International Institute for Carbon-Neutral Energy Research

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Energy Outlook

The Necessity of Renewable Energy

Hajime Okazaki

Senior Vice President, Director
Executive Director of the Research and Development Division
JX Nippon Oil & Energy Corporation

Special Interview

The Future of Energy

What Energy Problems Does Japan Face?

Towards a Carbon-Neutral Energy Society

Kuniaki Honda

Professor,
Energy Analysis Division
International Institute for Carbon-Neutral Energy Research (I^2CNER),
Kyushu University

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Director, Petros Sofronis

International Institute for Carbon-Neutral Energy Research

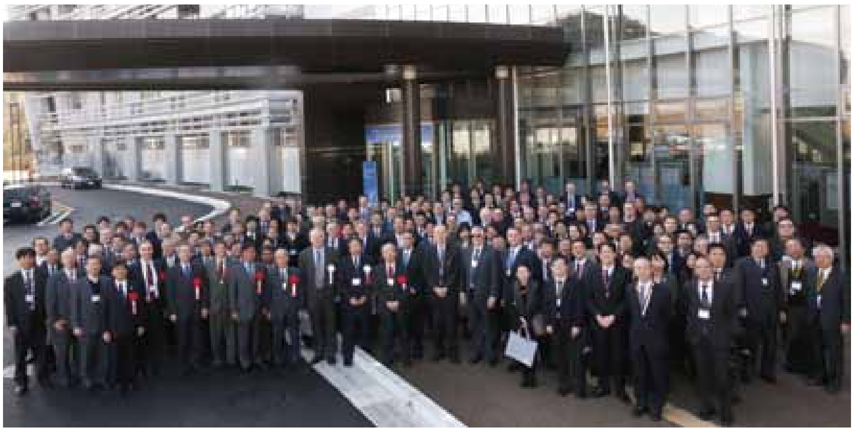
Professor Petros Sofronis, PhD
Director,
International Institute for
Carbon-Neutral Energy Research

Here at I²CNER, our mission is to contribute to the creation of a sustainable and environmentally-friendly society by conducting fundamental research for the advancement of low carbon emission and cost effective energy systems, and improvement of energy efficiency. Amongst the array of technologies that I²CNER's research aims to enable is the innovative, safe, and reliable production, storage, and utilization of hydrogen as a fuel in a hydrogen-based economy. Our research also explores the underlying science of CO_2 capture and storage technology, or the conversion of CO_2 to a useful product. Additionally, it is our mission to establish an international academic environment that fosters innovation through collaboration and interdisciplinary research (fusion).

A natural question in response to our mission statement is: How will I²CNER's fundamental research eventually enable carbon neutral technologies? In other words, how do we plan to translate basic science breakthroughs into technology innovation? The answer to that question lies at the heart of the I²CNER mission: collaborative/fusion research. Not only do I²CNER's researchers aim to collaborate with one another in order to advance the science fundamentals, but their goal is also to conduct research whose targets are informed by societal energy demands in order to ensure that the technologies we are enabling can impact the energy landscape in the next 20 to 30 years.

It is no secret that the face of cutting-edge research is changing. At I²CNER, we understand that the scientific challenges we face are complex international problems, and that the solutions to these problems will require a cross-disciplinary, academic-industrial hybrid approach to research and development. In short, we know that no single university, scientific discipline, or industry will be able to solve these problems alone. I²CNER's collaborative, issue-driven approach represents the evolving academic research structure and the active collaboration on energy between Japan and the United States. It is our goal to become the emblem of successful academic collaboration and international research partnerships. In addition, I²CNER aims to have a positive impact on the education of the engineer of the 21st century, as well as the opportunities we offer to our young faculty to succeed in an international environment in which continuous engagement and robust debate are the norm, and standards of performance are disparate.

With these goals in mind, I am pleased to present I²CNER's newest publication, "Energy Outlook", which aims to provide insight into our mission-driven, basic research that is informed by societal needs.



Special Interview

The Future of Energy

Discussing the future of energy

What Energy Problems Does Japan Face?

