Hello! I²CNER vol.9

International Institute for Carbon-Neutral Energy Research

Science Cafe

Toward the safe storage of carbon dioxide deep underground

Takeshi Tsuji

Lead Principal Investigator of CO_2 Storage Research Division, Associate Professor
International Institute for Carbon-Neutral Energy Research (I²CNER), Kyushu University

Waseda Saga Senior High School students

Impacting Society By Solving Problems

wpi World Premier International Research Center Initiative
I²CNER
KYUSHU UNIVERSITY
ILLINOIS UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Welcome to I²CNER!

Hiroshige Matsumoto

Professor
Hydrogen Production Research Division

I came to Kyushu University in 2004 and joined I²CNER in October 2013. In order to create a carbon-neutral society, it is crucial to use renewable energy in an efficient way. To that end, we need an efficient energy storage system for renewable power, which we can achieve by storing electricity in the form of hydrogen through "water electrolysis" and then reproducing electricity using a fuel cell. I focus on key concepts such as "solid materials which carry away a hydrogen ion" and "Nanoparticles." I research functional materials and the devices that are useful to development of such a system. I enjoy cooking on holidays.

Kwati Leonard

Post-doctoral Research Associate
Hydrogen Production Research Division

My research focuses on ceramic proton-conducting materials with compatible electrodes for the development of reversible solid oxide fuel cells for low-cost, highly efficient power generation and hydrogen production. I truly consider myself blessed to be a part of I²CNER, where excellent researchers with diverse academic backgrounds gather and work on research in the field that I enjoy immensely. I have an innate and insatiable desire to know "why" and "how", and to me there is nothing more fundamental than materials. Fukuoka is a very nice and beautiful place, and people are very friendly and helpful. I enjoy sports and reading during my leisure time.

Daniel Orejon

Post-doctoral Research Associate
Thermal Science and Engineering Research Division

After pursuing Ph.D. from the University of Edinburgh in the U.K., I joined I²CNER in October 2013. My research focuses on the study of new materials and the development of more thermally efficient processes aiming to reduce CO_2 emissions. In addition, I am involved in the characterization of novel metal hydrides for hydrogen storage. I was very happy to join I²CNER so that I can pursue simultaneously my personal goals and I²CNER's main objectives. Also I am very excited about the opportunity to explore the Japanese culture, traditions, language, and food while living in Japan. So far, I am in love with sashimi and tempura!

Helena Tellez Lozano

JSPS Postdoctoral Fellow
Hydrogen Production Research Division

I am originally from Spain. I spent the last two years at Imperial College London in the U.K. and joined I²CNER in September 2013. My research interests are focused on the application of advanced ion beam surface analysis techniques to understand the relationship between surface chemistry and catalytic performance in electro ceramic materials, in particular, for high temperature solid oxide electrolyzers. In addition to the wonderful Japanese food, one of the most interesting things I am discovering in Japan is that there are a lot of similarities between Japan and the South of Spain. Kotatsu (we call it brasero in Spain) is one of them. I feel like I am at home already.

"Coffee & Collaboration[co²]"

I²CNER holds "Coffee & Collaboration (CO^2)" on Tuesdays and Fridays from 3 to 4 P.M. in the I²CNER Lounge. CO^2 is a regular networking event which is designed to gather researchers and staffs from all of I²CNER's divisions into one place. I²CNER's strategy behind CO^2 is to encourage fusion research by providing consistent, comfortable opportunities for the researchers to interact. An attractive feature of this event is the relaxed, "coffee shop" environment which facilitates open discussion and free exchange of information and ideas.

The CO^2 "buzz"

Daniel Orejon

Post-doctoral Research Associate, Thermal Science and Engineering Research Division

CO^2 brings the researchers from different divisions to one place so we can exchange information, share experiences, and discuss any ideas and thoughts that we have. Since we all share the same goal, it is important that we hear the new ideas of others and keep "up to date" on their latest work. These regular interactions strengthen our team camaraderie. We enjoy communicating over delicious coffee!

