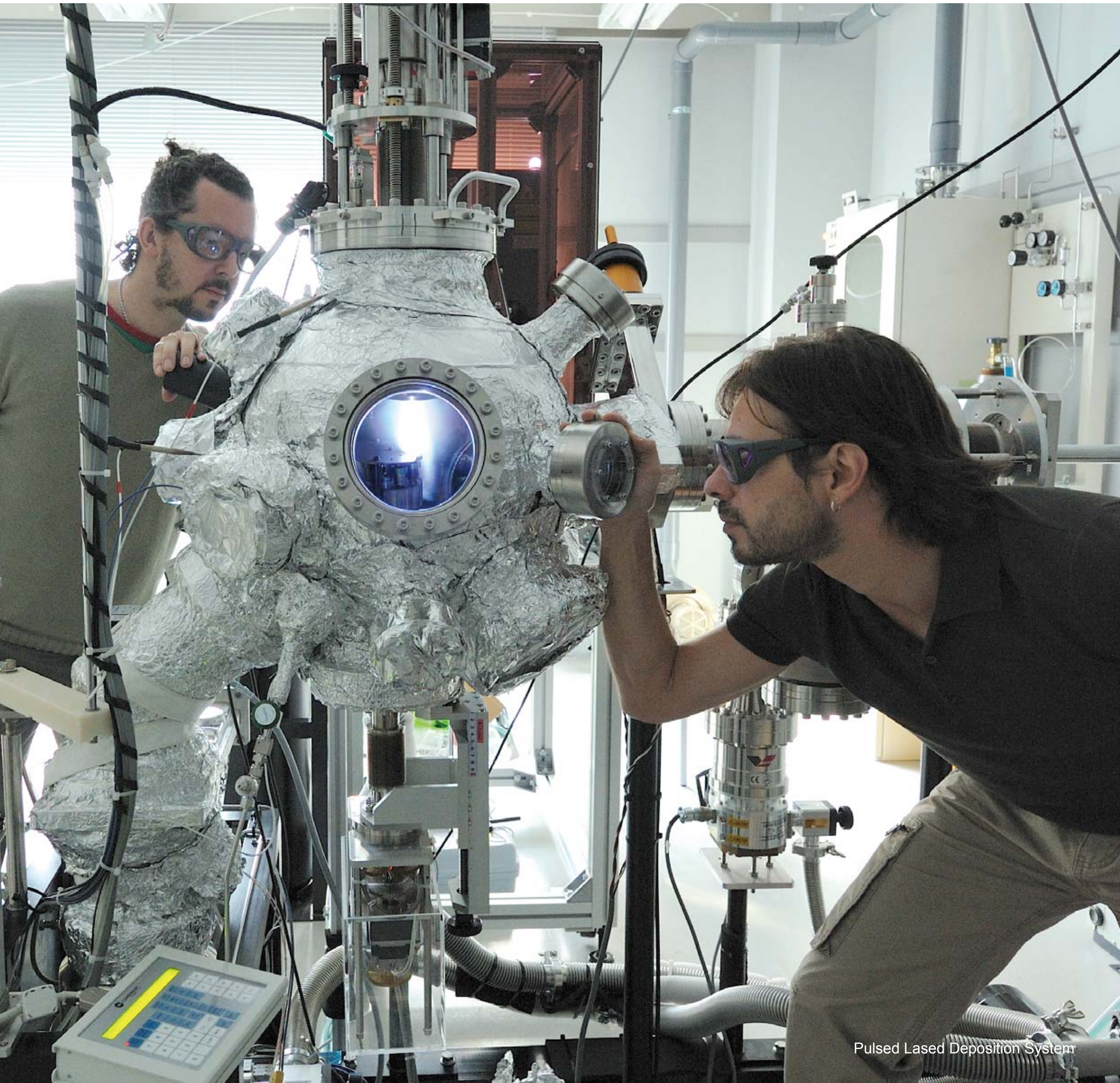
NIMS NOW International

2009. November

Creating World-class Research Centers in Innovative Fields



Pulsed Lased Deposition System

Creating World-class Research Centers in Innovative Fields

**Two years have passed since Japan's MEXT* launched the World Premier International Research Center Initiative (WPI Program) to creating research centers with "global visibility."
IPMU and MANA received high marks among the five WPI centers from the program committee in the fiscal year 2008. NIMS NOW features an interesting talk between the heads of those two Centers.**

*MEXT: Ministry of Education, Culture, Sports, Science and Technology

Hitoshi Murayama
Director, Institute for the Physics and Mathematics of the Universe (IPMU)
The University of Tokyo

Masakazu Aono
Director General, Research Center for Materials Nanoarchitectonics (MANA)
National Institute for Materials Science (NIMS)

Dr. Murayama, you have decided to move from a professorship at the University of California, Berkeley. How are things going at IPMU?

Murayama: It's exhausting, actually. We are aiming very high and this is an extremely ambitious plan of creating a research center on the same level as other world-renowned centers within a 10-year period while we're receiving government funds. We should keep striving, and I don't know if we'll get there or not. I've always thought that it would be great if we could create international research centers in Japan, and eliminate the barriers between Japan and other countries. On this point, I strongly agree with the WPI concept. However, when the group at the University of Tokyo approached me about becoming Director, I had to decline for three reasons: First, I even don't know how to write proposals in Japan. Second, I didn't think that anybody would give ¥1 billion to somebody as young as myself. And thirdly, I really couldn't believe our particular field would be chosen to receive such funds. Then, my proposal, which I didn't think would fly at all, did. I felt like I was set up (Laughs).

How about at MANA, Dr. Aono?

Aono: We've really been searching our best way since started, as the WPI Program is to create an unprecedented new system. This isn't simply a research project, it is the creation of a new institute for the period of 10 years with ¥1 billion budget per year, and 200 people scale. Doing that inside an Independent Administrative Institution like NIMS creates a bit of strain. So we're using some ingenuity in this.

Murayama: Speaking of tensions within the university, because egalitarianism is a basic concept of the university for faculties or departments, it seems that there were considerable barriers to the creation of such a special entity as IPMU. At present, the University of Tokyo calls IPMU a special district.

How would you sum up the distinctive features of the IPMU?

Murayama: Everybody seems very happy. What I mean is that, until now, there was a quite strong feeling that individuals couldn't realize their own potential because they were busy with various odd jobs and under constraints in the university, but once they came to IPMU, they could spread their wings. That feeling of happiness is what pleases me the most.

