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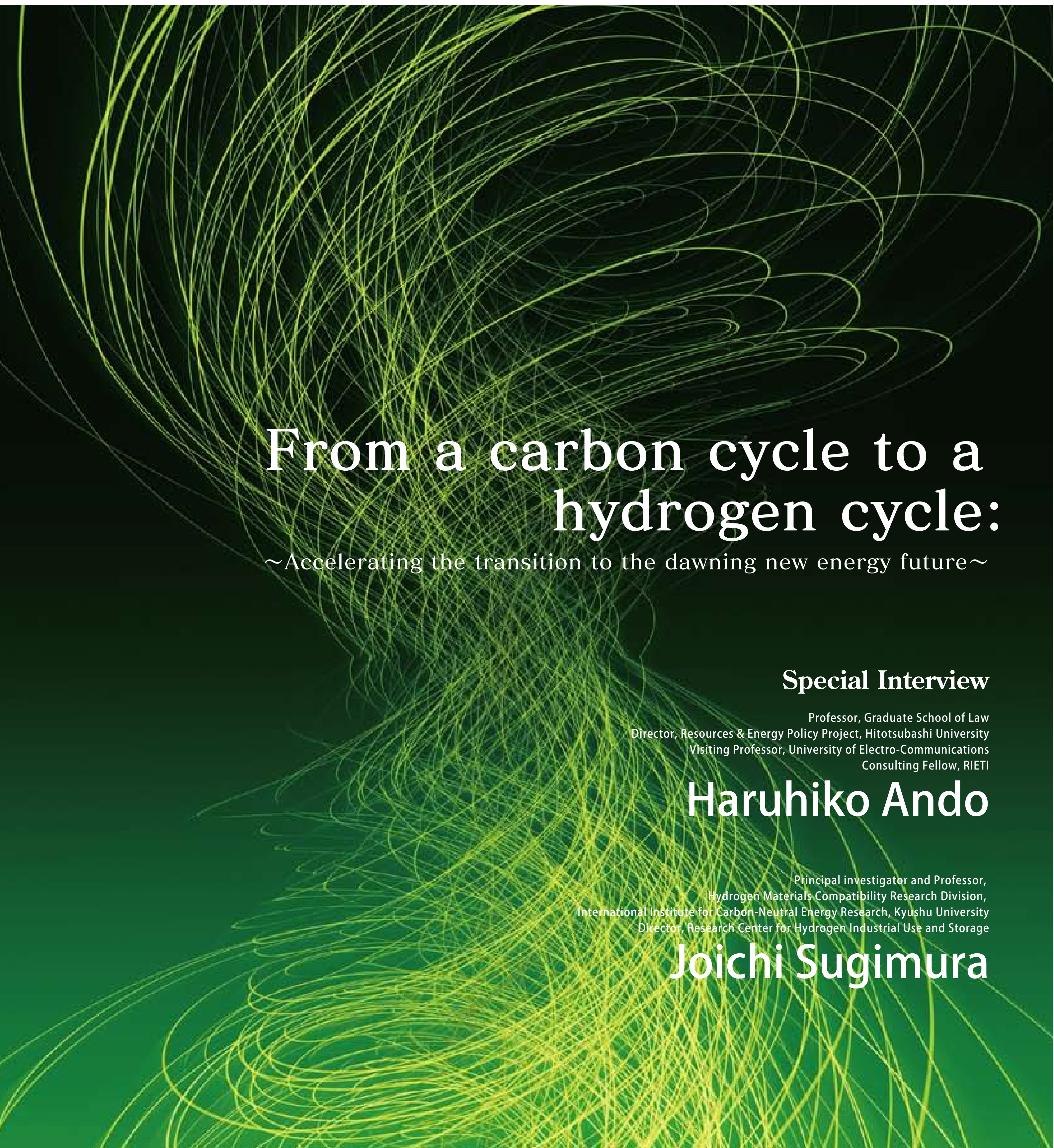
EnergyOutlook