The CO^2 "buzz"

Sayoko Fujino

Technical Staff, CO_2 Capture and Utilization Research Division

Since I²CNER has many foreign researchers, most of the conversations that take place at CO^2 are carried out in English. I am happy to say that joining CO^2 improves my English skills! Also, the relaxing environment of CO^2 enhances the communication between participants, enabling us to exchange more of our cultural and personal backgrounds with each other. I have learned so much about the researchers at CO^2! Having a better understanding of their backgrounds and perspectives on research has helped me to provide better assistance to each researcher.

Research Division Introductions

What is a carbon-neutral society?

This is a society where CO_2 emissions generated by energy use are reduced to a minimum, and where a balance is achieved between emissions and the amount absorbed and stored in the nature world.

Energy Analysis

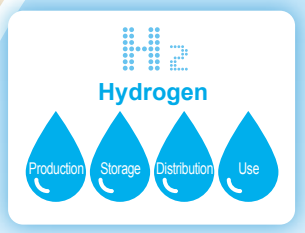
Energy Analysis of the relevance of I²CNER research from Science, Technology, and Time Scale viewpoints.

Hydrogen Production

Researches a hydrogen production method with zero CO_2 emissions that uses solar power.

Hydrogen Materials Compatibility

Investigates the mechanisms by which hydrogen is deleterious to the strength of metals, and conducts research into materials that can handle hydrogen safely.



Hydrogen Storage Materials

Conducts research on materials that can store hydrogen compactly and safely.

Catalytic Materials Transformations

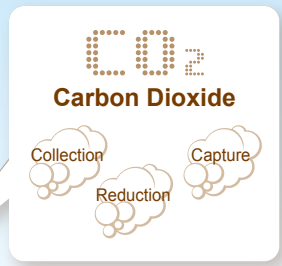
Studies green chemical reactions that realize materials transformation without producing waste as a by-product.

Fuel Cells

Conducts research on next-generation fuel cells that can efficiently realize direct electricity generation from hydrogen etc., and proposes new concepts to that effect.

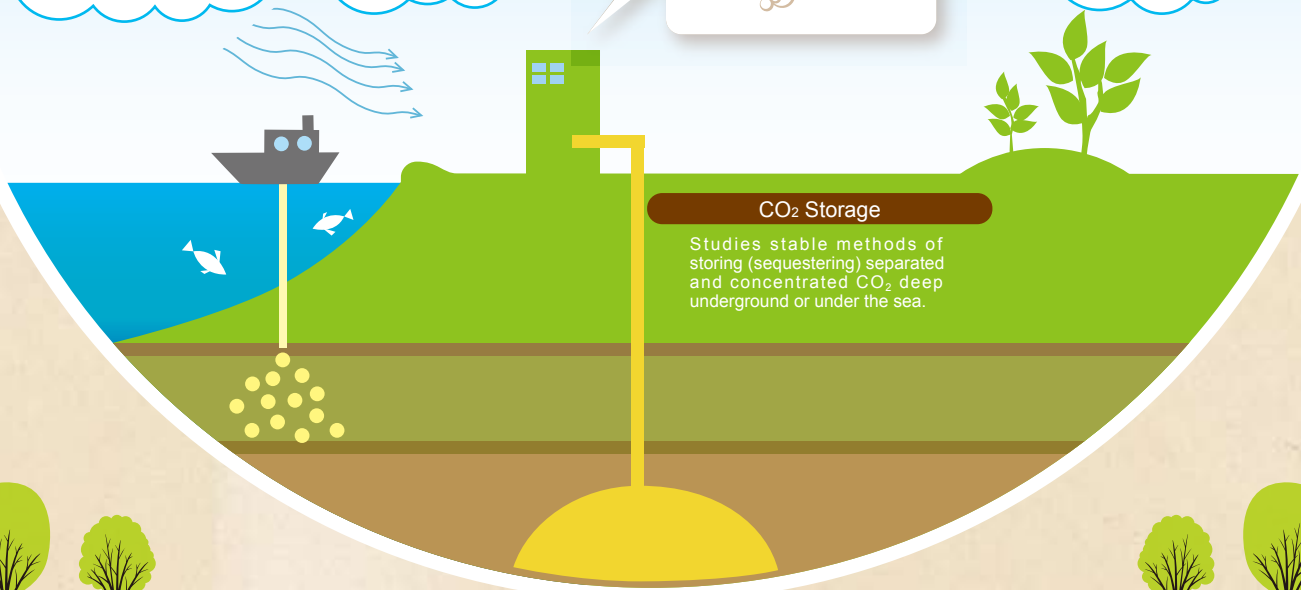
Thermal Science and Engineering

Conducts research on the thermophysics of hydrogen and CO_2 in various conditions, including high pressure behavior and heat conductive properties, and studies how heat is transmitted.