The International Institute for Carbon-Neutral Energy Research (I²CNER) is pursing research toward the realization of an environmentally friendly, sustainable society.

Kuniaki Honda

Professor,
Energy Analysis Division
International Institute for Carbon-Neutral Energy Research (I²CNER),
Kyushu University

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Hajime Okazaki

Senior Vice President, Director
Executive Director of the Research and Development Division
JX Nippon Oil & Energy Corporation

The expectations and realities of renewable energy

Honda: Since the Great East Japan Earthquake, the Japanese people have paid more attention to resource and energy issues, and have begun to question whether the present energy system is right for the country. In recent years, shale oil and shale gas have been mined in the USA, and the price of natural gas has been falling amidst increasing diversification of energy sources. In this situation, our Institute has been studying how to establish a carbon-neutral energy society using renewable energy. How is JX Nippon Oil & Energy Corporation approaching the future of renewable energy?

Okazaki: Our company has grown by being engaged in the refinement and sales of petroleum. However, the adoption of measures to reduce CO_2 emissions is an important challenge. Also, from the viewpoint of soaring crude oil prices, brought about by instability in the Middle East, we consider renewable energy to be essential. At the same time though, we cannot deny that renewable energy is facing excessive expectations. Renewable sources of energy, such as solar and wind power, have limits in terms of weather conditions and periods of operation, and we cannot count on them for a stable energy supply.That said, we should still remain open to the potential of renewable energy sources.

Energy reform, looking ahead to a hydrogen-based economy

Honda: To the best of my memory, oil prices at the time of the oil shock in the 70's nearly exceeded $60 a barrel. At those prices, new energy sources such as solar and wind power would have been competitive. But shortly after that, oil prices dropped to the $10 range, and research on new energy sources came to a halt. However, now the price has surged back to over $100 a barrel. In spite of the need for a low-cost alternative energy, we still depend on petroleum and natural gas because the cost of the new forms of energy is too high, possibly as a result of the previous halt in research on new energy sources. Under these circumstances, has the oil industry come up with a strategic vision for renewable energy?

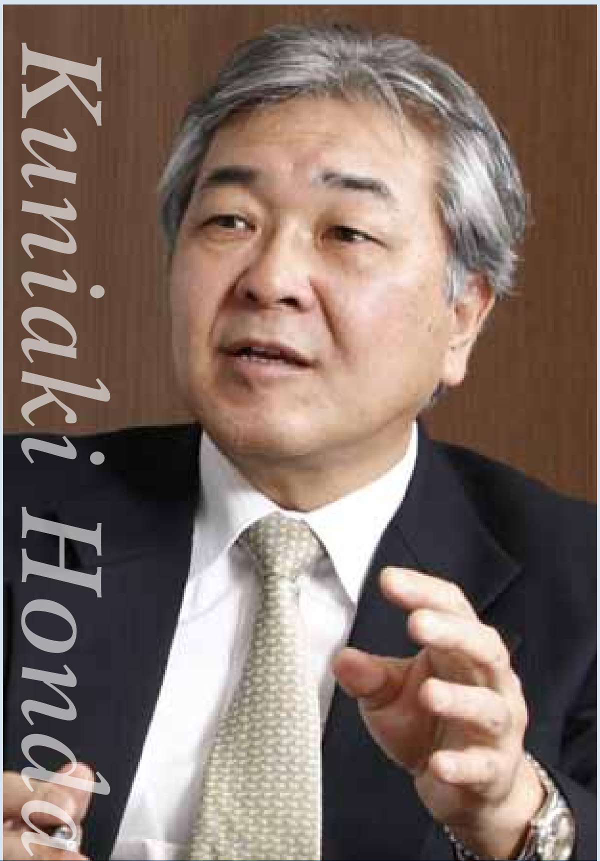
Okazaki: We started research and development on fuel cells in preparation for a decrease in demand for oil products at an early stage, which meant the development of new uses. We started the research because of our desire to build a new energy axis, including new supply formats. We also considered it to be a complementary axis for renewable energy. I think the projects we are proceeding with will contribute to improvements in the energy situation in Japan.

