Upcoming Events

MANA International Symposium 2014

The MANA International Symposium 2014 will be held at the Tsukuba International Congress Center (Epochal Tsukuba) over a 3-day period from March 5 (Wednesday) to March 7 (Friday), 2014. This event, which is the 7th in the series, will feature invitational lectures by distinguished scientists from Japan and other countries, beginning with Prof. Leo Esaki, who was the 1973 Nobel Laureate in physics, and Prof. Makoto Kobayashi, the 2008 Nobel Laureate in physics, as well as oral and poster presentations on recent research results by MANA researchers. (No charge for participation.)

Website: http://www.nims.go.jp/mana/2014/

MANA/ICYS Reunion Workshop

A MANA/ICYS Reunion Workshop will be held over 2-day period March 3-4 (Monday-Tuesday), 2014. MANA/ICYS alumni, that is, researchers who were formerly affiliated with MANA or ICYS, will give presentations on their research achievements. The event is also expected to encourage exchanges between fellow alumni and alumni and currently-affiliated researchers, and to strengthen and expand the global network of nanotechnology researchers.

Website:
http://nims.nims.go.jp/mana/reunion/WS_2014/index.html

Event Reports

Swiss-Japanese Nanoscience Workshop: Materials Phenomena at Small Scale

As part of the "150 Years Anniversary of the Establishment of Diplomatic Relations between Switzerland and Japan," a Swiss-Japanese Nanoscience Workshop was held jointly by the Japan Science and Technology Agency (JST), Swiss Federal Institute of Technology in Zurich (ETHZ), and Japan's National Institute for Materials Science (NIMS) Over a 3-day period October 9-11, 2013. Japanese and Swiss research institutes introduced cutting-edge research achievements, and researchers from the two countries enjoyed active exchanges.

Science Agora 2013

MANA participated in the "Science Agora 2013" event held at Odaiba, Tokyo over a 2-day period November 9-10, 2013. MANA's Smart Biomaterials Group of the Biomaterials Unit, Nano-Life Field, exhibited and gave demonstrations on "'Smart polymer,' the future material for diagnosis and treatment of diseases." To explain smart polymers in an easy-to-understand way, the group created "Smapo Rangers - A science manga picture-book," which MANA researchers handed out and explained while dressed as "Smart polymer rangers." The MANA researchers also introduced future applications of biomaterials, which include diagnostic materials that will be useful in early discovery of diseases, nanofiber mesh as an effective material for treatment of cancer, and others, demonstrating that it's possible to have fun while learning about science.


An explanation by a researcher dressed as a "Smart polymer rangers."

Awards and Prizes

MANA Director-General Prof. Masakazu Aono Wins the Nanoscience Prize 2013

Prof. Masakazu Aono, Director-General of MANA, was selected to receive the Nanoscience Prize 2013 by the Organizing Committee of the 12th International Conference on Atomically Controlled Surfaces, Interfaces and Nanostructures (ACSIN-12). The award recognizes Prof. Aono's "Outstanding record of achievements in research on atomic-level control of surfaces, interfaces, and nanostructure and contributions to nanoscience and nanotechnology."


Prof. Aono (left) at the award ceremony.

Independent Scientist Dr. Yusuke Yamauchi Receives the Chemical Society of Japan Award for Young Chemists

The Chemical Society of Japan (CSJ) announced that MANA Independent Researcher Dr. Yusuke Yamauchi receives the 63rd CSJ Award for Young Chemists (award for FY2013). The award was based on the high evaluation of Dr. Yamauchi's ground-breaking original research, "Tailored Synthesis of Nanoporous Metals by Molecular Templates" in Japan and the international scientific community.


Independent Scientist
Dr. Yusuke Yamauchi

CONVERGENCE No.16, Eng. Ed., issued in February, 2014

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"CONVERGENCE" is the keyword used to symbolically describe the entire project of MANA, where outstanding researchers from around the world assemble and converge in the "melting pot" research environment to bring together key technologies into nanoarchitechtonics for the creation and innovation of new functional materials.

