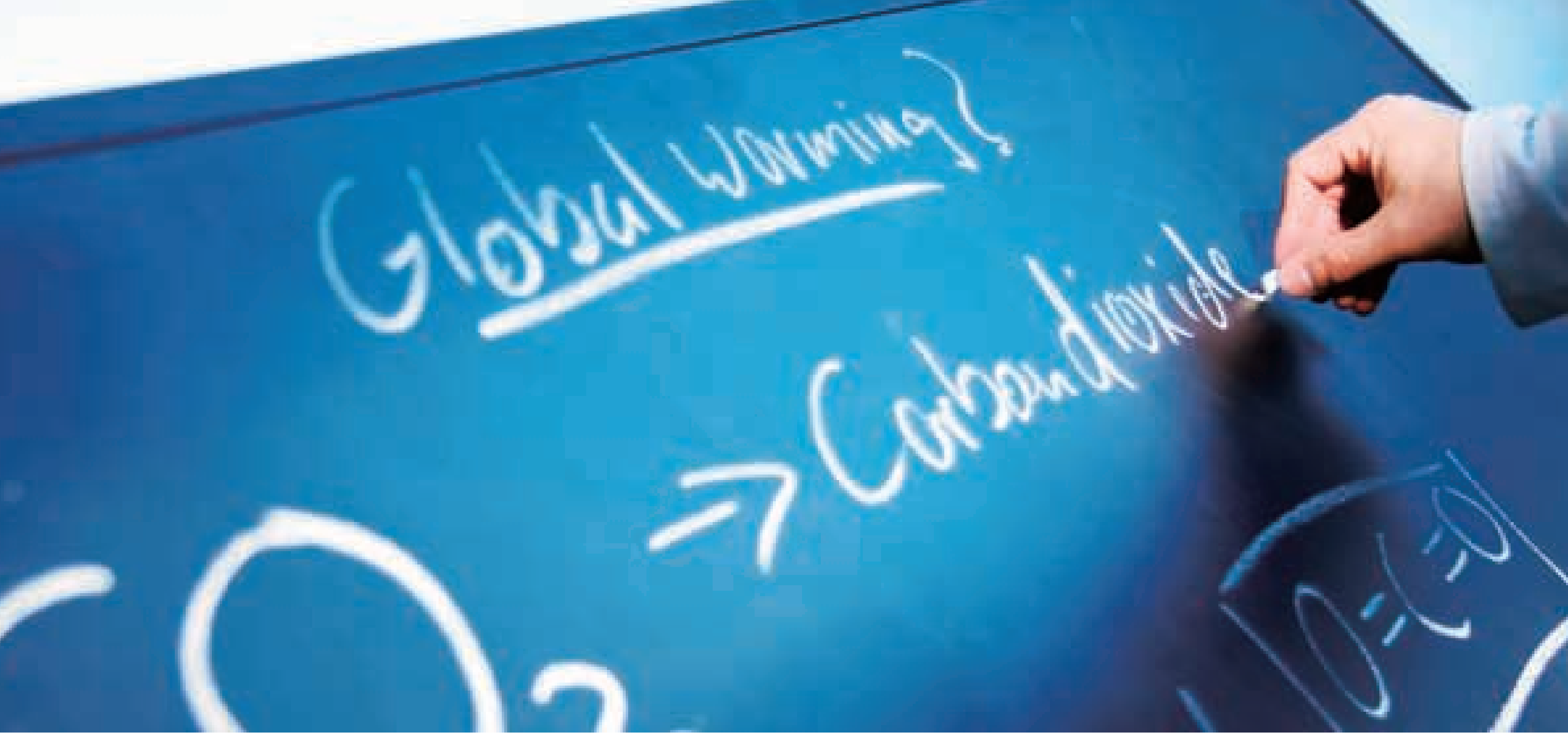
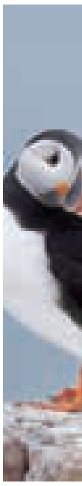
ALCA

Change the game with technologies!



Are We Causing Global Warming?



CO_2 as a Greenhouse Gas

After solar radiation reaches our planet, passes through the atmosphere and hits the ground, it is subsequently sent back out to space as reflected or radiated heat. Earth's atmosphere helps to limit any sudden changes in temperature. Carbon dioxide in the atmosphere makes up a mere 0.04%, but this small amount plays such a vital role in absorbing radiation reflected from the earth in the infrared range to maintain an average surface temperature of 15°C. Dubbed a "greenhouse gas," it is this carbon dioxide that is causing global warming.

Rising Atmospheric CO_2 Concentrations

The IPCC (Intergovernmental Panel on Climate Change) has released five assessment reports over the last 25 years. The Fourth Assessment Report released in 2007 in particular stated that "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations." From the 19th century, humans have consumed a vast amount of fossil fuels such as coal and oil in line with industrial development, and the amount of carbon dioxide in the atmosphere has increased 30% compared to 200 years ago.

Towards the Future Low Carbon Society

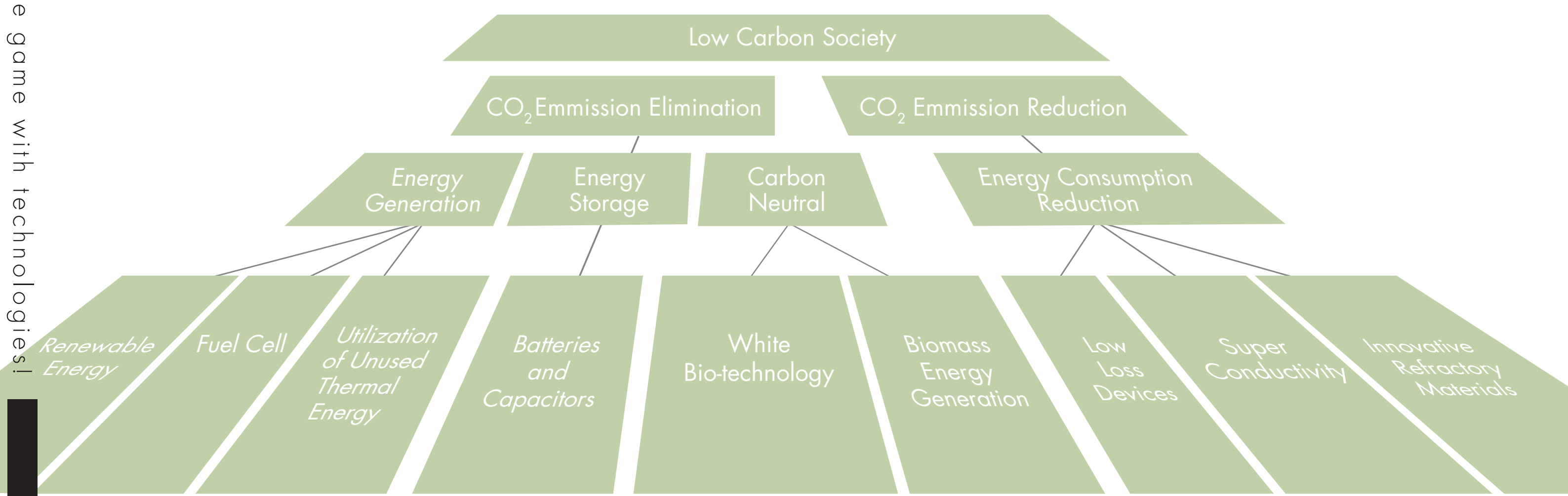
Mitigation Options for CO_2 Emissions

Carbon dioxide is one of the main greenhouse gases that is causing global warming. Creating a low carbon society aimed at limiting emissions of such gases is a challenge the whole world needs to focus on. There are two main approaches available for resolving the issue of global warming, the adaptation option and the mitigation option, and it will be vital to implement these two complementary. The first option aims to make changes to nature and society in order to reduce the impact caused by global warming. The second is to limit the emission of greenhouse gases that is causing temperatures to rise. A low carbon society can be created by implementing a wide array of technical and political initiatives, which include increasing the efficiency of fossil fuels, utilizing more alternative energy sources such as renewable energy, implementing modal shift actions, focusing on energy efficiency and shifting to carbon fixation.