Honda: You advocate a hydrogen society as well as fuel cells. What's your opinion on hydrogen?

Okazaki: We already have the technology to handle hydrogen, although we need to improve its purity. It would be ideal if we could have a hydrogen production plant at the oil refinery site, to take advantage of existing land and infrastructure.

Honda: You seem to have already taken measures. Could you give me a specific time frame for when hydrogen will be commercialized, and for when a hydrogen society will actually be realized?

Okazaki: Auto manufacturers and infrastructure-related businesses have jointly announced that they will market fuel cell vehicles on a full-scale basis by 2015. It all depends on whether problems with cost and safety can be resolved, but we predict that the diffusion ratio of fuel cell vehicles will rise by around 2030.



PROFILE

Kuniaki Honda

Professor,
Energy Analysis Division
International Institute for Carbon-Neutral Energy Research (I²CNER),
Kyushu University

1972: Graduated from the Department of Chemical Engineering of the Faculty of Science and Engineering, Doshisha University, and joined Osaka Gas Co., Ltd. Engaged in sales of industrial gasses and gasses for professional and home use and equipment development. During this service, he was on loan to the Japan Cogeneration Society for three years.
July 2005 to July 2009: Assumed the post of Executive Member of the Council for Science and Technology Policy.
Until March 2008, served as a coordinator of the Coordination Program for Science and Technology Projects (hydrogen use / fuel cell field)
2009: Obtained a doctoral degree in engineering at Kyushu University.
Since April 2011, has served as a visiting professor at the International Institute for Carbon-Neutral Energy Research (I²CNER), Kyushu University.
July 2012: Assumed his current post as Professor of the Energy Analysis Division of I²CNER.

Evaluation of renewable energy

Honda: While we speak of a true carbon-neutral hydrogen society based on renewable energy such as solar power, wind power and biomass, there is also another type of hydrogen society that adopts fossil fuels such as oil and coal. From the viewpoints of cost and CO_2 reduction, how do you compare high efficiency, energy conservation, and smart grids with the introduction and promotion of renewable energy?

Okazaki: From a cost perspective, it would be much more beneficial to promote increased efficiency and energy saving. However, the fact remains that hydrocarbons are still burned. As we all want to reduce CO_2, using another atom to replace the "C" would be ideal. The easiest solution is to use hydrogen. By using the already established technology of steam reformation, we can enjoy the advantages of reduced costs, and produce hydrogen not only from fossil fuels, but also from other materials, including biomass. On the other hand, in order to realize a hydrogen society, we naturally need to improve CO_2 handling technology. Of course, there are various problems concerning CCS (CO_2 capture and storage), such as how long the stored CO_2 can remain stable. In my view, without spending a certain amount of time to develop these research themes, a hydrogen society in the true sense will not be realized. What we can do now is address the challenges, one at a time, and take gradual steps. I think ideally, we should first put into practice a hydrogen society combined with fossil fuels, and then decrease CO_2 emissions gradually.

Promotion of industry-academia-government cooperation

Honda: I²CNER is a research institute that was established to pursue basic scientific research aimed at the realization of an environmentally harmonized and sustainable carbon-neutral society. Since our research is long term, we set milestones and proceed by always assessing our progress relative to a roadmap and our targets. In addition, at I²CNER, we are conducting basic

research whose results may take time to translate into technology. However, we would like our research to be relevant to both short and long term societal needs. Could you please tell us how you view university research institutions like ours, regarding the issue of research translation?
Okazaki: I expect you to advance research covering the elements of mass production and commercialization. Then, your research may eventually go beyond the natural science fields and expand into social science and political categories. At the final stage, the utilization of research technology, cost effectiveness, customer satisfaction, and compliance are called for. I hope I^{2}CNER will provide achievements not only in basic research, but also be engaged in the verification of technology and product development, hopefully working in cooperation with business.