International Institute for Carbon-Neutral Energy Research



From a carbon cycle to a hydrogen cycle:

~Accelerating the transition to the dawning new energy future~

Special Interview

Professor, Graduate School of Law
Director, Resources & Energy Policy Project, Hitotsubashi University
Visiting Professor, University of Electro-Communications
Consulting Fellow, RIETI

Haruhiko Ando

Principal investigator and Professor,
Hydrogen Materials Compatibility Research Division,
International Institute for Carbon-Neutral Energy Research, Kyushu University
Director, Research Center for Hydrogen Industrial Use and Storage

Joichi Sugimura

wpi World Premier International Research Center Initiative
I²CNER
KYUSHU UNIVERSITY
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From a carbon cycle to a hydrogen cycle:

Accelerating the transition to the dawning new energy future

A new method for extracting crude oil, well-drilling, was first tested in the state of Pennsylvania in the United States in 1859. This test yielded the first commercially viable oil strike, marking the start of humankind's dependence upon oil. During the subsequent 150 years, we have reaped enormous benefits from oil. However, the substance has turned out to be a double-edged sword, and today we face the problems of resource depletion and global warming. How can we advance the transition to hydrogen, the clean energy medium of the near future?

Haruhiko Ando

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A free fortress where the "SAMURAI" of fuel cell and hydrogen research gather

Joichi Sugimura: Professor Ando, how did you first become involved with fuel cells and hydrogen?

Haruhiko Ando: My first encounter must have been around 1984, when I happened to see a book entitled *Fuel Cells* on the shelf at a bookstore during my days as a college student. I read the book and found the technology interesting.

Sugimura: : My interest in energy was born of the Oil Shock, which I experienced as a teenager. I was still a student when the Sunshine Project began in 1974, but I was interested in solar power and hydrogen.

Ando: I began to be involved with fuel cells professionally in 2003. I was appointed to a first Director for fuel cells and international strategy that position was newly created at the Agency for Natural Resources and Energy of Ministry of Economy, Trade and Industry (METI). When U.S. president George W. Bush proposed "$1.2 billion in research funding so that America can lead the world in developing clean, hydrogen-powered automobiles" in his State of the Union Speech at the beginning of the year, Japan found itself faced with the need to act quickly.

Sugimura: So that led you to set about creating a facility to pursue hydrogen research.

Ando: I decided to manage creating an unprecedented, unique and the only cutting-edge National Laboratory on hydrogen advanced materials which such kind of research laboratories didn' t exist then. I thought that Kyushu University had strong and indispensable potentials in this important research field. Finally "HYDROGENIUS" , Research Center for Hydrogen Industrial Use and Storage was created in Kyushu University as a part of the National Institute of Advanced Industrial Science and Technology (currently integrated into a part of Kyushu University).

Sugimura: I heard that you were also responsible for recruiting Professor Etsuo Akiba, who was working at the National Institute of Advanced Industrial Science and Technology in Tsukuba, Ibaraki Prefecture, at the time I²CNER was in its formative stage.

Ando: I visited him on a day when it was snowing heavily, and he demurred, but before I knew it, he ended up at I²CNER [grins]. I came to understand that I²CNER naturally attracts "SAMURAI" researchers who are characterized by their passionate aspirations concerning fuel cells and hydrogen.