ALCA Launched to Mitigate Emissions of CO_2 with Game-changing Technologies

As international efforts picked up the pace, Japan also embarked on programs to reduce greenhouse gas emissions. ALCA, the Advanced Low Carbon Technology Research and Development Program, was launched in 2010 by JST with the aim of mitigating emissions of greenhouse gases through mitigation policies. While there are a wide range of potential fields and technologies available for development under such mitigation policies, ALCA focuses on the development of methods to limit the generation of CO_2 through energy creation, storage and carbon neutral initiatives, as well as energy efficient technologies aimed at cutting back emissions if generating CO_2 cannot be avoided.

ALCA calls these innovative solutions "game-changing technologies" as they are anticipated to redefine the way traditional fossil fuels are used. ALCA is operating with the mission of contributing to major reductions in emissions in greenhouse gases by implementing these "game-changing technologies."



ALCA Mitigation Options

Next Generation Batteries with High Energy Density

Innovative Batteries for Electric Vehicles

While electric vehicles are often considered essential for combating global warming, the electric vehicles that are currently available for consumers suffer from a lack in driving range. To increase the popularity of electric vehicles amongst consumers, they will need to have a 500 km driving range from a single charge in line with a gasoline vehicle, as well as a storage battery with a high energy density and high power output. This goal is not realistically possible with current lithium ion battery technology, and the industry awaits development of innovative, next-generation batteries that will perform better than lithium ion batteries. ALCA is making an extra effort to focus on initiatives in the field of secondary batteries, and is currently moving forward with R&D into various types of next-generation battery technology for vehicle use.

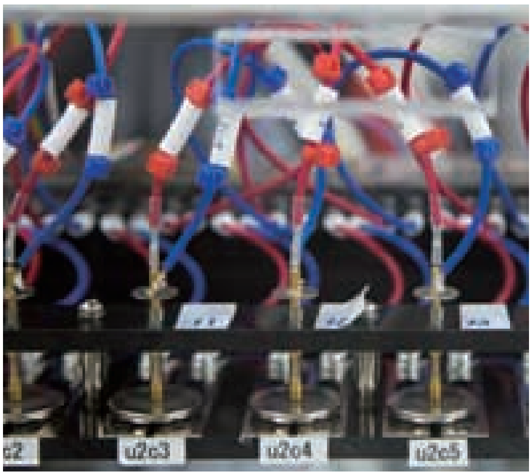
Key Components of the Smart Grid System

As the amount of power generated from renewable energy sources continues to increase, storage batteries will play an important role for the stability of electric power systems. Large stationary batteries are essential for implementing Smart Grid, a next-generation power distribution network where electricity generated by solar and wind are delivered to electric power systems for use by society as a whole (as in the below schematic). One example of the for the stabilized power supply problems that are currently being faced is related to the increase in the amount of power generated by solar systems during clear weather. Feeding this power directly into electric power systems can cause the voltage throughout the distribution network to rise, leading to damage to electrical components. Feeding this electricity to storage batteries first can limit the increase in voltage. When the output of power generated by solar begins to drop, electricity can be supplemented from the batteries. This type of Smart Grid system requires large capacity storage batteries, as it operates on the concept of three ideals: Energy Generation, Energy Storage, and Energy Saving, where the fluctuating output of solar power is coupled with intricately controlled charging and discharging of batteries.

ALCA is taking a leading role with R&D for next-generation vehicle batteries, and effective stationary batteries can also be expected through this R&D.

Photo Provided by TOSHIBA CORPORATION.

Schematic image of the Smart Grid System



All-Solid-State Battery with High Safety and Reliability

"All-solid-state" batteries do not use combustible organic electrolytes, and are beneficial in that they can increase safety and durability by eliminating concerns over explosions or fluid leaks. They can also be stacked directly in an electrode-electrolyte-electrode-electrolyte layout, with the potential for a higher volumetric energy density.

ALCA is involved in the development of all-solid-state batteries using sulfide glass-ceramics electrolytes with high Li+ conductivities developed by the team under Professor Tatsumisago of Osaka Prefectural University. Dr. Takada of NIMS and his team at NIMS are also aiming to develop an all-solid-state battery using a solid oxide electrolyte.

Lithium Sulfur B attery with Higher Capacity and Lower Weight

Lithium sulfur batteries use relatively low-cost sulfur compounds as the cathode, and lithium allows as the anode. While sulfur is known to drastically increase the storage capacity of batteries when used as the cathode, this technology suffers from the fact that the sulfur cathode dissolves into electrolyte during the reaction process. Professor Watanabe at Yokohama National University and his team developed electrodes using electrolytes developed from their own ionic liquid, called the "Watanabe Electrolyte" with the aim of resolving a problem related to dissolving sulfur. ALCA is developing new lithium sulfur batteries based on this technology.

Metal Air Battery Using Air as the Cathode

"Metal air batteries" generate power from oxygen in the air via an air electrode (cathode). The design differs to other batteries in that the active cathode material is not needed inside. The additional space inside the battery can be used to pack the active anode material to make a larger capacity battery.

There are still numerous problems to be solved, such as the metal ion within the electrolyte precipitating onto the anode when charging and discharging (and introducing the risk of short circuits), electrolytes vaporizing, and ventilation holes becoming blocked. ALCA is working to resolve these problems from a multitude of different perspectives.

Magnesium-ion Battery with High Capacity

Magnesium-ion batteries use oxide materials for the cathode and magnesium metal for the anode. Each ion carries with it two electrons, which in theory provides a greater capacity than lithium ion batteries. The drawback is that magnesium ions cannot move easily through the electrolyte or active material, and the surface of the magnesium is easily made inactive, limiting the amount of any stable and useful precipitation reaction in solution. ALCA is conducting investigative research into electrolytes as well as active materials for electrodes with the view developing magnesium ion batteries.

Sodium-ion batteries based sodium's low cost and natural abundance

Research is being conducted into "sodium ion batteries" that use sodium ions instead of lithium ions. Using sodium is a beneficial approach when considering the availability of resources, as sodium is available in much greater quantities than lithium, a resource that is quite rare. Sodium-based batteries already include commercial NAS batteries for storing electricity, but the ceramics used for solid electrolyte needs to be heated to a relative high temperature (approximately 300°C).

Professor Hagiwara and his team at Kyoto University has developed prototype sodium ion batteries that operate at 300°C, and is also researching batteries that operate at higher temperatures for use as storage batteries as part of their development into new electrolytes that operate at much higher temperature ranges than ordinary electrolytes.

