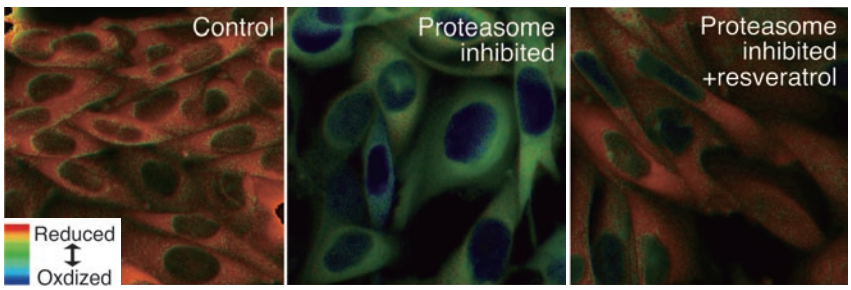
Cutting-Edge Research at Kyoto University

Kyoto University is known for the quality and diversity of its research. Each issue of Research Activities can only highlight a small selection of those endeavors, but we hope to convey an impression of the university's rich academic milieu.

MOL-CELL-BIOL

Anti-aging Compounds Act in Mitochondria

Resveratrol and sesamin function as antioxidants in mitochondria against cell death.



Visualized intracellular redox state

Impairment of proteasome that is the protein machinery responsible for degradation of abnormal proteins have been strongly associated with cell death–mediated aging and the pathogenesis of neurodegenerative disorders, eg Alzheimer's and Parkinson's disease. However, the mechanism by which inhibition of proteasome in cells causes cell death is still unclear. By visualizing intracellular redox state, we revealed that proteasome inhibition led to mitochondrial oxidation followed by cytosolic oxidation, which could be prevented by mitochondrial-targeted antioxidants. Moreover, compounds found in red wine and sesame — resveratrol and sesamin, respectively — prevented intracellular oxidation and improved cellular survival by maintaining mitochondrial function.

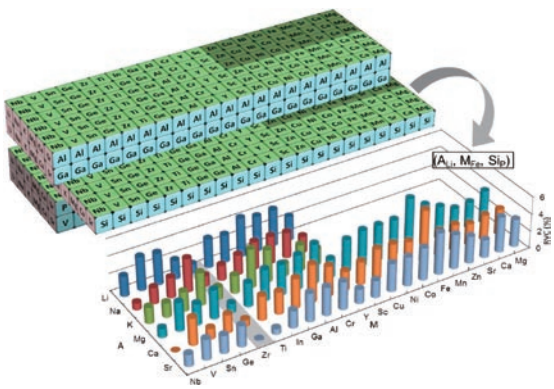
Yasuyoshi Sakai, PhD (left) *Professor, Graduate School of Agriculture*
Jun Hoseki, PhD *Associate Professor, Research Unit for Physiological Chemistry*
www.seigyo.kais.kyoto-u.ac.jp/

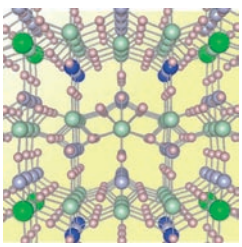
MATS-SCI

Battery Materials with a 70-Year Cycle-Life

Computer-Aided Discovery of New Materials.

Large-scale battery systems are essential for efficiently utilizing renewable energy power sources from solar and wind, which can generate electricity only intermittently. The use of lithium-ion batteries (LIB) to store the generated energy is one solution. A long cycle life is critical for LIB when used in these applications. Together with an industry partner, we demonstrate a novel cathode material with estimated capacity





retention of 25,000 cycles that corresponds to a 70-year lifetime with a daily charge/discharge cycle. The material with a lifetime six times longer than the conventional one is found by exploring a wide chemical composition space using computers. The targeted material is successfully synthesized by an elaborate chemical route and shows excellent cycle-life performance as lithium-ion battery cathodes.

Isao Tanaka, PhD *Professor, Graduate School of Engineering*
cms.mtl.kyoto-u.ac.jp/

ANIM-BEHAV

Wolves Communicate with their Eyes

Understanding the behavior of wolves through gaze communication.

Our research interest involves understanding how gray wolves (*Canis lupus*) use their gaze to communicate. Wolves have facial color patterns that make their gaze direction easily identifiable. Although wolves show various body color variation, they all have eyes with a bright yellow iris. To the human eye, their gaze seems very sharp and impressive. Through our research comparing facial color patterns and behavior in Canidae (dog family), we suggest that facial color patterns are related to gaze communication and that gray wolves communicate with one another via gaze signal.