CO_2 Capture and Utilization

Studies inexpensive methods of efficient separation and utilization of CO_2.



CO_2 Storage

Studies stable methods of storing (sequestering) separated and concentrated CO_2 deep underground or under the sea.

Introducing the nine research divisions of I²CNER, who are engaged in cutting edge research to create a green and clean carbon-neutral society free of CO_2 emissions.

Science Cafe
HELLO!! I²CNER
2014

Discussion Members

Lead Principal Investigator of
CO_2 Storage Research Division
Associate Professor
International Institute for Carbon-Neutral
Energy Research (I²CNER), Kyushu University

Takeshi Tsuji

VS

Waseda Saga Senior High School students

Yoshiki Sunagawa, first-year student
Yuuki Kiyohara, first-year student
Hotaru Tsuji, first-year student

Toward the safe storage of carbon dioxide deep underground

Due to the increase in the level of mankind's energy consumption since the industrial revolution, the amount of greenhouse gas in the atmosphere is also increasing. Greenhouse gas is a general term for gases in the atmosphere such as carbon dioxide (CO_2) and methane that absorb certain bands of infrared radiation from the earth's surface, creating what is called "the greenhouse effect." CO_2 makes up the majority of these gases, so various measures to reduce CO_2 and prevent the greenhouse effect are being deployed rapidly. In general, these measures can be divided into two categories: emission reduction and prevention of the release of CO_2 into the atmosphere. Associate Professor Tsuji and a group of Waseda Saga Senior High School students held a discussion specifically about the issue of emission reduction through safe, deep underground storage of CO_2.

CO_2 continues to increase rapidly

Tsuji Do you all know what kind of research the International Institute for Carbon-Neutral Energy Research (I²CNER) at Kyushu University is currently working on?

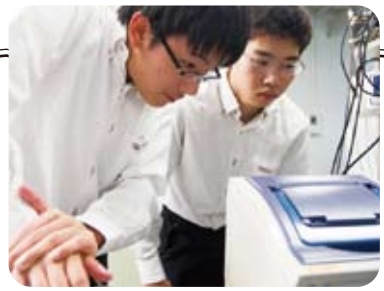
Kiyohara The reference materials say one issue you're addressing is the reduction of CO_2 emissions and another is the development of energy systems that use non-fossil fuels, such as hydrogen energy.

Tsuji Excellent, it looks like you've done your research thoroughly. So how interested are you in climate change issues?

H Tsuji Regarding climate change, I have an embarrassing memory from elementary school. When I was doing a presentation on climate change for my free research project, I stated that the cause was steam, and the teacher pointed out that I was wrong.

Tsuji Steam? Well actually, steam is





also a greenhouse gas. However, since the industrial revolution, the gas which is increasing due to human activity is CO_2.

From a variety of statistical data, it has been confirmed that the concentration of CO_2 in the atmosphere is consistently increasing each year, and when we compare modern levels to the levels before the industrial revolution, we find that at present, the CO_2 levels have increased to about 1.5 times the pre-industrial revolution levels. The problem is that if we fail to do anything about it, it may increase at an even faster rate in the future, which may cause various negative effects on the Earth.

Sunagawa I have heard that if the surface ocean temperature increases, the intensity of typhoons greatly increases.

Tsuji That is certainly true. And what else might happen?

Kiyohara If the ice at the North and South Poles melt, then sea levels would increase and countries such as Tuvalu in the Pacific Ocean could possibly become submerged.

H Tsuji If temperatures rise, there would also be great changes in the ecosystem.

Tsuji You all know quite a lot. The primary cause of climate change is not CO_2 alone. However, we can be fairly certain that increases in CO_2 promote climate change. Moreover, climate change greatly affects the natural environment when it comes to things such as food production. The potential result of this is serious social problems, such as regional conflicts over productive land.