ALCA Advanced Low Carbon Technology Research and Development Program

SPRING

Specially Promoted Research for Innovative Next Generation Batteries

Reducing CO_2 Emissions from Power Plants with Improved Thermal Efficiency

In the wake of the Great East Japan Earthquake that struck in 2011, Japan has grown increasingly reliant on thermal power stations to supply its electrical power due to the shutdown of its nuclear power stations, and as a result, CO_2 emissions have also increased. In the leadup to COP21 scheduled to take place in the fall of 2015, the Japanese government has focused on determining the optimum mix for its energy composition for 2030 as well as initiatives to reduce emissions of greenhouse gases. The ratio of thermal power stations used to cover baseload power generation is likely to remain unchanged, which means that CO_2 emissions will need to be reduced drastically through efforts such as further increasing efficiency and developing CCS technologies.

Developing Materials for Coal-fired Electric Generating Plants

While renewable energy sources look increasingly promising, the value of coal as an energy source continues to remain king, simply due to its cost merits (its fuel price per 1 kW of generated power is less than half that of LNG). Coal will continue to remain an important energy source to meet power demand into the future, however given that CO_2 emissions of coal combustion are almost double that of natural gas, the need for innovative technologies aimed at cutting CO_2 emissions is higher than ever.

In Japan, coal-combustion thermal power stations are cutting back on CO_2 emissions by operating at the highest possible thermal efficiency using the latest Ultra Super Critical (USC) technology, which elevates steam turbine pressure and temperature up into the ultra super critical range. The Integrated Gasification Combined Cycle (IGCC) that combines gas turbines and steam turbines by turning coal into gas and applying the force of expansion to generate power via a gas turbine. Exhaust gases are routed into a boiler for greater generation efficiency, and the technology is being utilized at a greater number of power stations.

The Integrated Gasification Fuel Cell Cycle (IGFC) based on SOFC (Solid Oxide Fuel Cells) has also been developing aiming at the next generation system.Combining solid oxide fuel cells (SOFC) at high temperatures drastically increases power generation efficiency, while also mitigating CO_2 emissions by approximately 30% compared to existing technologies.

ALCA is involved in the R&D of materials used for steam turbine blades and peripheral equipment that can withstand even higher temperatures.

High Temperature Materials for LNG Gas Turbines

Gas turbine power generators use the high-temperature gases generated when burning LNG to operate turbines, and are actually a type of internal combustion engine that converts energy into rotating mechanism. As LNG results in less CO_2 emissions and produces fewer nitrogen oxides during the combustion process than other fossil fuels, it is expected to become the main type of thermal power generation used into the future. Gas turbines operate at a high temperature and generate exhaust gases with a high residual heat. The high-efficiency Gas Turbine Combined Cycle (GTCC) that combines exhaust heat recovery boilers and steam turbines is being more widely used. Gas turbines have higher levels of heat resistance to improve the thermal efficiency of operation, with recent models used at temperatures of 1,500 to 1,600 °C. ALCA is also developing heat-resistant materials for use in next-generation gas turbines that are capable of achieving combustion temperatures up to 1,700°C.

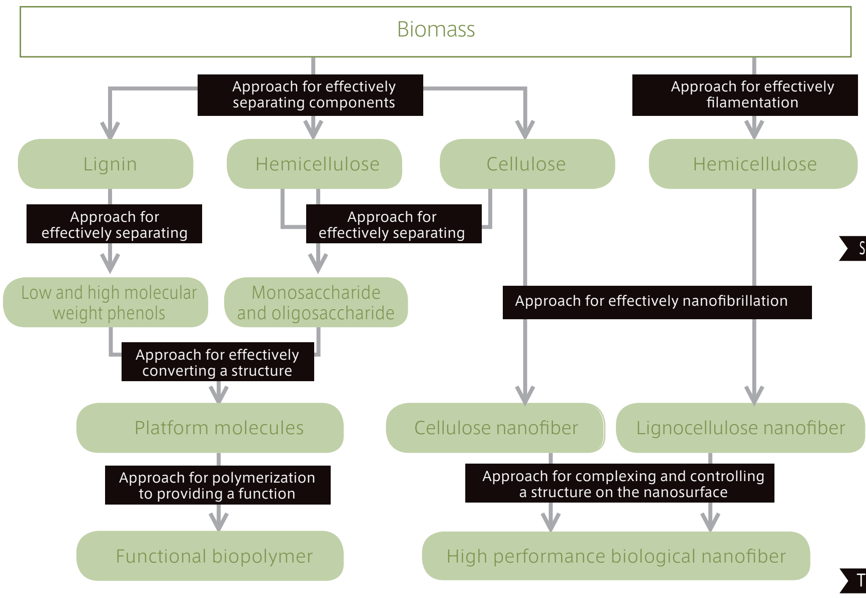
Paradigm Shifts in Chemical Industry with White Biotechnology

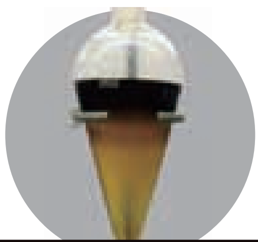
Biobased products are made chiefly from plant material that contains stores of CO_2 captured through the photosynthesis process. They can be considered a low carbon technology as they have minimal impact on atmospheric CO_2 levels during their useful lifetime (a property that is called carbon neutral), if the energy used for manufacturing is excluded. The concept of manufacturing chemical products from biomass is called biorefinery, or white biotechnology. ALCA embarked on a white biotechnology project from 2015, integrating its technical achievements in the field of biotechnology with its developments in the chemical processing industry.

Biomass is made up of cellulose, hemicellulose, lignin, starch and other plant-based substances. Various types of functional biopolymers are usually manufactured through a series of complex physiochemical preprocessing, followed by the enzymatic saccharification process and microbial fermentation process to create base material. The final process is applying chemosynthesis based on technologies such as synthetic chemistry and catalyst science.

Eucalyptus pulp

Bio-plastic film





Separated phases in the ligmin degradation process

TEMPO-oxidized cellulose nanofibers

Bio-plastic products

Bioprocesses have minimal environmental impact as they do not involve processing at high temperatures or the use of chemical catalysts. In some cases, end products can even be made with fewer steps than chemical processes by effectively harnessing the specific chemical reactions of individual materials. Yet there is no contesting the fact that chemical processes are the most effective way of mass-producing the required material quickly, with a consistent level of quality.

ALCA's white biotechnology maximizes its strengths by combing these chemical processes and bio processes fragmentarily promoted each other in ALCA in its goal of solving technical bottlenecks present in the main processes of 1) cellulose extraction from biomass, 2) conversion into candidate biorefinery, and 3) production of functional high-molecular compounds.

Bio-based Polymers Derived from the Biomass

Japanese scientists are at the forefront of products made from biomass.