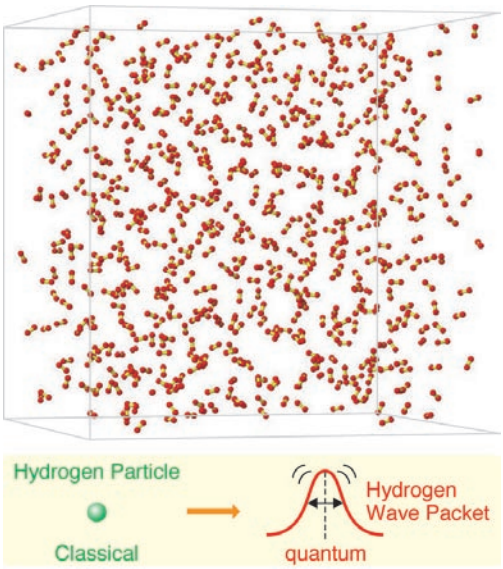
As dogs are domesticated wolves, they share the ability of gaze communication and can understand other dogs' as well as human gaze signals. Our study can be helpful not only in understanding the behavior of wolves but also domestic dogs, the most popular companion animals.

Sayoko Ueda, PhD (left) **and Shiro Kohshima, PhD**
Academic Affairs Staff and Professor, Wildlife Research Center
www.wrc.kyoto-u.ac.jp/en/index.html

STAT-PHYS

When Simple Liquids are not so Simple

Simplest hydrogen liquid exhibits mysterious properties that never appear in ordinary liquids.



Hydrogen (H_2) is the simplest of all molecular species. Defining a hydrogen nucleus, the lightest atom in the periodic table, is not straightforward. Instead of a "particle", it is rather like a wave packet. Actually, this simplest atom exhibits strong nuclear quantum effects (NQEs) — the nucleus cannot stop "beating" and can be spatially delocalized. Such NQEs of hydrogen nuclei in an H_2 liquid dominate the structure and thermodynamic properties, making it mysterious. Liquids exhibiting NQEs are called quantum liquids, and show phenomena that have never been observed for ordinary classical liquids. Understanding microscopic molecular dynamics and the resulting anomalous properties of quantum liquids remains an open problem. I am elucidating unexplained anomalous properties of quantum liquids by developing a new computational method taking into account NQEs that can be applied to a many-molecule system with feasible computational cost. The developed method provides intuitive understandings of real-time dynamics of H_2 molecules even in the liquid phase including its H-H bond vibrations, molecular orientations and librational motions.

Kim Hyeon-Deuk, PhD
Assistant Professor, Graduate School of Science
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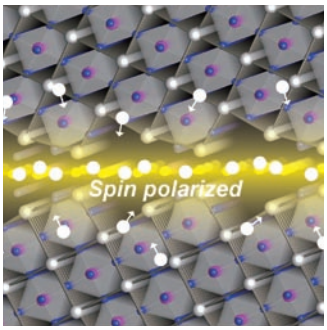
From the Editor This research got an honor of the first paper listed and introduced in the formal email letter of *The Journal of Chemical Physics*.

MECH-ENG

Multi-Physics in Nanostructures

Mechanical strain in nanostructures develops novel functionalities.

Materials of nanoscale dimensions arouse remarkable interest, motivated by the diverse utility for nanotechnology. However, the functionality of materials is suppressed and often destroyed due to their extremely small dimensions. Using a state-of-the-art approach based on quantum mechanics, I have demonstrated that the mechanical stress or strain applied to materials strongly enhances, recovers, and sometimes newly develops, the electric, ferroelectric, magnetic, and various properties at the nanoscale, ie, "Multi-Physics", due to nonlinear behaviors of atoms and electrons. Engineering mechanical strains at the nanoscale therefore enables us to exploit and design novel functionalities and open up new avenues for promising paradigms and novel functional devices.



Emergence of magnetism in deficient lead titanate nanocrystals

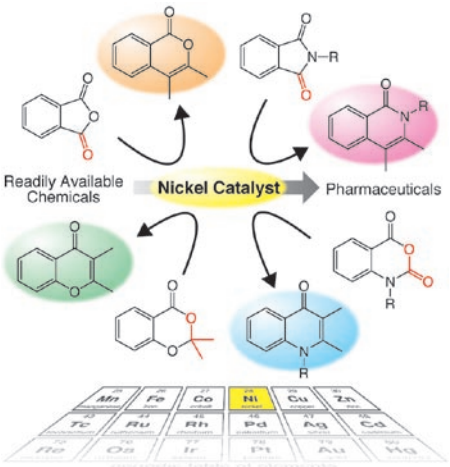
From the Editor By this achievement, Dr. Shimada received the Young Scientists' Prize of the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology this year.