Aono: Because I was fascinated by astronomy when I was a child, I'm extremely interested in the research that you're doing at IMPU, and I think you're really lucky.

Murayama: Then maybe you should come to the IPMU (Laughs).

What are the distinctive features of MANA?

Aono: IPMU and MANA are in strong contrast to each other. In particular, MANA always thinks about contribution to society. The motto of NIMS is "the true value of materials is in their use." For us, its actual use as a material is also important. It will be necessary to develop many new technologies for sustainable society of 21st century. Our mission is to develop the new materials that will support those technologies. For this, a new paradigm of material development methodology is required. We define this kind of innovation by a new term, "Materials Nanoarchitectonics."

Murayama: Looking at the current research trends, when we considered what the combinations might be right for a new science, we thought that we might most successful with a combination of the relevant parts within the three fields of astronomy, physics, and mathematics. That feeling is incorporated in the idea that you mentioned.

Aono: I see. That's quite similar to our own thinking. These are basically traditional fields individually, but even so, each can create innovation. And, a skillful fusion of the three may lead to the creation of a completely new field, at the same time. That's also the basic concept of our MANA.

What is the secret of the rapid growth of your two Centers?

Murayama: One thing that we have in common is that we've made great progress in internationalization at both Centers. The extent to which we were able to employ non-Japanese researchers is an important indicator. My policy is "No matter what it takes." It's extremely difficult to hire truly outstanding non-Japanese researchers, so I've put my whole heart into being a PR man. We've made IPMU T-shirts like the one I'm wearing today, and we attend international conferences wearing it. And I always spend the first 5 minutes of any presentation introducing IPMU.

Aono: I think there are two reasons why MANA has been highly evaluated. The first is internationalization as you said. I also spend my first or last 5 minutes on PR for MANA (Laughs). At present, 52% of the researchers at MANA are non-Japanese. About how many do you have at IPMU?

Murayama: It's around 55%, if it is only full-time researchers.

Aono: The second reason for MANA's high evaluation is that we've systematized our method of training young researchers. We've created an environment for young researchers as MANA Independent Scientists, ICYS-MANA Researchers and MANA Research Associates who can do the research as they like by adopting our human resource development system. If their performance is good, we also consider a career path to research leader or other positions for them.

Dr. Murayama, I believe you said you want to keep a global presence.

Murayama: The first thing that foreign researchers worry about is that if they're in Japan, they'll be buried here. Continuing the joint research we've conducted so far and maintaining personal contacts have been critical for international visibility. Our policy is that all researchers must spend at least one month each year overseas, and can go for as long as 3 months. This puts our foreign researchers at ease from the very beginning. The idea of a "porous wall" is also considered to be a distinctive feature of IPMU. This means that our people can come and go freely. It makes people active and creates an environment in which people can do good work.

Aono: Internationalization is completely different from having no national identity. To attract people from around the world, we have to offer something specific, they can't find anywhere else. Russia tends to be strong in theoretical science, India, in software, and Japan, in materials and nanotechnology. If you don't respect and encourage those differences, you can't have internationalization.

Murayama: Because there's no reason to come if there's nothing particularly attractive. . . .

You're also very enthusiastic about publicizing your work to the general public.

Murayama: When we proposed IPMU to the selection committee, I told them that the work we intended to do would not be useful, but even if so, what we can do most is to stimulate interest in the sciences, particularly among young people. Then, through those activities, we can perhaps play a role in preventing high school students to shy away from sciences, and in ensuring a better understanding of the importance of science and technology among the general public. I committed myself to that from the very start.

Aono: Publicity is not a one-way street activity, which is just informing the world what we're doing. To ensure sound activity in an organization, we have to expand our PR activity externally, and then you monitor the reaction and review your own work. That's one of the important parts of PR activity. For this reason, I think that MANA's PR must effectively speak up our goals.

Did the Evaluation Committee indicate that your Centers should actively develop overseas satellites?

Murayama: IPMU does not have any satellites at present, but collaborating institutes such as Princeton. Their motivation is very clear. They don't have a large telescope, like Japan's Subaru, which is extremely powerful in terms of range and also has good image quality. We, together, plan to make various improvements on the Subaru, and they will gain the right to use our instrument by contributing to those efforts. For us, because Princeton has an extremely high intellectual level, we'll be able to learn how to milk as much science out of the data as possible. Thus, I think this will be a win-win relationship. In the case of Europe, they are interested in sending young researchers to be trained at the University of Tokyo's Institute for Cosmic Ray Research at Kamioka. Because we want people who can work at this facility, this also has value for both sides. One thing that I will try to do in the future is to create a good environment at Berkeley as a satellite.

Aono: MANA has four overseas satellites, UCLA and Georgia Institute of Technology in the United States, the University of Cambridge in the United Kingdom, CEMES/CNRS in France, we actively work with those institutions. The concept of satellites was not highly evaluated at the beginning, but, its true value is now recognized as a result of our activities.

Well, what do you see 10 years down the road?

Murayama: That's a vexing question. What worries me, when I think that our project will end in 10 years, is that people will begin to leave around the 6th year, and nobody will be left by the 10th year. It's really difficult to stop that exodus. For this reason as well, I have already started to working on finding supports for IPMU continuation after the 10 year period.

Aono: We are devoting ourselves entirely to the technology of material nanoarchitectonics. Ten years from now, we hope to make MANA a global hub of new materials development utilizing innovative nanotechnology. At that time, I hope that many of our young research leaders will be able to leave the nest at MANA and venture out into the world.

This interview was held in July, 2009, translated by NIMS PR office.

The First Two Years of MANA

Progress in Internationalization

55% International Researchers

"I was in a dilemma because I had another offer from a famous US school. Eventually I picked NIMS since I believe MANA would be more challenging and rewarding." That is how Prof. Enrico Traversa explains his decision to come to Japan with four young Italian researchers, and join MANA as a fulltime Principal Investigator in January 2009, despite having had a large research group at the University of Rome Tor Vergata in Italy.

Prof. Traversa, who is an authority of fuel cell materials, is involved in the development of small-scale fuel cells which operate at low temperature. Although Japan had frequently lost out to the United States in past recruiting efforts, at the end of a fierce competition, MANA succeeded in attracting Prof. Traversa.

MANA Azzurri: From left, Dr. Magnone, Dr. Mandoli, Prof. Traversa, Dr. Pergolesi, Dr. Fabbri
On the cover: Two young Italian scientists explore fuel cell materials.