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CONVERGENCE

Bringing Up "Big" Researchers - The Challenge of Creating a Research Environment where Young Scientists with High Aspirations Can Flourish and Grow

— Yoshinori TOKURA

Play by NANO, Towards the Future

— Minoru OSADA

Career Enhancement for Young Researchers

MANA's Research Outcome

Nanogenerators as a New Energy Technology — Zhong Lin WANG

Impact of Extracellular Environments on Collective Cell Migration — Jun NAKANISHI

Drastic Modification of Electric Property by One-atomic interfacial Layer for High Energy Efficiency — Michiko YOSHITAKE

Discovery of Dynamic CO_2 Breathing in a Layered Clay Mineral — Shinsuke ISHIHARA

Bringing Up "Big" Researchers - The Challenge of Creating a Research Environment where Young Scientists with High Aspirations Can Flourish and Grow

Yoshinori TOKURA

Prof. Tokura graduated with a B.S. from Dept. of Applied Physics, University of Tokyo, in 1976. After obtaining his Ph.D. in Engineering in 1981, he became a Research Associate at the Graduate School of Engineering, University of Tokyo. He was promoted to Lecturer in 1984 and to Associate Professor in 1986. He became a Professor at the University of Tokyo's Graduate School of Science in 1994, and a Professor at the University of Tokyo's Graduate School of Engineering in 1995. In 2001, he began a joint appointment as Director of the Correlated Electron Research Center at the National Institute of Advanced Industrial Science and Technology. In 2007, he took up a joint appointment as Director of the RIKEN Cross-Correlated Materials Research Group. He has served as Director of the RIKEN Center for Emergent Matter Science since April 2013. Since 2009 he has also been the Core Researcher at the Quantum Science on Strong Correlation (QS2C) Project under the Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST). Prof. Tokura is a leading Japanese physicist, having discovered "strongly correlated electron materials", which show unusual critical point properties of electrons in a solid, and has contributed to open up the new research field of quantum physical science. In 1990 he was awarded the Nishina Memorial Prize and the IBM Japan Science Prize. He received the James C. McGroddy Prize for New Materials in 2005, and has been honored with numerous other domestic and international awards, including the 2013 Imperial Prize and Japan Academy Prize.

Realizing the "third energy revolution."

—What is the aim of this new Center, which brings together many leading scientists in RIKEN?

The aim of our Center for Emergent Matter Science (CEMS) is work that will lead to the "third energy revolution," that is, creating energy from the electrons in solids.

In the first energy revolution, the human race learned how to produce mechanical energy from thermal energy. That is, thermal energy obtained by burning fossil fuels was converted to steam, and that steam was used as the driving force to generate electricity. We have now created a network for transmitting electricity to every corner of society. In the second energy revolution, we harnessed atomic power, in other words, nuclear energy. In both the first and the second energy revolutions, electric energy was obtained by way of mechanical energy. However, in the third energy revolution, electricity will not be produced via mechanical energy, but rather, light and heat will be converted directly to electric energy. This should also make it possible to build information technologies that use virtually no energy.

Just how great the benefits will be is still an unknown, but while aiming at this, we also hope to create one of the world's top centers by concentration and fusion of the knowledge, thought, and technologies of leading experts not only in narrow scientific fields, but for example, in condensed matter physics, functional materials, quantum information electronics, nanoelectronics, and others.

—What are the common points in the directions of RIKEN and NIMS? Could you explain how your own research is related to NIMS?

One common point is that both NIMS and RIKEN are Independent Administrative Institutions under Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT). Both have budgets from the national government, in other words, we use taxpayers' money. From that viewpoint, we at CEMS are conscious of the importance of returning results to society, and we carry out activities in the belief that our research will lead to important breakthroughs for solving Japan's energy problems. I think that the mission of CEMS is to realize ultra-high efficiency energy collection and conversion, and to lead the way to electronics with ultra-low energy consumption.

We do have a relationship with NIMS. Three years ago, we discovered that it is possible to control the nanoscale spin vortices called "skyrmions" in an electric field, and we then attempted to create a new path toward realizing ultra-low energy consumption electric logic and magnetic memory devices. In a research project from 2001 to 2008, which was also linked to this series of research efforts, we carried out joint research with NIMS from around the search for a unique electromagnetic response, which is shown by the electrons' spin-orbital superstructure. In the world's first direct observation of a skyrmion, we received enormous help from Dr. Yoshio Matsui of NIMS and his group, who was pros in the field of electron microscopy.

—How is the research environment different from a university? What is only possible at CEMS?

I don't think the research environment at CEMS is particularly different from that at universities. At universities, students will grow into researchers who can do good work and write good papers if we do our best to give proper guidance. Conversely, researchers may have to be given guidance beginning with how to write papers.

Regarding what is only possible at CEMS, we give special consideration to creating an environment that really facilitates research. Researchers share all laboratories and living spaces; this removes the distinction between researchers and students, so everyone can speak out in free discussions. I think that kind of environment fosters good research.

