ALCA Breakthrough

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

Kazuhito Hashimoto,
Program Director, ALCA

The reason why I entitled such high-handed like this title today 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 the low carbon technology. However, improving the existing technologies cannot reach such an ambitious goal. Thus, the creation t of such game-changing technologies is a “mission” 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

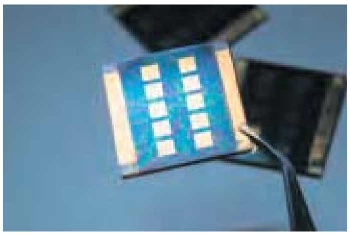
The JST established ALCA as a new research program in 2010 to create innovative technologies – which we call game-changing technologies - to drastically reduce GHG emissions. We aim to contribute to the global reduction of GHG emissions. Therefore, we are not satisfied with the development of excellent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

In the ministry-related research programs, almost all projects have their 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 a practical application in as short a time period as ten years. As mentioned above, we aim to develop technology to reduce CO_2 emissions by 2030. However, even if such an innovative technology as can contribute to solving the global warming problem were invented around 2030, it would only be able to make actual contributions in 2050 or beyond. Therefore, ALCA is positioned to develop technologies by 2030, back-casting from future low carbon society in 2050.

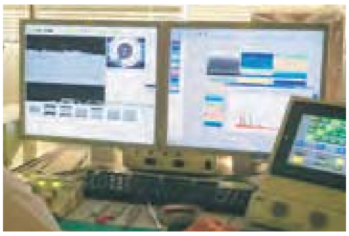
Small-start and stage-gate evaluation system

We set the smaller research budget size with the aim of adopt many challenging PIs under a limited budget. We call this way the “small-start” system. In this system, the initial number of ALCA PIs is narrowed through stage-gate evaluations; the PIs will be more funded than before 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 were skeptical of the stage-gate system. In fact, some criticized our approach, saying, “basic research cannot be resulted in such a short-term”. We thought that it was absolutely right. We do not conduct the stage-gate evaluation, expecting such short-term results, but attempting to direct the ALCA PIs towards the ALCA target that 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 empha-





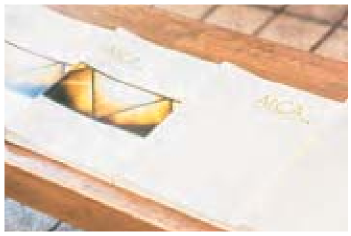












size that the evaluations are based on the potential contribution to the ultimate goal of ALCA, and we do not determine only on the scientific view.

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 a 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 consider that it is 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 (METI), Trade and Industry 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, heat resistant materials, etc., to promote research and development in each technological area.

As a wide range of research areas are dwelt in 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 the project, and 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, PO has to pay more attention to the project management. In order to practice it, 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 a 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 PO actually visits the PIs and offers advice on the spot 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."

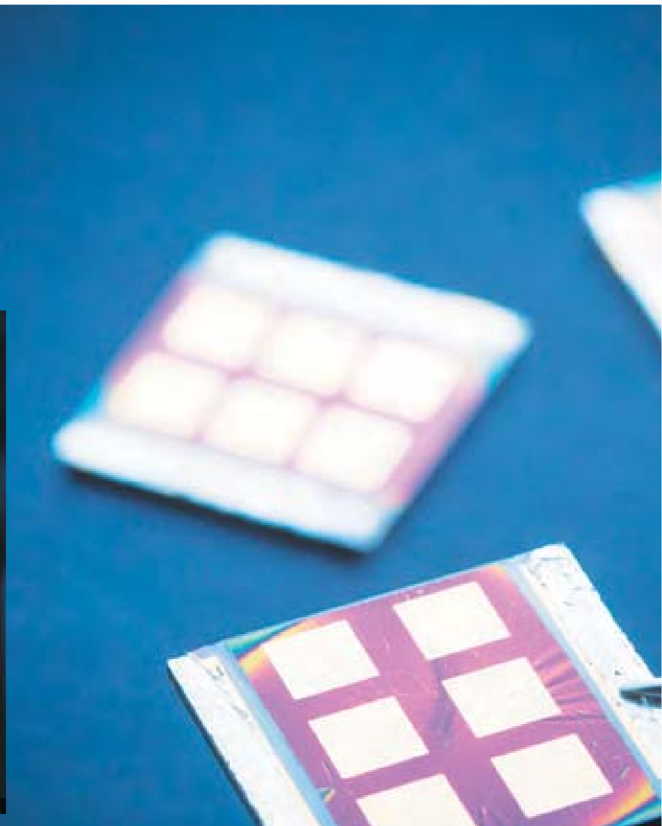
How to identify the bottleneck problems and solve them

It has been six years since the launch of ALCA. As Program Director, I am keenly find it important to first identify specific bottlenecks in the research and development of low carbon technologies, and then pursue the solution 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 inhibit the research and development. I think that it would be desirable to bring together the wisdom of experts for experts and experienced people 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 the open call.

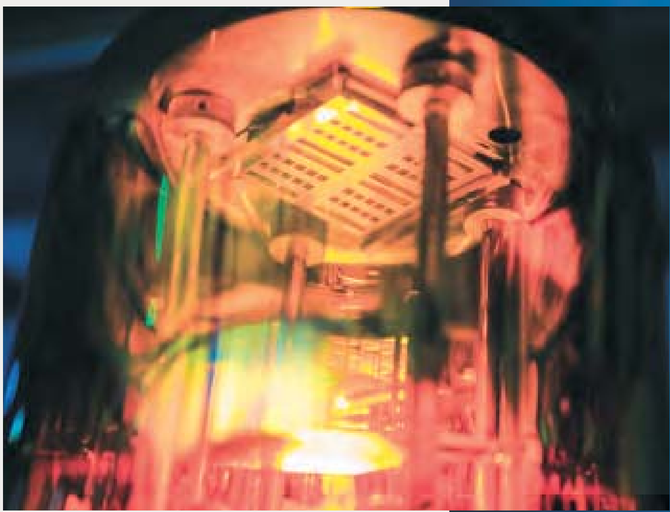
We intend to promote research and development while remaining keenly focused on the societal implementation of the research results in the future. In addition, we would like to set up more ALCA research areas for top-down type management. The three elements of small-start funding, stage-gate evaluation,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

Photovoltaics

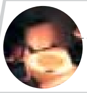


Vacuum deposition of Au counter electrode



Thermal annealing of a perovskite film on a hotplate

Perovskite film casting by spin-coating method



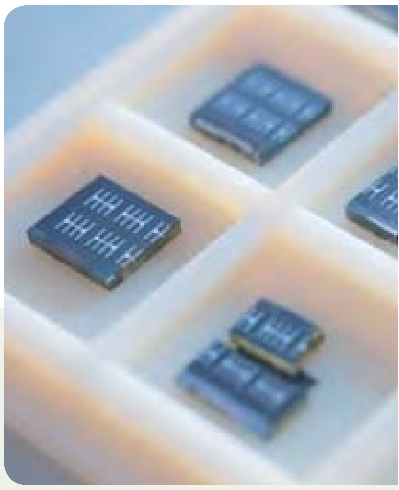
Tomoyoshi Motohiro
Professor, GREMO, Nagoya University

A concept model for an automobile system with electricity feeding part by a laser beam

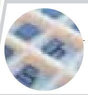
Sunlight-induced lasers installed at regular intervals along a road irradiate a laser beam into a solar battery on the roof of an automobile. The battery is instantly charged with sufficient electricity to run the automobile to the next irradiation site. This system allows continuous long-distance driving with a small capacity battery carried on an automobile.