Message to students andthe next generation

Honda: Thank you very much for your encouraging advice. In conclusion, can you offer any advice to students in terms of employment opportunities in the future energy industry?
Okazaki: I think human resources who are familiar with distribution and the economy will be needed in the future labor market of the energy industry. Also, we are looking for people who are equipped with the ability to identify competitors, analyze market trends, and propose strategies.
Honda: That means you are looking for people in the research fields of social science, who are aware of social perception of technologies, right?
Okazaki: Yes, that's right. I would like students to learn a mechanism through which they can reflect their studies on society.
Honda: Thank you very much for your significant contribution today.
Okazaki: Thank you very much.

PROFILE

Hajime Okazaki

Senior Vice President, Director
Executive Director of the Research and Development Division
JX Nippon Oil & Energy Corporation

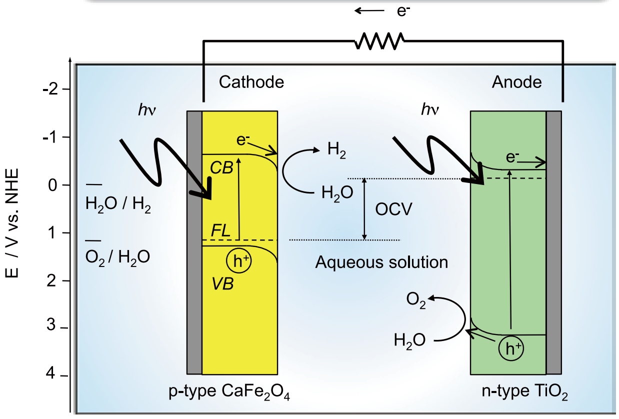
1975: Graduated from the Department of Fuel Chemistry of the Faculty of Engineering, Kyoto University.
1978: Completed the course of the Department of Fuel Chemistry of the Graduate School of Engineering, Kyoto University, and joined the Central Technical Research Laboratory of Nippon Oil Corporation. Engaged in research and development of oil refinery processes and catalysts.
April 2002: Vice Director of the Central Technical Research Laboratory
June 2004: Director of the Central Technical Research Laboratory of the Research and Development Division
2010: Obtained a doctoral degree (engineering) at Nagoya Institute of Technology.
July 2010: Assumed his current position as Senior Vice President and Executive Director of the Research and Development Division of JX Nippon Oil & Energy Corporation.

Photoelectrochemical hydrogen production from water using p-type and n-type oxide semiconductor electrodes

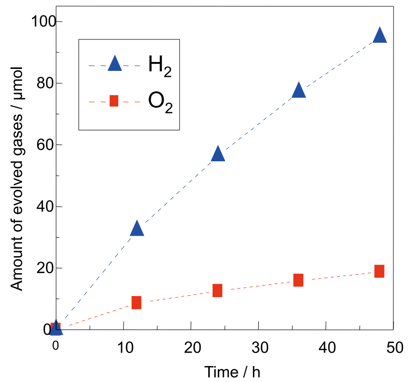
Shintaro Ida, Keisuke Yamada, Maki Matsuka, Hidehisa Hagiwara, Tatsumi Ishihara
Electrochimica Acta 82 (2012) 397– 401

Photoelectrochemical hydrogen and oxygen production from water were demonstrated without external voltage using calcium iron oxide (p-type) and TiO_2 (n-type) semiconductor electrodes. The calcium iron oxide electrode with the ratio Fe/Ca of 1.9, which consisted of two crystal phases (main phase: $CaFe_2O_4$, impurity phase: $Ca_2Fe_2O_5$), showed the highest photocathodic current in 0.1 M NaOH aq. at potentials below +0.30 V vs. Ag/AgCl under a 500 W Xe lamp illumination, and TiO_2 showed photo-anodic current in 0.1 M NaOH aq. at potentials over −0.78 V vs. Ag/AgCl. In the system where the two electrodes were connected under illumination, the open-circuit voltage was 1.09 V and the short-circuit current density was 550μA cm^{-2}. Hydrogen and oxygen were successfully generated from this present system without applying an external voltage. The ratio of hydrogen/oxygen evolved after 12-h reaction with both the electrodes short-circuited was around 3.7. This system is an ultimately artificial photosynthesis system where hydrogen and oxygen are generated separately under illumination. It is believed that this present system can form the basis of the future artificial photosynthesis system where hydrogen and oxygen are produced directly from water and sunlight.