In building this Center, we were particularly mindful of creating a "showcase of researchers." In other words, we're "selling" the fact that we have brought together many of the world's top researchers. In recent years, we have entered an era when even excellent researchers are employed under a limited-term contract system and have to go out looking for work. Many researchers are still very reluctant to jump into the limited-term system. However, when researchers consider their options, we want to make CEMS an attractive destination that will make them think "I want to be there!" This is because young people will take the plunge if we bring together a number of researchers with outstanding leadership qualities, whom young people find inspiring. Our aim is also to create an environment where researchers who do take the plunge can grow as young leaders. Since MANA already had a number of capable young researchers when it started, I hope that we can learn from your experience.

Running in the world's front line in a competitive international society.

—Who had or continues to have the greatest influence on you as a researcher?

For example, I'm receiving good stimulation on a daily basis from Prof. Naoto Nagaosa of the RIKEN Strong-Correlation Theory Research Team, a theorist who is doing research right beside me. I also recall that I was doing research at IBM in the United States when the world was all agog when Bednortz and Muller received the Nobel Prize for superconductivity in 1987. It was only a period of 1 year, but my boss at the time, Dr. Jerry Torrance, was a man who possessed a combination of great aspiration and wonderful leadership. I was very much influenced by him. I heard that he was a descendant of a family of pioneers who opened the American West. Although his original specialty was organic matter, he had the courage to leap into new fields, whether it was superconductivity or whatever, and I was strongly impressed by his aggressive, energetic figure. I remember reading around 20 scientific papers together each day and exchanging many ideas as a way of promoting research. Even now, I feel that I have an attitude that lets me jump into different fields thanks to Jerry Torrance.

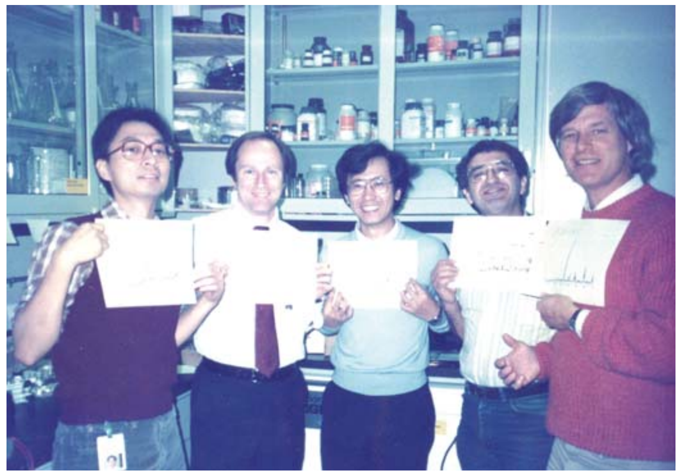
—What is important in order to run in the world's front line?

I don't know if I'm running in the world's front line or not. I'll leave that for others to decide. However, perhaps what is important is to aim at your own dreams and goals in a pure way. When I was a child, the "scientist" was my hero. That was the era of the Japanese scientists Yugawa and Tomonaga, who were both Nobel Laureates in physics. I clearly remember being excited by the news of their discoveries and inventions and wanting to become a "cool scientist."

The situation in other countries has changed in recent years. In other words, where is the front line now? Not so long ago, America appeared to be overwhelmingly superior, but now, that country seems to lack outstanding human resources in the fields of physics and materials science. Germany, as always, excels in its systematic research systems; it has a high level of both basic and applied science and is also strong in human resources. Recently, China's level has risen considerably. It is promoting an extensive range of research, from basic to applied science, and has also produced many top class researchers.

—What kind of relationship do you have with researchers in other countries?

I have many opportunities for exchanges with foreign researchers, and there are also many areas where we compete for leadership in this field. However, I feel that outstanding researchers are also outstanding persons. From that viewpoint, I don't see foreign researchers simply as rivals, but rather, I think that we keep a "relationship of friendly competition." I feel this is a cooperative relationship in which discussion is possible.



Dr. Yoshinori Tokura with colleagues at the IBM Almaden Research Center.
(Center: Dr. Tokura, facing at right: Dr. Jerry Torrance).

Valuing thinking and thought-out logical thinking.

—What do you keep in mind in your dealings with young researchers?

This may be influenced by the fact that I'm a physicist, but I would say, "Do research after first thinking it through to the end, and thinking it out" or "don't act without thinking." In this field, hard study is necessary, and theoretical thinking that leads from many alternative possibilities to conclusions and results by carefully thinking is critical.

