From Kyushu University to the world.
Introducing research activities that will bring us to the realization of a carbon-neutral society.

Hello! I²CNER

October 2014
vol.11

International Institute for Carbon-Neutral Energy Research

Science Cafe

The Key to Solve the Energy Problem Is to Make the Fullest Possible Use of Hydrogen Energy

Hiroshige Matsumoto

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

Shingu High School

Impacting Society By Solving Problems

wpi World Premier International Research Center Initiative
I²CNER
KYUSHU UNIVERSITY
ILLINOIS

Welcome to I²CNER!

Introduction of New Researchers

Masanobu Kubota

Professor
Hydrogen Materials Compatibility Research Division

I have worked for I²CNER since 2011, when I was a faculty member of the Department of Mechanical Engineering at Kyushu University. This year, I joined I²CNER as a full-time member. My research area is materials and hydrogen interactions relating to materials strength. Research on fretting fatigue receives attention not only from academia, but also from industry. Since joining I²CNER, my research is developing more than ever because I am taking up new perspectives, which are fostered by collaborations with many other researchers from different fields.

Yuki Honda

Post-Doctoral Research Associate
Hydrogen Production Research Division

I joined I²CNER in April 2014. My research field is applied biochemistry. Previously, I studied industrially important microorganisms and enzymes at Waseda University and Kyushu University. At I²CNER, my efforts are dedicated to developing an efficient hydrogen production system by creating a novel photocatalyst fused with an enzymatic function. On holiday, I often go to historical places in order to get better acquainted with the culture of Kyushu.

Ju-Hyung Kim

Post-Doctoral Research Associate
Hydrogen Production Research Division

I am from the Republic of Korea. Before joining I²CNER in 2014, I studied and worked at various universities and institutes in Korea and Japan. My research focuses on soft-lithography, organic devices, and organic-metal contact. My experience covers structural design based on the device principle, analysis of device performances, and more. I am easy-going person and I love mingling with people. I enjoy playing and watching both basketball and baseball on weekends. I am really happy to join I²CNER, since it is concerned with various energy resources, science, and engineering.

Kevin Lee White

Post-Doctoral Research Associate
Hydrogen Production Research Division

Howdy! I am a native Houstonian (Texas, USA), and have been in Fukuoka since completing my doctorate in Mechanical Engineering at Texas A&M University in December 2013. I joined I²CNER in April, and will be working on hydrogen production and friction reduction applications. I also hope to make contributions to other research areas. My professional interests are in structure-property relationships of nanomaterials. In addition to being a sports fan, particularly baseball, I enjoy playing guitar and am slowly learning the Japanese language, culture, and cuisine.

Sho Kitano

Post-Doctoral Research Associate
Catalytic Materials Transformations Research Division

After studying for 9 years to complete my Ph.D. at Kinki University in Osaka, I joined I²CNER beginning this April. In I²CNER, I work for the development of a new energy system which does not produce CO_2 as a waste product. Particularly, I am studying the development of catalysts which effectively convert nitrogen compounds. Even though this is my first time living in Kyushu, I feel that Fukuoka is more comfortable than Osaka. For example, I feel much more relaxed on holidays.

Ryota Watanabe

Post-Doctoral Research Associate
Catalytic Materials Transformations Research Division

I am from Hokkaido. I joined I²CNER as a post-doctoral researcher beginning this April. Our current energy society, which is dependent upon fossil fuels, causes problems such as energy loss, emission of the greenhouse gas CO_2, etc. To solve such problems, my research focuses on the establishment of a clean and efficient energy cycle which is free of CO_2 emissions because it uses a commonplace alcohol. My favorite part of Ito campus is that is surrounded by nature on all sides. I feel better each day when I see the beautiful wildlife all around Ito campus.

Tatsunori Ikeda

Post-Doctoral Research Associate
CO_2 Storage Research Division

After receiving my Ph.D. from Kyoto University, I joined I²CNER beginning this April. My specialty is geophysical exploration using seismic waves to estimate underground structures. In I²CNER, I will utilize seismic approaches for understanding reservoir conditions and monitoring injected CO_2 in carbon capture and storage projects. I'd like to contribute to a carbon-neutral society through my research. On the weekends, I like to work out at the gym.

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

Production Storage Distribution Use

Hydrogen Storage

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.

Carbon Dioxide

Collection Capture Reduction

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 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.