Prof. Traversa is not the only foreign researcher who has found the optimum environment for his or her research at MANA. As of October 2009, a total of 190 researchers were affiliated with MANA. Of these, 104 persons, or 55%, were foreign researchers, and the number of talented international scientists who are interested in doing research at MANA is continuing to increase.

Composition of MANA researchers

Position	Number of researchers	Non-Japanese researchers
Principal Investigator (PI)	19	4
Principal Investigator (Satellite)	10	5
MANA Scientist (NIMS)	44	9
MANA Independent Scientist (NIMS)	13	3
ICYS-MANA Researcher (Postdoctoral)	14	10
MANA Research Associate (Postdoctoral)	62	52
Graduate student	28	21
Total	190	104

(As of October 2009)

Heaven for Researchers

The reasons for this include the high level of research at NIMS, which is now No.3* in the world in the institutional citation ranking in the field of materials science, and the world class research facilities at NIMS. The fact that MANA has created a support system irrespective of nationality is also an important attraction for non-Japanese researchers.

"I was at several places before in USA and Europe but MANA research environment is clearly the best I have ever seen. MANA is a paradise for scientists!" This was the judgment of Dr. Martin Pumera, who is developing protein biosensors and DNA arrays using carbon nanotubes. For researchers from the United States and Europe, it is not an easy decision to do research in Japan, with its different language, culture, and customs. The mission of the administrative office of the WPI Center is to "reduce or eliminate researchers' duties not directly related to research, and to provide an environment in which researchers can devote themselves completely to research." Dr. Pumera's comment suggests that MANA is realizing this goal.

MANA offers this kind of environment, which provides Japanese service that "reaches the spot that itches" quickly and effectively to all researchers irrespective of nationality. However, this was not achieved in a day. It was possible to create this environment precisely because NIMS had the know-how and human assets gained through hard work in the International Center for Young Scientists (ICYS) program over a period of 5 years before MANA was launched.

* Citations for the period of 4 years and 6 months from January 2005 to June 2009 were ranked based on the data in Thomson Reuters' Essential Scientific Indicators dated September 1, 2009.

Toward the Realization of a Sustainable Society

Materials Nanoarchitectonics, which was first proposed in 2000 by Dr. Masakazu Aono, the Director-General of MANA, is a new concept of materials development which attempts to extract and utilize the ultimate functions of materials by fully understanding the interactions of individual nanostructures and intentionally arranging those structures.

It is no exaggeration to say that the realization of a sustainable society is a common issue for all of humankind in the 21st century. Since the inception of MANA, one focus of its activities has been the development of innovative materials that enable sustainable growth. Director-General Aono describes this decision by saying, "Science and technology have both light and dark aspects. Today, the dark aspect is continuing to cause serious problems on a global scale. However, at MANA, we hope to develop materials which overcome this."

Nanoarchitectonics is classified into 5 key technologies. MANA is grappling with research in the 4 fields of Nano-Materials, Nano-System, Nano-Green, and Nano-Bio by converging these key technologies.

MANA's objective is to produce revolutionary innovations in the fields of the environment, energy, and health, while continuing to create new materials and systems for realizing the sustainable society of the future. According to Dr. Aono, "It is often said that 'materials are the mother of science and technology,' but we want to contribute to building a sustainable society by developing innovative materials and systems which go beyond the framework of the existing scientific disciplines and the fields of inorganic, organic, and bio." Dr. Aono is committed to realizing this dream as the goal of the WPI program.

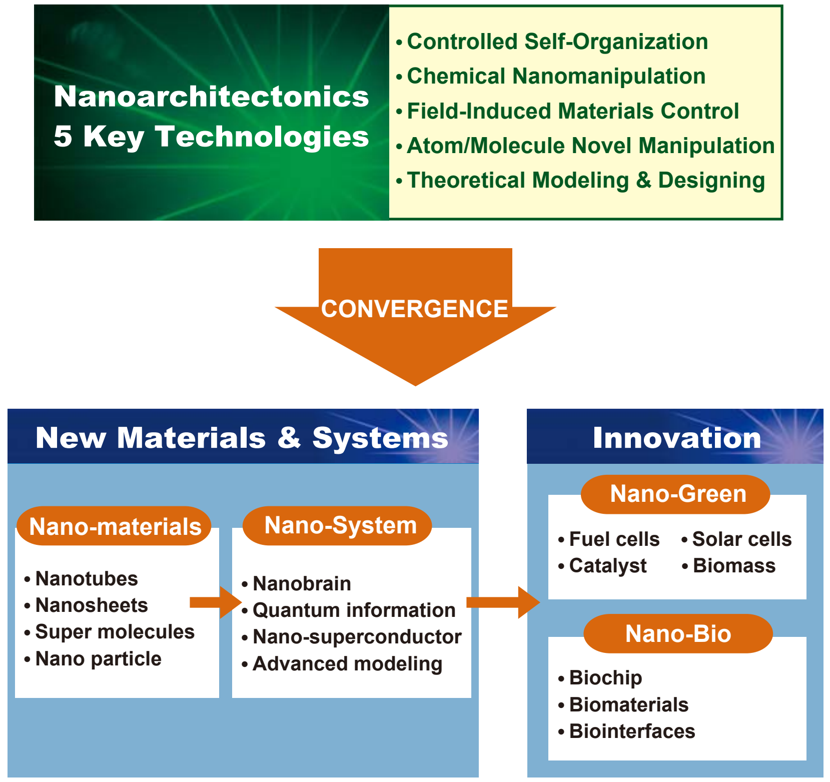


Fig. Research system at MANA

MANA Independent Scientists

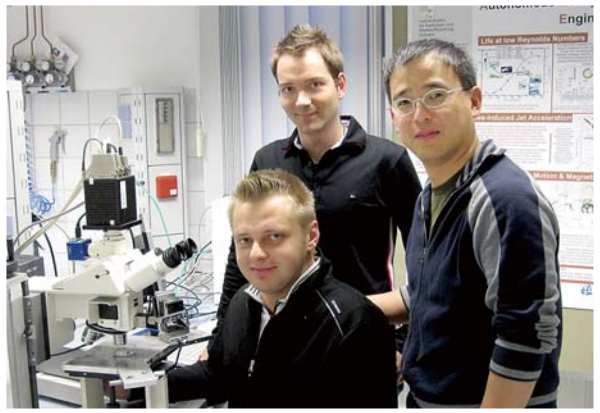
"Independent Scientist." Although the words sound unfamiliar, this is a new system which MANA introduced as a means of training young researchers. Training the young scientists who will be responsible for research in the next generation is one of the key missions of MANA. Until now, when a young scientist joined NIMS, he or she invariably belonged to a research group and carried out research under the guidance of the group's leader. While transmission of technology from senior researchers could be expected under this system, there was concern that it limited the originality of the young scientists. Independent Scientists are young scientists in their 30s who do not belong to a conventional research group, but rather carry out research independently based on their own free concepts. (Dr. Yusuke Yamauchi, who appears in the Research Highlights article on p.7, is an Independent Scientist who is in his 20s.)