The breakdown of climate systems caused by climate change

Tsuji Do you know about ocean circulation? Ocean circulation is the flow of water which starts at Greenland in the North Atlantic Ocean, where water sinks to the ocean depths, and over a period of about 1,500 years, moves deep under to rise close to the surface in the Indian and North Pacific oceans, before returning to its origin. The Cold water is thus carried to tropical areas, and warm water is carried to the poles. This global flow of water is a way of maintaining constant global temperatures.

H Tsuji It sounds kind of like a massive air conditioner.

Tsuji That's a very good analogy. However, since the ice in Greenland has already begun melting due to climate change, serious problems are now beginning to occur.

Kiyohara When the ice melts it becomes fresh water, doesn't it? If you think about fresh water, it should be lighter than salt water.

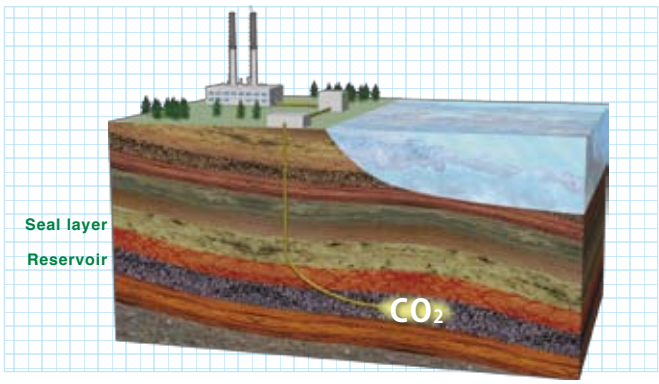
Sunagawa In the future, the water that should sink near Greenland will become lighter, and the sinking effect will weaken.

Tsuji That's right. The worry is that the effect will weaken and ocean circulation itself will stop. If that happens, then the temperature in areas near the equator will increase further and, conversely, the polar areas will begin to get colder. If ocean circulation stopped, it would be very difficult for mankind to restore it.

This is just one example out of many complex components which have linked together to regulate the temperature on Earth for all this time.

Now, that balance is being disrupted.

Schematic image of Carbon Capture and Storage

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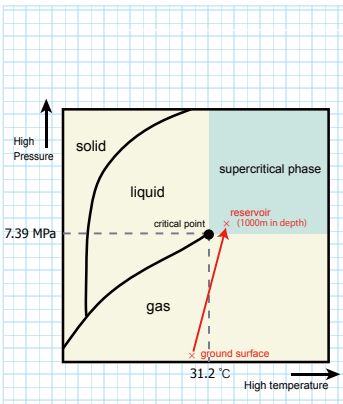


Figure1: The phase diagram of CO_2

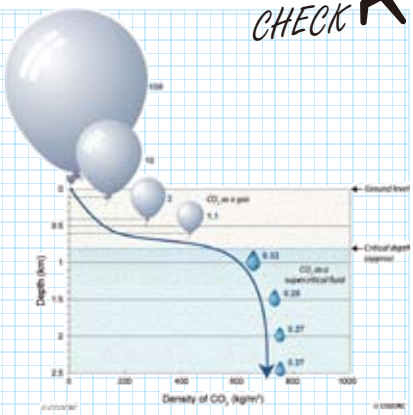


Figure2: The relationship between density of CO_2 and depth

In other words, if you use the supercritical form, you can fit about 300 times the amount of atmospheric CO_2 in the same storage space.

Kiyohara That's really efficient. But then, it can't be that simple to make it into a supercritical form, can it?

Tsuji In order to change CO_2 into a supercritical form, certain conditions need to be met. In addition to the temperature being over 32 degrees, you need to apply about 7.3 atmospheres of pressure. But ideal conditions for both temperature and pressure exist 1,000 meters underground, even without performing any artificial processes.

Storing CO_2 in the atmosphere deep underground

Tsuji So, in order to achieve a great reduction in CO_2, we are currently researching a technique called Carbon Capture and Storage, or CCS for short, which involves collecting the CO_2 emitted from electric power plants and factories and storing it underground.

Kiyohara When you say storing underground, does that mean you dig a giant tunnel and put the CO_2 in there?