Takahiro Shimada, PhD *Assistant Professor, Graduate School of Engineering*
kyouindb.iimc.kyoto-u.ac.jp/e/gT3rQ

ORG-CHEM

What Does a Catalyst Do?

Catalyst opens the way for divergent synthesis of pharmaceuticals.



Various catalysts perform essential functions to produce a wide variety of chemical substances that are an indispensable part of our daily life. Therefore, the development of new catalysts to provide valuable chemical substances, which cannot be made by conventional methods, is a topic of great interest not only in the laboratory but also in industrial production research. During the course of my research to develop new organic reactions with catalysts, I found that one particular element, nickel, could facilitate the production of many chemicals for pharmaceuticals; the nickel catalyst opens the way for divergent synthesis of pharmaceuticals from readily available chemicals.

From the Editor By this achievement, Dr. Kurahashi received the Young Scientists' Prize of the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology this year.

Takuya Kurahashi, PhD
Associate Professor, Graduate School of Engineering
www.dfm.kuic.kyoto-u.ac.jp/

The John Mung Program

Opportunities to Explore Global Frontiers

Kyoto University launched the John Mung Program* (Kyoto University Young Scholars Overseas Visit Program) in 2012, as a project to support mid- and long-term research by junior faculty members at leading academic institutions overseas.

*The program is named after the Japanese sailor, Nakahama Manjirō, also known in English as "John Mung," who was the first Japanese to set foot on American soil in 1841. After he returned to Japan, he became a pioneering figure in developing the country's international relations.

DISASTER-MANAG

Neighborhood Power

Rebuilding homes and neighborhoods after the 1991 East Bay Firestorm


Dr. Ochiai (left) with Prof. Tobriner

ICT

Toward a New Epilepsy Model of Care

Development of a Seizure Prediction System.

Epilepsy is a common neurological disorder characterized by seizures, which afflicts around 1% of people worldwide. If patients can be given a warning before seizure onset, their quality of life may be improved because they can avoid accidents.

Based on a theory that excessive neuronal activities associated with epilepsy affect the heart rate pattern, we have developed an epileptic seizure prediction system through monitoring patients' heart rate patterns. Our system consists of a heart rate sensor and a smartphone app; the sensor measures the heart rate pattern and the app analyzes it for seizure prediction in real time.

Wearable HR Sensor

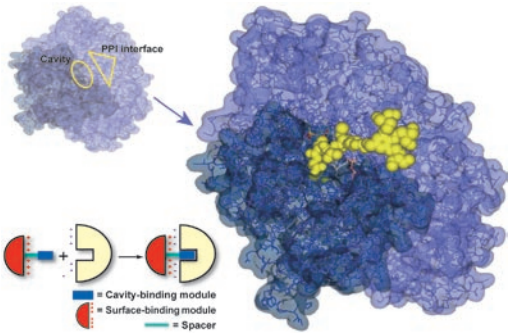
Our system has been tested in hospitals, and it will be ready for practical use hopefully in about ten years. There is a possibility that our system may lead to the creation of a new epilepsy patient care scheme.

Koichi Fujiwara, PhD *Assistant Professor, Graduate School of Informatics*
human.sys.i.kyoto-u.ac.jp/fujiwara/eng/index.html

BIOORG

Chemicals Modulate Protein Interactions

Assembled, mid-sized molecules recognize large and flat protein surfaces.



In humans, hundreds of thousands of protein-protein interactions (PPIs) play critical roles in regulating biological functions, and their dysregulation causes a number of diseases. Compounds that control PPIs have gained much attention due to their large potential application in new therapeutics. My research focuses on design of synthetic agents that recognize large protein surfaces, and disrupt and detect PPIs that are implicated in pathogenesis. Our molecular design is based on the module assembly; small compounds are designed for local protein surfaces, and are assembled to create mid-sized multivalent agents. For example, the assembled chemical probe consisting of an antitumor agent was found to detect intracellular PPIs efficiently. This probe may be useful for understanding the biology underlying the unique antitumor activity.