Photovoltaics

Solar cells are one of the most promising technologies for the solar energy utilization among renewable energy resources. Currently, Si-based solar batteries are being implemented. ALCA promotes the development of the next generation solar cells, aiming to further improve power conversion efficiencies and lower production costs. Recently, ALCA has focused on perovskite-type solar cells, which is emerging among the solar cell research in the world. Dr. Miyasaka, of Toin Yokohama University, pioneered the perovskite-type solar cell and has been leading Research & Development of these solar cells at ALCA PI since 2015.



$Cu_2ZnSn(SSe)_4$ thin-film solar cells

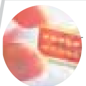


Akira Yamada
Professor, Tokyo Institute of Technology

Photovoltaics

Perovskite solar cells
(active area: 0.25 cm²)

Reddish purple part is a lamination film of perovskite/organic hole transport material. Each gold square operates as a photovoltaic cell



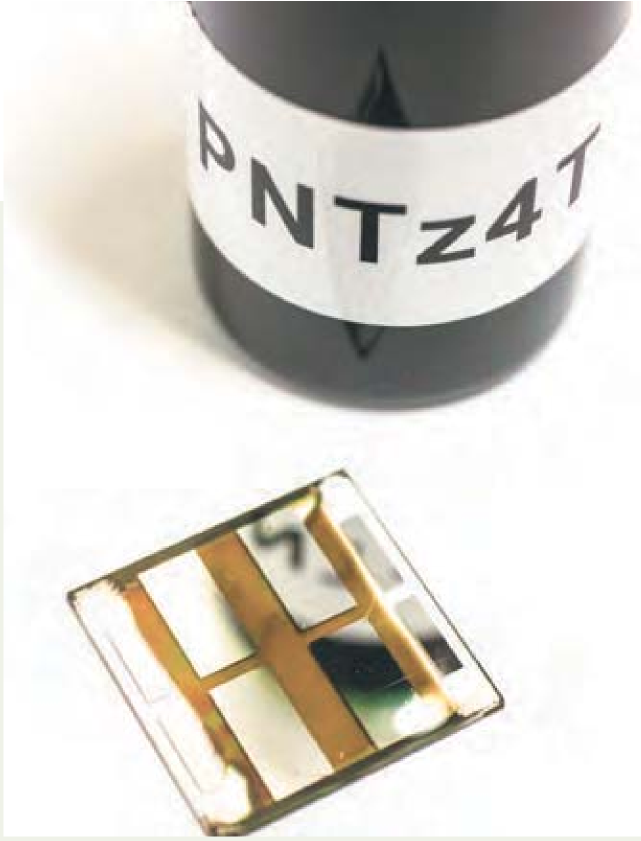
Tsutomu Miyasaka

Professor, Toin University of Yokohama

Perovskite solar battery

The solar batteries with a perovskite structure, which Professor Miyasaka himself discovered, are characterized by high conversion ratios close to those of the market, and by their simple manufacturing process. These characteristics now make them one of the most studied classes of solar batteries in the world.

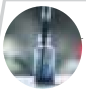
Fabrication perovskite solar cell device in the dry and clean room



Developed polymer ink (above), solar battery manufactured by painting (below)

Pipetting the polymer ink

Measurement of the properties of a solar battery by irradiation with simulated sunlight



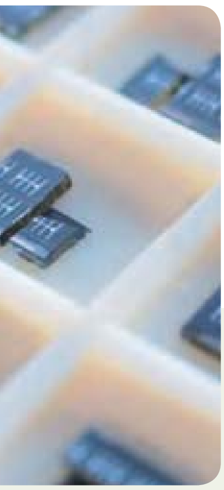
Itaru Osaka

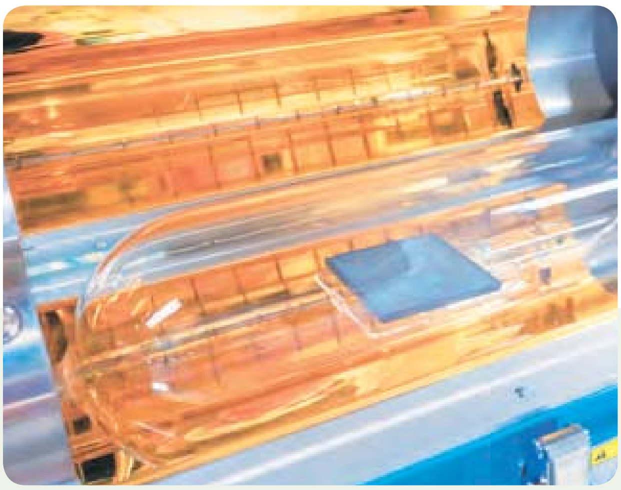
Senior Research Scientist, RIKEN

FY2016 : Professor, Hiroshima University

Polymer solar battery

Organic thin-film solar batteries are produced by a printing method using a semiconductor polymer. The battery is characterized by its light weight, flexibility, and conversion ratio of over 11%.





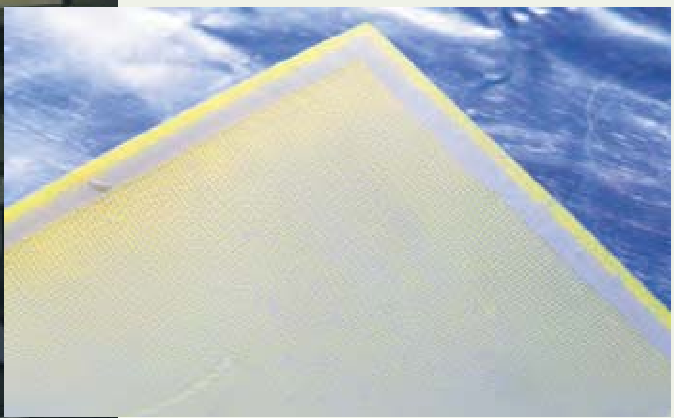
Annealing furnace for $Cu_2ZnSn(SSe)_4$ films

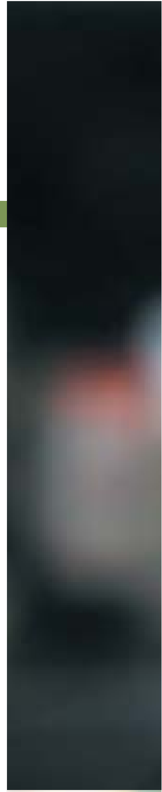
Chalcopyrite solar cells

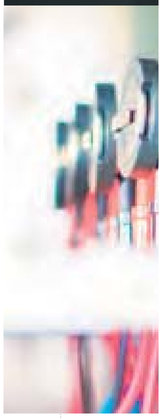
A chalcopyrite material, $Cu_2Zn(SSe)_4$, is used in a low-cost painting process to produce solar cells that achieve a conversion ratio of 9.1%. Currently, previous findings are being utilized to attempt to develop a high conversion-rate tandem solar cell based on perovskite and chalcopyrite materials.