Tsuji Not quite. This involves injecting CO_2 into the gaps between particles of rocks in reservoir formations located deep underground. These rocks have millions of tiny holes that the eye can't see, which make up about 20% of their volume. That's where we take the CO_2 to inject it after we've changed it into a supercritical form, which is a state somewhere between a gas and a liquid.

Tsuji The advantage of converting it to supercritical form is that you can make the CO_2 very compact. For example, if we take the volume of CO_2 as a gas in the atmosphere as 1, then convert this to supercritical form, it would be condensed by as much as 0.003.

One issue for CCS is storage site monitoring

Kiyohara Where is CCS actually being implemented now?

Tsuji There are already several sites around the world where CCS operations have begun. In Japan, the government is conducting tests in order to demonstrate the practicality of CCS at gas fields in Nagaoka city, Niigata prefecture, as well as at Tomakomai city in Hokkaido. Overseas, they are actively implementing CCS in countries such as the United States, the United

Experiment

Bridging discussion and practical application

～ Attempting an experiment in the carbon capture and storage experiment laboratory ～

After discussion, the students visited Asst. Prof. Keigo Kitamura's lab, where they attempted a simple experiment on fundamental CO_2 storage research. First, the students placed drops of water on two rocks with different properties (one rock that absorbs water easily and one that doesn't), and by observing the difference in the apparent degree of penetration between the two, they confirmed the difference between rocks which can be used for carbon storage and rocks which can be used as cap rocks. Also, the students fired sound waves on a dry rock and a rock that had water on it, then measured the speed of the sound waves on both. From the difference in the speed of the sound waves, they confirmed how this would work in monitoring scenarios before and after storage.

Keigo Kitamura

Assistant Professor
CO_2 Storage Research Division

Currently conducting basic reseaches for CCS implementation, such as an experimental research of Rock-physics for the basic studies of Geological CCS and the development of the estimation methods for physical-and chemical-characters of formation water.

Kingdom, Norway, and Australia.

Kiyohara If you carry this out in countries whose land mass is small like Japan, could the stored CO_2 leak and potentially cause an accident?

Tsuji In order to avoid this risk, it is necessary to constantly monitor the conditions underground. Currently, we are conducting research using refractive seismic surveys as a method of monitoring. This method involves sending sound waves toward the earth, and analyzing the shape of the waves that come back to determine the underground conditions.

Kiyohara You might be able to ascertain the conditions underground using sound waves, but are you able to get a grasp of the state of the injected CO_2?

Tsuji We compare the conditions before and after CO_2 injection; we record the changes and analyze them.

H Tsuji You must have counter-measures to put in place immediately if there is any possibility of even the smallest of leaks.

Tsuji Actually, there is something called a “cap rock,” which is a layer of impermeable rock that acts as a lid to prevent any leakage when material is injected underground. Even so, we still need to monitor the conditions constantly.

Sunagawa In that case, the issue becomes how well you can minimize costs.

Tsuji Indeed. In order to minimize monitoring costs, we are also researching monitoring techniques which use ambient noise. It is possible to do this type of measurement with accelerometers like the ones found in smartphones, which allows us to cut significant costs.

I must say, besides being highly concerned about climate change, you’re also all very knowledgeable. In a few years, why don’t you join I²CNER as researchers and help us to work toward achieving a carbon-neutral society together? I’m looking forward to that day.

Message for students: Associate Professor Tsuji

Throughout the course of my studies, rather than cramming knowledge, I have utilized the knowledge I gained to its maximum potential, and I place great importance on trying to actually understand various phenomena. Now I feel that the accumulation of small exertions of effort over time has given me the opportunity to engage in this exciting research. From now on, you will be the valuable human resources upon which the future of the world depends. In addition, I would like for you to try to study with an awareness of the proper practice and application of knowledge so that you will be able to tackle and find solutions to problems on a global scale in the future.

Takeshi Tsuji

Lead Principal Investigator of CO_2 Storage Research Division
Associate Professor
International Institute for Carbon-Neutral Energy Research (I²CNER), Kyushu University

Post-discussion

Waseda Saga Senior High School students

This discussion was made possible by the cooperation of the students of Waseda Saga Senior High school. Waseda Saga Senior High school is a private institution which was established in Karatsu-city, Saga prefecture, Japan in 2010, and is affiliated with Waseda University of Japan. The school focuses its efforts on fostering students who have "Advanced professional knowledge" and "sophistication", also can exercise “good judgment." In addition, the School is devoted to training its students to become Global Leader and Global Citizens. As part of this effort, the school actively provides various off-campus learning opportunities through which the students can obtain valuable life experiences.