One Independent Scientist, Dr. Jun Nakanishi, says that "It's not only that we can do the research we like. The fact that we work in competition with researchers from our own generation in different fields in a true 'melting pot' is also really stimulating." In this environment, MANA's Independent Scientists have already launched a number of original cross-disciplinary research projects, and it is no mere dream to think that this may yield results with the potential for a future Nobel Prize. MANA not only expects its Independent Scientists to produce creative research results, but hopes that they will also grow as future group leaders.

3D System

MANA operates a unique system for training young scientists called the 3D (Triple Doubles) system. Under this system, young scientists are encouraged to have two mentors (Double-Mentor), one of whom is a Principal Investigator at MANA and the other, an eminent researcher from overseas, to have two affiliations (Double-Affiliation), and to conduct research spanning two fields (Double-Discipline). The system was originally begun with Independent Scientists as its object, but because it is also extremely useful for nurturing young scientists with multi-faceted capabilities and a global sensibility, it is being expanded to young scientists other than Independent Scientists.

Dr. Samuel Sanchez, who is an ICYS-MANA researcher, began joint research with Germany's Institute for Integrative Nanosciences (IIN) utilizing this system. Dr. Sanchez is attempting to develop a nano-robot that operates by chemical reaction and apply it to the medical field. Dr. Sanchez says, "I definitely need to learn the technology of IIN to realize my nanorobot. I emailed to the IIN scientist in charge and proposed a joint research project. To my delight, his reply came back immediately expressing his willingness to start coopera-



Dr. Sanchez (center) at IIN, Germany, with group leader Dr. Mei (right), and Mr. Solovev, PhD student.

tion." Using the 3D system, he stayed in the IIN and soon produced research results. With his eyes sparkling, Dr. Sanchez says, "As a chemist, the IIN technology based on physics theory is surprising to me and my research also looks rather new to them. The fact that I'm allowed to conduct research at an overseas institution is fantastically exciting." Dr. Sanchez will invite several IIN researchers to MANA, where further development of this cross-disciplinary research is planned.

The MANA Family: Satellites

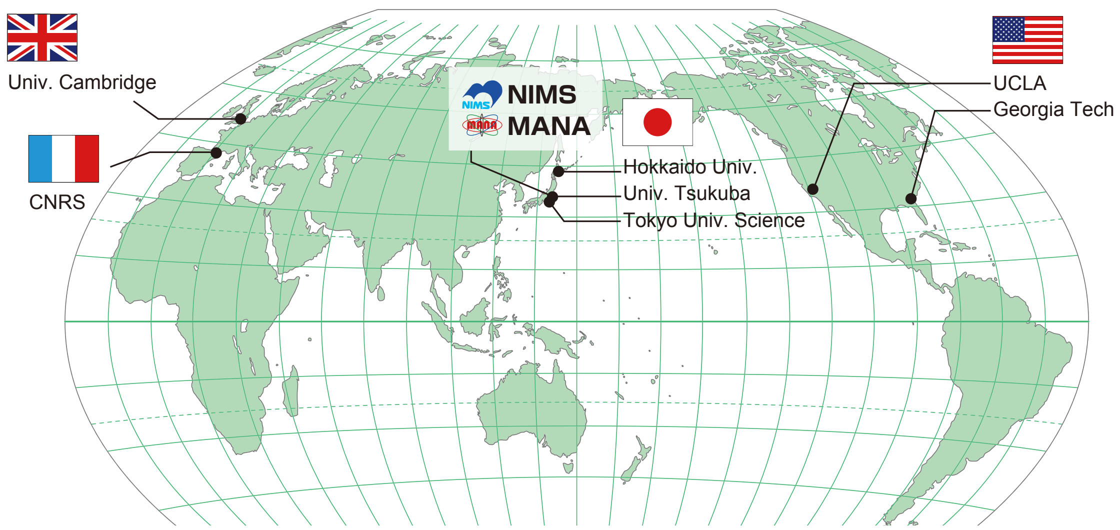
MANA has seven "satellites." These include three in Japan, the University of Tsukuba, Hokkaido University, and Tokyo University of Science, and four in other countries, the University of California at Los Angeles (UCLA) and Georgia Institute of Technology in the United States, the University of Cambridge in the United Kingdom, and in France, the Center for Materials Elaboration & Structual Studies of the National Center for Scientific Research (CNRS). In order to achieve the research targets at which it aims, MANA appoints the world's top level researchers, including scientists who are not affiliated with NIMS, as Principal Investigators. The institutions with which these outside Principal Investigators are affiliated are called "satellites" and conduct research in close collaboration with MANA itself.

Prof. Zhong-Lin Wang of Georgia Institute of Technology, who is one of MANA's satellite Principal Investigators, is a distinguished scientist whose indivisual citations in the materials science field ranks 5th in the world. At MANA, he is responsible for the development of optical devices using "bio-inspired and bio-templated nanomaterials" and as a mentor in MANA's 3D system, he accepts a MANA Independent Scientist and carries out joint research on nanodevices using silicon nanowires. Prof. Wang commented as follows regarding the MANA satellite system: "If my group can join forces with MANA, we can do remarkable research. In this satellite system, I think that MANA goes beyond the Japanese framework and will become a center for achieving the world level." (NIMS NOW International carried a Special Interview with Prof. Wang in its June 2009 issue (Vol. 7, No. 5)).

With the University of Cambridge and UCLA, MANA is not only conducting joint research, but also holds an annual Summer School for doctoral students, which is hosted in rotation by the three institutions. This program, which began when Director-General Aono expressed his concern that "Japanese students have absolutely no international vision," was held for the 6th time in the summer of 2009. "Bring together a dozen or so students from Japan, a dozen or so from foreign countries, and keep them together for a week, studying, playing soccer, and dancing the traditional bon-odori dance. We interfere as little as possible and leave everything up to the planning to them. When they go home, they've really grown up," Director-General Aono says with pleasure.