HELLO! I²CNER 2014

Science Cafe

The Key to Solve the Energy Problem Is to Make the Fullest Possible Use of Hydrogen Energy

Discussion Members

Professor,
Hydrogen Production Research Division,
International Institute for
Carbon-Neutral Energy Research (I²CNER),
Kyushu University
Hiroshige Matsumoto

&

Shingu High School
second-year students
Ayaka Segawa
Erika Tsuruta

first-year students
Erika Shiraishi
Arisa Yanagi

The world's recent history involves developments such as the industrial revolution, the extensive use of fossil fuels, and important world issues such as climate change. Energy from fossil fuels enabled an unprecedented economic development and made life more convenient in several respects. However, use of fossil fuels led to an increased production and release of CO_2 in the atmosphere, and thus there is a pressing need to reduce CO_2 emissions. To this end, Professor Hiroshige Matsumoto, an environment and solid-state electrochemistry researcher, and students from Shingu High School in Fukuoka Prefecture discussed hydrogen which is anticipated as a new energy.

Light and Shadow of Scientific Technologies

Matsumoto A great many scientific technologies have made our lives richer and more convenient. What technology do you think brings the most convenience to your daily life?

Yanagi For me, it is air conditioning. I receive so much benefit from it that I wonder how people ever managed without it.

Tsuruta In my case, it would be the mobile phone. Messaging services such as SMS have become an integral part of my life.

Matsumoto Other technologies have enriched our lives, through the manufacture of automobiles, the construction of buildings and in many other ways, in every corner of society. However, there is also a negative side to technology. Do you know anything about that?

Tsuruta I heard about the environmental pollution that occurred in the past. Air and water were polluted, and people got sick.

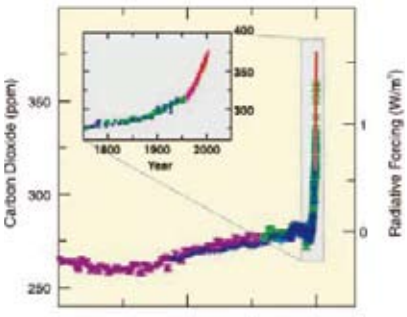
Segawa The large amount of vehicle emissions has caused acid rain, damaging forests.

Yanagi I worry about global warming. It is a problem that will affect our future.

Matsumoto In the long run, global warming, a possible cause of climate change, is a grave concern. One of the suspected causes of global warming is the sharp increase in levels of atmospheric CO_2.

Accelerating Effects of CO_2

Shiraishi If I remember correctly, CO_2 accounts for as little as 0.03% of the entire atmosphere. Does such a small amount really affect the entire globe?



(Excerpt from Page 38 of IPCC2007)

Matsumoto Look at this graph. The atmospheric concentration of CO_2 soared from 280ppm (0.028%) before the industrial revolution to 379ppm (0.0379%) in 2005.

Tsuruta That surge has affected the rise in average temperatures around the world.

Matsumoto Sea water temperatures are increasing and sea water is expanding. Some point out the danger that Antarctic ice will melt in the future. Global warming is the suspected reason for the abnormal weather patterns we have seen with increasing frequency.

Segawa We have learned that the industrial revolution was an energy revolution. Humans acquired new energy by burning coal, one of the fossil fuels. As a result, a large number of useful scientific technologies has emerged. But have these technologies also caused massive damage to our environment?

Matsumoto Coal and petroleum took more than tens of thousands of years to accumulate as carbon storage materials, but people have been burning it for just the past 100 years or so. As a result, atmospheric CO_2 concentrations are increasing at frightening speeds.

Creating a Carbon-Neutral Society

Tsuruta If CO_2 contributes to global warming, we must reduce CO_2 somehow.

Matsumoto I'd like you to remember the name of the facility we are in right now. I²CNER stands for International Institute for Carbon-Neutral Energy Research. Do you know what carbon-neutral energy is?

Yanagi As carbon is CO_2, would it be energy that does not increase CO_2?