The model figure of a water splitting cell



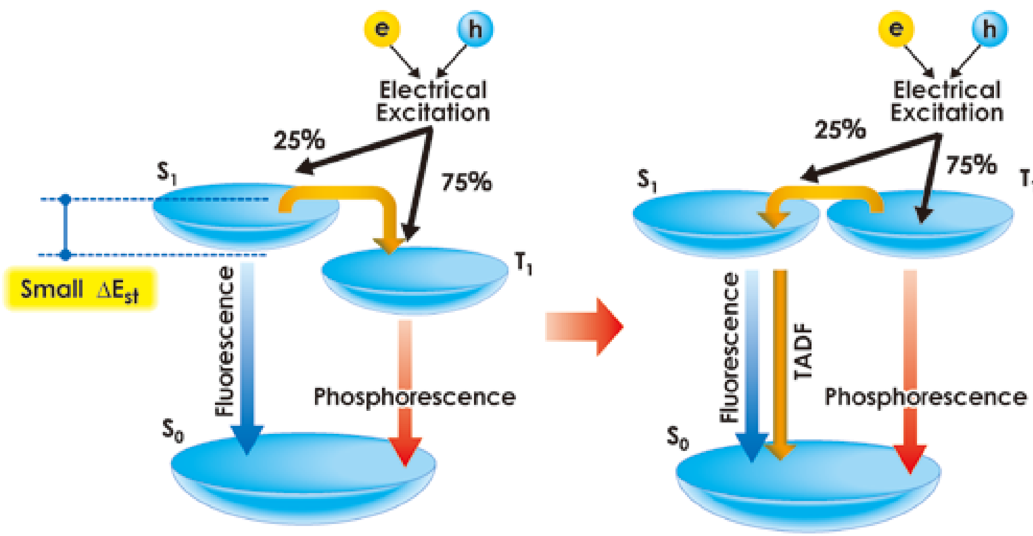
Amounts of H_2 and O_2 gases generated from CFO (Fe/Ca = 1.9) and TiO_2 electrodes system as a function of illumination time



Highly efficient organic light-emitting diodes from delayed fluorescence

Hiroki Uoyama, Kenichi Goushi, Katsuyuki Shizu, Hiroko Nomura, Chihaya Adachi
Nature 492,234–238(13 December 2012) doi: 10.1038/nature11687

The inherent flexibility afforded by molecular design has accelerated the development of a wide variety of organic semiconductors over the past two decades. In particular, great advances have been made in the development of materials for organic light-emitting diodes (OLEDs), from early devices based on fluorescent molecules to those using phosphorescent molecules. In OLEDs, electrically injected charge carriers recombine to form singlet and triplet excitons in a 1:3 ratio; the use of phosphorescent metal–organic complexes exploits the normally non-radiative triplet excitons and so enhances the overall electroluminescence efficiency. Here we report a class of metal-free organic electroluminescent molecules in which the energy gap between the singlet and triplet excited states is minimized by design, thereby promoting highly efficient spin up-conversion from non-radiative triplet states to radiative singlet states while maintaining high radiative decay rates, of more than 10 decays per second. In other words, these molecules harness both singlet and triplet excitons for light emission through fluorescence decay channels, leading to an intrinsic fluorescence efficiency in excess of 90 per cent and a very high external electroluminescence efficiency, of more than 19 per cent, which is comparable to that achieved in high-efficiency phosphorescence-based OLEDs.