Yuuki Kiyohara

Until now, I didn’t have a very clear image of the measures for the recovery of the global environment, so I didn’t understand them, but this visit has improved my understanding. Despite the complexity of this cutting edge research, I was able to get familiar with it through practical experience.

Yoshiki Sunagawa

Until now, I didn’t know that this CCS initiative was being carried out as a measure for CO_2 reduction. Through this visit, I was amazed to learn about the cutting edge research behind CCS.

Hotaru Tsuji

I was happy to feel close to a researcher who was doing work at the cutting edge of the issue. I’ve been interested in science since I was young, so I want to maintain and develop that interest.

I²CNER Event Report

I²CNER at Kyushu University Open Campus 2013

Event.01 August 4th, 2013

The International Institute for Carbon-Neutral Energy Research (I²CNER) participated in "Kyushu University Open Campus 2013" on August 4th, 2013. I²CNER's research efforts and activities were introduced through "I²CNER Introduction", "Mini-Lectures by I²CNER Young Researchers", and " I²CNER Lab Tours". In the Mini-lectures, 4 young researchers from 3 divisions (Hydrogen Production, Hydrogen Storage, and CO_2 Storage) gave brief presentations on their research, then moved on to a discussion session where participants asked many questions such as "Why did you choose to become a researcher?" or "What is your advice for aspiring researchers?". Since some of the participants are actually considering going into the energy field in future, there was a very active discussion and exchange of ideas. During the lab tour, the participants visited 3 labs where they observed ongoing research such as a "Hydrogen storage system using renewable energy" and fundamental research efforts related to the development of fuel cells and carbon capture and storage technology. Despite the heavy rain, a group of 35 people (mainly high school students) participated and enjoyed the program.

【Mini-lectures were given by the following young researchers】
Asst. Prof. Masamichi Nishihara (Fuel Cells Research Division) **Asst. Prof. Stephen Lyth (Fuel Cells Research Division)**
Asst. Prof. Huaiyu Shao (Hydrogen Storage Research Division) **Asst. Prof. Keigo Kitamura (CO_2 Storage Research Division)**

Science Agora 2013

Event.02 November 9-10, 2013

The World Premier International Research Center Initiative (WPI) institutions, including the International Institute for Carbon-Neutral Energy Research (I²CNER), participated in "Science AGORA 2013" which was held at the National Museum of Emerging Science and Innovation and 6 other venues in Tokyo on November 9th and 10th, 2013. This annual science event, organized by Japan Science and Technology Agency (JST), was established in 2006 as "Agora" where the communication between "science" and "society" can be enhanced in Japan. This year, I²CNER was one of 230 organizations to host a booth. The I²CNER booth was designed to represent our scientific efforts and research projects to the public. Specifically, we introduced our research activities through demonstrations of a hydrogen-fueled car and rock that can be used as a CO_2 reservoir. In addition, 3 of I²CNER's researchers gave special lectures to the public in the "WPI Science Live!" corner. Many people of all ages attended the lectures and got an in-depth perspective on I²CNER's latest research. Science AGORA 2013 had a total of approximately 8,500 visitors over 2 days.

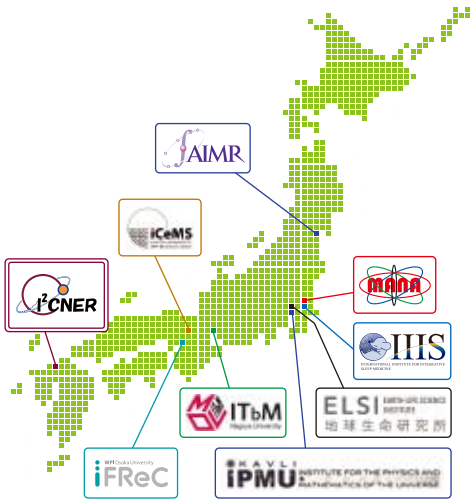
【"WPI Science Live!" Speakers】
Prof. Chihaya Adachi (Principal Investigator of Hydrogen Production Research Division)
Assoc. Prof. Shigenori Fujikawa (Lead Principal Investigator of CO_2 Capture and Utilization Research Division) **Asst. Prof. Aleksandar Staykov (Hydrogen Production Research Division)**

What is WPI?

wpi World Premier International Research Center Initiative

The World Premier International Research Center Initiative (WPI) is a project that was launched by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in 2007. The WPI seeks to form an ideal research environment within visible research centers that maintain high research standards, where leading researchers will be attracted from all over the world.