Laboratory Visit

Leonard Kwati

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

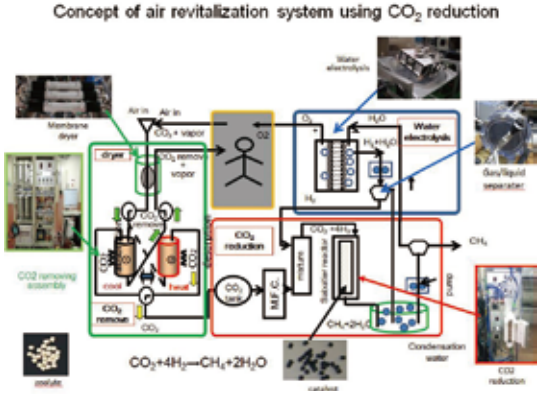
Hydrogen Generator

We study nonconventional electrolysis, using titanium oxide powders with a proton-conducting surface. One of the features of titanium oxide is its usability under weightless conditions. In normal electrolysis, hydrogen and oxygen rise in water, which accelerates the reaction; whereas in weightless conditions, since the hydrogen and oxygen can't rise, the reaction is not facilitated. Proton conductors, however, can solve this problem.

Current Tester

Fuel cells generate electricity via the opposite process of water electrolysis. That is, the reaction of hydrogen and oxygen generates electricity, heat and water. Specifically, hydrogen gas is separated into protons (hydrogen ions) and electrons by the catalytic reaction of platinum at the hydrogen electrode. The protons move to the oxygen electrode and react with oxygen to form water. The electrons then move to the anode to generate electricity. The picture shows students measuring the electricity generated using a tester.

The Japan Aerospace Exploration Agency (JAXA) has high expectations of Professor Matsumoto's Research



Air Revitalization System in Outer Space (Provided by JAXA)

It is thought that 600 liters of oxygen a day are needed for a person to live in outer space. Since there is no oxygen in outer space, we need to manufacture it, and the generation of oxygen using water electrolysis is one possible option (see the illustration). Since water electrolysis cannot be facilitated without gravity, Japan currently depends on other countries that have special equipment that supplies oxygen. For this reason, JAXA has great hopes for Professor Matsumoto's electrolysis method using titanium oxide powders. This method enables the separation of liquid and gas, so that the gas does not stay in the liquid, accelerating water electrolysis even in weightless conditions to finally acquire oxygen.

Matsumoto That's right. Our institute has two main research themes. One is to prevent the CO_2 that is generated by the use of fossil fuels from being discharged into the atmosphere. We study how to safely collect and bury CO_2 underground. The other research theme is how to use fossil fuels as efficiently as possible, or even how to do without fossil fuels. Our research includes the mechanisms of renewable energy sources such as solar and wind power, which can be alternatives to petroleum. The key energy source among others is hydrogen.

Shiraishi I don't understand hydrogen energy very well yet. How can hydrogen replace petroleum?

Utilizing Hydrogen Energy

Matsumoto Hydrogen is expected to play two roles, for both storage and generation of electricity. One example of storing energy is to store electricity generated by photovoltaic power generation in the form of hydrogen.

Segawa I may be wrong, but doesn't that process utilize the electrolysis of water?

Matsumoto Excellent. How did you know? Voltage that is applied to water triggers a decomposition reaction, and generates hydrogen and oxygen. This is called water electrolysis. The opposite reaction, or the reaction of hydrogen and oxygen, can recreate the electricity that was applied. This is the basic mechanism of a fuel cell.

Tsuruta So, hydrogen serves as the energy source for those fuel-cell cars that are attracting so much attention.

Matsumoto That' s right. I study proton conductors as a material that can enhance the efficiency of water electrolysis. With the use of proton conductors, we can extract hydrogen more efficiently than with simple water electrolysis. Other research at I²CNER includes the production of hydrogen using the electrolysis of water vapor at high temperatures of 600℃ to 800℃, and a photocatalyst that can directly decompose water to form hydrogen and oxygen with the use of sunlight or other light energy. We believe that technologies that can make hydrogen from renewable energy sources, including sunlight and wind power, will be critical in the future.

Message to Students from Professor Matsumoto

Hiroshige Matsumoto

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

Research at universities aims at innovation. Innovation means creating something that has never existed before. To create innovative and useful materials for societies and people, it is necessary to discover new scientific principles. Clarifying new principles will lead to new discoveries. The biggest motivation in research is curiosity. Nurture your curiosity about many things, and let's study together at I²CNER in the future.