However, in research, the results aren't always as expected; they aren't as I predicted and also aren't as a young researcher thought. If that sometimes leads to a new discovery, sometimes it also ends in a wasted experiment. When things don't go smoothly and I hear a young person say that "there wasn't enough spirit," it makes me think, "you understand." In other words, enthusiasm for good research is necessary.

The ideal environment for researchers in Japan.

—Could you give us your advice on how MANA can become a true world's premier research center?

In many cases researchers wander around the researcher community, repeatedly changing jobs as individual players. It reminds me of an old yakuza movie, in which a poor lonely soul sets out with only "one kitchen knife, wrapped in a bleached cotton cloth" in hopes of becoming a real cook. Like professional baseball players who are paid according to their ability, in the United States, the annual salaries of exceptionally talented researchers and professors is also exceptionally high. That isn't the case in Japan. Today's Japanese society doesn't recognize excellence unless a scientist wins the Nobel Prize. It's difficult to bring up exceptional researchers under such circumstances. Outstanding research will not progress unless young people with high aspirations flock to scientific fields. At MANA, I hope that you will create an environment where young people with potential can flourish and grow into "big" researchers.

Interviewer: Akio ETORI, Science Journalist

Play by NANO, Towards the Future

Minoru OSADA
Nano-Materials Field, Soft Chemistry
Associate Principal Investigator, MANA

We recently interviewed Dr. Minoru Osada, who was promoted to Associate Principal Investigator in the MANA Nano-Materials Field in 2012. Dr. Osada's research interest is the development of novel electronic materials based on oxide nanosheets.

I understand that you're involved in research on nanosheets. Could you explain your work in more concrete terms?

We're investigating the synthesis of functional materials with the potential for use in electronic devices in the future. Oxide nanosheets are the basic blocks for those materials. Nanosheets are paper-like nanomaterials with a molecular-level thickness. We utilize these nanosheets as building blocks in the LEGO-like assembly, and develop new electronic materials. As another way of explaining this process, it's like creating a mille-feuille pastry, literally a "cake of a thousand leaves," but with control at the molecular level. This delicious cake is made by placing cream, strawberries or other fruit, or other fillings between a large number of thin sheets of pie pastry. So, imagine a block in which nanosheets correspond to the sheets of pie pastry, and molecules corresponding to the filling are inserted to give the material new functions.

Is synthesis of nanosheets difficult? Are these expensive materials?

Not at all. Synthesis itself is surprisingly simple. First, we synthesize a layered oxide with the desired chemical composition and prepare something like the stack of pastry sheets in the mille-feuille cake. Then, we delaminate the layered oxides into their molecular single sheets via solution-based process. For developing new materials and devices, we focus on an artificial superlattice technique, which is much like children playing with LEGO blocks. By alternately stacking different nanosheets and combining functional molecules, oxide nanosheets are organized into various nanoarchitectures. That's the entire process of making novel materials and devices.

Dr. Minoru Osada

2012 - present	Associate Principal Investigator, MANA, NIMS
2009 - present	Associate Professor, NIMS Joint Graduate School, Waseda University
2007 - 2011	Principal Researcher / MANA Scientist, NIMS
2003 - 2007	Senior Researcher, NIMS
1998	Ph. D., Tokyo Institute of Technology

Today, our electronic devices are evolving toward smaller size and higher functionality, and new classes of functional materials are necessary to continue this trend. We expect that our oxide nanosheets will respond to this demand. For example, Ti- or Nb-based oxide nanosheets realize superior high-*k* dielectric performance even in extremely thin films with a few nanometer, which is essentially required for next-generation electronics. These nanosheet-based capacitors exceed textbook limits, opening a route to new capacitors and energy storage devices in our mobile phones and PCs. There is also enormous interest in building devices and functional materials based on oxide nanosheets of different compositions. Those include batteries, solar cells, touch panels, etc.

MANA has a rich international atmosphere, but how do you feel this in your daily research life?

I'm very much satisfied with the research environment here. Because MANA has so many international researchers, English is the standard language for communication, not only in our group, but in the organization as a whole. On the other hand, even though all the members of my group are from other countries, they're also working hard to learn Japanese. At MANA, I also feel that researchers benefit from mutual stimulation in a good sense.

Our research on nanosheets is truly cutting-edge, and we are always in a competitive relationship with research groups overseas, for example, in Europe and the United States, Korea, and elsewhere. I have many new friends who are researchers in other countries, but even though we're friends when we spend an evening drinking together, we're still rivals when it comes to research.

Do things like national character and the natural and cultural climate of countries have any relation to research?

I would say, perhaps they do. In the United States and Korea, once it's decided that a certain research topic is important, human and financial resources gravitate toward that topic, and this accelerates research. MANA is among the well-supported organizations, but there are still many in Japan where this isn't the case.