Three-dimensional regular structure projected onto a screen

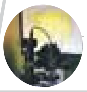

A thick cathode layer membrane ($LiCoO_2$) formed on a solid electrolyte.


Solid electrolyte with hole-array structure
Both strength and a high-speed electrical charge and discharge properties have been achieved.





Storage


Kiyoshi Kanamura
Professor, Tokyo Metropolitan University

Elemental technology supporting next generation batteries

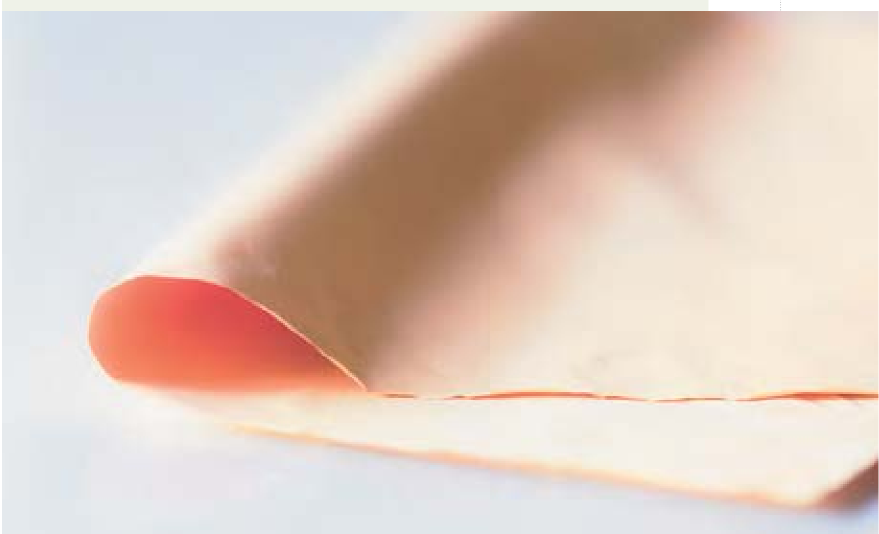
Batteries are devices that are composed of elemental technologies such as electrode materials, electrolytes, separators, etc.

3-Dimensionally Orderd Macro-porous (3DOM) separator with a regularly arranged bottleneck structure (pore size: 300 nm)

Lithium metal dendrite formation can be suppressed by using this 3DOM separator, resulting in almost no internal short circuit in batteries.

Energy Storage

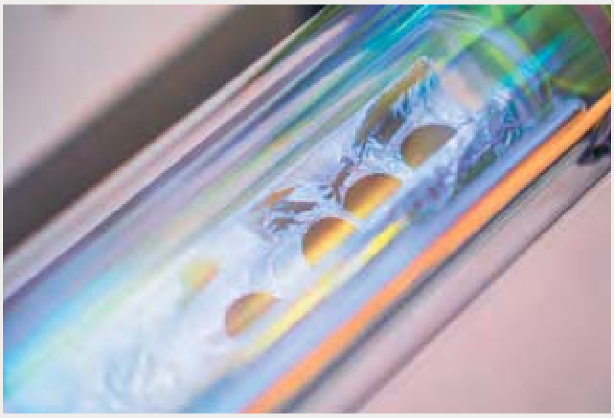
Energy storage devices, such as secondary batteries and capacitors, are key technologies for electric vehicles and a stable renewable energy electricity supply. ALCA promotes the research and development of next generation batteries, such as all-solid-state batteries and lithium-sulfur batteries, as a priority technology area.



"Solvated ionic liquid" used as a non-inflammable electrolyte.

A "solvated ionic liquid" is used to solve the problem of the sulfur cathode eluting into the liquid electrolyte in Li-S batteries.

Trial-manufactured Li-S batteries in an electrical charge and discharge test



A cathode for trial-manufactured batteries during the drying process

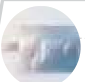
Glass oven for drying trial-manufactured cathodes

Masayoshi Watanabe

Professor, Yokohama National University

Li-S batteries

Li-S batteries, which use sulfur as an active cathode material of cathode, are low-cost and have a high theoretical capacity. The biggest problem of the sulfur cathode is its degeneration as the reaction intermediates dissolve in the electrolyte. The use of a unique solvated ionic liquid as the electrolyte is intended to resolve this problem to enable the practical application of such batteries.



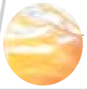
Wataru Sugimoto

Professor, Shinshu University

A hybrid capacitor composed of aqueous electrolyte and solid one (AdHiCap™)

High energy density and safety were achieved by combining a water stable battery-type anode and a pseudocapacitive cathode with high capacitance.

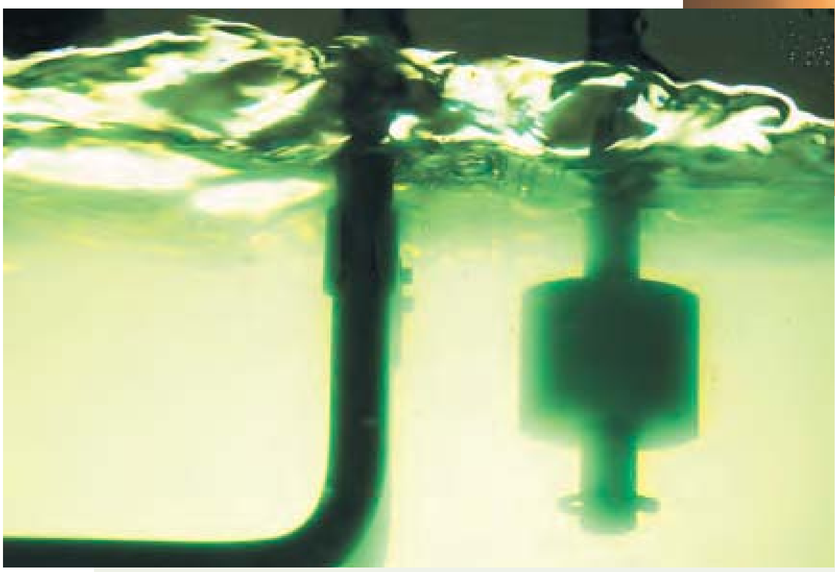
Cathode pseudocapacitive material with high capacitance (colloidal solution of ruthenium oxide nanosheets)



Yasuhiro Kashino
Associate Professor, University of Hyogo

The brown liquid medium with diatom

The brown liquid medium contains diatom cells (~10μm). This brownish color depends on the characteristic of light absorption by unique accessory pigments that assist highly efficient photosynthesis.



