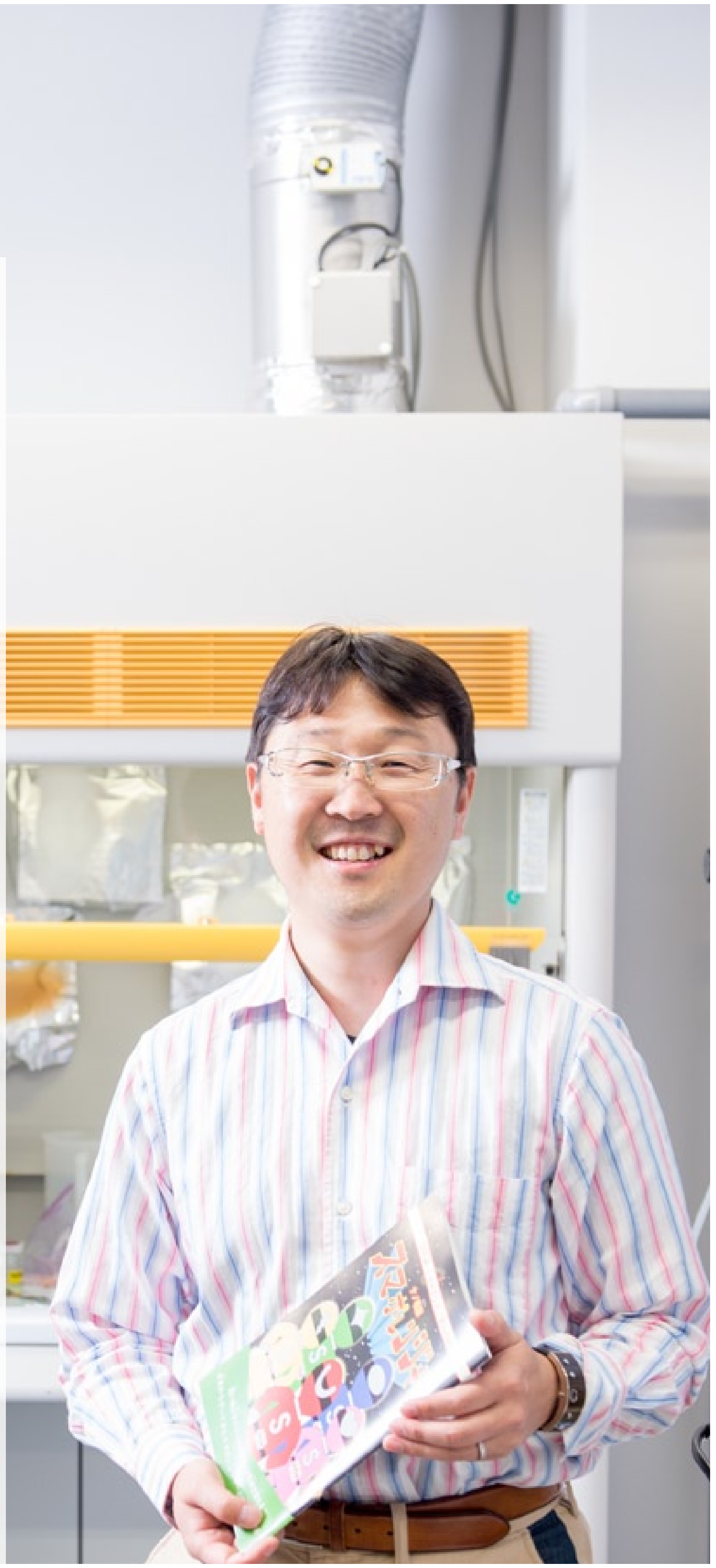
Emerging MANA Researcher

Mitsuhiro Ebara



The cartoon book called "Nano Squad: The Smart Polymer Rangers" is published by MANA and has become a great hit with children. Dr. Mitsuhiro Ebara's dream is filled in this book. "Smart polymer rangers" are medicines of the future which are made from the new material "smart polymers." The "Nano Squad" consists of five kinds of smart polymers. Squad members enter the bloodstream and while changing their own shapes and properties, they work together to search out and brilliantly eradicate viruses.

Dr. Ebara explains his thoughts of this research as follows: "Many of today's medical technologies cannot be used without the proper infrastructure. For this reason, we can't do anything in the developing countries, or even in Japan if a major earthquake strikes. I want to create medical materials that can be used even under those circumstances."

For example, simply rubbing your fingers generates heat that can provide the energy source necessary for smart polymers to be activated. If biomarkers that show the causes of diseases in the blood or urine are available, diseases can be diagnosed from those markers. A nonwoven nanofiber, which Dr. Ebara developed for use in treating cancer, simultaneously releases heat and medical drugs in response to an external magnetic field in order to attack cancers. Dr. Ebara's research on this "Anti-cancer nanofiber mesh" has won high marks and was recognized by the award of the Project Prize (Nano-Life Field) at the 13th International Nanotechnology Exhibition & Conference in 2014.

One other important message is also included in the cartoon book: "Manufacturing is the product of even small ideas that anybody can have. This can cure diseases. I want to communicate the fact that materials, and particularly nanosized materials, have enormous power."

Profile

Mitsuhiro Ebara
MANA Scientist, Smart Biomaterials Group, Biomaterials Unit, MANA Nano-Life Field
Ph.D. in Chemical Engineering. His specialties are smart materials, biomaterials, and medical devices.

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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.