During my student days, I had the experience of studying in Sweden, and I received a culture shock. Even though the research equipment and budgets weren't so plentiful, I could really feel the history and depth of scientific research with my skin. Many ordinary citizens were fluent in English, and I also felt that the culture of science had permeated the nation's people. In Sweden, once students or scientists start a discussion, they like to continue a heated debate for hours.

As other examples from my friends, German research tends to be steady, perhaps reflecting the conservative and strong nationality. French research, on the other hand, has an expansive, unhurried feeling. France is a natural home for soft chemistry. Research in which the scientist sets up an experiment and then waits to see what happens might be recommendable for the French, with their national character of enjoying leisurely conversations over wine. (Laughs)

What are your thoughts on the ideal form of Japanese science in the future, and what do you see yourself doing 10 years from now?

Japan needs more programs that develop and foster young researchers. With the number of Japanese who go overseas on the decline, MANA lets young researchers immerse themselves in an environment that's close to studying overseas while still remaining in Japan. For that reason, MANA has created an environment where young people can grow without feeling the barriers in going overseas. Japan needs many more environments for fostering young scientists and researchers in the country as a whole.

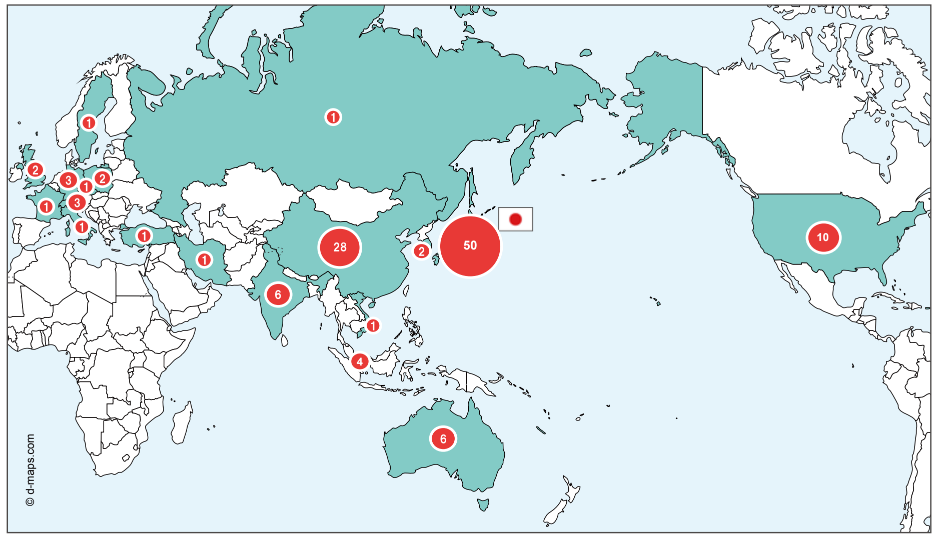
As for myself, I imagine that my management-related work will have increased 10 years down the road, but I want to continue a friendly rivalry with growing young researchers, while also enjoying discussions with them. I hope that I will always be a researcher with a youthful spirit, and will never forget the joy of new discoveries in the actual research site.

Career Enhancement for Young Researchers

MANA regards promotion of research in the field of materials science as one of its missions, and is working energetically to train and provide human resources to achieve this goal. The policy of MANA is not simply to bring together young researchers from around the world for training to become outstanding scientists, but also to ensure that our MANA researchers and alumni have a good understanding of Japan and can improve their career prospects in countries throughout the world.

■ Spreading wings - From MANA to the world !

In the past 5 years, 7 MANA alumni made successful career move to NIMS. During the same period, 117 MANA researchers have also advanced to active careers as researchers in universities and research centers in Japan and other countries. Although about 40% of MANA alumni researchers take positions in Japan, the remaining 60% set out for countries around the world, centering on Asia and also including Europe and the US. In this way, we are continuing to expand the network of nanotechnology researchers with MANA as its hub.



Employment destinations of MANA alumni (unit: Number of people)

■ Training scientists by the MANA "3D system"

MANA has created a unique system for training young researchers which we call the "3D (Triple Double) system." At MANA, young researchers have 2 mentors (Double-Mentor), one who is a NIMS scientist and the other from outside of NIMS (particularly from another country), belong to 2 organizations (Double-Affiliation), and are encouraged to do research spanning 2 fields (Double-Discipline). The aim of this system is to train scientists with an international and interdisciplinary vision by doing interdisciplinary research with the world's top scientists.