The current energy crisis and hydrogen as a savior

Sugimura: Fuel cell-powered automobiles will finally be on market in 2015. In preparation, energy suppliers has started building hydrogen filling stations this year. As we prepare to mark the dawn of the hydrogen era, what can you tell us about the role that hydrogen energy will play?
Ando: Hydrogen has an extremely important role as the clean energy medium of the near future. It's not well known in Japan, but the Strait of Hormuz, which serves as the lifeline for crude oil imports, is an important world location. Were the Strait to become nonoperational shipments of crude oil and natural gas to Japan would almost completely stop. Seeing as our nuclear power plants have been shuttered at the moment, we would see rolling blackouts nationwide in short order.
Sugimura: Most people aren' t aware that Japan finds itself in such a sink-or-swim situation. Even setting aside the risk of oil shipments to Japan for the moment, Japan' s balance of trade has been thrust into the red due to the high cost of the fuels we're using to generate electricity. For Japan, developing energy to take the place of oil and natural gas is an urgent priority.
Ando: As we think about energy security today, ensuring "diversity" is the most important point. An example would be the DESERTEC project being pursued by Chancellor Angela Merkel of Germany.
Sugimura: Just to clarify, you're referring to the ambitious project seeking to generate solar power in the Sahara Desert in Northern Africa and send the resulting power to Germany.
Ando: The countries of EU-MENA region (European Union, Middle East and Northern Africa) have come together in the project, and they're planning to invest €400 billion in total. Yet despite what you might assume given European countries' status as an environmentally advanced nation, the project's primary goal is not to reduce CO_2. Its first priority is to ensure energy security to protect against sudden and possible interruptions in the natural gas supply, for which the continent depends on Russia. Its second priority is to revitalize the EU-MENA economies through large-scale investment, and its third priority is to create water resources to avoid possible regional conflicts. Reducing CO_2 is the project's last one.

Joichi Sugimura

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Director, Research Center for Hydrogen Industrial Use and Storage

The required transition from the carbon cycle to a hydrogen cycle

Sugimura: There's no doubt that hydrogen is a key factor in terms of energy security. What do you think about the methods for obtaining hydrogen?
Ando: A Japanese company has already developed revolutionary technologies. Hydrogen will be added to toluene using a "nano" -catalyst and then shipped in normal tanker trucks under conditions of normal temperature and pressure. The company has already built a demonstration plant by itself, and they' re planning a clean hydrogen-fueled power plant in Tokyo Bay. Surplus by-product hydrogen from the Middle East and Southeast Asia will be used for the time being, but in the future it may be possible to use carbon-free hydrogen from the world's enormous unused bank of hydro and wind power resources.
Sugimura: However, there are a number of issues that must be addressed in order to popularize use of hydrogen. How should the necessary infrastructure be developed, for example the tanks and pipes that will store the hydrogen? Thorny problems include hydrogen embrittlement of metal materials, which is one area being addressed by our research.

Special Interview

Ando: At the start of his tenure, former U.S. Secretary of Energy and recipient of the Nobel Prize in Physics Steven Chu was skeptical of the prospects for realizing a hydrogen-based society due to the need to simultaneously resolve issues in the four areas of production, storage, supply infrastructure, and fuel cells, quipping, “If you need four miracles, that’s unlikely: saints only need three miracles.” However, he appears to have become somewhat more optimistic by the time he resigned.
Sugimura: In addition to hydrogen embrittlement, it must be conceded that we lack an adequate understanding of such areas as the material characteristics of seals and other parts, tribology, and even the physical properties of hydrogen itself.
Ando: I have high expectations for the efforts underway at Kyushu University. Here at the University you’ll find laboratories unrivaled in the entire world, where personnel are spearheading cross-sectional and comprehensive investigations into every research domain that relates to hydrogen issues. These researchers believe that resolving the challenges posed by fuel cells and hydrogen is a top priority not for Japan, but for the future of humankind.