MANA's mission is to introduce new concepts in materials development along the axis of nanotechnology while pioneering the way to true internationalization. Today, MANA is steadily advancing toward the goal of creating a "World Premier International Research Center."

Summer School at UCLA. (July, 2009). 29 students participated in total; 10 from NIMS, 9 from Cambridge and 10 from UCLA.



MANA satellites

Platinum Nano-*Kompeito*

Success in the Development of Platinum Nanoparticles with an Ultrafine Mesostructure


MANA Independent Scientist,
JST PRESTO Researcher (concurrent)
Yusuke Yamauchi

MANA Research Associate†
Wang Liang†

Platinum is known to possess high activity as a catalyst, and is widely used as an industrial catalyst and an electrode in batteries. If the surface area of platinum can be increased, dramatic improvement in catalytic performance can be expected, as the exposed area also is increased. Active research on the synthesis of new platinum nanomaterials, including nanoparticles, nanofibers, nanotubes, nano (meso) porous materials has been underway for a number of years. However, the surface area of these substances was limited to at most around $30m^2/g$, which is the same level as the platinum black used as an industrial catalyst. Nanoparticles with a large surface area have also been synthesized by the reverse micelle method and other processes, but because the particles tend to agglomerate when heated to high temperature due to their small size, low thermal stability has been mentioned as an issue. In view of the strong social demand for reduced use of rare elements, there have been heightened calls for the development of a technology for securing high functionality with low use of platinum by producing nanostructured materials with larger surface areas.

Therefore, we developed a high speed synthesis technique for nanoparticles with a shape similar to that of *kompeito* sugar candy **(Fig. a)**. This material features a significantly increased surface area in combination with high thermal stability. Fine nano-level irregularities are produced on the platinum surface by adding a reducing agent to an aqueous solution of a surfactant and platinum ions, and utilizing the interaction between the hydrophobic group of the surface-active molecules and the surface of the platinum **(Fig. b)**. Because the reaction time after introduction of the reducing agents is short, at approximately 10 minutes, and yield is 100%, conversion to a mass production process can also be expected. Electron microscope observation **(Fig. c)** revealed that the particle size of the product is uniform, and because a *kompeito* (dendritic) state could be observed, this material was named "Platinum nano-*kompeito*." This *kompeito* shows high dispersion in aqueous solutions **(Fig. b)**, and also displays high thermal stability, being able to withstand temperatures up to 250°C. Its surface area is more than $55m^2/g$, thus achieving the highest area among all existing platinum nanomaterials.

As other important features, the size of the formed particles can be controlled by adjusting the amount of reducing agents used, which means that it is possible to produce particles with sizes matched to the desired application. This technique is also enables alloying with other metals. In the future, the authors will aim at order-made design of metallic nanomaterials with compositions matched to specific applications. High expectations are placed on the development of "platinum nano-*kompeito*," which possesses high thermal stability and a large surface area, as a high performance catalyst surpassing existing platinum nanomaterials.

A report of this achievement was published in the Journal of the American Chemical Society (publication of the American Chemical Society). (Liang Wang and Yusuke Yamauchi*, "Block Copolymer Mediated Synthesis of Dendritic Platinum Nanoparticles," J. Am. Chem. Soc., 131, 9152-9153 (2009).)

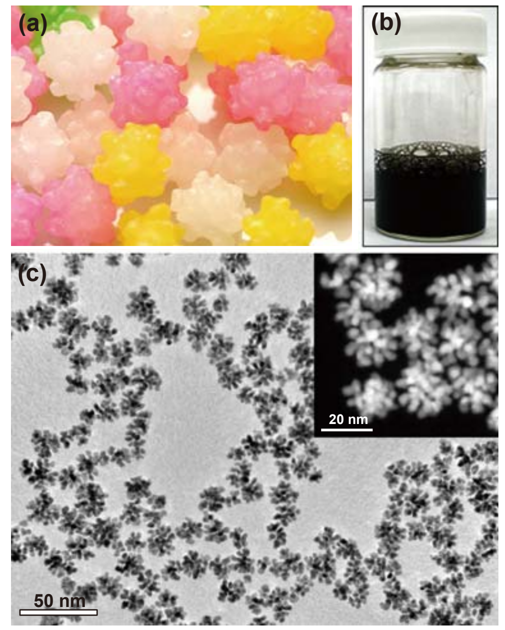


Fig. (a) Photograph of typical *kompeito* sugar candy, (b) dispersed solution of platinum nano-*kompeito*, (c) electron microscope images of platinum nano-*kompeito*.

Establishment of Stacking Structure of Chlorophyll Macromolecules

The NIMS 930MHz Solid State NMR Plays the Crucial Role

High Field NMR Group,
Advanced Nano Characterization Center

Group Leader
Tadashi Shimizu

Research on pigment-sensitized solar cells using chlorophyll has attracted considerable attention in recent years as part of the development of solar cells with the aim of resolving environmental and energy problems. Chlorophyll has both absorbing light (causing an excited state in molecules by absorbing photons) and generating electric power (producing free electrons). The molecular structure of chlorophyll **(Fig.)** is a metal complex consisting of one magnesium atom with four-fold coordination (bonding with four anions) in the center of a ring. Approximately 10 related types with slight structural differences are known. In fact, single molecules of chlorophyll are able to absorb light, but unable to generate electric power. The electric power generation appears until amacromolecule is formed (type of supramolecule) by stacking approximately 10 to 100 chlorophyll molecules. The detailed structure of this macromolecule is still not understood. In order to elucidate the mechanism of electric power generatiion in chlorophyll, clarification of the structure of the molecular assembly is indispensable.

Recently, important progress in understanding the structure of this molecular assembly was achieved using the 930MHz solid state NMR at NIMS by joint research with experts in chlorophyll research. NMR is an abbreviation for nuclear magnetic resonance. NMR devices are analytical instruments which are used to investigate the molecular structures and electronic states of substances and materials utilizing the magnetic nature of the nucleus of atoms. NMR measurements are performed by placing the material which is to be measured in a magnetic field, and sensitivity and resolution improve with the strength of the magnetic field. In this case, 930MHz expresses the strength of the field, meaning that this solid state NMR is capable of producing the world's highest magnetic field of 21.8T.

