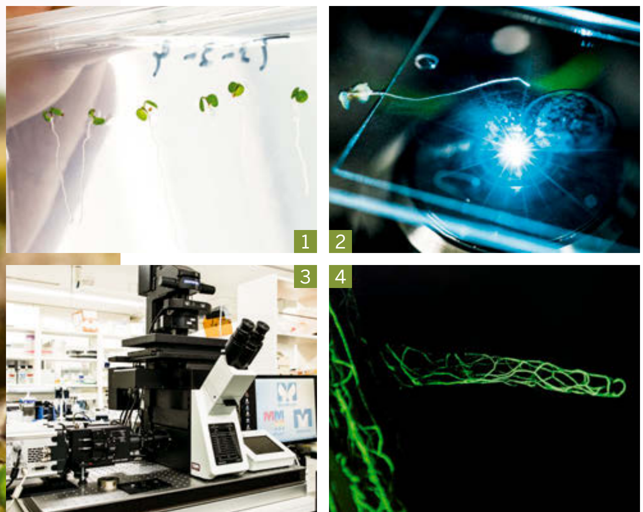


Cytoplasmic streaming is a common intracellular movement occurred in the cell of every plant, and is considered essential for the transportation of plant hormones and nutrients. Cytoplasmic streaming is generated by the motor protein myosin XI bound to organelles moving along actin filaments. In this research project, we have succeeded in increasing of plant size and seed production in such plants as Arabidopsis, Brachypodium, Camelina, and moss, by artificially increasing the velocity of myosin XI. The technology using high-speed myosin XI can be applied to various plants. Thus, we can expect to reduce CO_2 emission on a global scale as well as enhancement of biomass energy and feedstuffs by boosting production of resource plants such as corn.

Motoki Tominaga, Associate Professor

Faculty of Education and Integrated Arts and Science, Waseda University

MOTOKI TOMINAGA



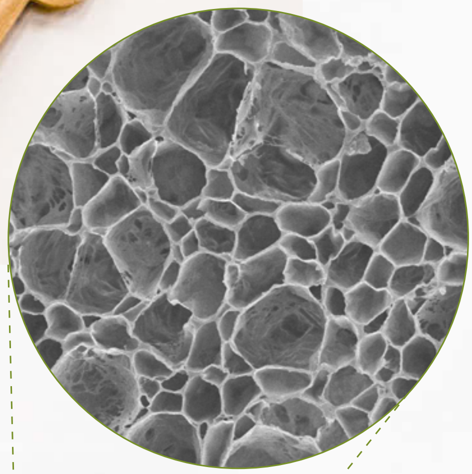
1 Seedlings with growing roots
2 3 Observation with an imaging device (Laser microscope)
4 Actin filaments in a root (a filamentous protein that acts as the track for myosin)

Development of mass production technology for fine-cellular polymer foams with the ultra-high expansion ratios




1 Evaluating the thermal properties of the polymer itself and composites 2 Foam injection molding technology is applied to produce the foams 3 The foam containing CNF (left) has higher cell density compared to the foam without CNF (right) 4 Observing the cellular structures

The mixture of CNF-PP masterbatch (brown) and virgin polypropylene (white) pellets is fed into the foam injection molding machine and foamed.



SEM image of the cross-sectional area of ultra-high expansion ratio foam with a fine cellular structure.

MASAHIRO OHSHIMA

When cellulose nano-fiber (CNF) is added to polypropylene (PP), which is one of the commodity plastics, the polymer viscosity is increased at a low shear rate and the crystalline size is reduced. Taking advantage of these characteristics, we have developed an injection molding technology to produce ultra-high expansion fine cellular foams of the CNF-polymer nanocomposites, such as 21-fold expansion ratio and micro-nanometer scale cell-size foams. CNF dispersed in the polymer can reduce the cell size and reinforce the cell wall, ultimately improving the mechanical properties of the foams. When and if these ultra-high expansion fine cellular foams are used for automobile parts, the fuel efficiency can be increased and CO_2 emission can be reduced by reducing the weight of the parts and improving thermal insulation properties.

Ohshima Masahiro, Professor
Graduate School of Engineering, Kyoto University

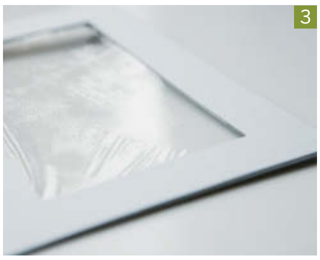
Electroless plating can also be applied to the polymer foams.

21-hold expansion ratio foam was achieved.