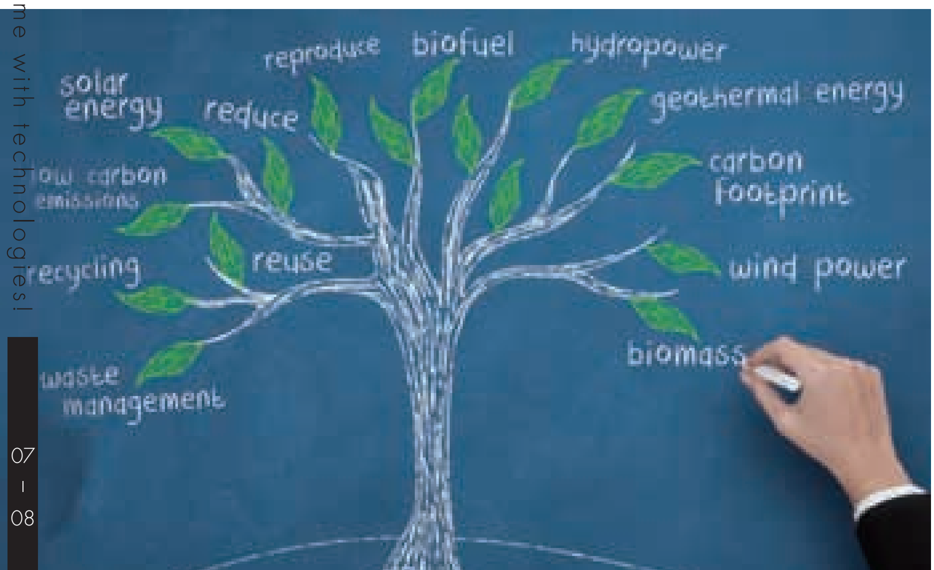
Associate Professor Tatsuo Kaneko and his group at the Japan Advanced Institute of Science and Technology developed high heat-resistant bioplastics by applying photochemical methods to cinnamon-based molecules derived from microbes. These plastics are likely to be adapted to various technologies such as materials to replace the metals and glass used in electrical components and other parts.

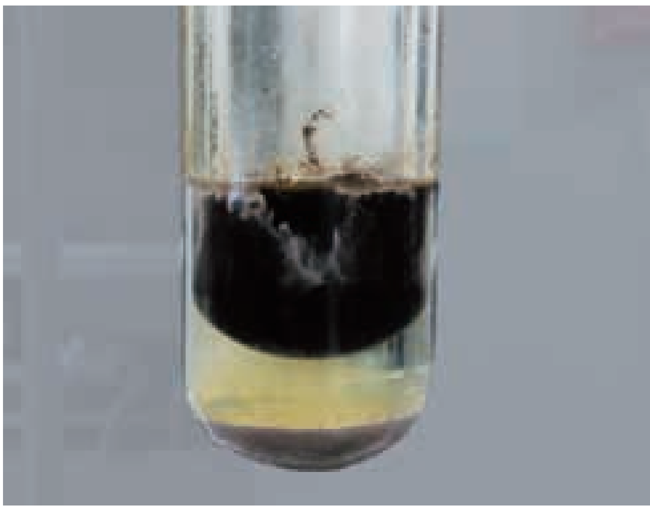
Dr. Masatoshi Iji's team at NEC Corporation successfully developed a method of creating bioplastics by making base cellulose expand into gel form within an organic catalyst, which drastically reduced the amount of CO_2 emissions compared to previous manufacturing methods.

Catalytic Conversion of Biomass to Platform Chemicals

Professor Michikazu Hara and his team at the Tokyo Institute of Technology came up with an innovative process for converting glucose into 5-hydroxy-methyl-furfural (HMF) by developing a new solid catalyst made of cheap titanium dioxide (TiO_2) that can function underwater.

Professor Atsushi Fukuoka's team at Hokkaido University successfully produced sugar from biomass at a low cost using an activated charcoal-based carbon catalyst. (Right photo.)



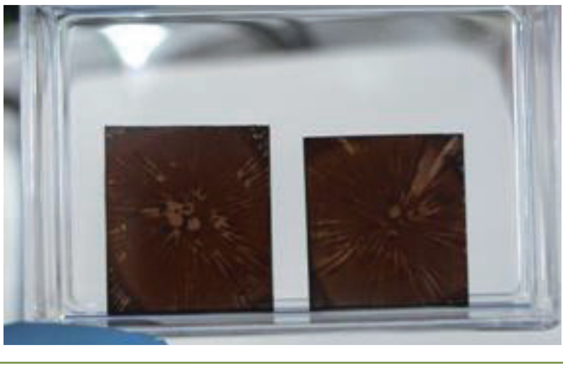


HMF production over water-tolerant heterogeneousLewis Acid catalyst

Renewable Energy

ALCA Mitigation Options 01

To make any significant reduction in the amount of greenhouse gas emissions, there needs to be greater utilization of renewable energy (such as solar light, wind, hydro, geothermal, solar thermal, unused heat, tidal, biomass), as well as implementing changes to the energy makeup that currently relies too heavily on fossil fuels. In addition to a lower risk of becoming depleted, renewable energy is showing increased promise due to the fact that almost no carbon dioxide is emitted when they are used to generate power. Countries around the world are making considerable efforts to utilize renewable energy with the aim of cutting back on greenhouse gas emissions.

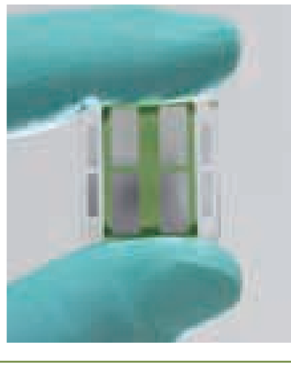


Thin-film Perovskite Solar Cell

Absorbs visible light up to 800 nm on a glass substrate, and changes color to dark brown. The "thin-film perovskite solar cell" was discovered in 2009 by Professor Tsutomu Miyasaka and his team at the Toin University of Yokohama. Their achieving "10.9%" efficiency was published in "Science" in 2012, leading to intense global competition today.

Highly efficient and stable organic thin film solar cells based on semiconducting polymers

The OPV cells were fabricated by spin-coating the semiconducting polymer solution (shown at the inserted photo). It enabled the development of low-cost, light-weight, flexible, and large-area electronic devices.

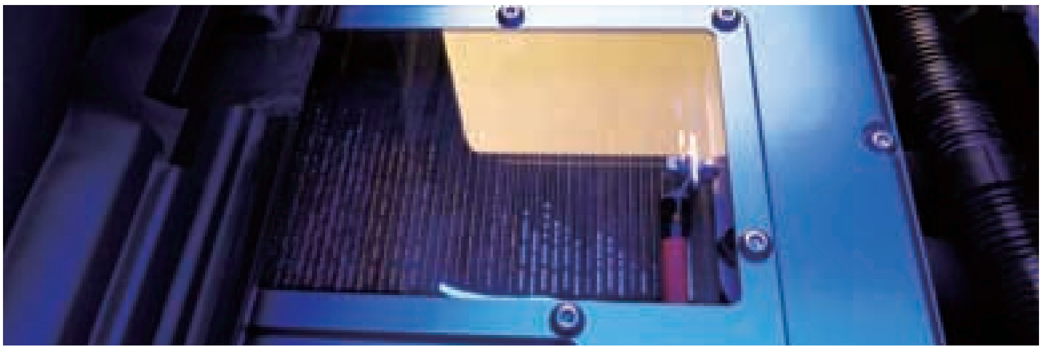


Fuel cells are devices that continually generate electricity when they are supplied with hydrogen fuel and oxygen in the air to undergo an electrochemical reaction at ambient or high temperatures. Normal power generation systems convert the chemical energy stored in fuel to thermal energy, and then convert that to mechanical energy and finally electrical energy via thermal engines. Fuel cells differ to these systems in that they convert chemical energy directly to electrical energy through electrochemical reactions with higher power generation efficiency. The by-product of the reaction is just water, making it a clean power generation technology as no CO_2 is emitted.

Clean Energy

ALCA Mitigation Options 02

Photo Provided by DAIHATSU MOTOR CO., LTD.