Demonstration of display that used a light-emitting material of TADF

A New Nonmetallic Inclusion Rating Method by Positive Use of Hydrogen Embrittlement Phenomenon

Shinji Fujita, Yukitaka Murakami
Metallurgical and Materials Transactions A, January 2013, Volume 44, Issue 1, pp 303-322

A new inclusions rating method using hydrogen embrittlement of a tensile test specimen is proposed. This method is essentially based on the statistics of extremes for inclusion rating where the maximum inclusion size is determined by simple tensile testing of a hydrogen-precharged (H-precharged) specimen. Tensile tests were conducted using two bearing steels (SAE52100 *HV* 346, *HV* 447, *HV* 559, *HV* 611, *HV* 678 and ASTM-A485-1 *HV* 706, *HV* 715) and one spring steel (SAE5160, *HV* 651). Fatigue tests were conducted using SAE52100 bearing steel (*HV* 682). All H-precharged tensile specimens (SAE52100, ASTM-A485-1 and SAE5160) were fractured from internal inclusions except the SAE52100 tensile specimens with a Vickers hardness of *HV* 346. It was confirmed that the distribution of extreme values of inclusion sizes obtained by SAE52100 tensile testing with H-precharged specimens coincided with those obtained by SAE52100 fatigue testing. From these results, it is presumed that the inclusion rating method by fatigue testing can be replaced by simple tensile testing with H-precharged specimens. The proposed method is more convenient and reliable than other existing inclusion rating methods, i.e., fatigue testing and optical microscopy. The proposed method can be applied to specimens with a Vickers hardness of higher than *HV* 447.

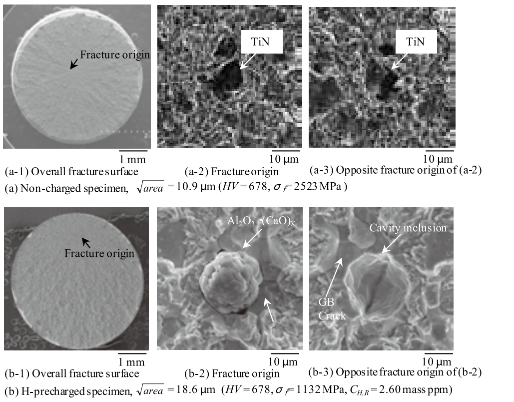


Fig. 1 SEM images of tensile fracture surfaces for the SAE52100 specimens. Cross head speed: 1mm/min, Time from the end of H-precharge to the start of tensile test: 2 h, $C_{H,R}$: Residual hydrogen content.

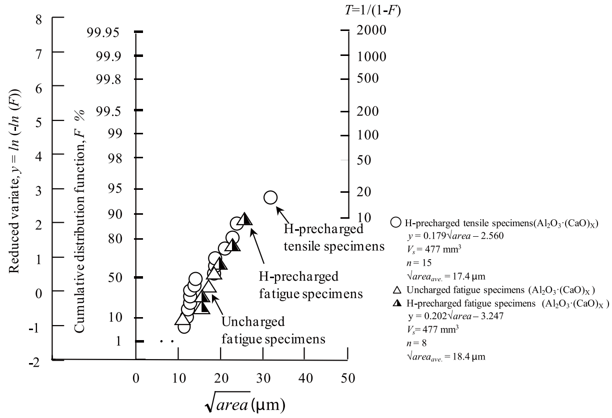
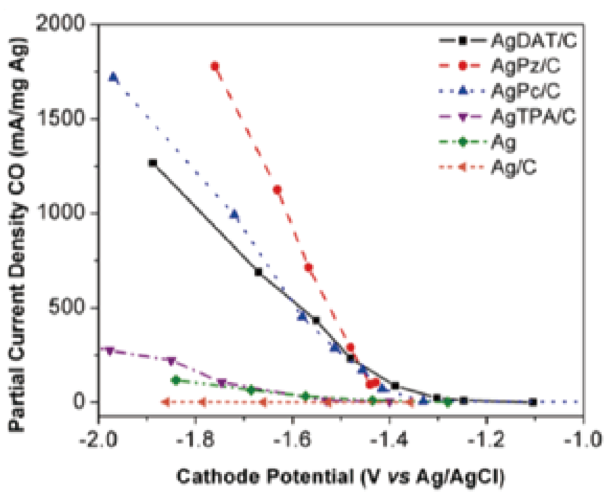


Fig. 2 Statistics of extremes distribution of $Al_2O_3\cdot(CaO)_X$ inclusions contained in the SAE52100 H-precharged tensile specimens and in SAE52100 fatigue specimens.