Takashi Osanai
Assistant professor, Meiji University

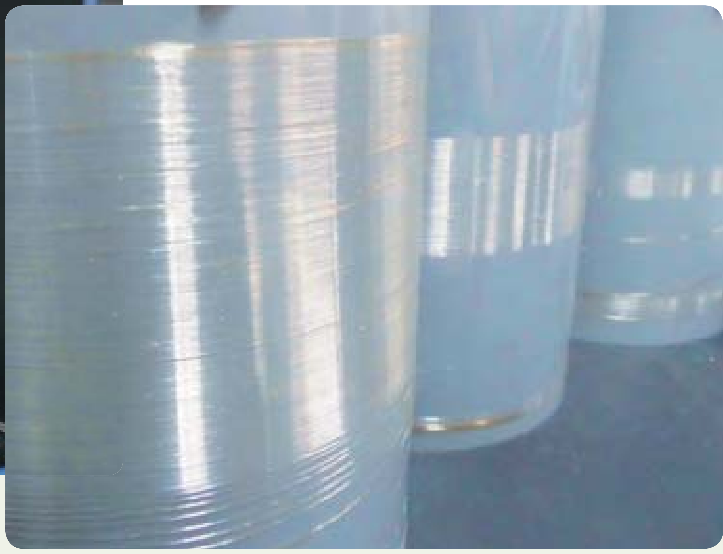
Seawater cultivation of a freshwater cyanobacterium *Synechocystis* sp. PCC 6803

In this study, we have found that unicellular, freshwater cyanobacterium *Synechocystis* sp. PCC 6803 cells can grow in seawater supplemented with nitrogen and phosphorus sources.

White Biotechnology

White biotechnology, in which chemicals are produced from biomass, can make significant contributions to reducing CO2 emissions. ALCA has been promoting innovative elemental technologies, such as (i) the increase in production of algal biomass, including diatoms and blue green algae, (ii) the synthesis of polymer materials using microorganisms, and (iii) the development of solid catalysts for the synthesis of backbone polymers based on biomass.

Non-natural-type polysaccharide polymerized in vitro by using an enzyme cloned from a tooth decay fungus



Melt-spun fibers processed from polysaccharide ester derivatives

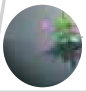
The melt-spun fibers were processed from ester derivatives of ß-1,3-glucan, one of polysaccharides, synthesized by a microorganism. The fibers show high-thermal stability at the same level as nylon.

Tadahisa Iwata

Professor, The University of Tokyo

Polysaccharide bioplastics

Natural-type polysaccharide or the polysaccharide prepared through enzymatic polymerization are used as raw materials to attempt to create high-performance bioplastics.

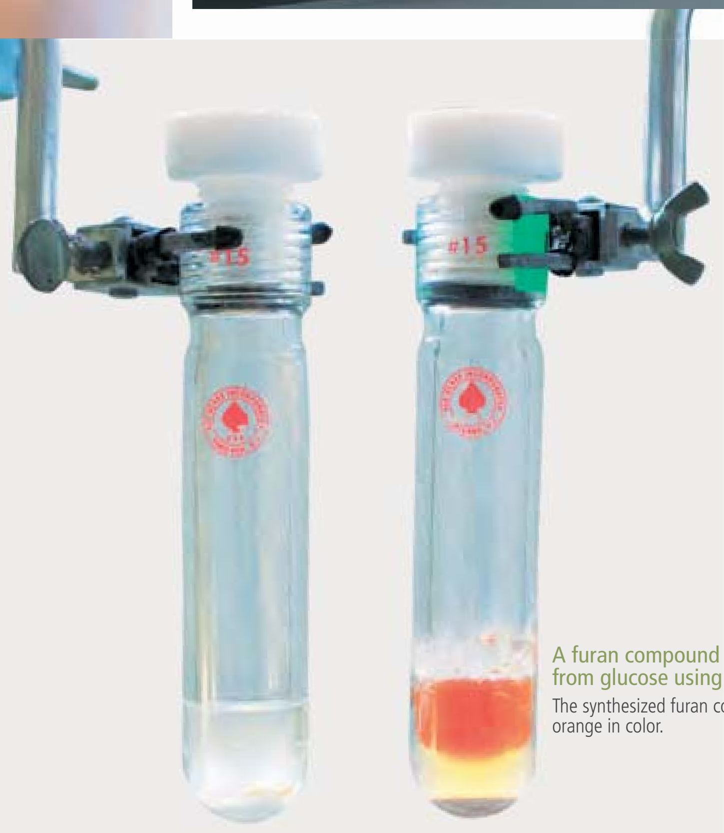


Masatoshi Iji

NEC Corporation Research Fellow

Cellulose bioplastic embodying exquisiteness of Japanese traditional lacquerware

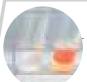
Coloring technology, which was developed for a cellulose resin with a jet-black appearance, Urushi black, has been applied to a resin under development in ALCA.



A furan compound synthesized from glucose using solid catalysts

The synthesized furan compound is orange in color.

Developed solid catalyst



Michikazu Hara

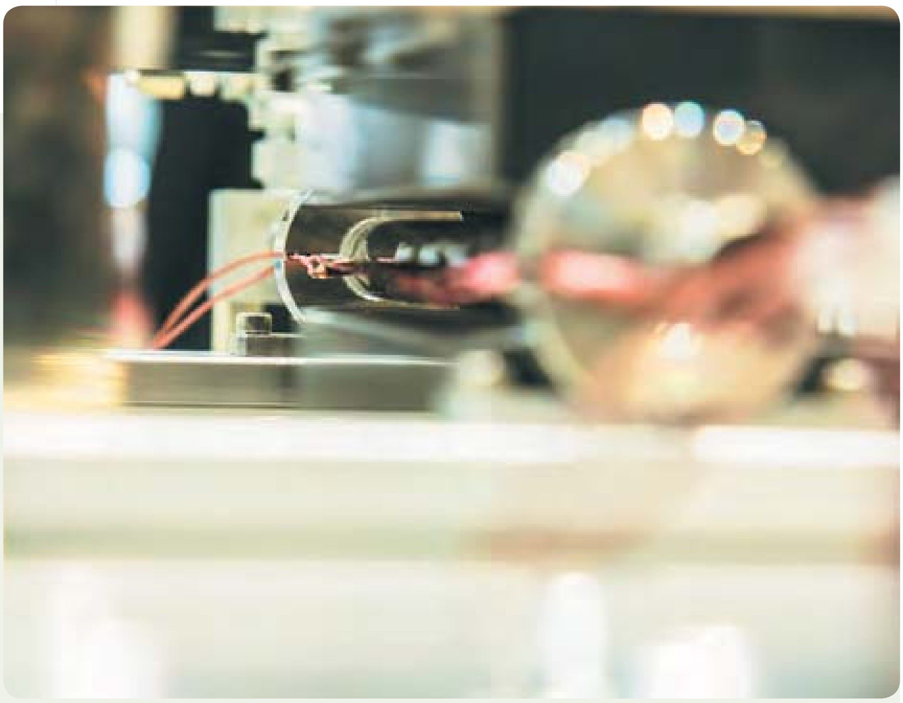
Professor, FRC, Tokyo Institute of Technology

Development of multifunctional heterogeneous catalysts

Glucose from cellulose-containing biomass is used to establish manufacturing technologies for furan based monomers.