Dr. Samuel Sánchez of the Max Planck Institute for Intelligent Systems in Germany is one researcher who has truly spread his wings through the 3D system. While at MANA as an ICYS-MANA Researcher, Dr. Sánchez was able to carry out joint research with the German institute through the 3D system, and as a result, he has now made a big step up in his career by joining one of Germany's representative research institutions.

Dr. Samuel Sánchez (Former ICYS-MANA Researcher)
Research Group Leader,
Max Planck Institute for Intelligent Systems, Germany

Being a scientist in Japan has boosted my scientific career, there is no doubt about it.

I found a very friendly, polite and professional staff that made my -and my family- daily life comfortable and safe.

The top-class facilities are simply impressive. The working atmosphere was exceptional; surrounded by excellent scientists from all over the world in a melting pot with the best resources scientists can imagine.

Japan has been a trampoline for me to find a leading position in prestigious research institutes in Germany. But also...a cultural experience that I will always remember!

■ Building a network through MANA's "alumni system"

MANA/ICYS Alumni Association was established recently for researchers affiliated with MANA and ICYS (International Center for Young Scientists). The purposes of this "alumni system" are to build a global network of MANA/ICYS alumni and to encourage exchanges between fellow alumni and present researchers and alumni.

A MANA/ICYS Reunion Workshop will be held over a 2-day period March 3-4, 2014, with approximately 20 alumni invited. In addition to reports by researchers on their respective research work, the participants will also discuss what types of exchanges are possible by using this network, and outstanding ideas will be reflected in MANA's work.

MANA Alumni website: http://www.nims.go.jp/mana/alumni/

Nanogenerators as a New Energy Technology

Zhong Lin WANG
Principal Investigator
Nano-Materials Field
Georgia Tech

In the last half century, the developing trend of electronics is miniaturization and portability. New technologies that can harvest energy from the environment as *sustainable self-sufficient micro/nano-power* sources offer a possible solution for dealing with the worldwide energy needs.

We have been developing an area of nanoenergy, aiming at using nanotechnology to harvest the energy required for sustainable, independent and maintenance free operation of micro/nano-systems and mobile/portable electronics. The self-powering approaches that we developed at Georgia Tech are a new paradigm in nanotechnology and green energy for truly achieving sustainable self-sufficient micro/nano-systems, which are of critical importance for sensing, medical science, infrastructure/environmental monitoring, defense technology and personal electronics.

We have recently invented the triboelectric NG (nanogenerator) at Georgia Tech for generating electricity by utilizing the triboelectric effect. The triboelectric effect is a type of contact charging effect in which certain materials become electrically charged after they come into contact with other materials. According to a material's tendency to gain or lose electrons upon contact with other materials, a triboelectric series is formulated. Such an effect is usually regarded as an annoying or even hazardous phenomenon because it may lead to ignition, dust attraction, and damage to electronics. Very few efforts have been made to utilize this effect in energy harvesting. Recently, we demonstrated a miniaturized triboelectric NG with low cost and easy fabrication. Owing to the coupling of contact charging and electrostatic induction, electric generation was achieved with repeating contact between two polymer films that differ in polarity in triboelectric series. The instantaneous electric power density reached as high as 300 W/m2 and 400 kW/m3. Triboelectric NG has been demonstrated as an effective means for harvesting wind energy, motion/vibration energy and even ocean wave energy.

A self-powered nanosystem is that it can operate wirelessly, independently and sustainably. The goal of this proposal is to develop the self-powering as a new paradigm in nanotechnology for truly achieving sustainable self-sufficient micro/nano-systems, which are of critical importance for sensing, medical science, infrastructure/environmental monitoring, defense technology and even personal electronics. We anticipate seeing that nanogenerator will play a key role for driving small electronics in a few years.

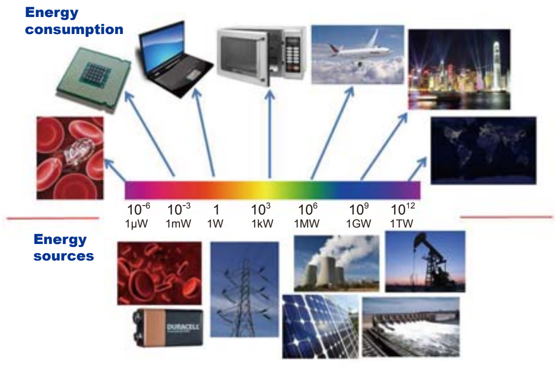


Figure 1 The scale in power. The right-hand side is the large-scale energy needs. The ones at the left-hand side is the field of nanoenergy for portable electronics, which is the focus of our present research.