Bio-polyimide (organic glass) has the disadvantage of flammability, but flame resistance has been achieved by mixing with nano-glass (white dots)

Bio-polyimide (organic glass) is highly transparent and heat resistant

Development of heat-resistant organic glass derived from amino acids



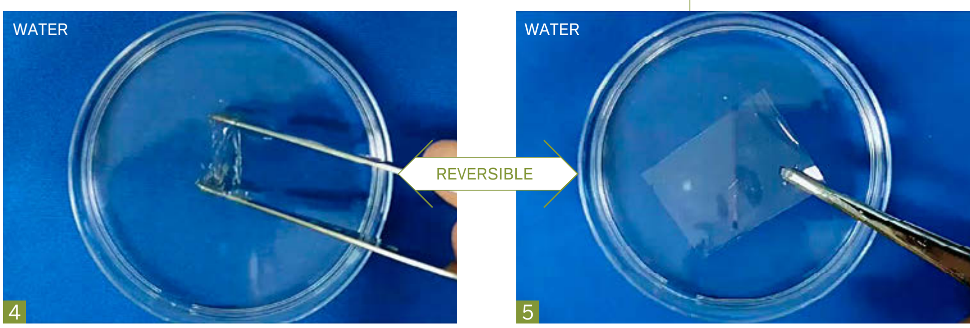
1 4-Aminocinnamic acid derived from biomass (an effective production technique using microorganisms has been developed) 2 World's first aromatic polyimide derived from biomass has been synthesized from 4-aminocinnamic acid 3 Producing a highly durable transparent sheet of aromatic polyimide

We have produced various transparent bioplastics, using 4-aminocinnamic acid, a kind of amino acid generated by E. coli, as a starting material, and by photoreactions and polycondensation with high efficiency. In particular, bio-polyimide, which contains two cyclobutanes, is processed into an excellent organic glass with both transparency and high heat resistance. The bio-polyimide has a high Young's modulus and can be applied to transparent substrates to make flexible panels. In the field of electronics, flexible solar cell panels can innovate nature-energy utilization, and organic EL lighting may lead to a significant illumination, achieving great low carbon results. Recently, we have successfully synthesized bio-polyimide salts having extremely high water solubility, which enables safe production of films and fibers without exhausting organic solvents.

Tatsuo Kaneko, Professor

Japan Advanced Institute of Science and Technology

TATSUO KANEKO



4 Water-soluble polyimide film 5 Water-soluble polyimide film turns insoluble when processed with acid and calcium

“Positioning ALCA in the Energy and Environment Strategy of Japan”

The reason why I gave such a high and mighty title like this one is that I became convinced our research program may play a leading role in the future promotion of research in the field of energy and environment in Japan.

A mission given to the scientific community

International promises are now being made one after another concerning the problem of global warming. Japan has pledged to reduce CO_2 emissions by 26% (relative to emissions in 2013) — equivalent to a reduction of more than a billion metric tons of CO_2 carbon dioxide emissions — by 2030. Furthermore, an agreement was reached to decrease total greenhouse gas (GHG) emissions worldwide to half the present level by 2050. This includes emissions from developing countries, meaning that advanced nations must aim for a reduction of more than 80%. Such a reduction can be achieved only with low carbon technology. However, simply improving existing technologies cannot reach such an ambitious goal. Thus, the creation of game-changing technologies is a “mission” that has been given to the scientific community.

Japan set out its “Innovation Strategy for Energy and Environment” in April 2016 to officially define its approach to long-term research and development into reducing GHG emissions by 2050.

Game-changing technologies for a low-carbon society

The JST established ALCA as a new research program in 2010 to create innovative technologies, which we call game-changing technologies, to drastically reduce GHG emissions. We aim to contribute to the global reduction of GHG emissions. Therefore, we are not simply satisfied with only the development of excellent devices or systems, but also seek technologies that will spread throughout the world in the future — aiming for 2030.

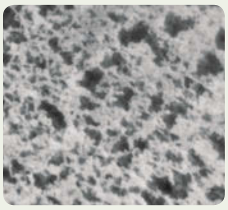
In the ministry-related research programs, almost all projects have a five-year duration. Considering the nature of our research and development, we have designed a framework to support research and development for as long as ten years. Generally, it would be exceptional for basic research to reach practical application in as short a period as ten years. As mentioned above, we aim to develop technology to reduce CO_2 emissions by 2030.

However, even if an innovative technology that can contribute to solving the global warming problem were invented by around 2030, it would only

Program Director, ALCA

Kazuhito Hashimoto







be able to make actual contributions in 2050 or beyond. Therefore, ALCA is positioned to develop technologies by 2030, backcasting from the future low carbon society of 2050.

Small-start and stage-gate evaluation system

We set a smaller research budget size with the aim of adopting many challenging Principal Investigators (PIs) under a limited budget. We call this the "small-start" system. In this system, the initial number of ALCA PIs is narrowed through stage-gate evaluations; the PIs will receive more funding than before by passing through the stage-gate. In other words, the small-start funding and stage-gate evaluations can be regarded as the same entity.

Initially, the research community was skeptical of the stage-gate system. In fact, some criticized our approach, saying, "basic research cannot produce results in such a short term." We thought that was absolutely right. We do not conduct the stage-gate evaluation expecting such short-term results, but are attempting to direct the ALCA PIs towards the ALCA target of reducing CO_2 emissions in the future. A research program that does not pass a stage-gate evaluation is not necessarily held in low scientific esteem. I would like to emphasize that the evaluations are based on the potential contribution to the ultimate goal of ALCA, and we do not evaluate only from a scientific view.