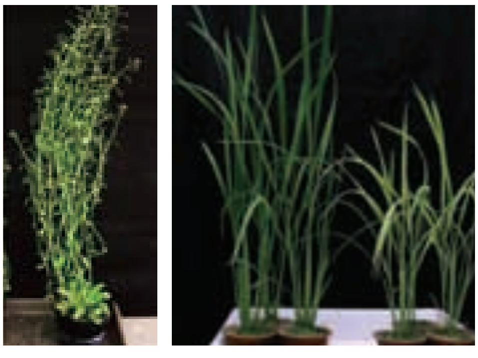


Platinum Group Metal-free Direct Hydrazine Fuel Cell

Development of a fuel cell that eliminates the need of rare metal catalyst by using a new anion exchange membrane.

Carbon Neutral

The CO_2 emitted from chemical products and fuel made from biomass does not exceed the amount of CO_2 that was absorbed when that biomass was growing. Carbon neutral is a concept for reducing CO_2 emissions by shifting from petroleum-derived energy sources to bio-based ones. The development of carbon neutral systems is well underway. This involves increasing the production of plant-based biomass by applying plant and metabolic engineering, and ensuring that the useful components of the biomass are metabolized efficiently to trap CO_2 from the atmosphere as well as lead to more efficient utilization.



H^+ATPase Overexpression Plant (45 days old)

Plasma membrane H^+-ATPase was increased using only stomatal arabidopsis, leading to a 25% larger stomatal opening. This improved the amount of CO_2 absorption of the plant (amount of photosynthesis) by approximately 15%, enhancing production of plants 1.4 to 1.6-fold. The technology is expected to help increase production of agricultural plants and biomass resources, as well as used to reduce CO_2 levels through increased use by plants.

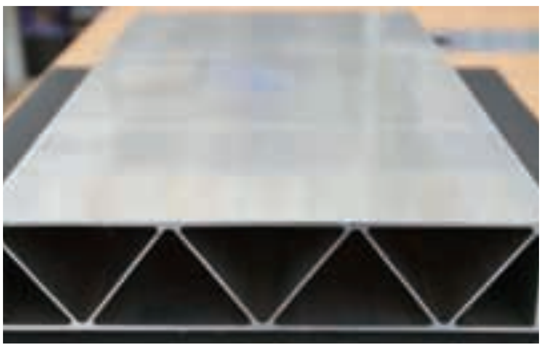
Wood Formation in Poplar

Adding various genes to plants that do not grow to make wood helps to develop new plants capable of being used as timber. The technology can be used to increase production of biomass resources with easily separable useful components.

Light Weight Materials

ALCA Mitigation Options 04

Developing groundbreaking lightweight material substitutes used throughout core social infrastructure such as transportation equipment, industrial machinery and energy conversion facilities is an important step to building a low carbon society. Lighter weight rolling stock and vehicles in particular are directly related to improvements to fuel efficiency, and is a highly effective approach to reducing CO_2 emissions. Impressive weight savings can be achieved by using non-ferrous metals such as titanium and magnesium alloys, or carbon-fiber-reinforced plastic (CFRP) instead of steel, which is currently the most widely used material for transportation equipment.

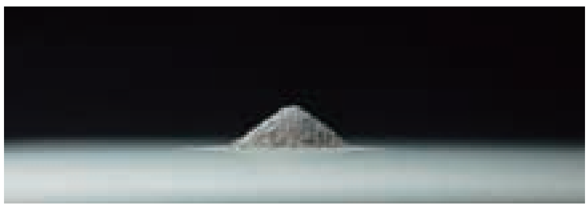


Extruded Mg-based Alloys with High Mechanical Properties

Development of magnesium alloys with excellent extrusion and mechanical properties. Applying the technology to the Shinkansen and other types of rolling stock is hoped to achieve an energy-efficient transportation system.

Powdered Ti Made with New Smelting Process

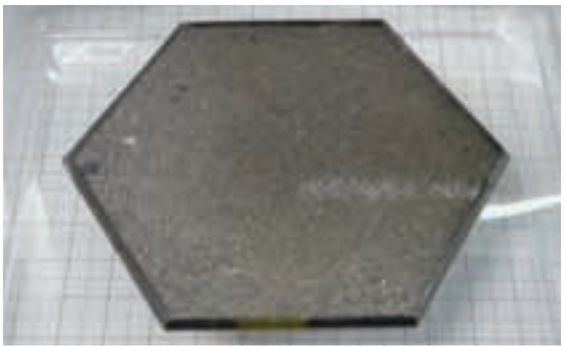
A new smelting process for titanium has been proposed, using vacuum distillation to continuously refine the BiTi alloy segregated from liquid Bi that is obtained after magnesiothermic reduction of $TiCl_4$. With higher yields and energy efficiency than current batch methods, the technology is hoped to contribute to increased uptake of the lightweight metal titanium.



Ultra Low Power Devices

ALCA Mitigation Options 05

As electronics continue to evolve, the rapid increase in various electronic appliances around the home are leading to an increase in energy consumption. The number of vehicles and industrial machinery that use electric motors controlled by inverters and other electrical components is also expected to rise dramatically moving forward. Reducing the amount of loss in core electronic devices such as these is the most effective approach to reducing energy consumption of electrical appliances. The amount of CO_2 emissions can be cut back dramatically by reducing loss and developing ultra low power devices.

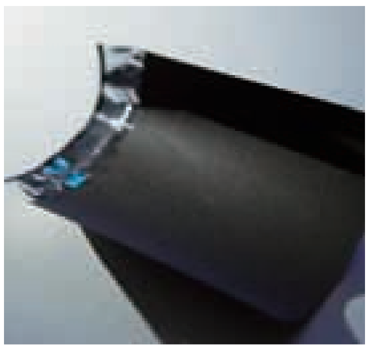


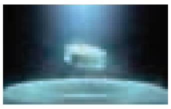
High-quality 4-inch diameter GaN Wafers

The Na flux method was used to make large-diameter, high-quality GaN substrate with a low dislocation density, which is a defect on an atomic level. A 4-inch diameter is currently available, with the aim to reach a large 8-inch diameter in the future. The technology is hoped to lead to energy-saving power devices with low loss.

Graphene-based supercapacitor

This stacked supercapacitor made of graphene and carbon nanotubes (CNT) with a proprietary method is one type that is showing promise with high power density.





Superconductor Systems

ALCA Mitigation Options 06

Superconductors are devices with properties with almost no electrical resistance. The use of superconductor power generators, superconductor cables and superconductor energy storage devices will be able to minimize electrical loss in equipment using electrical energy used through the transportation, industrial and IT segments. The technology is also expected to play a major role in increasing the effective utilization of renewable energy sources that suffer from natural fluctuations in power generation, despite not emitting greenhouse gases.

MgB_2 small solenoid coil

A compact prototype coil is made by using MgB2 wires fabricated by powder-in-tube (PIT) methods. MgB_2 wires can be extended relatively easily and do not use expensive rare earth materials, which makes them commercially viably. The superconductive properties of MgB2 were discovered by Akimitsu et.al in Japan in 2001.

20 kW-class High Temperature Superconducting Induction

Currently under experimental studies with the aim of being mounted to transportation equipment. This is expected to be the core technology of ultra energy-saving transportation systems.

Adopting New Innovative Technologies for a Low Carbon Society

Almost five years have passed since ALCA was established. ALCA program director Kazuhito Hashimoto and 10 other Program Officers gathered and talked about the significance of ALCA as one of Japan's science and technology innovation programs, as well as touching on other points of interest, hurdles that were overcome and future aspirations.