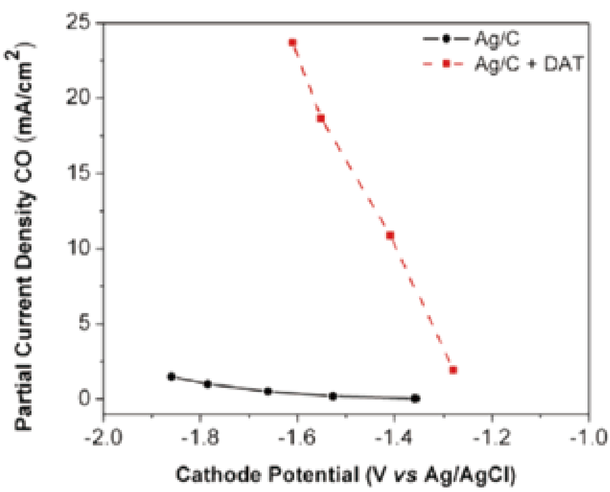
Nitrogen-Based Catalysts for the Electrochemical Reduction of CO_2 to CO

Claire E. Tornow, Michael R. Thorson, Sichao Ma, Andrew A. Gewirth, and Paul J. A. Kenis
Journal of the American Chemical Society. 2012 Dec 5; 134(48):19520-3. DOI: 10.1021/ja308217w.

The synthesis and application of carbon-supported nitrogen-based organometallic silver catalysts for the reduction of CO_2 is studied using an electrochemical flow reactor. Their performance towards the selective formation of CO is similar to the performance achieved when using Ag as the catalyst, but comparatively at much lower silver loading. Faradaic efficiencies of the organometallic catalyst are higher than 90%, which are comparable to those of Ag. Furthermore, with the addition of an amine ligand to Ag/C, the partial current density for CO increases significantly, suggesting a possible co-catalyst mechanism. Additional improvements in activity and selectivity may be achieved as greater insight is obtained on the mechanism of CO_2 reduction and on how these complexes assemble on the carbon support.



1) Partial current densities vs. cathode potential for CO relative to the cathode Ag loading using N-based Ag catalysts.



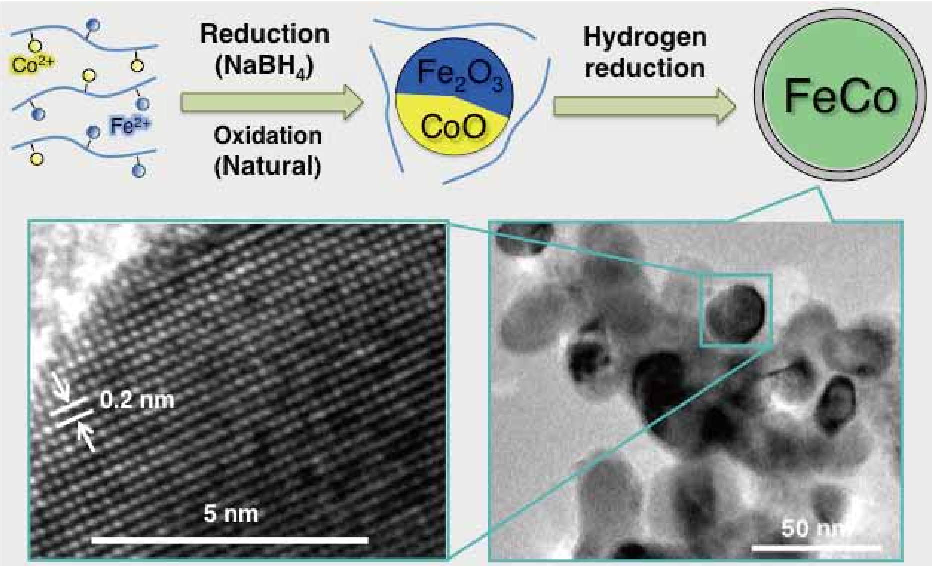
2) Partial current density for CO with a Ag/C electrode compared to a Ag/C electrode with addition of DAT.