Dual types of technology area: bottom-up and top-down

In ALCA, there are two types of technology areas: those with a bottom-up management approach, based on the creativity of researchers, and those with a top-down approach, targeting a clear research and development goal. Here, the bottom-up approach is different from a typical basic research program in that it is focused on the objective of making a significant contribution to reducing GHG. Initially, there was only the bottom-up approach, but as technology fields in ALCA naturally branched out, we were confronted with some difficulties in integrating the fragmental technologies in our program. We were afraid we cannot achieve the ALCA goal only with scientists' proposals, and considered it important for experts to have extensive discussions on a radical advance in substantial CO_2 reductions. In this context, a committee was organized among the ministries: the Ministry of Economy, Trade and Industry (METI) and the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The committee identified next generation batteries and white biotechnologies as the technology area to be promoted systematically.

Program Officers' Management

Mitigation measures to achieve a low carbon society were classified into two groups: measures to reduce CO_2 emissions, and measures to decrease the total amount of CO_2. These measures can be grouped into categories such as energy saving, energy generation, energy storage, carbon neutral, etc. In addition, they can be further broken down into technological areas, such as solar cells, batteries, and heat resistant materials, etc., to promote research and development in each technological area.

As a wide range of research areas are dealt with by ALCA, a management system is extremely important to oversee such diverse projects. At present, eleven Program Officers (POs) respectively manage their technological areas. The POs have very important roles in managing their project, they are closely involved in individual research themes, and have discussions to provide guidance and advice so






that the research themes proceed under the objectives of ALCA.

Top-down and bottom-up research require considerably different types of management. In the top-down research areas, the POs have to pay more attention to the project management. In order to manage the project, the POs in charge of the top-down type areas frequently hold general meetings with PIs and visit the research sites to point them in the proper direction. POs of the bottom-up areas, on the other hand, respect the creativity of the researchers and do not initially exercise strong leadership. However, if the research begins to diverge from the purpose of ALCA, the POs actually visit the PIs and offer advice regarding various ways to make a correction. Although the two types of management differ considerably, I would like to emphasize that the POs' roles are extremely important for research programs with a clear problem-solving focus such as ALCA, whether the bottom-up type or the top-down approach is adopted.

ALCA received an international evaluation in March 2016, the fifth year since its establishment. The evaluation stated, "ALCA takes a unique approach. It is particularly important for the publicly funded basic research on low-carbon technologies to install such a small-start and stage-gate system."

How to identify the bottleneck problems and solve them

It has been six years since the launch of ALCA. As Program Director, I keenly find it important to first identify specific bottlenecks in the research and development of low carbon technologies, and then pursue solutions for them. An enormous amount of research results has been accumulated over many years, and various attempts have been conducted around the world. We know a specific bottleneck often inhibits research and development. I think that it would be desirable to bring together the wisdom of experts and those with experience to discuss to identify these bottlenecks, and to solicit scientists from different fields in order to take advantage of their viewpoints and resources to solve these issues. In fact, since 2015, we have attempted to identify several technological bottlenecks and present them at open forums.

We intend to promote research and development while remaining keenly focused on the societal implementation of the research results in the future. In addition, we would like to set up more ALCA research areas for top-down type management. The three elements of small-start funding, stage-gate evaluation, and bottleneck identification will become increasingly more important for ALCA management in the future.

This article is based on the keynote lecture at the ALCA symposium (at Pacifico Yokohama, June 30, 2016).

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National Institute for Materials Science (NIMS)

Senioir Researcher Kei Nishikawa

Principal Researcher Kimihiko Ito

Doshisya University

Professor Morimitsu Masatsugu

Tokyo Institute of Technology

Professor Masao Takeyama

Associate Professor Satoru Kobayashi

National Institute for Materials Science (NIMS)

Research Adviser Hiroshi Harada

Kyoto University*

Associate Professor* Kaszuki Nakanishi

*at the end of ALCA

Nagaoka University of Technology

Professor Shigeharu Kamado

Assistant Professor Taiki Nakata

Kyusyu University

Associate Professor Yu Hoshino

Nagoya University

Assistant Professor Hirohi Machida

Nagoya University

Professor Toshinori Kinoshita

Postdoctoral Researcher Yusuke Aihara

Postdoctoral Researcher Yuki Hayashi

Postdoctoral Researcher Eigo Ando

Waseda University

Assistant Professor Motoki Tominaga

Kyoto University

Professor Masahiko Ohshima

Assistant Professor Yuta Hikima

Japan Advanced Institute of Science and Technology

Professor Tatsuo Kaneko

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.

03-3512-3543

www.jst.go.jp/alca/en/

alca@jst.go.jp

国立研究開発法人
科学技術振興機構
Japan Science and Technology Agency

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