Cover : MANA Principal Investigator,Takayoshi Sasaki at WPI-MANA building

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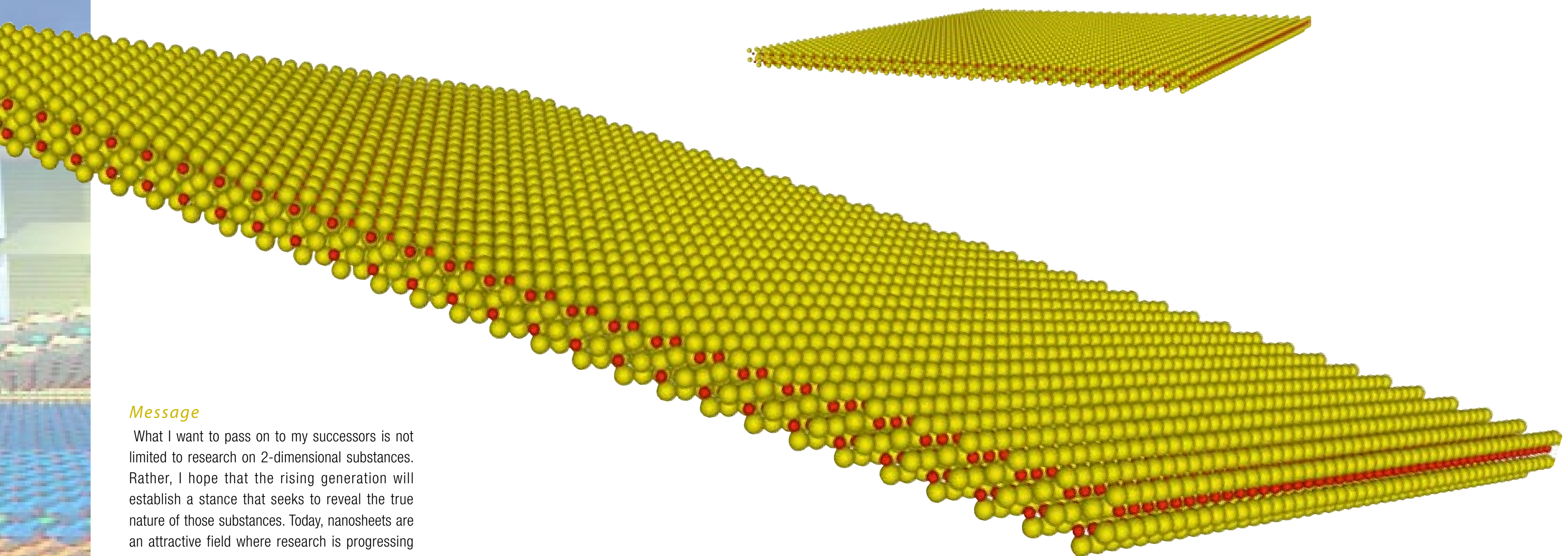
Makoto Kobayashi



Message

What I want to pass on to my successors is not limited to research on 2-dimensional substances. Rather, I hope that the rising generation will establish a stance that seeks to reveal the true nature of those substances. Today, nanosheets are an attractive field where research is progressing rapidly. I feel that a large number of papers can be written, and of course, I hope that many researchers will participate. However, if researchers take an easy approach, simply moving at random from one topic to the next, their efforts will gradually lose focus. Moreover, when a researcher becomes a leader, it is essential to provide a unique direction that will guide the group.

Nanosheets -Opening the Way to the Future

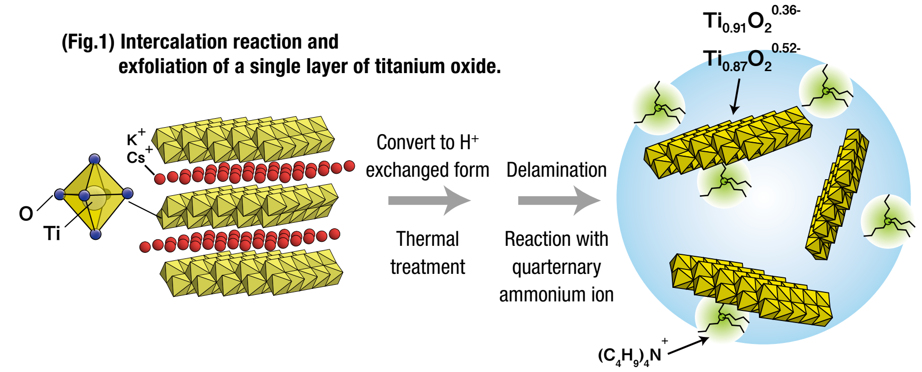
Takayoshi Sasaki

NIMS Fellow and MANA Principal Investigator, Nano-Materials Field

In nanotechnology, "nanosheets" have attracted particular attention. Advanced new functions can be realized by integrating the functions possessed by various types of nanosheets. MANA Principal Investigator,Takayoshi Sasaki, is one of the pioneers in this field and has been involved in research on nanosheets for nearly 20 years. In this interview, we asked Dr. Sasaki to discuss the background and future outlook for these fascinating nanomaterials.

◉Interviewer : Akio Etori, Science Journalist

(Fig.1) Intercalation reaction and exfoliation of a single layer of titanium oxide.



Layered materials; the starting point for nanosheets

It is generally said that the origins of nanotechnology were the discovery of the fullerene in 1985 and the discovery of carbon nanotubes in 1991.

"Research began with the discovery that materials display unique properties not in bulk, but rather, when reduced to small sizes. Early research focused on 3-dimensional and 1-dimensional materials, that is, carbon nanotubes and nanoparticles. In contrast, work on 2-dimensional materials was considerably delayed due to the difficulty of fabricating molecularly thin 2-dimensional materials by the existing synthesis methods."