Junko Ohkanda, PhD *Associate Professor, Institute for Chemical Research*
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I had an opportunity to conduct independent research at the University of California, Berkeley, USA for a year from October 2013 to September 2014. Receiving direction from Berkeley Professor Mary Comerio and Professor Emeritus Steven Tobriner, who are internationally recognized experts in disaster recovery architecture, I focused my study on how citizens in neighborhoods reconstructed their homes and communities after the large scale 1991 fire in Oakland and Berkeley, with particular emphasis on understanding citizens' efforts to influence reconstruction efforts. The John Mung Program was essential in providing an opportunity to investigate these aspects of reconstruction, including meetings with scholars, visiting archives, and interviewing survivors. I will continue my study to better understand the social dynamics of disaster reconstruction.

Neighborhood emergency exercise

Chiho Ochiai, PhD
Assistant Professor, Graduate School of Global Environmental Studies
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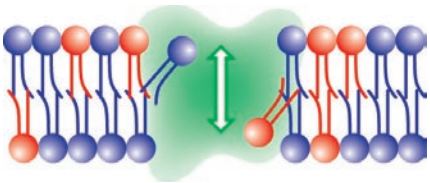
MED-CHEM

Phospholipid Scrambling on Plasma Membranes

Identification of membrane proteins regulating phospholipid scrambling.



Phospholipids are asymmetrically distributed at plasma membrane in normal cells, but their distribution is collapsed by phospholipid scrambling in various biological situations such as blood clotting and apoptotic cell death. Although the molecular mechanism of phospholipid scrambling was unknown until recently, Dr. Shigekazu Nagata and I found that phospholipid scrambling is mediated by at least two independent mechanisms. An eight transmembrane-containing protein TMEM16F Ca(2+)-dependently promotes the phospholipid scrambling in activated platelets for blood clotting. On the other hand, a six transmembrane-containing protein Xkr8 is activated by caspases during apoptosis and promotes the phospholipid scrambling, thus exposing phosphatidylserine as an "eat-me-signal".

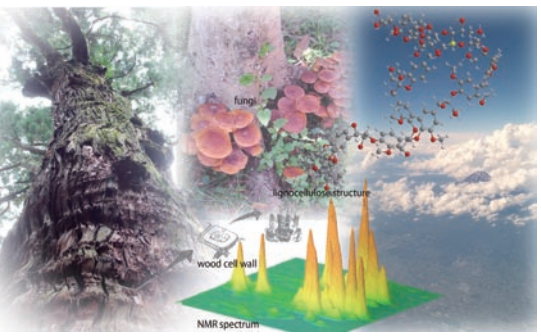
From the Editor Dr. Suzuki received Young Investigator Prize from The Japanese Biochemical Society and The Young Scientists' Prize from the Minister of Education, Culture, Sports, Science and Technology.

Jun Suzuki, PhD *Assistant Professor, Graduate School of Medicine*
www2.mfour.med.kyoto-u.ac.jp/~nagata/english/index.html

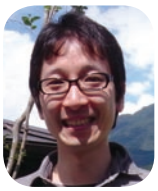
WOOD-CHEM

Trees, Fungi, and Humans — in Harmony with the Earth

Open complicated wood molecules and bioconversion.



Trees are essential to life. Their tall, large structures are supported by a recalcitrant substance called lignocellulose, made up of complex and large molecules consisting of polysaccharide and lignin, which are assembled and form a 3D network. My investigations concern the molecular structure and formation of lignocellulose in wood cell walls. Fungi have a deep association with trees. Wood-rotting fungi have an ability to degrade wood. How they "eat" wood is the other question. To explore these areas, I work on the development of analytical methods using nuclear magnetic resonance and mass spectroscopy. Trees can be used not only for wooden buildings and products but also for chemicals and energy. Thus, learning from nature and converting lignocellulose in an environmentally friendly system, trees and fungi would help to promote a sustainable future.



Hiroshi Nishimura, PhD *Assistant Professor,Research Institute for Sustainable Humanosphere*
www.rish.kyoto-u.ac.jp/W/LBC/

ART-HIST

Longing for Curiosity, Novelty, and Preciousness

Paintings on Special Supports in Sixteenth-Century Europe.