Waste Heat Recovery

A considerable amount of heat is lost via waste heat from industrial plants, transportation, and residences. "Waste heat recovery" is the approach to improve overall energy efficiency and avoiding emissions of GHG by capturing and reusing this lost heat; this waste heat is intrinsic to all manufacturing processes and transportation systems. ALCA currently promotes research and development into advanced waste heat recovery technologies, such as "thermoacoustic engines" that use waste heat below 300℃ for electricity generation, freezing, and heating and "highly efficient steam engines" that use waste heat below 100℃. The alternative freon for refrigerants has a high global warming coefficient. To solve this problem, ALCA promotes research and development of "magnetic heat pumps," which have high efficiency heat exchange with no refrigerant.



Magnetic heat pump device

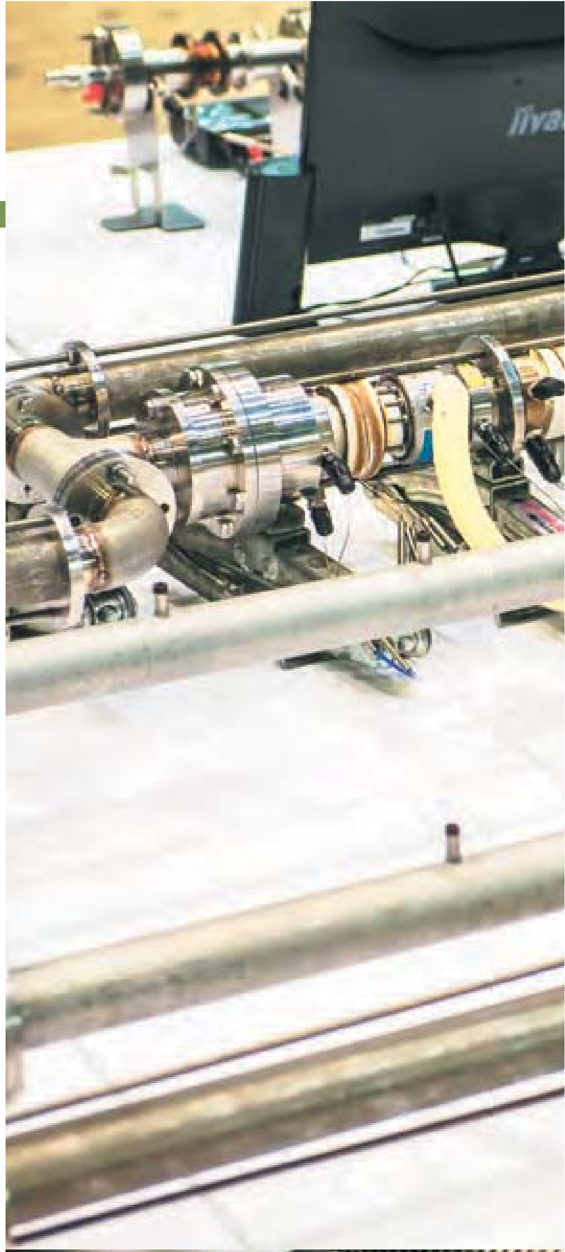
Tsuyoshi Kawanami
Associate Professor,
Kobe University

FY2017: Associate Professor,
Meiji University

Highly efficient magnetic heat pump with no greenhouse gas

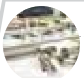
A heat storage regenerator based on the principle of heat absorption and generation by altering the magnetization direction of a magnet (magnetocaloric effect).
Development of a heat storage regenerator with multi-device structure to expand the temperature control range.

Mn-based Magnetocalonic material



Thermoacoustic refrigerator

Condensation (above) due to the temperature difference with room temperature; further freezing (right)

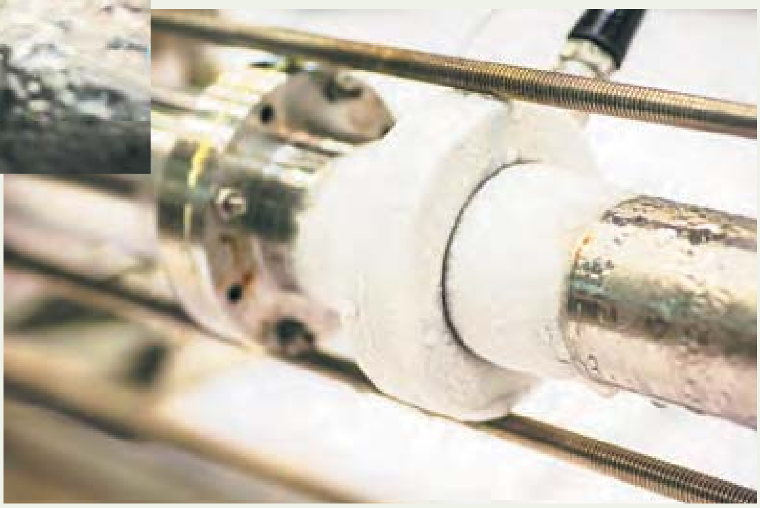


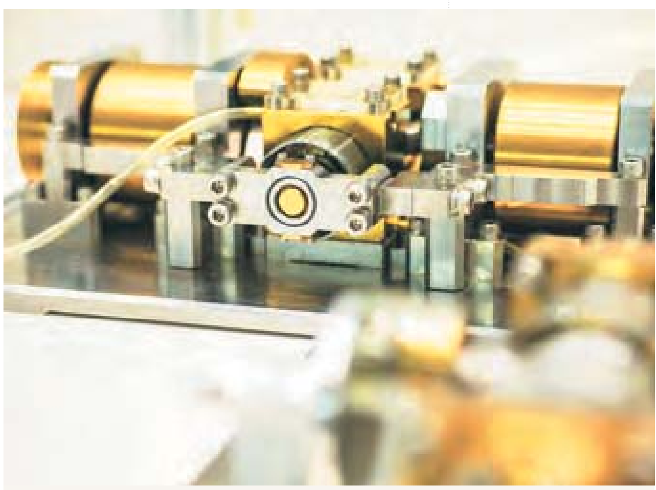
Shinya Hasegawa

Associate professor,
Tokai University

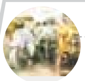
Thermoacoustic refrigerator

A thermoacoustic engine is an external combustion engine based on the Stirling cycle. It has the potential to take work out of multiple heat sources such as a combination of industrial waste heat. In this study, we designed and build a prototype of a traveling-wave thermoacoustic refrigerator driven by a multistage traveling-wave thermoacoustic engine. The refrigerator achieved a minimum cold temperature of -107.4°C when the hot temperature was 270°C.