Dr. Sasaki joined the National Institute for Research in Inorganic Materials (NIRIM), which is one of the predecessors of NIMS, in 1980 and began research on the topic of layered titanium oxides. Layered titanium oxides are compounds that have a structure in which layers with a thickness of 1 nm are formed by a network of titanium and oxygen atoms that strongly bonded in the lateral direction, and these layers are stacked. Because a binding force between the layers are comparatively weak, an intercalation reaction occurs. This is a reaction in which guest molecules or ions enter into the interlayer galleries. In Dr. Sasaki's original research, he made an exhaustive investigation of how the structure and physical properties of layered titanium oxides change as a result of the intercalation reaction.

"Synthesis of ceramic materials is often performed at a high temperature around 1000°C, but the intercalation reaction occurs at a low temperature, i.e., room temperature. The approach called 'soft chemical synthesis' or 'soft chemistry,' which uses intercalation as a synthesis technique for creating new materials, appeared around that time, and this also became the name of our NIMS Soft Chemistry Group."

In 1993, Dr. Sasaki participated in an international symposium on soft chemistry, where he encountered advanced research in which layered compounds, including clay minerals exfoliated in a solution and changed to a colloidal form. This was a powerful inspiration for his subsequent work, and he thought that it might be possible to exfoliate the layered titanium oxides that he had been studying up to that time. This was the origin of research on nanosheets.

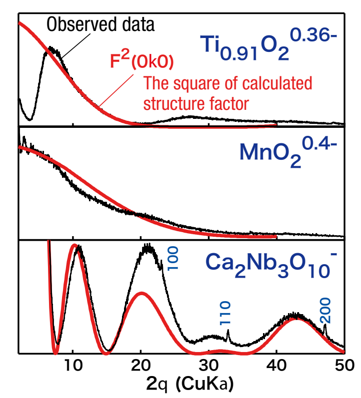
In the nanosheet synthesis method developed by Dr. Sasaki and his colleagues, basically, swelling is induced by intercalating certain guest species and solvent molecules (Fig.1). As this swelling enhances, the force that acts between neighboring layers becomes weaker, and it is possible to peel off the layers into unilamellar crystallites. Because the interlayer space is equivalent across the crystal, the swelling reaction occurs uniformly. Thus, in principle, it should be possible to obtain a large amount of a single-layer substance. As a result of such experiments, a colloidal suspension wasobtained, but no method for ascertaining whether the sample was composed of single layers or not could be found. An investigation was attempted using electron microscope, but the sheet-like substance tended to overlap when it was removed from the solution, and, its essential nature was lost.

"Since nanosheets are a living thing, we need only to see them in that form. Ultimately, we found a method of recording *in-situ* X-ray diffraction data of the colloidal sample itself, and we were able to demonstrate that delaminated single sheets were dispersed in the suspension (Fig.2)."

The paper announcing this achievement was published in 1996. Since the resulting materials were molecularly thin and 2-dimensional in shape, they were named "nanosheets," in distinction from nanotubes and nanoparticles.

(Fig.2)

X-ray diffraction data demonstrating exfoliation to single layers, showing a distinctive continuous pattern.



The world's smallest capacitor device, realized by nanosheets

Research on nanosheets started with the synthesis of titanium oxide nanosheets and then deepened to elucidation of their structures and properties. In parallel with this, attempts were also made to synthesize nanosheets from various other layered materials, and 20 to 30 types of nanosheets were created, including manganese, tantalum, and niobium oxides. In that process, graphene appeared on the stage in 2004, and the visibility of 2-dimensional materials increased rapidly.

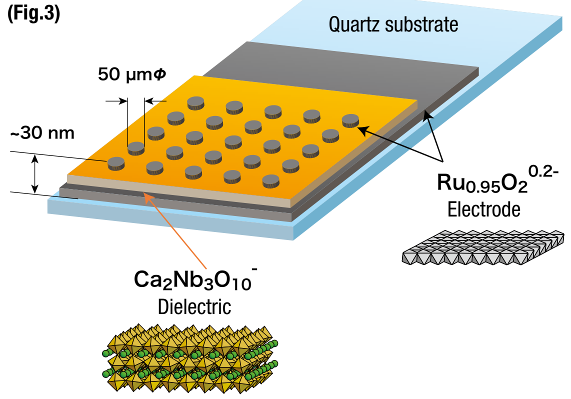
Nanosheets are extremely thin around 1nm in thickness consisting of several atoms. In contrast, their lateral dimensions are several hundred to several million times larger. Nanosheets exhibit distinctive functions reflecting this unique 2D morphology. Considering this, we may ask how nanosheets will be used in the future.

For example, titanium oxide nanosheets absorb ultraviolet light efficiently and thus show a high photocatalytic property. Particles of titanium oxide are already used as an ingredient in foundation cosmetic products, but problems occur when their performance is enhanced by reducing the particle size, as uneven spots can easily occur when the foundation is applied, and sunburn is possible if the foundation is not spread properly. When thin flakes made from nanosheets instead of particles were used, it was found that the foundation spread well and was pleasant to the touch, and a new product was commercialized taking advantage of these features.

As an application of the photocatalytic property, titanium oxide coating films have been developed in order to prevent soiling of window glass. In this case as well, if a particle coating film is applied, dirt tends to collect around the particles due to the unevenness of the film, but this problem can be solved by using nanosheets, which are extremely smooth and do not attract dirt when applied to glass. As a further advantage, since a hard film can be formed if nanosheets are used, the film does not peel when washed. Performance tests have also been performed by using railway cars of Japan's shinkansen superexpress train.

One current focus of work by Dr. Sasaki's team is development of dielectric thin films. As part of the progressive downsizing of electronic components, the function of conducting electricity has been realized in nanosized devices by using graphene, but the development of new dielectric materials which store an electric charge has been delayed. The Soft Chemistry Group is searching for high dielectrics that function even at the nano-level thickness and has discovered that titanium oxide and pervoskite-type nanosheets demonstrate high performance. Dr. Sasaki's group is fabricating nano-capacitor devices by stacking these nanosheets one layer at a time, and in 2014, they

(Fig.3)



Schematic diagram and cross-sectional TEM image of the world's smallest high performance condenser device. 2D nanosheets were used as the dielectric and electrode materials.

succeeded in reducing the thickness of the device to 30 nm (Fig. 3). In comparison with commercially-available MLCC (multilayer ceramic capacitors) and similar products, the newly-developed condenser is the world's smallest. And in spite of this small size, its performance, as measured by the dielectric constant, is approximately 2000 times higher than that of MLCC.