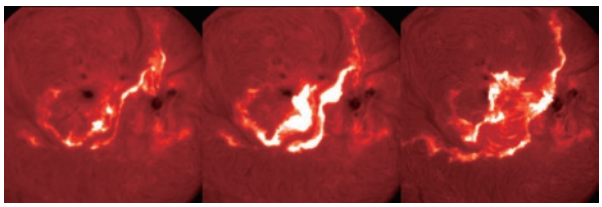
The standard form of painting in European art, that is, oil painting on wood panels or canvas, was established in the late sixteenth century. Some artists, however, went against the stream and ambitiously used stone, metal, or silk as painting supports. The aim of my study is to clarify how paintings on special supports were invented and widely spread in sixteenth-century Europe. During my research stay at Trier University, I focused especially on the pioneering experiments with painting supports by the German Renaissance painter Albrecht Dürer. Trier, a border city between Germany and Luxembourg, was an ideal location for field research in Northern Europe. Moreover, I became acquainted with many talented researchers in the Social History of the Artist Research Center at Trier University. The professional network I developed there was the most valuable outcome of my stay.

Kayo Hirakawa, PhD *Associate Professor, Graduate School of Letters*
www.bun.kyoto-u.ac.jp/aesthetics_and_art_history/aah-wah_hiraka_en/

SOL-PHYS

Storms in Space

Exploring how the Sun governs "space weather."



Solar flares, the most energetic explosion in the solar system, are very spectacular, and they are accompanied by a variety of dynamic phenomena. They often affect environmental conditions of the Sun-Earth system and even the space surrounding the Earth, which cause intense geomagnetic storms at Earth. Therefore, understanding the current environmental conditions and forecasting the effects of disturbances as "space weather" are becoming more and more important.

I analyze various phenomena associated with solar flares, a crucial source of disturbances, by using a number of observed data to gain an overall understanding of flares, which may contribute greatly to the development of space weather researches.

From the Editor By this achievement, Dr. Asai received the Young Scientists' Prize of the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology this year.

Ayumi Asai, PhD *Associate Professor, Unit of Synergetic Studies for Space*
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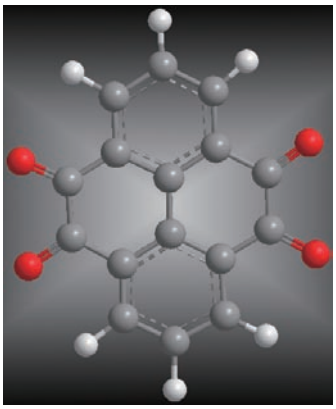
ORG-CHEM

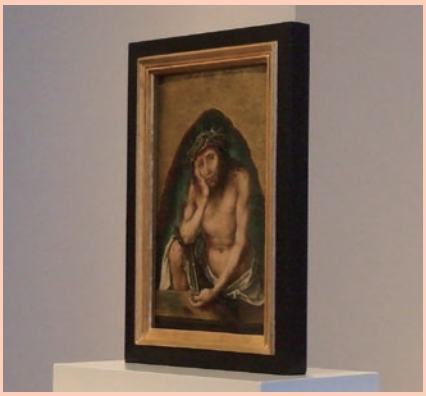
Organic Materials for Lithium-Ion Batteries

Promising candidates for sustainable and versatile energy storage.



Organic rechargeable batteries have received significant research interest from the viewpoints of structural diversity and sustainability. Prof. Yoshida and Assistant Prof. Shimizu designed core structures of organic cathode materials for lithium-ion (Li-ion) batteries based on molecular orbital calculations, which indicated that six-membered cyclic 1,2-diketones serve as excellent core structures because of favorable coordination of the oxygen atoms to Li and the aromaticity of the reduced form. The Li-ion batteries composed of pyrene-4,5,9,10-tetraone, which has two six-membered cyclic 1,2-diketone units, bound to polymethacrylate exhibit remarkable charge-discharge properties with a high specific capacity, excellent rechargeability (500 cycles), and fast charge-discharge ability.

Jun-ichi Yoshida, PhD (left)
Professor, Graduate School of Engineering
Akihiro Shimizu, PhD
Assistant Professor, Graduate School of Engineering
www.sbchem.kyoto-u.ac.jp/yoshida-lab/en/



Albrecht Dürer, *The Man of Sorrows*, ca. 1496, Staatliche Kunsthalle, Karlsruhe (photo: Dr. Kayo Hirakawa)

THE PROGRAM is named after the Japanese sailor, Nakahama Manjirō, also known in English as "John Mung." Rescued by an American whaler after a terrible shipwreck in 1841, Manjirō became the first Japanese to set foot on American soil. He enthusiastically learned about new technologies, laws, and customs. After he returned to Japan, he became a pioneering figure in developing the country's international relations. Inspired by his colorful life story, the program seeks to give junior faculty, staff members, and students opportunities to explore new academic and professional frontiers throughout the world.

PHOTO: Wikipedia