The chlorophyll used in this research is a type called bacteriochlorophyll-c (BChl-c), which occurs in some phototropic bacteria. To date, six different structural models have been proposed for the molecular assembly of Bchl-c. The main point of difference in these six types is only the manner of arrangement (symmetry) of the assembled molecules. Although much research, including work with X-ray diffraction, has been done over the years in an attempt to resolve the problem of what structure the actual molecular assembly takes, no crucial experimental evidence had been obtained.

In the present research, the Mg-NMR in BChl-c was measured, and as a result, it was found that the magnesium in the BChl-c molecular assembly consists of two types of coordination number, one five-fold and the other six-fold **(Fig.)**. Conventionally, the major opinion had held that six-fold coordinated Mg does not exist. Although magnesium has four-fold in single molecules, the coordination number increases because the hydrogen bonds and Van der Waals bonds occur via the magnesium atoms in the supramolecule. Since only 1 type among the six models mentioned above is capable of explaining these NMR results, the problem of the stacking structure of the macromolecule of BChl-c has been resolved.

This research was also the world's first measurement of Mg-NMR in chlorophyll . With the conventional techniques, observation of magnesium and similar elements had been difficult due to insufficient sensitivity and resolution. This research demonstrated the possibility of observing such elements by using a high magnetic field. In the future, it is expected to be possible to resolve various unsolved problems by expanding the observational range of the solid state NMR to numerous other elements. This research was the result of joint work with a research group under Prof. Yasushi Koyama of the Kwansei Gakuin University and JEOL Ltd.

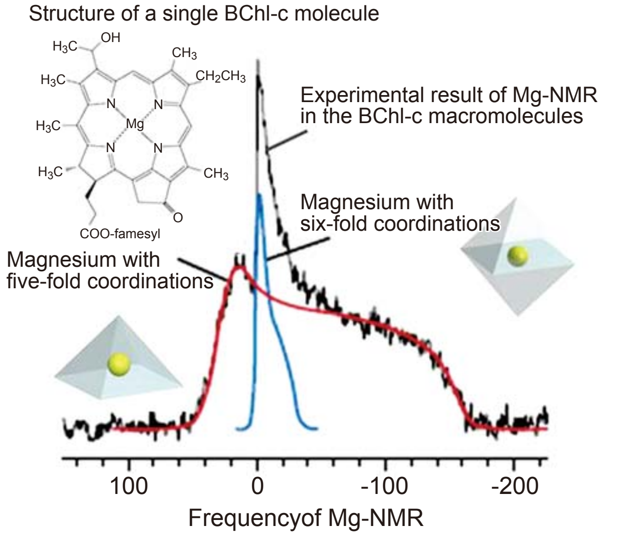


Fig. Mg-NMR spectrum in the BChl-c macromolecules. The red line (5-fold coordinations) and blue line (6-fold coordinations) are simulations. The magnesium in a single BChl-c molecule (see inset) is only 1 type having 4-fold coordinations . (Kakitani, et al., *Biochemistry*, 48(2009)74).

Research Highlights

Molecular assembly allowing 16-bit parallel signal transmission

Advanced Scanning Probe Microscopy Group,
Advanced Nano Characterization Center

Anirban Bandyopadhyay

Our group has made an important breakthrough in the development of molecular machines, which are defined as systems that allow movement at the atomic level. Control of molecular machines requires large numbers of versatile instructions to allow multiple operations, but no molecular machine has been previously developed with the potential to control the decisions of other molecular machines or to simultaneously communicate with multiple systems. Linear connections between molecular machines will allow transmission of only one instruction at a time. In contrast, radial connections of molecular machines to a single central control molecule will allow simultaneous transmission of multiple instructions. The present advance involves the development of a machine capable of simultaneously transmitting multiple instructions at the molecular level.

The advance is based on the characteristics of a molecular assembly of a number of 2,3,5,6-tetramethyl-1-4-benzoquinone (duroquinone, DRQ) molecules. **(Fig. 1)** DRQ is known to have four logic states (0, 1, 2, and 3), each associated with a specific rotation of the alkyl groups, which can be controlled by a suitable electrical pulse from the probe of a scanning tunneling microscope (STM). The new machine assembly combines 17 DRQ molecules **(Fig.2)** within a supramolecular architecture consisting of a ring of 16 analogous DRQ molecules, which act as the execution units (EUs) of the machine, arranged around a single DRQ molecule which acts as the central control unit (CCU). Consequently, the single central molecule or CCU can simultaneously transmit instructions to the 16 surrounding molecules with a total of 4^{16} different final states. The molecular machine was assembled from 17 DRQ molecules randomly distributed on an Au (111) surface in an ultrahigh vacuum (UHV) STM chamber at 77 K. The molecular composition could be confirmed by comparing the theoretical STM images generated from the appropriately oriented molecular assembly on Au. The supramolecular assembly self-configures to integrate the DRQ molecules in a specific way. Signals to the CCU will transmit simultaneous signals to the EUs. The characteristics of the supramolecular assembly allow specific instructions to be transmitted to the 16-bit signal array by applying a single STM pulse to the CCU as shown in **Fig. 3**.

This supramolecular assembly machine can achieve synchronized one-to-many control of the states of the 16 EUs by sending instructions using a STM pulse applied to the CCU, which in turn sends 16 unique instructions simultaneously to the 16 EUs. This concept has the potential to allow the simultaneous transmission of billions of decision-making instruction sets to control logic machines. The development of a nano-central processing unit, the equivalent of the central processing unit based on a silicon chip in a personal computer, to control the independent operation of multiple molecular machines using a single control unit is targeted.

This research topic has now been incorporated into the physics textbook "Quantum Nanoelectronics"
By Edward L. Wolf (May 2009, Publisher: Wiley-VCH)

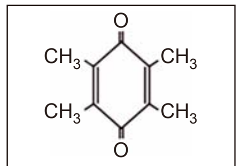


Fig.1 Molecular structure of DRQ.

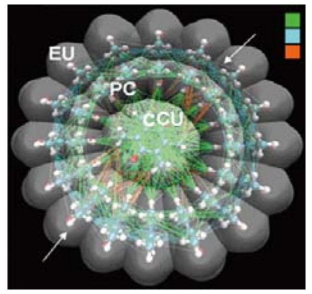


Fig.2 Molecular model of the architecture showing three divisions: CCU, PC, and EU.
Green denotes hydrogen bonding between CCU and EU,
Blue denotes hydrogen bonding between EU neighbors,
and Red denotes a special hydrogen bonding initiated by CCU oxygen atoms.