"In this research, manufacturers were in contact with us from an early stage, and we carried out joint research with a major company."

Nanosheets as a standard-bearer for "nanoarchitectonics"

In the high performance dielectric device which was successfully trial-manufactured at this time, a pervoskite-type oxide nanosheet ($Ca_2Nb_3O_{10}^-$) is used in the dielectric layers and a ruthenium oxide nanosheet ($Ru_{0.95}O_2^{0.2-}$) is used in the electrode layers. The device is equivalent to one unit of an electrode/dielectric/electrode (MIM) structure of a conventional MLCC. Because the nanosheets can be obtained as a colloid dispersed in a solution, this dielectric device can be manufactured by a room temperature solution process. This means the environmental load of the manufacturing process is small, and costs are lower. Moreover, this feature will also be an advantage in multilayering, which is an issue for the future.

"Nanosheets are, so to speak, the "parts" for manufacturing. Since various types of nanosheets can be produced, it will be possible to realize advanced functions in the future, depending on how those parts are combined, in the same way that various electronic circuits are now manufactured by combining electronic parts. That is truly "nanoarchitectonics."

Nanosheets have diverse features. The titanium and niobium-based oxidenanosheets mentioned earlier have excellent photocatalytic and dielectric properties, and tungsten oxide nanosheets display a photochromic property, that is, they change color when stimulated by light, etc. Manganese/cobalt oxide nanosheets can show redox properties and magnetism. Creating new nanomaterials and devices by utilizing these properties is the concept of nanoarchitectonics.

"One more advantage of nanosheets is the fact that they are compatible with a variety of substances, not limited to nanosheets. Since it is also possible to combine nanosheets with various clusters and metal complexes, it can perhaps be said that the functions which can be created by this approach are truly infinite."

Diverse functional materials can be created by using nanosheets as the starting materials, and application of those materials to a wide range of fields, such as electronics, environmental and energy technologies, and others, can now be seen.

Jinhua Ye
Principal Investigator / Nano-Power Field

Nanoarchitectonics of Photocatalytic Materials for Efficient Solar Fuel Production & Environment Remediation

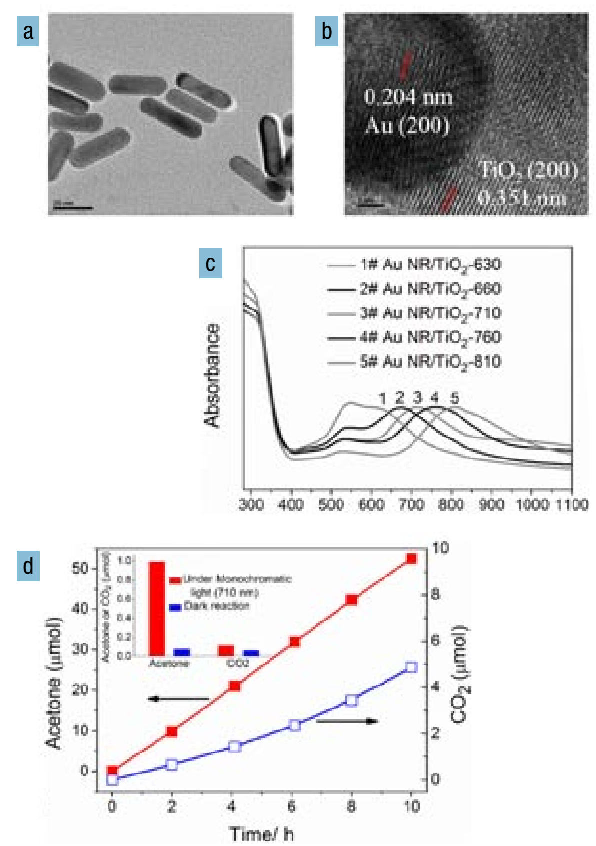
Semiconductor photocatalysis offers a potential solution for the worldwide energy shortage and environmental pollution issues by solar fuel production as well as environment remediation utilizing solar energy. In MANA, we have been challenging possibilities of nano-photocatalytic materials, by exploring new materials via energy band engineering for more efficient harvesting of solar light, controlling of surface/interface nano-structures for achieving higher reactivity, and unveiling reaction mechanism from both experimental and theoretical approaches. Up to now, a new material Ag_3PO_4 with the world's highest quantum efficiency (~90% at 420nm) in photocatalytic water oxidation, the key process of artificial photosynthesis, has been developed by a unique designing guideline. The new material also showed extremely high visible-light activity in decomposing various organics pollutants. Sophisticated control of surface/interface structure of nano-metal/oxide has further enabled efficient light harvesting, charge separation, and surface reactivity, making a big step towards realization of practical applications.

Nevertheless, the currently developed photocatalytic materials are still confined to the region of ultraviolet or a small part of visible light due to difficulty in satisfying not only the thermodynamic but also the kinetic requirements for a photocatalytic reaction. In view of both chemistry and practical applications, it is highly desirable to develop photocatalytic materials that harvest photons in a wide range of visible or even infrared light.