Refer to:
MEXT Website http://www.mext.go.jp/english/research_promotion/1303822.htm
JSPS Website http://www.jsps.go.jp/english/e-toplevel/index.html



I²CNER Kyushu University International Institute for Carbon-Neutral Energy Research (I²CNER)

Toward the realization of a low-carbon society, I²CNER aims to resolve the challenges of the use of hydrogen energy and CO_2 capture and sequestration by fusing together sciences from atomic level to global scale.

AIMR Tohoku University Advanced Institute for Materials Research (AIMR)

Integrating physics, chemistry, materials science, bioengineering, electronics and mechanical engineering, AIMR is striving to create innovative functional materials. A mathematical unit joined the team in 2011 to help establish a unified theory of materials science, aiming at the realization of a global materials research hub.

iFReC WPI Osaka University Osaka University Immunology Frontier Research Center (IFReC)

An innovative research center, which pursues the goal of comprehensive understanding of immune reactions through the fusion of immunology, various imaging technologies, and Bioinformatics.

MANA National Institute for Materials Science International Center for Materials Nanoarchitectonics (MANA)

A major focus of our activities is the development of innovative materials on the basis of a new paradigm "nanoarchitectonics," ground-breaking innovation in nanotechnology.

iCeMS Kyoto University Institute for Integrated Cell-Material Sciences (iCeMS)

Established to integrate the cell and material sciences, the iCeMS combines the potential power of stem cells (e.g., ES/iPS cells) and of mesoscopic sciences to benefit medicine, pharmaceutical studies, the environment, and industry.

IPMU Kavli Institute for the Physics and Mathematics of the Universe (Kavli IPMU), Todai Institutes for Advanced Study, The University of Tokyo

With accumulated research on mathematics, physics and astronomy, this research core works to bring light to the mysteries of the universe, such as its origin, and to provide an analysis of evolution.

ELSI Tokyo Institute of Technology EARTH-LIFE SCIENCE INSTITUTE(ELSI)

ELSI focuses the origins of Earth and life. Both studies are inseparable because life should have originated in unique environment on the early Earth. To accomplish our challenge, we establish a world-leading interdisciplinary research hub by gathering excellent researchers in Earth and planetary sciences, life science, and related fields.

IIIS University of Tsukuba International Institute for Integrative Sleep Medicine(IIIS)

IIIS seeks to elucidate the fundamental mechanism of sleep/wakefulness, to develop strategies to regulate sleep, and to contribute to the enhancement of world health by combatting sleep disorders and associated diseases.

ITbM Nagoya University Institute of Transformative Bio-Molecules (ITbM)

The goal of ITbM is to develop innovative functional molecules that make a marked change in the form and nature of biological science and technology (transformative bio-molecules). ITbM will connect molecules, create value, and change the world, one molecule at a time.

Editor's note: "Hello I²CNER" "Energy Outlook"

- I²CNER holds a variety of events.
  For details, please see: ➡ http://i2cner.kyushu-u.ac.jp/ja/results/seminar.php
  (I²CNER Event Information)
  Search by I2CNER
- 2014 is the 4th year of establishment of International Institute for Carbon-Neutral Energy Research (I²CNER). As an Institute, we hope that this year will be our most productive year ever – that we are determined to intensify our research efforts in order to produce more outcomes and findings which will contribute to the creation of a carbon neutral society. We hope that you continue to enjoy reading about the broad range of topics that we introduce here in "Hello!I²CNER" & "Energy Outlook".

Hello! I²CNER vol.9 JANUARY 2014
[Published by] International Institute for Carbon-Neutral Energy Research (I²CNER)
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