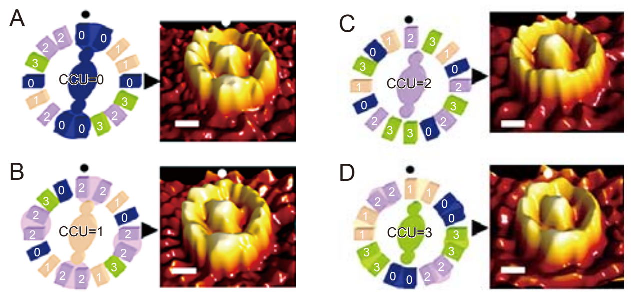
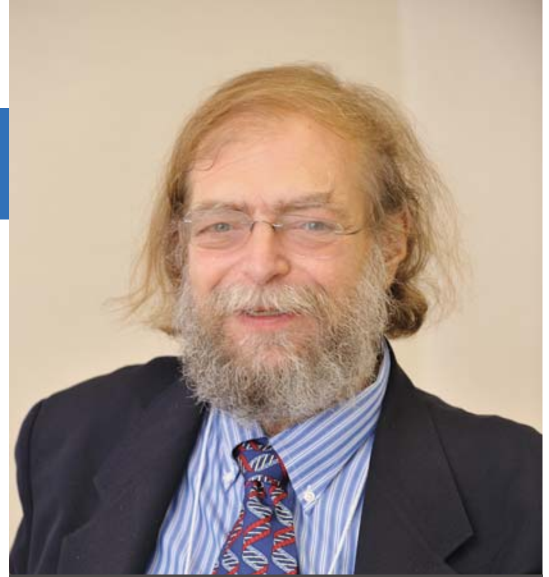


Fig.3 Four specific instruction arrays (A, B, C, and D) were induced in the EUs for CCU states 0, 1, 2, and 3, and the corresponding changes in the STM images were recorded.

Copyright ©2008 by National Academy of Sciences, USA. Reproduced with permission from PNAS. DOI:PNAS March 11, 2008 vol. 105 no. 10 3668-3672

Great Science, Good Art Needed To Overturn Paradigms

Dr. Nadrian C. ("Ned") Seeman of New York University (NYU) leads the DNA architecture-creation field based on use of "branched DNA motifs" that can self-assemble to form objects, lattices and devices. Because of his contribution to this field, he was awarded the 1995 Feynman Prize in Nanotechnology. His work is important because one day in the future small units of molecules will self-assemble and create any architecture. This will revolutionize industry because of the level of control for the structure of matter on the finest possible scales.
In terms of achievements, Dr. Seeman and his researchers have already used anti-parallel double crossover molecules as components to create 2D and 3D DNA crystals. In addition to producing periodic arrays, an algorithmic assembly has also been performed. His approach has been used to organize DNAzymes and gold nanoparticles.



Prof. Nadrian C. Seeman
Department of Chemistry
New York University

What is the state of your research currently?

I am a crystallographer who considers himself to be good at all aspects of crystallography except for growing crystals... . This is the reason why I ended up becoming a "programmer" in the main, before realizing that stably branched DNA molecules - with their sticky ends - could be used to produce crystals. I was inspired in this by recognizing the connection between 6-arm branched DNA junctions and M.C. Escher's drawing of repeating arrays of fish in his woodcut 'Depth.' As such, I am researching these kinds of DNA crystals. However, instead of fish I now see tracks for "walkers" (nanorobots that walk) that move around at the nanometer level.

It was in September of 1980 that I thought up and then started to work in the field of DNA nanotechnology, but by latest count there are perhaps some 40 to 50 laboratories involved in this area. I seem to have spawned a lot of competitors, computer scientists as well as materials scientists, which may or may not be good for our particular laboratory. Nevertheless, it means the creation of a new research field. Our lab is apparently still the only one taking the crystallographic angle so that allows us to maintain ourselves at the leading edge.

What are your major projects today?

A major effort in my laboratory is devoted to nanotechnological applications of DNA, looking at it not as a genetic material but as a molecule. The attachment of specific sticky ends to a DNA branched junction enables the construction of "stick figures" with edges consisting of double-stranded DNA. We have already used DNA to build stick figures with the connectivities of a cube and a truncated octahedron. The goals for this technology, among others, are ultimately the synthesis of periodic matter in a "rational" fashion and the assembly of complex computational systems, as well as smart nanostructures, e.g., nanorobots.

The reason for trying to synthesize periodic matter in this manner is the weakness of the crystallization protocol now being utilized and the possibility of applying DNA sticky ends to facilitated construction of DNA scaffoldings (or "cages") to contain "oriented guests" - let us call these tiles. With such technology, humankind will be able to crystallize all types of biological molecules easily, for example. Using this approach, a new form of computing has been proposed where the DNA tile "circuitry" gives you the "DNA-Based Computation solution" to the problem to be solved.

To be a bit more technical, our interest in branched DNA was originally stimulated by a desire to characterize Holliday junctions. These are 4-arm branched DNA molecules that are found to be structural intermediates in genetic recombination. The focus of the work on these unusual molecules is to characterize the biophysics of recombination intermediates, particularly their structure, dynamics and thermodynamics, and to establish the relationship between these properties and their biological function.

When and why did you choose to become a scientist?

At The College of The University of Chicago, I started out as a pre-medical student but switched to biochemistry when I realized becoming a professor at some university was a way to be "paid to play all day"... . I went on to gain my doctorate from one of the few "Departments of Crystallography" around, in 1970, at the University of Pittsburgh, then did some post-doctoral work at Columbia and MIT before becoming a professor, first at the State University of New York at Albany, and then at NYU's Department of Chemistry.

Can you provide a message and a favorite quote to young scientists?

My message to young scientists would be: "Follow your nose and keep the faith, usually you are doing the right thing." As for a quotation, "To do good science it is important to be well-grounded in all the disciplines, ranging from math, physics, crystallography and computer science to chemistry and biology, but one should never forget the arts, which inspire notions that can overturn paradigms: Great science is good art."