Recently, we have succeeded in applying the phenomenon of localized surface plasmon resonance (LSPR) of nano metal to expand the active region of TiO_2 from UV to visible and even near-infrared light by sophisticatedly tuning the aspect ratio of Au nanorod (NR) via a seed-mediated synthetic route (ref.). Fig.1 shows the morphology as well as the photocatalytic performance of Au NRs sensitized TiO_2. It's found that not only transversal plasma which is similar to sphere Au particles (~520nm), but also longitudinal plasma of Au NRs in visible-infrared light region could be observed, corresponding to the oscillation of the free electrons along and perpendicular to the long axis of the rods. Fig.1 d shows the photocatalytic oxidation of volatile organic compounds IPA under a wide range of visible light 400<λ<820 over sample 3, Au NR/TiO_2 -710. IPA was found to be decomposed to acetone firstly and then to CO_2 finally, not only under visible light irradiation, but also under monochromic light as long as 710nm, demonstrating clearly the contribution of longitudinal plasma of gold NRs in the photocatalytic reaction.

We are now further challenging possibility of applying the LSPR phenomenon to achieve a harsher uphill photocatalytic reaction, namely photocatalytic water-splitting or CO_2 conversion to hydrocarbon fuels. Diversity of nano metals in chemical composition and morphology, as well as the compositing with oxide photocatalysts are believed to offer a new opportunity to overcome the limited efficiency of oxide-based solar chemical conversion.

(Fig.1)



a Au NR, and b Au NR/TiO_2-660 photocatalyst.
c UV-vis diffusion reflectance spectra of Au NR / TiO_2 photocatalysts with different Au NR aspect ratio, and d potocatalytic oxidation of IPA over Au NR/TiO_2-710 under visible light irradiation (400<λ<820nm) as a function of reaction time. Inset: reaction carried out under monochromc light (710nm) irradiation.

Reference : Lequan Liu, Shuxin Ouyang, Jinhua Ye, Angew. Chem. Int. Ed., 52: 6689, (2013) .

Makoto Kobayashi

◉Interviewer : Akio Etori, Science Journalist

Active discussion nurtures people and research.

—— How did your joint research with Prof. Maskawa begin?

I joined the laboratory headed by Prof. Shoichi Sakata at Nagoya University, where Prof. Maskawa was 5 years ahead of me and was already a research associate there. Thus, Prof. Maskawa was in the position of teacher to me as student. My participation in Prof. Maskawa's research group was the beginning of our collaboration.

In the field of particle physics, around that time, much attention was focused on the problems of chiral symmetry, CP symmetry, and the like. In particular, chiral symmetry was founded by Prof. Yoichiro Nambu [co-winner of the 2008 Nobel Prize in Physics]. Prof. Sakata's laboratory had made great achievements in particle research and was also actively grappling with those issues. I was lucky to be included in that research group. In the laboratory, research was enthusiastically discussed, and I could participate freely in those situations. I feel that there was a vigorous, open atmosphere in the laboratory, and a tolerant attitude toward young students entering into discussion.

While I was still a graduate student at Nagoya University, Prof. Maskawa moved to Kyoto University. Three years later, I also received my degree, and I left to take up a new post as a Research Associate at Kyoto University. As a result, I was close to Prof. Maskawa and we could do research together again. We did the research that was the object the Nobel Prize several months after I went to Kyoto. Basic idea of the research came into my mind through enthusiastic discussion with Prof. Maskawa. After that, I continued to do research with Prof. Maskawa for many years.

—— At that time, did you have any premonition that you might win the Nobel Prize? And did anything change after you received the Nobel Prize?

I'd been interested in the problem of CP symmetry since my student days, but the concrete research on this problem with Prof. Maskawa began after I moved to Kyoto. At that time, I wasn't thinking about winning the Nobel Prize or anything of the kind. Even later, although this is more recent, I retired from KEK (High Energy Accelerator Research Organization), and I thought I'd be able to relax from then on. However, after I received the Nobel Prize, I could no longer lead a carefree life; in fact, I've become even busier than I imagined. I've given quite a few invited lectures in Japan and other countries, and I've accepted positions on a number of academic committees. Although these weren't jobs that I was seeking, if you accept the jobs that are requested, your work load will increase before you know it. However, I do turn down jobs if they're too far from my specialty.

—— From your viewpoint, how do you see the unsolved questions of particle theory progressing in the future?

Broadly speaking, I think there are two large challenges in particle theory as we go forward. One is experimental verification of theories that are considered to lie beyond the Standard Model, for example, supersymmetry and others. One of the key purposes of LHC (Large Hadron Collider, constructed by CERN; the world's largest collider-type circular accelerator), which became famous thanks to the discovery of the Higgs boson, is to search for particles that have been predicted based on supersymmetric theories. As a result of experiments related to CP symmetry and the discovery of the Higgs boson, we have achieved a certain stage in the flow of research on the Standard Model. However, there still remain many problems that cannot be explained by the Standard Model, and various possibilities are conceivable for solving them.

The second large challenge in particle theory is to complete a theory that can fully explain gravitational fields. "String theory" is considered to be effective for elucidating the theory of gravity, but it too is still incomplete. In the case of the Standard Model, progress has been made to the point where the interactions among three types of particles can be explained by gauge theory, but research concerning the theory of gravity is, so to speak, in the present progressive form. Because the theory of gravity is considered to encompass everything in physics, the direction of the final solution may also change, depending on the form in which this theory is completed.

Profile

Makoto Kobayashi

Born in Nagoya, Aichi Prefecture. Graduated from the Nagoya University School of Science, Department of Physics in 1967 and completed the doctoral course (Ph.D.) at the Nagoya University Graduate School of Science in 1972. While at Nagoya University, he was mentored by Prof. Shoichi Sakata among others. In 1972, he became a Research Associate at Faculty of Science of Kyoto University, where he and Prof. Toshihide Maskawa became colleagues. He joined National Laboratory for High Energy Physics (now KEK: High Energy Accelerator Research Organization) as an Associate Professor in 1979 and was subsequently appointed Professor in 1985. Prof. Kobayashi became Director of Institute of Particle and Nuclear Studies at KEK in 2003 and was named Trustee of KEK in 2004. He was also named Executive Director of Japan Society for the Promotion of Science (JSPS) in 2007. At present, he is Honorary Prof. Emeritus of KEK, Director of Research Center for Science Systems at JSPS, and a member of the Japan Academy.