Future priorities for I²CNER

Sugimura: What issues are there as you work to popularize household use of fuel cells going forward?
Ando: Before we talk about convenience and economy, we have to ensure safety. No technology whose safety cannot be assured can be pushed into widespread consumers’ use. And what we have to think about in this regard is the level of safety that needs to be ensured. To popularize use of fuel cells, it’s necessary to think about safety in connection with economic rationality. A reasonable line must be drawn with regard to safety.
Sugimura: International standards on safety are needed, but things get tricky when different countries’ approaches are involved.
Ando: Forging international standards requires a shared global understanding by scientists as a foundation for action. Kyushu University is already hard at work as the world’s core institution in this area.
Sugimura: You thought we needed to prepare science-based standards in advance in order to get past national differences in values. You conceived of HYDROGENIUS as a global institution for laying the foundation for such international standards. Then I²CNER, which is working on fundamental science for hydrogen related technologies took shape to contribute to the realization of the hydrogen economy.
Ando: I well know the argument made that Japanese regulations tend to be more rigorous than their counterparts in other countries, but if there is a shared, worldwide understanding founded in a global scientific community, eventually the process of rationalization will proceed in the same direction. At that point, Japanese companies will enjoy a dramatic expansion of opportunities to act on the world stage.
Sugimura: It’s also our responsibility as scientists to sweep away the negative image that some people have of hydrogen.
Ando: Feeling secure is a matter of emotion, while being safe is a matter of science, and these two issues must be separated in order to have a fruitful discussion. I think the Fukuoka Hydrogen Strategy (Hy-Life Project) pioneered by former Governor Wataru Aso and continued by current Governor Hiroshi Ogawa is an excellent promotional tool that effectively promotes the safety of hydrogen.
Sugimura: When you think about popularizing household use of hydrogen, Ene-Farm systems have a significant role to play. It’s hard to convince someone who has never used hydrogen that he or she should feel secure because it’s safe. However, that person can experience that sense of security directly if his or her neighbor is already using an Ene-Farm system.
Ando: Private industry and the METI are working hard to promote “Ene-Farm” (commercially distributed residential FC system), and 80,000 of the systems are expected to be installed within this fiscal year. Along with efforts at popularization similar to this, I’d like to see I²CNER pursue an aggressive program of advanced research. To better explain issues such as hydrogen embrittlement, crack growth, and ductile failure, it will be necessary to delve into quantum mechanics. I hope to see I²CNER continue to play a leading role in advanced hydrogen research and to foster the development of an ever-growing troop of young researchers who will play key roles in that process.
Sugimura: There’s no doubt that the future will be forged by young people. Many researchers have come to I²CNER from overseas, and the institution has a cosmopolitan atmosphere. We understand that it is our responsibility to take advantage of the special environment with which we’ve been blessed to cultivate world-class researchers.

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Profile

After graduating from the Department of Aeronautics and Astronautics in the University of Tokyo’s Faculty of Engineering in 1981, Sugimura completed the master’s program at the Department of Aeronautics and Astronautics at the University of Tokyo’s School of Engineering in 1983, followed by the Department’s doctoral program in 1986. He became a lecturer in Kyushu University’s Faculty of Engineering and then an associate professor in 1988. In 2004, he became a professor at the Graduate School of Engineering. In 2006, he became the leader of the Hydrogen Tribology Team at Research Center for Hydrogen Industrial Use and Storage (HYDROGENIUS), National Institute of Advanced Industrial Science and Technology. In 2010, he became a principal investigator at Kyushu University’s International Institute for Carbon-Neutral Energy Research (I²CNER). He assumed his current position in 2013.

Haruhiko Ando

Professor, Graduate School of Law
Director, Resources & Energy Policy Project,
Hitotsubashi University
Visiting Professor, University of Electro-Communications
Consulting Fellow, RIETI

Profile

After graduating from the University of Tokyo Faculty of Law in 1985, Ando went to work for the Ministry of International Trade and Industry. He accepted a planning position in the Cabinet Office (with responsibility for economic and financial research) in 2001, followed by a planning position in the Agency for Natural Resources and Energy (with responsibility for international strategy and fuel cells) in 2003. Then he became director of the Fuel Cell Promotion Office in 2004 and director of the New and Renewable Energy Division in 2005, before accepting a position as a Counselor in the Cabinet Office (with responsibility for science and technology) in 2008 and then as a Counselor in the Cabinet Office (with responsibility for intellectual property) in 2010. He assumed his current position in 2012.