Vibrationless cross balance reciprocal expander unit used for a trilateral steam cycle



Naoki Shikazono

Professor, IIS,
The University of Tokyo

Highly efficient steam engine using low-temperature waste heat

This work aims to develop a highly efficient trilateral steam engine with a new gas-liquid two-phase expansion unit, which allows us to use low-temperature waste heat.

ALCA

Change the game with technologies!

Discussion

Looking ahead for ALCA: Towards a Low Carbon Society

Kazuhito Hashimoto (PD)

Chairman of the Board of Directors, National Institute of Materials Science

Government public office positions (as of June 2016): Councilor of Science Council of Japan, Councilor of Council for Science, Technology and Innovation, Cabinet Office, Research topics include photocatalysts, environmental science and energy conversion.

Kohei Uosaki (PO)

Fellow of the National Institute of Materials Science, Head of Core Energy and Environment Materials Research, National Institute of Materials Science

ALCA Tech Area PO "Feasibility Study"(2011), "Innovative Energy-Saving and Energy-Producing Chemical Processes"(2012), "Next Generation Batteries"(2013~), Research topics include surface physics and chemistry, and interface energy conversion.

Tetsuhiko Ikegami

Visiting Researcher, National Institute of Science and Technology Policy, Ministry of Education, Culture, Sports, Science and Technology

Senior Vice President, NTT Corporation, Former President, University of Aizu, JAPAN, Research topics include telecommunications, optoelectronics, semiconductor device.

Kazuhiko Hombu

Visiting Professor, Graduate School of Public Policies, University of Tokyo; Managing Executive Director, Taisei Corporation

Deputy Director-General for Energy, Environment and Exposition, Ministry of Economy, Trade and Industry, JAPAN, Research topics include energy policy, climate change policy.

Hashimoto (moderator)

I would like to welcome the panelists: Dr. Ikegami and Mr. Hombu, external committee members; Dr. Uosaki, ALCA program officer; and Dr. Mori, ALCA PI. The panelists are asked to present their respective positions and discuss the expectations for and issues with ALCA towards the formation of a low carbon society. I would first like to ask Dr. Ikegami, Mr. Hombu, and Dr. Uosaki to deliver their lectures, and then we will move to a plenary discussion session.

Tetsuhiko Ikegami

The ALCA international evaluation meeting was held in March 2016 with a committee of eight members, four Japanese members and four from overseas. The work lasted for three days. They visited research sites in Tsukuba on day one, heard from 12 program officers, including Dr. Hashimoto, on day two, and conducted a general review on the last day. To encourage free discussion, the meetings followed Chatham House rules, in which neither the identification nor the affiliation of the speaker was revealed. This encouraged committee members to participate actively in the discussions. The results of the evaluation are briefly described below.

Challenges of the stage-gate system

We found it very unique to use a stage-gate evaluation system in academic research programs. While there is a tendency to assign an industry person as director for a basic research program, with the aim of future industrialization of basic research results, it is appropriate that Dr. Hashimoto conducts a basic research program within academia.

Stage-gate systems have been used by private enterprises when research and development is reviewed and improved at each gate, instead of using a bureaucratic evaluation. The committee considered whether this stage-gate evaluation system worked well for a basic research program.

We knew that a quarter of the initially adopted research themes would be allowed to continue for five years after several stage-gate evaluations. These data indicated that the stage-gate evaluation system was functioning in practice. However, it came to our attention that new challenges are not easily generated for fear of rejection under this system.

Further improvement of international collaboration

It is important for all ALCA researchers to envision research results for the "realization of a low carbon society." In addition, it has been pointed out that it might better to introduce commercialization onto the roadmap for progress management. Peer review by experts in each field of study is necessary to avoid the self-righteousness of researchers. I personally had the impression that the peer review system was functional at ALCA. However, overseas members of the committee consider it inadequate. It is necessary to have a venue for international, open discussions in the future.

Although ALCA deals with global issues, such as the "realization of a low carbon society," it may be that ALCA does not have adequate international collaboration, and I would like to study this matter from multiple perspectives. It is also an issue that ALCA has limited diversity with few female researchers as program officers or PIs.

We believe the nine ongoing technology areas need to be combined or abolished in the future, and we recommend that reorganization should be based on the impact and importance of low carbon technologies.

Overall, the committee gave a positive evaluation and indicated that the research programs are excellent. The committee chair was tired after three days of hard work. However, I believe all members had fulfilled their duties as all of them expressed satisfaction with the process.

Kazuhiko Hombu

Disseminating low carbon technologies among populous countries

In 2010, at the time of ALCA's launch, I served as deputy director of the Resource and Energy Agency, and I was Japan's chief negotiator for the UN's Convention on Climate Change. I think it is necessary to have a research program specifically for solving global warming issues. Therefore, I felt honored to participate in ALCA as an initial member of the evaluation committee. The new Paris Agreement is significant because advanced nations and developing countries have agreed to share responsibility for the first time at the UN. However, the objective of "keeping a global temperature rise this century well below 2°C above pre-industrial levels " is extremely difficult to meet.

In my experience as a policy maker in energy, it is necessary to disseminate low carbon technologies throughout the populous countries, such as China and India. To achieve this, the technologies need to be implemented at a low cost. I would like to emphasize that the social implementation of low carbon technologies has aspects quite different from other technologies.

The stage-gate system used at ALCA is excellent because the evaluation includes consideration of the social impact of low carbon technology. To ensure the stage-gate system is used effectively, I suggest we (i) pay careful attention to the competitors and (ii) conduct the evaluation systematically rather than on individual technologies.

Kohei Uosaki

Research and development of next generation batteries involving ministries and agencies

Among the eleven ALCA program officers, only I have served as program officer for both bottom-up and top-down research programs . I am going to talk on the basis of this experience today.

Although the stage-gate evaluation resembles a sieving process, we consider it to be a way to identify and encourage game-changing technologies. The stage-gate evaluation is likely to be more effective in bottom-up than top-down ALCA technology areas for promoting promising research.

When the next generation batteries project was launched in 2013 as a top-down research project, I was appointed as the program officer. Batteries are composed of various elemental technologies and we had to integrate them into the battery system. Batteries are one of the core technologies in the Japanese industrial structure. In fact, battery technology is prioritized among all the ALCA technology areas. We were very conscious of this situation as we conducted our program operations.

We are developing next generation batteries that could be superior to Li-ion batteries. Even at this early stage, we are getting industry members involved as project committee members to incorporate their viewpoints in future products.