Prof. Kobayashi's field of specialization is theoretical physics, and particularly particle theory. In recognition of his many achievements, which include the CKM matrix (Cabibbo-Kobayashi-Maskawa Matrix) and the Kobayashi-Maskawa theory, he was awarded the Nobel Prize in Physics in 2008. Honors in Japan include the 25th Nishina Memorial Prize (1979), the Prize of the Japan Academy (1985), the Asahi Prize (1995), the 48th Chunichi Cultural Prize (1995), the Person of Cultural Merit Award (2001), and the Order of Culture (2008). Prof. Kobayashi has also received numerous awards in other countries, such as the J. J. Sakurai Prize for Theoretical Particle Physics of the American Physical Society (1985), the High Energy and Particle Physics Prize of the European Physical Society (2007), and the Nobel Prize in Physics (2008).

Coexistence/fusion

of different viewpoints and efforts gives birth to new synergistic effects.

—— **Do you expect Japan to attract the ILC (International Linear Collider)?**

That's a complicated question. Speaking from the viewpoint of one high energy researcher, I hope this will be realized. The ILC is a device that can be achieved with the current technical capabilities, and it would be wonderful to be able to solve unanswered questions. However, in attracting this facility to Japan, thorough debate is necessary, including budgetary problems, the effect on other fields of science, and similar issues.

As a nation, issues should be discussed from a more macroscopic viewpoint.

—— **What do you consider to be necessary for training young researchers? Also, what should Japan do, as a nation, to ensure that many young people advance along the road of science?**

When a person is young, various experiences here and there are important, not limited to in Japan or other countries. I myself have no experience of a long-term stay overseas, but I had a variety of experiences in the laboratory while I was a graduate student, and those experiences have been useful ever since. In my case, just around the time that I finished graduate school was a period of important developments in particle research, or what could be called a turning point in particle theory. In a period like that, I could do research in an environment where active discussion was possible, regardless of age or experience. When I reflect on that, I feel that an open atmosphere and vigorous discussion are important conditions for nurturing young people.

Recently, the Japanese government has created budgets and implemented programs, citing the fact that young people, not limited to researchers, don't want to go overseas. However, if they're forced to go, it may have little meaning. If this isn't something that a young person does spontaneously, and not because of outside pressure, that person probably won't expand their abilities.

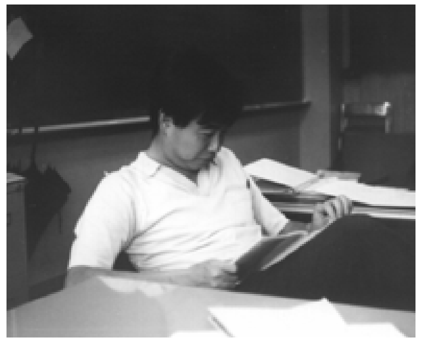
I also think ensuring that the form of Japan's education and science and technology policies is strong is extremely important for bringing up young people on the road of science. I feel that the "macro viewpoint" is somewhat lacking in Japan: For example, on what scale do we invest in science and technology, and on what scale do we train human resources? When we talk about expanding the scale of budgets for science and technology, aren't we discussing precisely how we should design the whole? A superficial debate, in which the criteria for judgment are limited to simply "will it be useful in society or not," leaves me feeling sad. Discovering and elucidating the principles and laws of natural phenomena may not be useful immediately, but it is extremely important for the progress of science.

Tell Japan and the world what fascinating research MANA is doing.

—— **Among Japan's Independent Administrative Institutes, MANA was the only organization that was selected to receive support as a center in the WPI Initiative (World Premier International Research Center Initiative). Could you tell us your expectations and thinking regarding MANA?**

MANA is an outstanding research center. You are doing excellent individual research projects that make the most of the special features of your field. In the future, I think that you will have to tell the world just what active, fascinating research you are doing here at MANA in order to attract top-class researchers from Japan and overseas. To raise the level of research in Japan - and this is not limited to MANA - it may be important to create a system so that people from other countries can build careers in Japan. That's not adequate in today's Japan. For example, Japan does little to promote systems so that senior-level scientists with careers in other countries will choose Japan for their final post. It might be difficult to create the necessary research environment and improve salaries and other treatment immediately. Nevertheless, if Japan creates an attractive research environment, and increases the number of research institutes in Japan where both young researchers and senior-level scientists can further improve their own careers, and also increases good results, even little by little, these efforts will be highly evaluated inside and outside Japan, and this will also be communicated to other countries.

Although I'm not a specialist in your field, it's my impression that the individual groups (units) of MANA are grappling with good advanced themes. Since MANA is doing so many outstanding research projects, I expect that you'll enjoy a "synergistic effect" as a result of the accumulated results. I expect that the different viewpoints and efforts between units will have mutual effects, and this will give birth to something completely new.



Dr. Kobayashi in his office when he worked on "Kobayashi-Maskawa theory" as a Research Associate at Kyoto University.