01

Promising operational stability of high-efficiency organic light-emitting diodes based on thermally activated delayed fluorescence

Hajime Nakanotani, Kensuke Masui, Junichi Nishide,
Takumi Shibata, Chihaya Adachi

Scientific Reports, 3, 2127, P.1-5 (2013) DOI: 10.1038/srep02127

Organic light-emitting diodes (OLEDs) are attractive for next-generation displays and lighting applications because of their potential for high EL efficiency, fiexibility and low-cost manufacture. Recently, a new route to high EL efficiency using materials that emit through thermally activated delayed fluorescence (TADF) was demonstrated. However, it is unclear whether devices that emit through TADF are reliable. Here we demonstrate highly efficient, stable OLEDs that emit via TADF by controlling the position of the carrier recombination zone, resulting in projected lifetimes comparable to those of tris(2-phenylpyridinato)iridium (III)-based reference OLEDs. Our results indicate that TADF is intrinsically stable under electrical excitation and optimization of the surrounding materials will enhance device reliability.

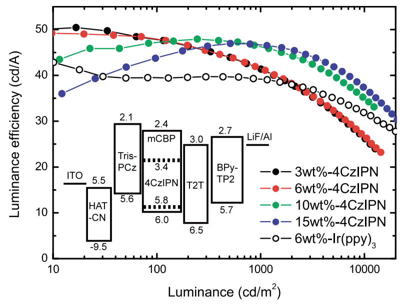


Figure 1：Performance of OLEDs with TADF emitters.

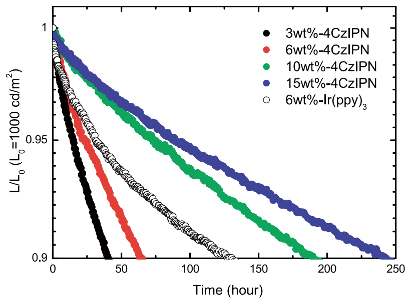


Figure 2：Normalized luminance as a function of operating time

02

Surface coating with a high resistance to hydrogen entry under high-pressure hydrogen-gas environment

Junichiro Yamabe, Saburo Matsuoka, Yukitaka Murakami

International Journal of Hydrogen Energy, 38, P.10141-10154(2013)
DOI: 10.1016/j.ijhydene.2013.05.152

Two aluminum-based coatings were developed: two-layer (alumina/Fe-Al) and three-layer (alumina/aluminum/Fe-Al) coatings, deposited onto cylindrical and pipe (Type 304 austenitic stainless steel) surfaces by immersion into a specially blended molten aluminum alloy. The coated specimens were exposed to hydrogen gas at 10–100 MPa at 270℃ for 200 h. Specimen hydrogen content was measured by thermal desorption analysis; hydrogen distributions were analyzed by secondary ion mass spectroscopy. Both coatings showed high hydrogen-entry resistance at 10 MPa. However, resistance of the two-layer coating clearly decreased with an increase in pressure. In contrast, the three-layer coating showed excellent hydrogen-entry resistance at a wide pressure range (10–100 MPa), achieved by the combined effect of alumina, aluminum, and Fe-Al layers.

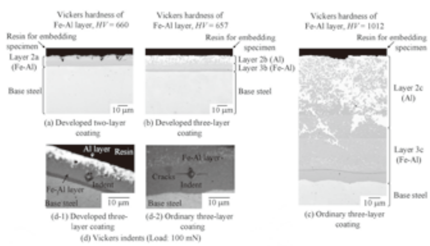


Figure 1：Optical micrographs of coated structures and Vickers indents on Fe-Al layers. The aluminum oxide layer (Layer 1) can not be identified by optical microscope, because its thickness is too small (～1 nm).