Post-discussion

Shingu High School

This discussion was made possible through the cooperation of students from the Science and Mathematics Course of Shingu High School. Blessed with beautiful natural surroundings in Kasuya District, Fukuoka Prefecture, this prefectural high school encourages students to balance study and extracurricular activities. It offers the General Course and the Science and Mathematics Course. The curriculum offers students opportunities to attend lectures of university professors and to visit companies, which help students visualize their dreams and future goals. More than 80% of the students engage in club activities, and the school is a well-known frequent qualifier for various prefectural tournaments. In the Project Study Lesson of the Science and Mathematics Course, students select their own research theme, and conduct experiments and analysis on their own. They visit univerisities and institutes on school trips to gain exposure to cutting-edge science and technology. The students are highly motivated, which is one of the advantages of Shingu High School.

Ayaka Segawa

There are still many things I don't know about CO_2 emissions, so it was a good opportunity for me to become more familiar with the global warming issue. The laboratory was full of tools and equipment that I had never seen before. Being able to visit the advanced research facility was very exciting.

Erika Shiraishi

Professor Matsumoto talked to us in an easily understood manner, and I learned much about the environment and science. I have also begun to appreciate the joy of science. I would like to become a researcher to study an area of my interest in the future.

Erika Tsuruta

The experience strengthened my awareness that science and technology are ubiquitous in our society. Learning about Professor Matsumoto's research made me realize the depth and pleasure of research, and my dream of working at JAXA has been reinforced.

Arisa Yanagi

I learned that new research can enrich our lives, not by depending on limited energy resources, but by finding new methods. I was thrilled to conduct an experiment in the laboratory. It was a good opportunity to reflect on my future.

Report

Student's Voice

As part of its effort to facilitate internationalization and researcher exchange, I²CNER encourages its graduate students from the University of Illinois at Urbana-Champaign (UIUC) to travel to Kyushu University (KU) to conduct research with collaborating faculty from KU. Not only do these exchange students act as important liaisons between KU faculty members and UIUC Satellite faculty members, but they also gain rich cultural experience through their interactions with their colleagues in Japan. Two UIUC graduate students who made the journey to visit KU in summer 2014 agreed to share their experiences with us.

Michaela Carlson

Satellite Faculty Supervisor
Prof. Tom Rauchfuss

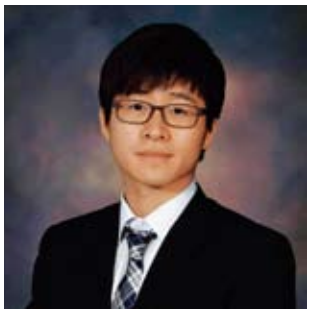
Kyushu University Host Researcher
Prof. Seiji Ogo

Much of Michaela's work falls in the area of inorganic chemistry. Specifically, she studies the catalytic cycle of [NiFe]-hydrogenase model complexes, which can activate or produce hydrogen, using femtosecond extreme ultraviolet transient absorption spectroscopy. She first became interested in inorganic chemistry because she wanted to better the world by promoting safer processes that produce less waste, e.g. through synthesizing new or modifying current catalysts to better suit the world's needs.

Michaela wanted to visit Japan ever since she was a small child. When Prof. Rauchfuss told her that he needed someone to visit the labs at KU, she jumped at the opportunity! This trip gave Michaela the opportunity to help the Ogo group with their project on the development of a highly reactive [NiMn] catalyst that is based off the Mn_3CaO_4 cubane found in photosystem II.

One of Michaela's most unforgettable experiences during her visit to Japan was her visit to the Dazaifu Tenmangu Shrine. Upon entering the shrine, she says that she walked on the beautiful past, present, and future bridges without realizing the significance. She was surprised to learn that each bridge meant so much more than she originally believed!

In the future, Michaela aspires to be a professor. Her goal is to inspire students through her teaching and research. She believes that international experiences, including this trip, will allow her to connect better with her students in the future.



Byoungsu Kim

Satellite Faculty Supervisor
Prof. Paul Kenis

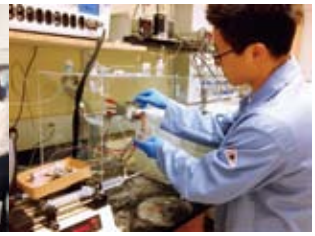
Kyushu University Host Researcher
Prof. Shigenori Fujikawa

Byoungsu studies the electrochemical reduction of CO_2 in I²CNER's CO_2 Capture and Utilization Division. Currently, he is working on two different I²CNER projects: diluted CO_2 as a feed on electrochemical CO_2 reduction and carbon nanotube (CNT) membranes to increase mass transport of CO_2. Though he has long been interested in research related to environmental science and technology, he became interested in this particular area upon discussing research with Prof. Kenis. Specifically, Byoungsu is fascinated by the idea of integration of CO_2 capture and the electrochemical reduction of CO_2.