Dmitri Goldberg
Principal Investigator / Nano-Power Field

State-of-the-art *in situ* HRTEM for Nanomaterial Property Studies

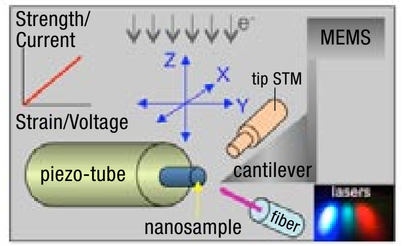
Nanomaterials are in the forefront of Materials Science over the last decades. Their intriguing mechanical, electrical, thermoelectric, electrochemical, magnetic, piezoelectric, ferroelectric, photoelectronic, and photovoltaic properties continuously excite the scientists and engineers. Needless to say, thorough measurements of these properties, especially on the individual nanostructure level, that gives the clearest artifact-free picture, is the key issue once the nanomaterial practical, rather than dreaming integrations into existing and/or new technologies are considered. However, in most cases, the nanomaterial property studies have been performed using instruments and methods having no direct access to the material internal structure (but rather to only its surface), namely, scanning electron (SEM), scanning tunneling (STM) and atomic force microscopes (AFM). This has significantly limited the relevance of the collected data since all peculiar inner structural features of a nanomaterial before, during and after testing have been largely hidden. Therefore, the measured figures may hardly be linked to a particular morphology, crystallography, spatially-resolved chemistry and defect structure of a given nanoobject. This would explain a commonly large scatter of property data reported in the literature that has often confused the practical engineers and led to many uncertainties with respect to the real nanomaterials' industrial potentials.

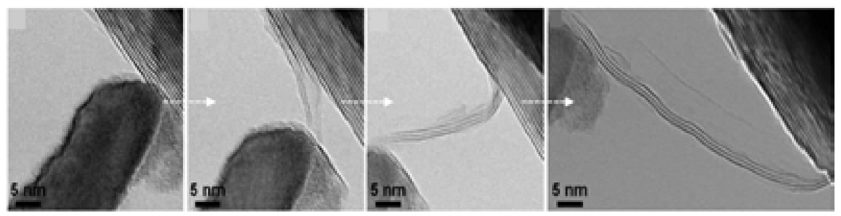
Keeping in mind the regarded pre-existing drawbacks we developed and for the first time effectively utilized the pioneering methods of *in situ* high-resolution transmission electron microscopy (HRTEM) which allow us to not only dramatically zoom-in the nanoobjects (up to 2.0 million times) and to get the deepest insights into their crystallography and the atomic lattice structures, but also to manipulate them at the nanometer-range precision, while in-tandem exploring their true mechanical, electrical, thermal and optical properties. Specially-designed holders combining the capabilities of a conventional HRTEM instrument and either an atomic force sensor, or a scanning tunneling microscopy probe, or a precisely positioned optical fiber Fig.1 become our powerful tools for the analysis of more than fifty various nanomaterial systems and morphologies, e.g. nanotubes, nanowires, nanosheets, graphenes and nanoparticles.

We became one of the world-leading groups in the demonstration of the full usefulness of the regarded techniques during elasticity, plasticity and strength analysis of nanotubes, nanowires and graphene-like structures, while employing direct bending or tensile tests, detailed electrical transport tracing and on-demand nano-engineering (thinning, filling/emptying, soldering, doping, peeling etc.) of nanostructures (Fig.2), and new optoelectronic and photovoltaic tests under applied strain in a high-resolution TEM column.

The main feature of all successfully accomplished experiments is that the nanomaterial properties have been investigated on an individual nanostructure level under ultimately high spatial, temporal and energy resolution particularly achievable in HRTEM. Thus the complete crystallography-based and defect-status information (i.e. stacking faults, dislocations, grain and phase boundaries, interfaces between various structural domains, individual vacancies and their agglomerates, nanosurface quality and oxidation states) may *in situ* be visualized at all measurement stages and in a real time. And the true structure-property relationship, which is the Holy Grail of the Material Science, may be unambiguously determined.

(Fig.1) Scheme of diverse *in situ* tests designed inside a HRTEM column





(Fig.2)

Consecutive HRTEM images revealing the kinetics of a "Scotch-tape" technique for atomic layer peeling; three atomic layers were peeled-off from a layered MoS_2 single crystal under delicate nanomanipulations with the metal tip.

Reference : D. M. Tang, D. G. Kvashnin, S. Najmaei, Y. Bando, K. Kimoto, P. Koskinen, P. M. Ajayan, B. I. Yakobson, P. B. Sorokin, J. Lou, and D. Golberg, Nature Commun., 5: 3631, (2014) .

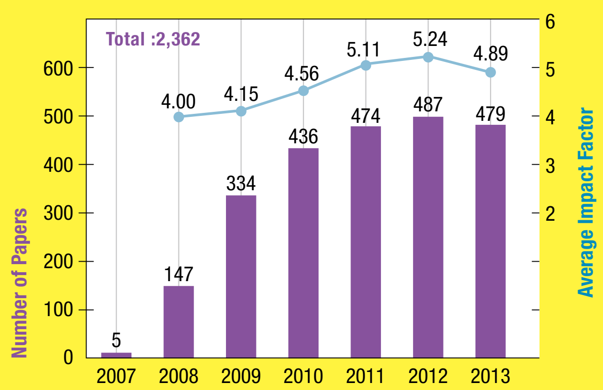
Progress of MANA

Research Achievements at MANA: The Numbers Tell the Story

Six and a half years have now passed since MANA was launched in October 2007.
During that time, researchers affiliated with MANA have produced a large number of remarkable research results, many of which were introduced in Convergence. The following is a statistical overview of MANA's achievements in scientific papers.

■During the past 6 1/2 years, the number of published papers by MANA-affiliated researchers has increased year by year, and has now reached a cumulative total of 2,362 (Fig.1). The high quality of research at MANA can also be seen in the large number of papers which MANA researchers have published in scientific journals with high impact factors (IF). In 2013, MANA-affiliated researchers published 479 papers, and the average IF of the journals where those papers were published was on a high level of 4.89.

(Fig.1)
Number of MANA affiliated Papers, Average Impact Factor



Note) The average impact factor is calculated upon each journal's impact factor of each year
(The value of year 2013 is exceptionally using year 2012 data).