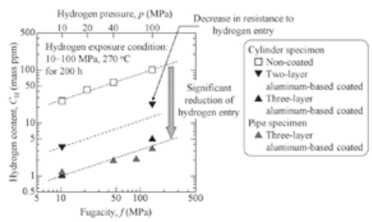


Figure 2：Relationship between hydrogen content (C_H) and fugacity (f) of non-coated, two-layer aluminum-based coated and three-layer aluminum-based coated specimens exposed to high-pressure hydrogen gas at pressures ranging from 10 to 100 MPa and temperature of 270 ℃ for 200 h measured by TDA

03

Chemical expansion and its dependence on the host cation radius

Dario Marrocchelli, Sean R. Bishop, John Kilner

J. Mater. Chem. A, 1, P.7673–7680(2013) DOI: 10.1039/c3ta11020f

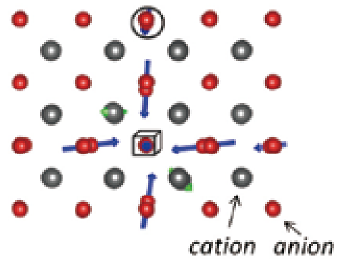


Figure 1: Ion relaxation around a vacancy in ZrO_2

Defect-induced lattice expansion (chemical expansion) can lead to mechanical failure in energy related materials such as solid oxide fuel cell electrodes and oxygen storage materials used in catalysis. In this work, relaxation patterns around oxygen vacancy defects (Figure 1) were examined as a function of host cation ionic radius (r_h) for cubic fluorite-structured oxides (Figure 2). From analysis of literature data combined with new molecular dynamics simulations, we found a maximum in the effective radius of an oxygen vacancy (r_V) for cerium. In other words, CeO_2 exhibits the largest chemical expansion. Significant asymmetric lattice relaxation around a vacancy for smaller cations (Figure 1) and 2nd nearest neighbor cation relaxations around a vacancy for larger cations play a strong role in forming the maximum. The impact of this vacancy relaxation on ionic conductivity is discussed, and a critical vacancy concentration, above which vacancy interactions exist, was derived.

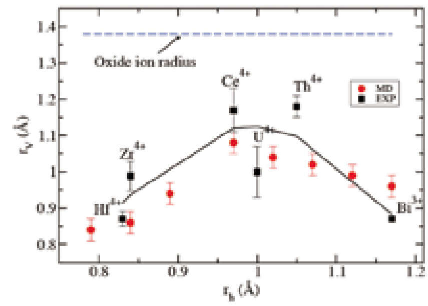


Figure 2: Oxygen vacancy radius shows a maximum near Ce^{4+}

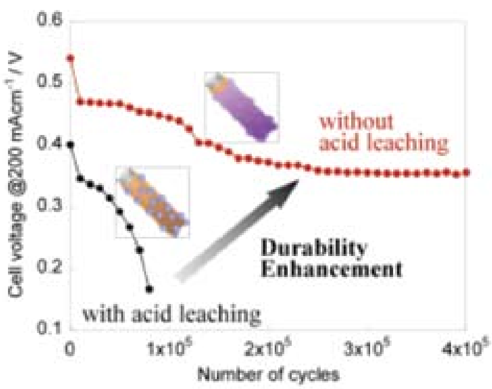
04

Remarkably Durable High Temperature Polymer Electrolyte Fuel Cell Based on Poly(vinylphosphonic acid)-doped Polybenzimidazole

Mohamed R. Berber, Tsuyohiko Fujigaya, Kazunari Sasaki , Naotoshi Nakashima

SCIENTIFIC REPORTS 3 : 1764 P1-7(2013) DOI: 10.1038/srep01764

Low durability of polymer electrolyte fuel cell (PEFC) is a major drawback that should be solved. Recent studies have revealed that leaching of liquid phosphoric acid (PA) causes inhomogeneous PA distribution that results in deterioration of PEFC performance during long-term operation. We found that a novel PEFC using poly(vinylphosphonic acid) (PVPA) in place of PA enables to avoid an acid leaching and shows high power density as well as excellent durability at 120˚C under a non-humidified condition. Especially, durability of the PEFC is 100 times higher than conventional PEFC . Successful construction of the well-defined hydrogen bonding network formed by PVPA serves such remarkable performance.



Durability test of MEA. Plots of the cell voltage at 200 mW/cm^2 for the PVPA-doped PEFC (red) and PA-doped PEFC (black).