Enhanced Magnetization in Highly-Crystalline and Atomically-Mixed bcc Fe-Co Nanoalloys Prepared by Hydrogen Reduction of Oxide Composites

Md Jafar Sharif, Miho Yamauchi, Shoichi Toh, Syo Matsumura, Shin-ichiro Noro, Kenichi Kato, Masaki Takata and Tatsuya Tsukuda
Nanoscale. 2013 Jan 3. DOI:10.1039/C2NR33467D

Nanomaterials with high magnetic moments have potential application in various fields, such as data storage, magnetic resonance imaging, and high performance transformers. Nano-scale alloys (nonoalloys) of Fe-Co are promising materials for these applications because the bulk bcc alloy has the highest saturation magnetization (Ms = 233 emu/g for Fe50Co50, 245 emu/g for Fe70Co30) in this class of metals and high Curie point (1173 K). Various synthetic methods of Fe-Co nanoalloys have been proposed, the Ms values of the resulting Fe-Co nanoalloys are still smaller than that of the bulk and fall in the range of 150 – 235 emu/g. Main reasons for the depletion of the magnetic properties are oxidation in ambient conditions, formation of carbide phase, and poor crystallinity. Post-synthesis thermal treatment can circumvent these problems; this treatment yields bcc Fe-Co nanoalloys covered by a carbon layer for protection against ambient oxidation.

In the present work, we developed a two-step method to prepare solid-solution type, Fe-Co nanoalloys, whose Ms value is as high as bulk alloys.



Homogeneously mixed, solid-solution Fe-Co nanoalloys were prepared by hydrogen reduction of the mixed oxide composites. The saturation magnetization of the Fe-Co alloys are higher than those reported previously and comparable to that of corresponding bulk Fe-Co alloys.

REPORT

International Institute for Carbon-Neutral Energy Research organized I²CNER in Tokyo Symposium "Japan-US Collaboration on Energy"

The International Institute for Carbon-Neutral Energy Research (I²CNER) organized the I²CNER in Tokyo Symposium which was sponsored by the Ministry for Education, Culture, Sports, Science and Technology (MEXT), Japan Society for the Promotion of Science (JSPS) and the U.S. Embassy in Japan at the National Center of Sciences in Tokyo on December 7, 2012. The symposium was attended by approximately 150 guests, including several international participants, as well as special guests Mr. Daisuke Yoshida (Director-General, Research Promotion Bureau, Ministry of Education, Culture, Sports, Science and Technology (MEXT)), Dr. Toshio Kuroki (WPI Program Director), and Ambassador John V. Roos (U.S. Embassy in Japan), who each gave opening remarks.

Dr. Katsuhiko Hirose (Project General Manager, R&D Management Division, TOYOTA Motor Corporation), Principal Investigator Kazunari Sasaki (Fuel Cells Research Division, I²CNER, Kyushu University), and Satellite Associate Director Kenneth Christensen (I²CNER, University of Illinois at Urbana-Champaign) outlined the current status and the future research directions of scientific research in order to make it possible to realize a low-carbon society. As special lecture, Dr. Monterey Gardiner (Technology Development Manager, Office of Hydrogen, Fuel Cells and Infrastructure Technologies, U.S. Department of Energy) spoke about the present and future of a hydrogen energy society in the United States. In addition, the panel discussion was moderated by WPI Visiting Professor Mark Paster (Energy Analysis Research Division, I²CNER, Kyushu University) and had a lively exchange of views on energy issues.

In the symposium, Director Petros Sofronis gave a talk on the realization of a sustainable and environment-friendly society, which is based on hydrogen energy, and the intent to work on energy issues deepening ties between Japan and the United States.

Daisuke Yoshida
Director-General, Research Promotion Bureau, MEXT

John V. Roos
Ambassador Extraordinary and Plenipotentiary, the U.S. Embassy in Japan

Panel Discussion