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Impact of Extracellular Environments on Collective Cell Migration

Jun NAKANISHI
Independent Scientist

Collective cell migration is the migration of cells in a group rather than as single cells. It is one of the most important properties in multicellular organisms for the formation and maintenance of their organized structures. For example, the change in collective characteristics is essential in embryonic development and morphogenesis. This phenomenon also has medical implications, since cancer metastasis can be considered a loss of the collective feature upon escaping from the original tissue and its retrieval on settling and forming a new colony in other tissues. Elucidation of the mechanisms of the processes that determine collective migration characteristics is important for the treatment of diseases and tissue engineering.

We are developing new materials and methods for clarifying the impact of cellular environments, composed of extracellular matrices (ECMs) and surrounding cells, on the determination of migration collectivity. Recently, we developed a new substrate for analyzing collective cell migration with precisely tuned cell-ECM interactions. The substrate bears periodically arrayed gold nanoparticles, where a photoactivatable ECM peptide is immobilized (Figure 1A). Cells are first patterned on this substrate in arbitrary geometries and sizes, and cell migration is induced by secondary irradiation of the surrounding regions (Figure 1B). In addition, the cell-ECM interactions can be quantitatively controlled by tuning the spacing between the nanoparticles. To our surprise, we found a decrease of migration collectivity, which is opposite from what had been expected from the conventional understanding based on the wetting behavior of soft condensed matter. The results indicate possible involvement of changes in cell-ECM interactions in cancer metastasis. Currently, we are focusing on the molecular mechanisms of the observed collectivity change in response to changes in cell-ECM interactions. We are also interested in building a new collective migration model based on the experimental results and mathematical calculations.

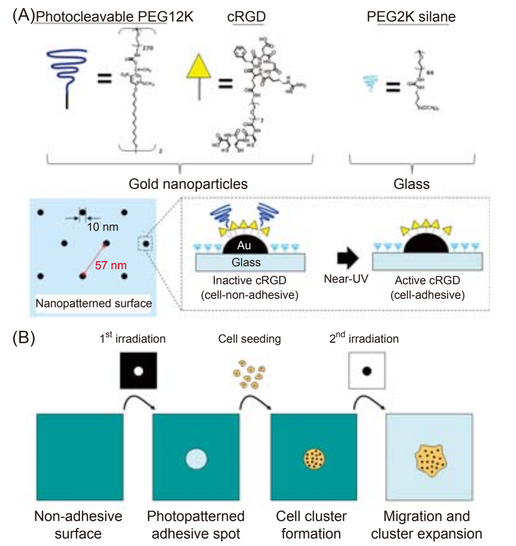

Figure 1 Analysis of collective migration with a photoactivatable nanopatterned substrate. (A) Surface design. (B) Procedure for induction of collective migration.

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Drastic Modification of Electric Property by One-atomic interfacial Layer for High Energy Efficiency

Michiko YOSHITAKE
MANA Scientist
Nano-Materials Field

Electronic devices such as transistors and sensors operate by applying voltage to electrodes. The operating voltage is determined by the relative position between the Fermi level and valence or conduction band, i.e., band alignment. In solar cell technology, this band alignment determines how effective electrons or holes generated by photons can be transferred.

We studied the interfaces between alumina thin films and Cu or Ni electrodes and developed a method for modifying the band alignment at the interface of a gate dielectric film with an electrode metal in transistors. Alumina is composed of oxygen and aluminum, and one of these elements is involved in interfacial bonding at alumina/metal interfaces. We fabricated well-defined interfaces between alumina and metals and determined the element involved in interfacial bonding by observing the Al 2p spectra in X-ray photoelectron spectroscopy. This study revealed that Cu and Ni bond to alumina through oxygen atoms, but when a small amount of Al is added to Cu or Ni, aluminum is the element that forms the bond between the metal and alumina (Figure a), b) and c)). Valence band spectra were also measured to extract the information about the band alignment. We concluded that the difference in the element involved in interfacial bonding causes a difference in band alignment of approximately 1.5 eV [1](Figure d), e) and f)). This means a 1.5 eV difference in the operating voltage in devices and in photovoltaic power in solar cells. This difference is 20-30% of the initial operating voltage or photovoltaic power.

We are now developing a general method to predict the element involved in interfacial bonding for any desired combination of oxides and metals[2].