This project was also identified as a key technology field during the joint conference of the MEXT (Ministry of Education Culture, Sports, Science and Technology) and the NETI (Ministry of Economy, Trade and Industry). A counterpart project is simultaneously proceeding at NEDO, a METI-related organization. The two collaborate to aim for future commercialization.

Dr. Hashimoto PD (moderator)

Although Mr. Hombu stated that "low carbon technologies must be low in cost to be disseminated in India and China," a Japanese industry person said, "competitive price in technologies is a serious problem." Between such a set of contrary opinions, I am troubled by this dilemma in the development of low carbon technologies.

Mr. Hombu

Technologies to be spread globally

Inherently low carbon technologies should be disseminated in the global market because they can help meet global targets for the reduction of CO_2 emissions. We should not confuse this with management matters, such as how to collect the initial R&D costs.

Low carbon technologies developed in advanced nations will spread globally with cost reductions, which means changes in the industrial structure. Businesses may not be able to survive unless they change in response to such structural changes.

However, now is not the right time to continue with this discussion. During stage-gate evaluations, it would be important, I think, to identify technologies that can spread globally and solve the global warming problem in the future.

Dr. Mori

Pausing both high value-added and lower cost technologies

Our technologies may be able to spread products with high value-added at low costs. First, GaN point seed crystals can be high value-added products because they have such a small volume that they can easily be distributed in the market. If large Japanese companies succeeded in commercializing low cost products on the basis of GaN point seed crystals, the venture firms could take charge of this highly profitable step. Specifically, after wafer makers produce bulk crystals from GaN point seed crystals, device makers could use them as a component; then these could spread widely as end products.

Dr. Uosaki (PO)

Can market share be maintained through market expansion?

Regarding next generation batteries, Japan's market share of secondary batteries has decreased rapidly during world market expansion. I fear that next generation batteries, in which we now lead the world, may follow the same path when they are put to practical use and spread more widely in the future.

Dr. Ikegami

It is also important to provide a social contribution

I used to be engaged in the research and development of optical fiber at the NTT (Nippon Telegraph and Telephone Corporation) research center. Optical fiber has improved communications infrastructure in developing countries. We might not have been able to continue to develop this technology if NTT had not been a public corporation.

Dr. Hashimoto PD (moderator)

Researching business models

It is strategically important to have many kinds of competitive technologies in the global market. About 15 years ago, Japan accounted for nearly 100% of Li-ion rechargeable battery production when they were first commercialized by Sony and Asahi Kasei, two Japanese companies. Furthermore, Japan held 70% of the patents for Li-ion batteries. However, South Korea surpassed Japan in Li-ion battery production about three years ago.

In addition to social contributions to mankind, as Dr. Ikegami pointed out, it is also important to steadily construct the business model. Along with the research and development of next generation batteries at ALCA, we are designing the business model for the research and development of next generation batteries with the participation of external experts.

Dr. Hashimoto PD (moderator)

Let us move to the topic of R&D management. We are operating our academic research programs in unconventional ways, in which the Program Officers give research directions to PIs or make a decision based on the stage-gate evaluation. We believe that it is necessary to take such a top-down approach for basic research programs of a certain problem-solving type, such as ALCA. You may have various criticisms. Please present approving or disapproving comments.

Dr. Uosaki PO

Leading researchers to form strong patents

Intellectual property (IP) management has become very important. Actually, we sometimes advise the ALCA researchers to obtain more data in order to reinforce a patent application, aiming to build a battery-related patent portfolio with global competitiveness. A sense of urgency is required for IP strategies; it would be a slow process for students trained under a professor's direction. Therefore, program officers have sometimes been encouraged to employ a technician for patent data, using their discretionary fund to accelerate patent applications. Generally, the program officers have given detailed advice and direction to the ALCA PIs, and such an approach has enhanced this individual research among the ALCA projects.

Dr. Mori

Research results from a intense effort

Facing a critical situation, we could show our potential power in a critical situation, as it were, a fight-or-flight response. Similarly, we could develop an excellent idea and go over a high hurdle, if research management gave us a clear sense of the crisis.

Mr. Hombu

More top-down approaches are needed

To substantially reduce CO_2 emissions, a top-down management approach may need to be promoted in priority areas for low carbon technologies, such as mitigating power fluctuations from renewable energy sources and innovation in utilizing fossil fuels.

Dr. Ikegami

Steady approach to clear issues

Global warming has been around for a long time. It is difficult to maintain the existence of both organisms and economic activities. However, the problems to be solved have been clarified. All we have to do is consider, "How should one approach them?" A hasty approach is no good. A steady approach is important.

Dr. Hashimoto PD (moderator)

Challenges beyond the existing framework

ALCA program officers, PIs, and external committee members have kindly identified some Strong points of our research program from their respective positions. At the same time, some areas of improvement were identified, especially regarding IP and international collaboration. As ALCA is based on public funds, we have to prioritize our country over foreign countries and cannot help set a limit to international collaboration. However, international collaboration is essential to basic research. As program director of ALCA, I believe that I have been given an important challenge to make both go well.

Towards the realization of a low carbon society, we have to continue to take on new challenges beyond the existing framework. For this purpose, we have to change the program system, management, and, further, all researchers. I, as ALCA program director, am constantly aware of this.

I heard various presentations from participants that deepened my understanding today, although time was limited. I would like to request your understanding of and support for the approaches taken by ALCA, and that you kindly use them for your reference.

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

Achievements by ALCA-SPRING, an outstanding, world-leader in research

Kiyoshi Kanamura

Professor, Tokyo Metropolitan University

Research topics include ceramic chemistry, electrical chemistry, and energy chemistry

The storage of electricity is essential for the utilization of renewable energy, and high-performance next-generation secondary batteries are a key technology for electricity storage. The movement from hybrid cars to electric cars will expand the use of electric energy using batteries. Batteries with higher energy density than current lithium ion batteries are in high demand. Additionally, the combination of hydrogen energy and batteries could help develop a low carbon society.

We at ALCA-SPRING* promote top-down battery research towards clear goals. The materials (anode, cathode, electrolytes, etc.) required for batteries are often different from those considered by materials researchers. We are promoting materials research for battery development. This can be a rigid research system. However, we believe this top-down research system allows research with a limited budget to proceed smoothly, and, further, to achieve its implementation in society.

The research conducted so far has clarified problems in all battery systems. We are in the process of finding solutions that have not been considered by researchers outside Japan. . We have already solved some of these problems. The following document is an introduction to some of our past research achievements, which are only a small part of the whole.

(1) All-solid-state batteries
Dr. Tatsumisago (Osaka Prefecture University), the team leader, oversees sulfide solid electrolyte materials, in which ALCA-SPRING is a world leader. Furthermore, Dr. Kanno (Tokyo Institute of Technology) and Dr. Tatsumisago discovered a material that possesses twice the electrical conductivity of the organic electrolyte used in current lithium ion batteries. At present, joint research with LIBTEC is occurring with the aim to industrialize this technology.