"Game-changing Technologies" for a Low Carbon Society

Hashimoto (moderator):Science and technology innovations will be essential in order to drastically reduce the amount of carbon dioxide emitted by human activities on a global scale. ALCA is an R&D program that pushes the boundaries with "game-changing technologies," to develop a low carbon society that will revolutionize the energy industry on petroleum-based resources. I would appreciate your honest opinions after serving ALCA Program Officers for the past five years.

Ohsaki:We are confident about the feasibility of low carbon society technologies being developed to be implemented in society around 2030. ALCA plays a key, novel role, as a fresh approach is being sought after with the fundamental science of creating game-changing technologies, as well as reviewing intermediate progress with stage gate assessments. I feel that many people now recognize these characteristics of ALCA and regard it as a publicly funded advanced R&D program。

Halada:I believe that one of the strengths of ALCA is that PIs and Program Officers share the common goal of "achieving a low carbon society," and work on designing the R&D process through constructive discussions as to how and when they will achieve game-changing technology. Under the keyword "game-changing," this is a truly unique program that defines the efforts of the R&D covered here.

Konagai:Game-changing technology in itself means so many different things. For example, in the field of solar power generation where I serve as a Program Officer, many scientists might consider game-changing technology to be material that can be used as alternative material for silicon currently used as a solar battery material. Meanwhile, game-changing technologies could also encompass the creation of new silicon-based solar batteries. Surely it doesn't matter if different researchers have different views as to what constitutes game-changing technology.

Doi:ALCA took the initiative and embarked on 21^{st} century science, rather than 20^{th} century science. The goal of 20^{th} century science was to pursue the scientific world, and scientists should not think about the socioeconomic value their findings would bring. On the other hand, scientists involved in 21^{st} century science work to discover more knowledge, but must also think about how their findings will be used in society. I think that ALCA is working on developing a methodology of "science for society."

Program Director
Kazuhito Hashimoto
President, National Institute for Materials Science

D.Sc., Professor The University of Tokyo from 2007, Appointed to current position in 2016, Research topics include photocatalysts, environmental science and energy conversion. Government public office positions (as of March 2014): Councilor of Industrial Competitiveness Council, Headquarters for Japan's Economic Revitalization Cabinet Secretary, Councilor of Council for Science, Technology and Innovation, Cabinet Secretary, Councilor of Science Council of Japan.

Fundamental scientists leading the way to a low carbon society

Kondo:Until now, problem-solving R&D programs rarely included those based on physical science as compared with engineering-based scientists with a view of practical use. A large number of topics were received by ALCA that focused more on physical science topics. Actually, some proposals were focused so much on fundamental R&D that there were hardly any commercial aspects involved. Yet even if these applications were not adopted, I think it is important to note that researchers of physical science also considered the way that their own fundamental R&D could meet the social needs.

Taniguchi:Even in the field of system device technology where I serve as a Program Officer, we have seen many researchers adjusting their own research to better match the concept of ALCA. In this sense, ALCA could be considered as playing a role in changing the way of thinking of fundamental scientists who had previously focused on research fields for scientific paper publications.

Hanada:The association that I chair rewards outstanding researchers in metallurgy with awards and prizes. More recently, as with ALCA, proposals by the physical scientists have been increasing rapidly and ALCA has taken a pioneering role in the change occurring throughout the S&T in Japan, and this is a fact that can be appealed to stakeholders.

Osaka:More than just game-changing technologies, ALCA is determined to take a back-casting approach for achieving a low carbon society in the future. This actually means conducting R&D by working backwards, identifying what technology is required to achieve a low carbon society, and which research topics are needed to develop that technology. As a result, a greater number of high quality researchers gather from many different fields including physical science. All of this means that ALCA has brought about a new R&D system that was previously not available anywhere else.

Hashimoto (moderator):With such a focus on game-changing technologies, ALCA does not sponsor taking a different approach to R&D for existing technology. Of course this means that R&D topics need to be found from the very basic fields or areas of physical science. Many fundamental scientists fail to think about how their eventual research results might be applied, but as Mr. Kondo mentioned, it is these types of researchers who think carefully about how their results can be implemented by society when they submit research topics. One of the key objectives of ALCA was the participation of fundamental researchers who are not too focused on resolving social issues like global warming or cutting back on CO_2 emissions. In this sense, ALCA has proven to be a success. The new fields of science that lead to game-changing technologies are not limited to any particular area, but instead involve researchers from a multitude of different fields who need to work together. ALCA has become a venue where researchers from a wide range of distinctions can work with each other.

A high level of motivation for young researchers

Hanada:I felt a high level of motivation amongst the young researchers that I met during site visits (where we check on ALCA research laboratories). In my experience, I have found that young researchers show greater enthusiasm when they come across an interesting research subject in a well-equipped research environment. Developing a low carbon society is an extremely important topic with social needs, and the excellent facilities provided by ALCA help to trigger a high level of motivation.

Hashimoto (moderator):For young researchers, the 2050 low carbon society needs to be approached by those who will be living in it. Moving forward, ALCA will be looking at developing outstanding researchers who are up for the challenge of resolving key social issues with science and technology. We'll address the topic of training young researchers again later on.

The difficulty of early stage gate evaluation

Hashimoto (moderator):When R&D is conducted for game-changing technologies, there are many topics addressing high risk issues with a low potential to be implemented successfully. These need to be evaluated in a timely manner to determine whether the research subject should be continued. To achieve this, ALCA implemented a stage gate evaluation system, which is quite rare amongst academic research programs. The criteria for stage gate evaluation is based on ALCA objectives as to whether research "contributes to building a low carbon society," and not based on the value of the fundamental research. Although many general people outside the program find this difficult to understand, we actually recommended that superior research subjects such as fundamental research should be conducted at other appropriate fundamental research programs if they do not meet the objectives of ALCA. This in itself symbolizes the characteristics of ALCA.

Program Officer
Makoto Konagai
Professor, Tokyo City University

D.Eng., Appointed to current position in 2015, Professor, Tokyo Institute of Technology from 2000 to 2014, Research fields include semiconductor properties, devices, solar cells, and solar power generation.

Program Officer
Hiroyuki Ohsaki
Professor, The University of Tokyo

D.Eng. Appointed to current position in 2004, Research topics include superconductive engineering and electrical equipment engineering.

Program Officer
Tetsuya Osaka
Advisor to the Office of the President, Senior Research Professor, Emeritus Professor, Waseda University

D.Eng., Appointed to current position in 2015, The Pergamon Gold Medal in 1999, Research topics include applicable chemistry, physical chemistry, electrical chemistry and nanoengineering.

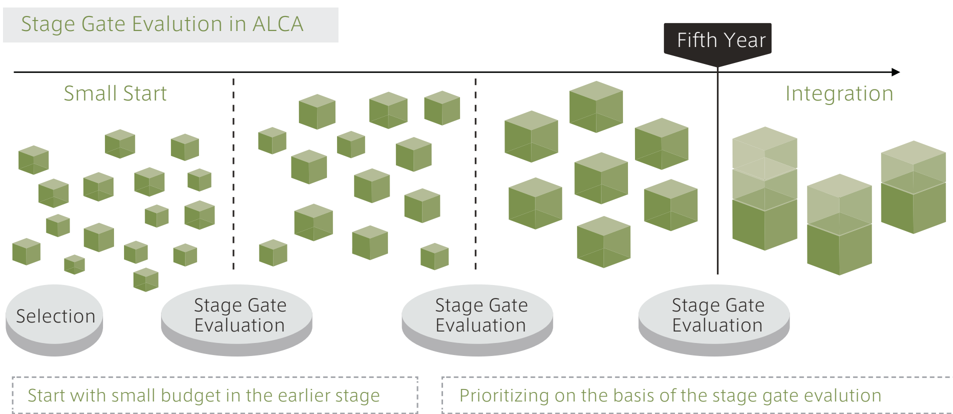
Uosaki:During the exploration stage announced in the second year of ALCA (2011), a large number of PIs were taken on with a minimal research grant for the first year. The following year, only 10% of those PIs were selected, with an increase in research grants to conduct R&D. This essentially means that the potentiality of game-changing technologies could be analyzed even in the first year. Even now, if it is difficult to determine whether or not research subjects will be feasible during the screening process, ALCA will conduct a short-term stage gate evaluation. The only drawback with this is that if the stage gate evaluation is rough and ready, the research may not have covered much ground or delivered any useful results.