University of Rome Tor Vergata: New NIMS Sister Instituion

Workshop attendees

(October 13, 2009) The workshop *Nanostructured Materials for Sustainable Development* was held at University of Rome Tor Vergata (URTV). The workshop was organized by Prof. Licoccia (NAST Centre for Nanoscience, Nanotechnology and Advanced Instrumentation) and Prof. Traversa (MANA-NIMS). The workshop was well attended by numerous researchers, not only from URTV, but also from the National Research Council and the National Agency for New Technologies, Energy and the Environment, Italy.

On this occasion, a comprehensive collaborative agreement between NIMS and URTV was signed by the Rector of URTV, Prof. Lauro, in the presence of the NIMS Vice President, Dr. Noda. The agreement stems from the invitation of Prof. Traversa to be a Principal Investigator at the International Center for Materials Nanoarchitectonics (MANA), where he has been engaged in research since January 2009. This agreement will reinforce the existing collaboration between NIMS and URTV, and will also provide the opportunity to expand into new fields such as polymeric fuel cells and nanotoxicology. Exchanges of researchers and students are foreseen, together with the organization of joint workshops and a joint Doctorate Course.

Test Drive Event at NIMS with Toyota Fuel Cell Automobile

Toyota's FCHV-adv

(October 13, 2009) An exchange of views on fuel cell automobiles with Toyota Motor Corporation and a test drive event with a Toyota fuel cell automobile were held recently at NIMS.

In the exchange of views, the Toyota engineers described the current status of the development of fuel cell automobiles, the necessity of creating a fuel infrastructure and legal system, and the importance of continuously promoting basic research on materials for fuel cells and development of structural materials with excellent resistance to hydrogen embrittlement. Toyota also confirmed that they will provide information on basic research needs to NIMS.

The vehicle used in the test drive event was a Toyota FCHV-adv equipped with a 90kw output solid polymer fuel cell. As fuel, the automobile uses hydrogen from a 156 liter capacity tank with a maximum filling pressure of 700atm. Performance includes a top speed of 155km/h and a range of approximately 830km in the 10•15 mode. NIMS researchers who test drove the automobile made various enthusiastic comments, noting that it "was completely noise-free," "was more powerful and had better acceleration than expected," and "its handleability has no difference from an ordinary automobile."

NIMS is actively engaged in research on environmental and energy-related materials which provide higher performance and have the potential for mass acceptance, and thus can make an important contribution to a low carbon society.

Dr. Seiji Kuroda Receives the Title of Fellow from ASM International, The Materials Information Society

(from left) Prof. S.Sampath, New York State Univ., Dr. M. Smith, Sandia National Laboratories and Dr.S.Kuroda, NIMS

(October 27, 2009) Dr. Seiji Kuroda, currently managing director of Hybrid Materials Center of NIMS, has been elected to the College of Fellows of ASM International. This honor was awarded at the ASM Awards Banquet in Pittsburgh.

ASM International is the society dedicated to serving the materials science and engineering profession. Since 1969, ASM international has recognized and honored those innovators who have made significant contributions in the field of materials science and engineering, and whose achievements represent the highest standards of contributory excellence.

Dr. Kuroda has achieved this honor with his pioneering contributions to the field of thermal spray technology, notably in the understanding of stress evolution during deposition, and the development of advanced corrosion control coatings.

Fellows of ASM represent a special group of colleagues whose breadth of experience represents the best in materials science research and technology from around the world.

2nd NIMS-WUT-EMPA Workshop in Tsukuba

(November 12-13, 2009) The Second NIMS-WUT-EMPA Workshop on "Nanomaterials for Sustainable Development" was held at NIMS on November 12th and 13th, 2009, with the first goal to stimulate the further international exchange of young scientists between the three institutions-NIMS, WUT (Warsaw University of Technology, Poland) and EMPA (Swiss Federal Laboratories for Materials Testing and Research, Switzerland). WUT was the host of the first workshop that was held in Warsaw in June 2008. A total of 21 oral research presentations which are focused on "Nanomaterials", "Biomaterials" and "Energy and Environment" were given by experienced researchers as well as by young scientists (Ph. D. students and postdoctoral researchers) from the three organizations. The workshop included a "Laboratory tour for young scientists" which visited high-quality user-facilities at NIMS.

Participants of the 2nd NIMS-WUT-EMPA Workshop at NIMS

Hello from NIMS

José Rafael Colmenares-Angulo (Venezuela)
Visiting Graduate Student
Coating Materials Group,
Hybrid Materials Center

My visit to Japan was motivated by research interests, since my lab, The Center for Thermal Spray Research in Stony Brook University and the NIMS Coating Materials Group have common scientific interests which have been promoted by the signature of a recent International Joint Graduate School agreement. But scientific excellence is only one of the few sides I have been fortunate to observe in this beautiful country. Having lived both in my native Venezuela and in the United States, the experience of Japan compares with no other. Japanese people are very committed to their culture and traditions but are also always eager to learn about other people's way of living. For example, I was really impressed to learn that there is a very active Salsa music community in Tsukuba, where people practice weekly and become much more proficient than the average Caribbean native dancer. The beauty of the Japanese landscape, Mt. Tsukuba being an example of seasonal diversity and splendor, is itself an experience to remember, especially considering that the urban marvel of Tokyo is so close it can be seen on a clear day. I am also happy to contribute to the scientific and cultural exchange between Venezuela and Japan, since currently the relationship between the countries is mostly commercial, with 15% of Venezuelan bauxite and aluminum production being bought by Japanese business.

[With my NIMS colleagues at a party]

[Enjoying wearing a *kimono* outfit at Ninomiya House]

Announcement : The 9th NIMS Forum

With the aim of making more people know about the latest research developments of NIMS, we will be holding a "NIMS Forum - Advanced Research and Technology Transfers of Materials Science".

Date: February 17th (Wed), 2010 **Site:** Tokyo Big Sight (http://www.bigsight.jp/english/index.html)

Online registration will start from mid January, 2010.

For more details: http://www.nims.go.jp/publicity/events/nimsforum/nimsforum09.html

National Institute for Materials Science
http://www.nims.go.jp/eng/news/nimsnow/

©2009 All rights reserved by the National Institute for Materials Science.

To subscribe, contact:
Mr. Tomoaki Hyodo, Publisher
Public Relations Office, NIMS
1-2-1 Sengen, Tsukuba, Ibaraki, 305-0047 JAPAN
Phone: +81-29-859-2026, Fax: +81-29-859-2017
Email: inquiry@nims.go.jp