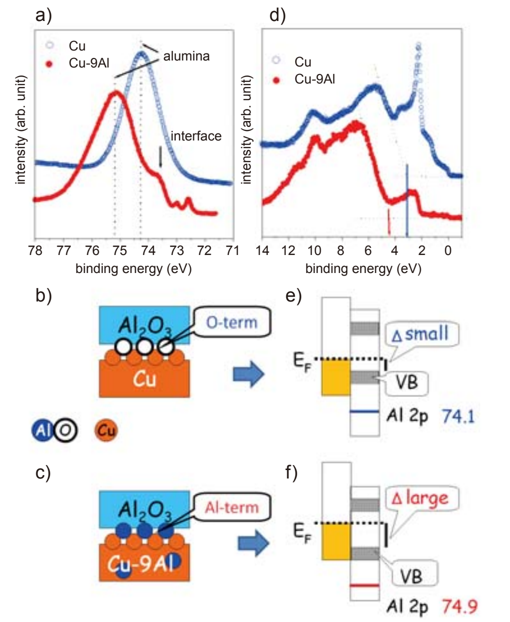

Figure 1 Relationship between interfacial bonding species and band alignment. The interfacial bonding species and energy difference between the Fermi level and valence band (VB), Δ, are deduced from the Al 2p spectra in a) and the valence band spectra in d).

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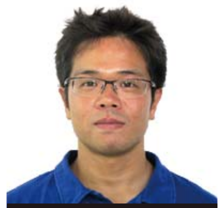

Discovery of Dynamic CO_2 Breathing in a Layered Clay Mineral

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The global carbon cycle has attracted interest because it is related to global warming. Carbonate solids involve the largest quantity of carbon, and the carbon cycle of carbonate solids is based on weathering and metamorphic events, which usually occur over millions of years.

Here we showed that carbonate anions contained in hydrotalcite, which is a class of layered clay minerals, undergo an ultra-rapid carbon cycle with atmospheric CO_2 under ambient conditions, which is substantially accomplished within a week (Figure 1).

The use of ^{13}C-labeling enabled monitoring by IR spectroscopy of the dynamic exchange between the initially intercalated ^{13}C-labeled carbonate anions and carbonate anions derived from atmospheric CO_2. As shown in Figure 2A, the conventional carbonate anion exhibits an IR peak at 1367 cm^{-1}, whereas the ^{13}C-labeled carbonate anion exhibits an IR peak at 1329 cm^{-1}. The IR peak of hydrotalcite which contained ^{13}C-labeled carbonate anions gradually shifts to a higher wavenumber if the sample is left in air, indicating that ^{13}C-labeled carbonate anions are exchanged with carbonate anions derived from atmospheric CO_2 (Figure 2B).

Theoretical calculations as well as gas adsorption experiments revealed that the interlayer of hydrotalcite has a capability to adsorb and desorb CO_2. Interestingly, N_2 molecules, which are smaller than CO_2, cannot enter the interlayer space of hydrotalcite. In addition, a solid-state NMR study demonstrated that carbonate anions within the interlayer of hydrotalcite have high mobility. This result indicates that the reactivity of the carbonate anions is high, which should be important for the dynamic exchange of carbonate anions with atmospheric CO_2.

Because various hydrotalcite-like clay minerals exist in nature, the global carbon cycle involving the lithosphere and atmosphere could be more dynamic than previously thought. These findings have connotations for studies on CO_2 circulation and radiocarbon dating. Finally, the unique interaction between hydrotalcite and CO_2 under ambient conditions may be applicable to energy-efficient separation processes and catalytic conversion of CO_2.

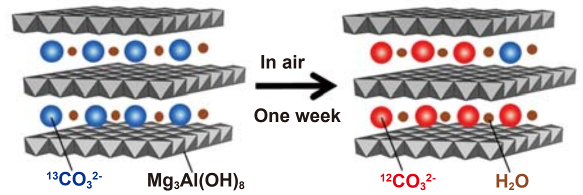

Figure 1 Exchange of carbonate anions in hydrotalcite and atmospheric CO_2.

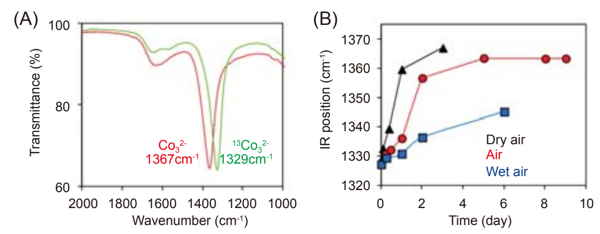

Figure 2 (A) IR spectra of hydrotalcite. (B) Exchange process of carbonate anions in hydrotalcite and atmospheric CO_2.

References
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