Hashimoto (moderator):This is probably something that can be addressed by assessing the future potential of that particular research topic. In most cases, it is relatively clear to fundamental researchers whether their research has potential in society. The reason we conduct short-term stage gate evaluations is not because we want to see research results quickly, but to determine early on whether the research has future potential, and whether it is properly tailored to be feasible in society.

Not focusing on stage gate quantified targets

Ohsaki:In the ALCA technology field of "superconductivity systems," each research subject is based on superconductivity technology, however the target equipment and systems based on superconductor vary with each PI. In this technology area, most of them address material science, where it is likely to be difficult for the PI and Program Officer to share the stage gate targets quantified.

Uosaki:PIs tend to insist that they accomplish the stage gate target after every small achievement, however much larger hurdles to pass actually lie ahead. Instead of focusing too much on stage gate quantified targets, it is important to ensure that the ALCA research is being conducted with the underlying goal of developing a low carbon society.



How to evaluate at the stage gate in ALCA?

In ALCA, individual R&D subject is evaluated at its stage gate set in starting the ALCA project under the agreement made between Program Officer and PI, typically once or twice in the initial five years in ALCA. At the end of first five years, the stage gate evaluation is conducted and Program Director and Program Officer determine whether let them go or not to the last five years duration.

Actually it is very difficult for Program Officers to identify the potential game-changing proposals among the applications. Therefore, it is inevitably needed to adopt a large number of talented PIs with small ALCA R&D fund (Small start), to make a strict screening for the candidate game-changers, and to let them grow with the prioritization in ALCA R&D funds.

Although the stage gate evaluation system itself has been well known as the industry standard for managing new product innovation, the stage gate evaluation system in ALCA is unique and challenging in terms of attempting in the academic R&D program publicly funded.

The most difference of the stage gate process between in ALCA and in industry is that ALCA stage gate requires the potential contribution to the future low carbon society, whereas the one in industry set the quantified target and measure their achievement based on them. Since ALCA stage gate evaluation is conducted in this context, it is not done in the context of the academic or scientific merit.

Program Officer
Shuji Hanada
President,The Honda Memorial Foundation

D.Eng., Appointed to current position in 2014, Professor Emeritus, Tohoku Univ. since 2005, 1987 to March 2005, Professor, Tohoku University from 1987 to 2005

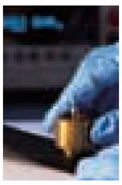
Deki:There have been numerous cases where the quantified targets have been achieved, but no new results were available.
Doi:If the goal of new science is just to meet a quantified target, the scale of that science becomes restricted. The underlying goal of 21st century science is also to create a new sense of value, as outlined earlier.
Hashimoto (moderator):Comparisons are often made with NEDO projects under another ministry, as our projects are also based on public funds. NEDO projects also focus on the development of environmental and energy-related technology, however there are more specific for quantified targets as those projects are directly linked to business opportunities. We also set a kind of quantified targets for the stage gate evaluation, however it is not important to meet all these targets. We check to make sure that projects are heading in the right direction, and have the potential to exceed our targets at some point in the future. The difference between these two is quite significant here.

Young researchers need to lead and play an active role

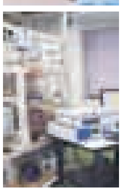
Tatsumi:There are many young PI teams with professors or associate professors acting as joint co-researchers in the ALCA project research, and it is clear that young assistant professors are doing more than enough in these cases. In this sense, the age of the PI is also one of the important criteria when we select research topics.
Kondo:ALCA definitely has a larger ratio of young PIs compared to other research programs.
Uosaki:That is certainly true. It is a good sign to see young PIs taking charge of their own research. When we conduct site visits, we see research laboratories brimming with young enthusiasm, but we also see the exact opposite sometimes. Smaller universities with projects led by younger researchers often deliver the best results. With the Japanese university system, it is difficult for young PIs to lead their own research projects, which is an issue.
Deki:In that regard, young PIs must find a source of constant funds for research, so many are giving the priority to pass the stage gate. To achieve this, there are many projects that are using young researchers as their labor force. There are concerns that the pressure of running the project or passing the stage gates may have a negative impact on the way PIs are instructing young researchers in their labs.
Taniguchi:I do feel that after we adopted the stage gate system, there has been an increase in the number of young researchers calling on the services of graduate students to help pass the stage gate. I am slightly concerned that graduate students working in such research labs will simply act like robotic researchers who are unable to think for themselves. As long as funding is coming from the Ministry of Education, Culture, Sports, Science and Technology, I would like to see, in addition to the research results, assessments checking how graduate students developed their skills.
Hashimoto (moderator):If ALCA is helping younger researchers to overcome archaic systems by applying pressure to young assistant professors acting as PIs, then I am all for it. Young researchers must lead and play an active role in order to continually develop game-changing technologies. Moving forward, ALCA needs to focus more on how outstanding young researchers are honing their skills.

Difficulty with medium-term career plans

Kondo:The use of stage gate evaluations does introduce the possibility of research projects being terminated midway, which makes it difficult to come up with medium-term career plans, and can affect recruitment opportunities with post-doctoral research. If the best post-doctoral researchers can provide their support for ALCA research, students will also be able to hone their skills more effectively.








Program Officer
Akihiko Kondo
Professor, Kobe University

D.Eng., Appointed to current position in 2007, Director, Biorefinery Center (concurrent post), Research topics include bioengineering and applied microbiology.

Program Officer
Takashi Tatsumi
President,National Institute of Technology and Evaluation

D.Eng., Appointed to current position in 2015, Director and Vice President, Tokyo Institute of Technology from 2013 to 2014. Awarded prize: Alwin Mittasch Prize (Society for Chemical Engineering and Biotechnology, Germany) in 2012. Research topics include zeolite, catalyst and resource engineering processes.

Program Officer

Kenji Taniguchi

Specially appointed Professor, Osaka University

D.Eng., Appointed to current position in 2016, Professor Graduate School of Engineering, Osaka University from 1996 to 2011, President Nara National College of Technology from 2011 to 2016. Research topics include semiconductor physics, integrated circuit manufacturing processes, semiconductor devices, and analog integrated circuit design.

Program Officer

Kohei Uosaki

Principal Investigator, National Institute for Materials Science

D.Sc.,. Appointed to current position in 2013, Professor Emeritus, Hokkaido University since 2010, Awarded prize: BCSJ Award in 2009, Surface Science Society Award in 2014, Research topics include surface physics and chemistry, and interface energy conversion.

I feel that we need to look at ways to find the best method to have the top post-doctoral researchers working with ALCA.

Doi:I wholeheartedly agree with post-doctoral researchers working at the same place for 3 to 5 years. Yet staying at the same place for too long introduces its own set of problems. ALCA is running some research projects that have run continuously for more than 10 years, yet we want to avoid post-doctoral researchers working at the same laboratory for that long.