05

Comparative study on the reversibility of pure metal borohydrides

Hai-Wen Li, Etsuo Akiba, Shin-ichi Orimo

Journal of Alloys and Compounds, in press (2013) DOI:10.1016/j.jallcom.2013.03.264

Improvement of the reversibility of metal borohydrides is a key issue for hydrogen storage applications. The first rehydrogenation of pure $Mg(BH_4)_2$ and $Ca(BH_4)_2$ was carefully investigated under a hydrogen pressure of 40.0 MPa. $Mg(BH_4)_2$ was produced even at a relatively low temperature of 473 K, and its amount increased with the temperature up to 673 K, leading to the increased rehydrogenation content and a maximum (7.6 mass%, equivalent to 51% of $Mg(BH_4)_2$) at 673 K. Under the same condition, more than 90% of rehydrogenation was confirmed through the formation of α-$Ca(BH_4)_2$. Comparison of the rehydrogenation properties of $Mg(BH_4)_2$ and $Ca(BH_4)_2$ suggests that control of dehydrogenation products would be an important approach to improve the reversibility of metal borohydrides.

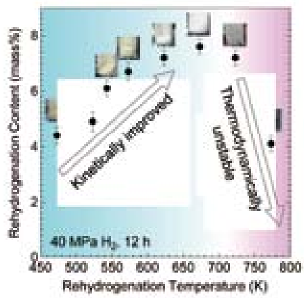


Figure 1：Dehydrogenation and rehydrogenation of $Mg(BH_4)_2$ and $Ca(BH_4)_2$

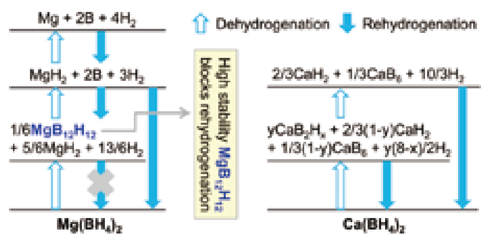


Figure 2：Rehydrogenation content of $Mg(BH_4)_2$ as a function of rehydrogenation temperature

06

On acoustic waveform tomography of wide-angle OBS data—strategies for pre-conditioning and inversion

R. Kamei, R. G. Pratt and T. Tsuji

Geophys. J. Int., 194, P.1250–1280(2013) DOI: 10.1093/gji/ggt165

Because change in seismic velocity can be used to monitor injected CO_2, the development of a method to estimate seismic velocity with high-resolution is crucial step in monitoring of CCS projects. By applying a new advanced method of waveform tomography to the Ocean Bottom Seismometer (OBS) data, we successfully estimated deep seismic velocity structures with high resolution. It is for first time that the detailed velocity structure has been resolved in deep earthquake faults in the Nankai Trough. The high-resolution velocity helps us identify precisely the location and character of fault and allows for a new interpretation of the fault geometry.

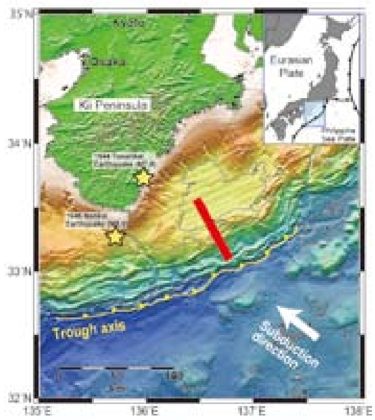


Figure 1：Location of survey line.

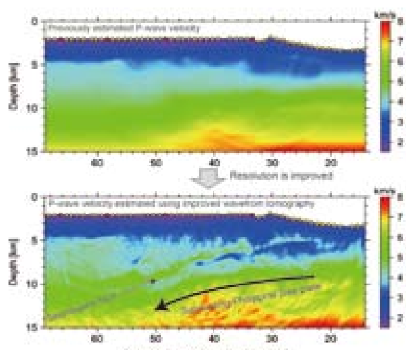


Figure 2：Seismic velocity estimated by previous method (above) and improved waveform tomography (bottom).