Oxide solid electrolytes have the problem of large ion-migration -resistance at the interface. Dr. Takada (MIMS), the team subleader, and coworkers are challenging to make a solution to this problem.

(2) Metal-air batteries
Metal-air batteries, which have a lithium metal anode and an air cathode, have a high energy density. In practice, they must have a multiple-layer structure. Dr. Kubo (NIMS) and coworkers produced a multiple-layer battery (a first in the world) and achieved a sufficiently high energy density. However, achieving a long cycle remains an issue. Researchers are working to find a solution within the limited remaining time.

(3) Lithium-sulfur batteries
A bottleneck of these batteries was the "elution of the sulfur from the cathode into the electrolyte." Dr. Watanabe (Yokohama National University) used a solvated ionic liquid as an electrolyte to solve this problem. We are now furthering this research in collaboration with researchers conducting theoretical calculations, and we have obtained good results in electrical charge and discharge tests.

(4) Metal lithium secondary batteries
ALCA-SPRING is studying the application of a new separator for metal batteries that we developed at NEDO. We had successful research results during trial production of a battery for smartphones using metal lithium as an anode. Its energy density was the highest achieved to date . This battery technology has had a significant impact on the global battery industry, as the industrial sector has long sought to develop a high energy density battery using lithium metal as an anode. We are studying further details using NIMS's battery research platform.

(5) Magnesium batteries
Although magnesium batteries have been studied throughout the world, to the best of my knowledge, no one has yet developed a successful magnesium battery. We are also using magnesium metal as an anode and an oxide as a cathode in our research. A bottleneck in this work is that the additives used for depositing and dissolving the magnesium are very unstable. Dr. Egashira (Nihon University) has led the development of a new electrolyte. Various other results have also been achieved, including new cathode materials. The magnesium battery itself is still in the fundamental research stage. In particular, the science of electrolytes must be explored more deeply.

A stage-gate evaluation was performed in 2015 to reorganize the team, three years after the beginning of the project. A special multidisciplinary research unit was formed because lithium metal anodes are a common technological issue across all lithium battery systems. The system was also changed to incorporate multidisciplinary analyses and evaluations. Further acceleration of the research will be attempted with this system.

Commercialization of the batteries developed in this project in society will require not only improved energy density, but also solutions to various technological problems, including the improvement of the battery cycle life and safety. We will continue with key research and development tasks, such as identifying applications, determining the specifications for relevant batteries, and producing several prototype batteries for testing, to make various innovative batteries commercially available.

*Specially Promoted Research for Innovative Next Generation Batteries

Creation of High Quality and Large Diameter GaN Wafers

Yusuke Mori

Professor, Osaka University

Research topics include nitride semiconductor materials

Gallium nitride (GaN) semiconductors theoretically possess the best energy efficiency among all semiconductor materials. Current devices are fabricated on a sapphire substrate. Defects, called dislocations, are generated in the GaN layer; high quality GaN crystals have not been obtained because of a difference in the lattice constant between GaN and sapphire. Poor quality crystals do not exhibit the intrinsic properties of GaN. Therefore, the fabrication of GaN wafers with high quality and large diameters is essential for high quality GaN devices.

If GaN wafers with high quality and large dimeter can be commoditized, they would be expected to lead to a wide range of new technologies, such as power devices with low power loss, ultra-high-speed transistors, high power LEDs, and laser diodes. Furthermore, the use of purple-colored LEDs as the exciting light on GaN wafers would produce white LEDs, which would eliminate LED's blue color, an issue for some critics.

Osaka University is now working to produce a high quality and large diameter GaN crystal using a sodium flux method. Several methods have been developed for decreasing the density of defects in the GaN crystal, and a new method for GaN crystal growth without the sapphire substrate has been proposed. Various techniques and results have been reported. However, none of methods have succeeded in adequately decreasing the density of defects. We have attempted to substantially decrease the contact area between the sapphire substrate and the GaN crystal to mitigate the internal stress resulting from the difference in their lattice constants. This point seed method (Fig. 1) has led to successful production of GaN wafers larger than four inches in diameter (Fig. 2). Compared with conventional methods, this method was found to substantially decrease the defect density to approximately 102 cm-2 in the areas with good crystal quality.

The current challenge is the production of crystals with uniformly high quality over a wide area. We aim to establish a business, in the future, to supply the seed GaN crystal.

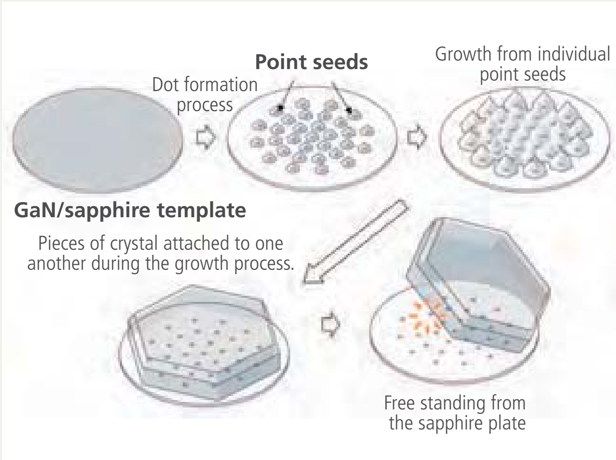


Fig.1 Schematic presentation of GaN crystal growth by the point seed method
The contact area of the GaN membrane on the template (GaN/sapphire) is reduced to 20% or less to prepare the seed crystal formed at the points

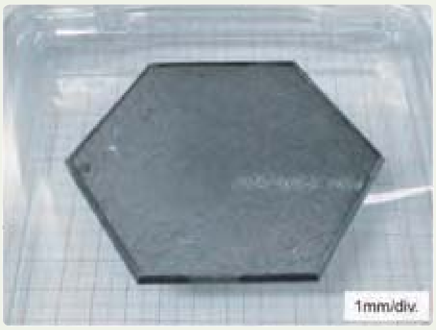


Fig.2 Freestanding 4 inch GaN crystal obtained by the point seed method.

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

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Postscript

We have renewed the first edition of the ALCA achievements report published in 2015. For this edition, we visited research sites and substantially increased the number of photographs. We would like to thank the researchers who kindly volunteered their time. It was informative to visit sites in a tension-filled atmosphere, but it was also beneficial to have unexpected opportunities to talk with ALCA PIs in a relaxed atmosphere. We sometimes followed a time-constrained schedule to visit multiple sites in a day under the scorching sun, but these are now fond memories we recalled when publishing this edition. We would very much like to thank the camera crew (Messrs. Kaizuka, Nagao, and Ishiwata), Ms. Yanagisawa of PLOT (who kindly participated in many preparatory meetings and was present at the photo sessions), and Ms. Terakado (who played a central role throughout this process).

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