Hashimoto (moderator):The issue with post-doctoral research is not limited to ALCA, but is present all around Japan. This comes from the fact that science and technology policy in Japan was strongly biased to competitive funding. Post-doctoral research is limited to 3 to 5 years with competitive funding, but the fact that ALCA is unable to provide any assurance for even 3 years remains a problem. Even now, there are national efforts to develop systems where young researchers are able to work with more reliable funding, rather than on research projects. One proposed solution for this is for staff and graduate students to work together until the first stage gate, and after passing that stage gate, they are provided with a more stable research environment where post-doctoral researchers can also join in.

Are the best teams being formed?

Uosaki:I'd like to point out a few issues with the team-based ALCA research. With team-based research, I find that there are more cases where team members join based on their personal relationship with the team leader, rather than the real need or suitability of team formation. As a result, the quality of the team is not always appropriate. Another issue is that team members are largely unaware of the underlying targets of ALCA, and research may be considered to be an extension of existing technology, rather than challenging game-changing technologies. It is problems like these that need to be addressed and corrected with stage gate evaluations. Team leaders need to select their team members and let them focus on research, yet members selected based on their personal relationship with the leader make it difficult to implement any serious decisions. Under conditions such as these, it is important for Program Officers running stage gate evaluations to ensure that the research system is operating in the optimum manner.

Hashimoto (moderator):If we think about whether the best teams are being formed to achieve ALCA's research targets, our message to future researchers is that ALCA will not allow researchers to join projects simply because they get along well with the team leader.

Young researchers of today will have a leading role in 2050

Kondo:We would like to see young researchers selected by ALCA developing their own fundamental skills required for playing an active role in 2050, during the course of the research at ALCA.

Osaka:To achieve this, it will be important to provide young researchers with an environment where they can focus solely on their research based on quality guidance.

Hashimoto (moderator):So the most important factors for outstanding young researchers are to provide them with the best environment for research, as well as a venue where they apply their skills. To achieve this within ALCA's budget, the best approach must surely be providing a stable research system after passing through stage gates. As mentioned earlier, the ideal research system after young PIs are selected by ALCA will be to work tirelessly with students, pass the stage gates and continue working in a stable environment where they will be joined by other young post-doctoral researchers. We are hoping to implement such a system.

Program Officer

Shigehito Deki

Professor meritus,Kobe University

D.Sc., Appointed to current position in 2015, Extraordinary Professor, Fuel Cell Nanomaterials Center, Univ. of Yamanashi from 2009 to 2015, Research topics include inorganic chemistry, electrical chemistry, surface chemistry and solution chemistry.

Further cooperation with industry

Ohsaki:ALCA values its partnerships with industry players, however as cooperation takes on many different forms, there needs to be a certain amount of flexibility present.

Tatsumi:Cooperation with industry players is vital in order to set effective stage gates. Young researchers in particular do not seem to have a proper understanding of the way commercialization or industrialization works. It is definitely the industrial world that can provide the most appropriate advice based on technological needs in industry. With this in mind, there needs to be some form of co-operation with industry. Projects are run by academia, so industry members can first act as advisers, however industry circles want to see results in the projects that will lead to bigger things in the future. If ALCA research can act as a bridge connecting the technologies required by business, it will be useful in many different ways. To ensure that stage gates remain effective, cooperation with industry will be essential into the future.

Kondo:Individual fundamental researchers may find it difficult to work with businesses immediately. One of the roles of the ALCA community should be to encourage partnerships by introducing companies that seem suitable for cooperation to researchers. Systematic initiatives need to be bolstered to forge partnerships with suitable companies at the ideal time, so that the results of ALCA research can be rolled out to society.

Hashimoto (moderator):In the case of ALCA, rather than just allowing any new concept to be developed, we ideally want to coordinate research while acquiring data on whether research will lead to actual technologies when viewed from a business perspective.

Better post-doctoral research

Doi:Adopting team-based research under the concept of "science for better science" generally results in researchers from the same field coming together, making the research even more specialized. Yet with ALCA's target of developing a "low carbon society," teams are formed by researchers from a range of different fields. With this type of research team, researchers hone their skills with each other, and become better researchers as a result. It does remain difficult for young researchers to act as team leaders and coordinate the entire team, so it might be better for ALCA to develop a co-working system with one young researcher and one post-doctoral researcher.

Deki:Research funds provided to team-based research are more substantial than individual research, however as there are more researchers that participate in the team, the amount per head is not actually that much. In many cases, teams have a priority in buying some experiment equipment, with many lacking the funds to call on post-doctoral researchers. The system needs to be fine-tuned so that post-doctoral researchers can join the team, otherwise they end up using students or trying to complete the research quicker. A more efficient approach to management is required for team-based research. There are various possible strategies available, such as teams hiring a post-doctoral researcher and assigning them to each different

Hashimoto (moderator):It has been 5 years since the launch of ALCA. We hope to continue conducting R&D with the view of achieving our target of developing a low carbon society. In addition to the aim of implementing this technology throughout society, ALCA will also strengthen its fundamental research efforts. This may prove difficult at times, but we consider this our mission, and will remain committed to achieve it. Thank you for your time today.

Program Officer
Kohmei Halada
Senior Special mission Scientist, National Institute for Materials Science

D.Eng., Appointed to current position in 2012, Director, Research Center for Strategic Materials, National Institute for Materials Science from 2009 to 2011, Research topics include metal engineering, ecomaterials and LCA.

Program Officer
Yoshiharu Doi
President,Japan Synchrotron Radiation Research Institute

D.Eng., Appointed to current position in 2013, Professor, Tokyo Institute of Technology from 2001 to 2004, Director, RIKEN from 2004 to 2013, Research topics include biodegradable polymers.

TEAM ALCA

TOGETHER EVERYONE
ACHEIEVES MORE

Mr. Akitsugu Koga
Director

Dr. Hideki Yoshida
Manager

Mr. Kenji Kaibe
Chief

Mr. Yasuhiko Amano
Chief

Ms. Tomoko Terakado
Research Advisor

Dr. Toshiharu Tominaka
Chief Research Advisor

Dr. Yoshihiro Arimoto
Chief Research Advisor

Dr. Tetsumasa Ito
Chief Research Advisor

Mr. Shinichi Hosaka
ALCA Management Advisor

Dr. Kunio Kikuchi
Research Advisor

Mr. Koichi Sugiura
Research Advisor

Creating the Low Carbon Society

Towards the future, ALCA will play more important role in implementing game-changing technologies throughout the society by the year 2030.

CO_2 emissions have also increased in Japan since the East Japan Great Earthquake Disaster in 2011 that caused accident at Fukushima Daiichi nuclear power plant mainly because Japan has grown increasingly reliant on fossil-fuel-based energy.

In June 2015, the Japanese government set its new energy policy for the country's optimal "energy mix" for 2030 that consists of 22-24% from renewable energy. On the other hand, coal still would account for 26% with LNG for 27%, although whole fossil-fuel-based energy would decline to 56% from the current 88%. That suggests that fossil fuels will continue to be a dominant part of the "energy mix".

Reducing CO_2 emissions and creating a low carbon society, developing renewable energy sources, high-efficiency thermal power stations and other technologies related to energy generation, energy storage, and energy saving have become so important.

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ALCA

Change the game with technologies!

Advanced Low Carbon Technology Research and Development Program

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Japan Science and Technology Agency

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