Byoungsu's visit to Japan is a "follow-up" of sorts to a visit by Prof. Fujikawa to the UIUC campus in Fall 2013. The primary purpose of Byoungsu's visit to Japan was to learn from Prof. Fujikawa how to make a carbon nanotube (CNT) membrane. Byoungsu also worked on silicon nanowire (SiNW) electrodes in Prof. Fujikawa's lab.

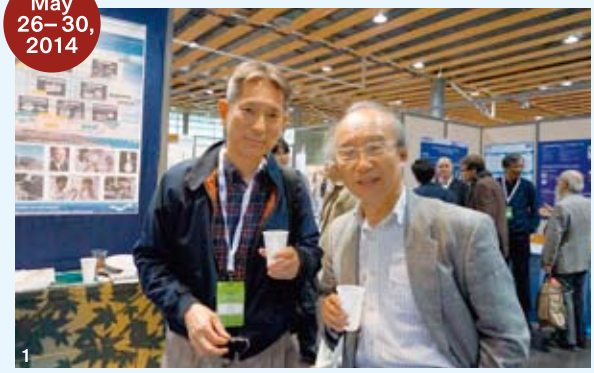
During his visit to Japan, Byoungsu said he was most impressed with the hospitality of all his I²CNER colleagues and supervisors, who gave him the opportunity to visit many of I²CNER's state-of-the-art labs. He also very much enjoyed the food in Japan. Thanks to the hospitality of Prof. Fujikawa's research team, he was able to try many different restaurants!

In the future, Byoungsu plans to continue his research related to the environment and energy during his Ph.D. studies.



I²CNER Event Report

May 26–30, 2014



1. Prof. Sakai (left) and Dr. Kuroki at the Reception (right)
2. Prof. Sofronis at the workshop
3. Prof. Adachi at the workshop
4. Prof. Sakai at the workshop

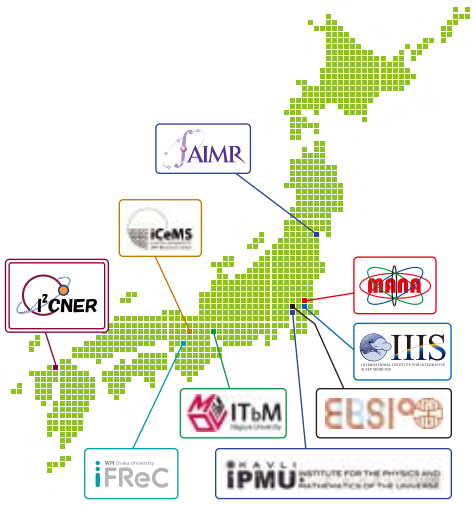
E-MRS 2014 Spring Meeting Lille, France

The World Premier International Research Center Initiative (WPI) was represented by four WPI centers, including I²CNER, at the European Materials Research Society (E-MRS) 2014 Spring Meeting in Lille, France, from May 26 to 30. Founded in 1983, the E-MRS today has more than 3,200 members from industry, government, academia and research laboratories, who meet regularly to debate recent technological developments of functional materials. I²CNER, along with AIMR, iCeMS and MANA, ran the WPI booth throughout the event, and hosted a reception entitled "Come together + Japanese Product Tasting" on May 27, where Dr. Kuroki, WPI program director, and researchers from the four WPI centers mingled with other E-MRS attendees over Japanese foods and *sake*. On May 28, the WPI program was featured in a workshop titled "Japan in Motion" by Dr. Kuroki, four directors including I²CNER director Sofronis, and selected researchers from each center. From I²CNER, Profs. Adachi and Sakai gave lectures to showcase their latest research findings. Nearly 70 researchers from all over the world participated in the workshop.

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.



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.

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

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 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
- It's hard to believe summer is already gone and fall is officially here (although we can still feel lingering summer heat in the daytime). This summer, we had chances to meet many high school students at various events such as "Hello! I²CNER" interview, Kyushu University Open Campus, and "Super Science High (SSH)" student workshop. We are always thrilled to witness their talents and creativity (and youth!), which make us want to work harder to improve the contents, so that our young readers will enjoy "Hello! I²CNER" even more.

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