■Furthermore, among the 2,362 papers published during these 6 1/2 years, 80 were "highly-cited" papers (top 1% papers), that is, papers which were in the top 1% for number of citations. Thus, top 1% papers accounted for a high percentage (3.4%) of all published papers. These numbers also show the high quality of research at MANA. Table.1 shows the journals in which many top 1% papers were published.

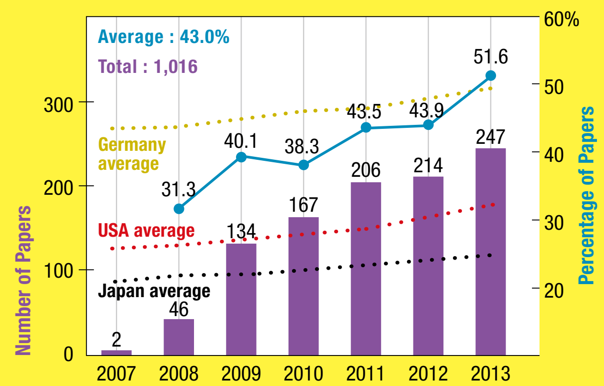
(Table.1) Journals publishing large numbers of MANA top 1% papers

Name of journal	Number of papers published
Advanced Materials (14.829)	14
Journal of the American Chemical Society (10.677)	9
Advanced Functional Materials (9.765)	7
Journal of Materials Chemistry (6.108)	6
Nature Materials (35.749)	3
Nano Letters (13.025)	3
ACS Nano (12.062)	3
Chemistry of Materials (8.238)	3

Numbers in parentheses ( ) show Impact Factor.

■The 2013 edition of Japan's White Paper on Science and Technology pointed out the importance of international joint authorship papers. international joint authorship papers are papers which are jointly authored by researchers in organizations that extend beyond national boundaries. The White Paper mentions that the number of international joint authorship papers is increasing rapidly in countries around the world as a result of acceleration of the international brain circulation, and also notes that international joint authorship papers tend to have high numbers of citations. Fig.2 shows the transition of the number of international joint authorship papers at MANA during the past 6 1/2 years. The number of international joint authorship papers is increasing annually, and these papers accounted for more than half of MANA's paper productivity in 2013. This is a high number and is comparable to the results Germany, which is world leader in international joint authorship papers. These numbers also show the progress of MANA's efforts in cooperative research by researchers from different countries.

(Fig.2)
Number of international joint authorship papers, Percentage of Collaboration papers



Source of National Average: SciVal database, Elsevier B.V. as of 2014 June

NEWS & TOPICS

Events

MANA/ICYS Reunion Workshop

The MANA/ICYS Reunion Workshop was held at the WPI-MANA Building Auditorium over a 2-day period March 3-4, 2014. The purposes of this Workshop, which was held for the first time this year, are to encourage exchanges between alumni who were formerly members of MANA or the ICYS (International Center for Young Scientists) and current members, and to strengthen the global research network. Research reports were presented by a total of 21 alumni and current members, and each was the focus of intense discussions. The event attracted 113 persons over the 2-day period. In addition to renewing old friendships, the participants also exchanged ideas on plans for future exchanges. The Workshop concluded with promises to hold similar events in the future.

Four WPI Research Centers Exhibit Jointly at the E-MRS 2014 Spring Meeting

Four WPI Research Centers, MANA, AIMR (Advanced Institute for Materials Research, Tohoku University), iCeMS (Institute for Integrated Cell-Material Science, Kyoto University), and I^{2}CNER (International Institute for Carbon-Neutral Energy Research, Kyushu University), exhibited jointly at the European Materials Research Society (E-MRS) 2014 Spring Meeting, which was held in Lille, France May 26-30, 2014. With the aims of increasing the global visibility of Japan's WPI program, attracting outstanding human resources, etc., the Japanese group held a workshop entitled "Japan in Motion - Recent WPI Advances in Materials," and also presented invited talks, oral presentations, poster presentations, and a booth exhibit.

WPI Booth

MANA International Symposium 2014

The MANA Symposium 2014 was held at the Tsukuba International Congress Center (Epochal Tsukuba) over a 3-day period March 5-7, 2014. The MANA Symposium is held each year to publicize the results of research at MANA in Japan and the international community. The recent event was the 7th in the series.This year's MANA Symposium 2014 featured Special Lectures by two Nobel Prize Laureates in Physics, Prof. Leo Esaki and Prof. Makoto Kobayashi, and Invited Talks by 19 distinguished scientists from Japan and other countries, as well as an introduction to recent research achievements at MANA by 11 oral presentations and 115 poster presentations. A total of 425 persons attended over the 3-day period. The symposium featured spirited question-and-answer sessions and concluded on a high note.

Participants of the Symposium

Awards

- Mitsuhiro Ebara, MANA Scientist, "nano tech 2014 Project Prize" (2014.1)
- Takako Konoike, Independent Scientist ,"The Physical Society of Japan Young Scientist Award" (2014.3)
- Kazuhito Tsukagoshi, Principal Investigator, and Toshihide Nabatame, Manager, MANA Foundry NIMS "President Incentive Prize for a researcher (jointly awarded)" (2014.4)
- Takashi Uchihashi, MANA Scientist, "NIMS President Incentive Prize for a researcher" (2014.4)
- Dmitri Golberg, Principal Investigator, "The Japanese Society of Microscopy JSM Seto Prize" (2014.5)
- Kohei Uosaki, Principal Investigator, "The Surface Science Society of Japan Prize" (2014.5)

New Face

Independent Scientist
Takako Konoike
2014.3.1

MANA Scientist
Wipakorn Jevasuwan
2014.3.10

Independent Scientist
Takashi Nakanishi
2014.4.1