Event 01 International Symposium on Innovative Materials for Processes in Energy Systems (IMPRES) 2013

On September 4-6, 2013, International Institute for Carbon-Neutral Energy Research (I^{2}CNER) co-organized the International Symposium on Innovative Materials for Processes in Energy Systems (IMPRES) 2013. The IMPRES has been held in every three years and this was the third international conference after the successful completion of IMPRES 2007 at Kyoto, Japan and IMPRES 2010, Singapore.
The conference was concerned with the application of novel materials in the field of energy systems with special focus on the multi-phase processes in various energy conversion systems. Materials for fuel cells, heat pumps, sorption systems and other energy conversion and storage devices ware discussed. Common concerns include material reactivity, heat and mass transfer characteristics, durability, stability under high-temperature and severe condition and cost. The conference aimed to bring researchers focusing on different aspects of multi-phase processes in energy conversion and promote an interchange of ideas across subjects. More than 180 national and international researchers attended the conference.

Event 02 Catalytic Concepts for Energy

On September 13, 2013, the I^{2}CNER Satellite at the University of Illinois at Urbana-Champaign (UIUC) hosted the Catalytic Concepts for Energy Symposium. The Dean of the College of Engineering, Professor Andreas Cangellaris, offered remarks on I^{2}CNER's value as a unique collaborative Institute of the university which promotes the College of Engineering's vision for sustainable energy initiatives.
Professor Fraser Armstrong, University of Oxford, delivered the keynote address on enzymes as inspirational electrocatalysts. Lectures were given by Dr. Etsuko Fujita, Brookhaven National Laboratories; Professor Sharon Hammes-Schiffer, UIUC; Professor Thomas Jaramillo, Stanford; Dr. Vojislav Stamenkovic, Argonne National Laboratories; Professor Naotoshi Nakashima, Kyushu University; Professor Aleksandar Staykov, Kyushu University; Professor Dan Scherson, Case Western Reserve University; and Professor Takahiro Matsumoto, Kyushu University. The symposium was attended by over 50 faculty and students.

Awards

The 67th Ceramic Society of Japan Awards

Prof. Tatsumi Ishihara
(Associate Director, Lead Principal Investigator of the Hydrogen Production Research Division)

Prof. Ishihara received the Academic Award from The Ceramic Society of Japan for his work on "Oxide Ion Conductivity in Perovskite Related Oxide and its application to Solid Oxide Fuel Cell."

The 39th Society of Fiber Science and Technology, Japan Awards

Prof. Keiji Tanaka
(Hydrogen Production Research Division)

Prof. Tanaka received an award from The Society of Fiber Science and Technology, Japan for his work on "Study on Aggregation States and Thermal Molecular Motion of Polymers at Solid Interface."

The 10th Honda Frontier Award

Prof.Zenji Horita
(Principal Investigator of the Hydrogen Storage Research Division)

Prof. Horita received the 10th Honda Frontier Award for his work on "Development of High Performance Materials Using Giant Straining Process."

2012-2013 Hydrogen Student Design Contest Grand Prize

Dr. Seiichiro Kimura, Post-doctoral Research Associate
(Energy Analysis Research Division)

The master's course students of the Department of Hydrogen Energy Systems, Faculty of Engineering, Kyushu University were awarded the Grand Prize (highest award) in the Hydrogen Student Design Contest hosted by the Hydrogen Education Foundation. Dr. Kimura, one of I^{2}CNER's Post-doctoral Research Associates, contributed to the award-winning team in his capacity as project advisor.

The Society of Exploration Geophysicists of Japan (SEGJ) encouraging prize

Prof. Takeshi Tsuji
(Lead Principal Investigator of the CO_2 Storage Research Division)

Prof. Tsuji received the encouraging prize from The Society of Exploration Geophysicists of Japan (SEGJ) for his paper on "Global optimization by simulated annealing for common reflection surface stacking and its application to low-fold marine data in southwest Japan."