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The 2008 Open Research Institute Declaration

- Aiming at Dramatic Progress from a Plateau -

SPECIAL Interview

Harold Kroto × Yoshio Bando

Nobel Laureate in Chemistry 1996 — NIMS Fellow

Fostering Creativity and Serendipity in Scientific Research

Research Highlights

- Synthesis of Deep Ultraviolet Light-Emitting Hexagonal Boron Nitride at Atmospheric Pressure
- A Novel Technique for Production of Nanoscale Inorganic Free-Standing Films

FACE フェイス interview

Dreaming of Half-Metals, the Key Material for Spintronics

Koichiro Inomata NIMS Fellow

The 2008 Open Research Institute Declaration

- Aiming at Dramatic Progress from a Plateau -

President, Prof. Teruo Kishi

First, I would like to wish all our colleagues and friends a very Happy New Year.

Our research results have shown steady growth. NIMS ranked first in the number of published papers and the number of patent applications per researcher, and also ranked superior in collaborations with private companies and introduction of external funds in last year's results of science and technology-related activities at Independent Research Institutes and National University Corporations. These are remarkable accomplishments.

However, in the international context, both these numbers and our Citation Index for papers in materials science are still inadequate, and these indicators have been flat over the past 2-3 years. This plateau tends to be seen periodically at research institutes which have become front-runners. At such times, it is necessary to review the direction of research and the form of systems and evaluations. Even though numerical results are a necessary condition for research, they are never a sufficient condition. Practical application, which is an institute's social contribution by research results, and systemization of education as its scientific contribution, are also strongly demanded. Of course, NIMS is steadily increasing its research products which lead to innovation, in other words, practical application. However, what is important is to achieve a transformation from an era in which our achievements are defined by quantity to one of quality, based on a constant awareness of the need to produce materials that can truly be used.

Until now, material research has been mainly conducted according to material fields such as metals, ceramics, semiconductors, and organic/biomaterials. For the future direction of research, however, development of hybrid/composite materials, which are a fusion of these materials, will become the main objective. Considering the development of research in the future, NIMS must make efforts to introduce organic, bio, and polymer technologies, with which we have only a limited tradition.

On the other hand, as a trend in recent years, the role of theory and technique has increased in the materials research field, and nanomaterials have attracted attention as materials. In any case, we must fully recognize that nanotechnology is a key technology for materials development. We have now entered an era in which nanotechnology and materials are inseparable.

Simultaneously with the direction of research, how we promote research is also extremely important. First, we must create an environment which will vitalize all our researchers. In order to achieve this, I would like to declare that the creation of an Open Research Institute as one of goals for 2008.

As a research institute which is open at all levels, international openness and openness to universities, private sector companies, and the general public are major elements. Furthermore, not only openness to those outside NIMS, but also internal openness is essential. It is my fervent hope that NIMS will become an institute which allows researchers from different units to discuss and exchange issues freely wherever and whenever they wish without any difficulties.

NIMS is also obligated to maintain and to make available our advanced facilities/equipment for external users. The High Magnetic Field Station, High Voltage Electron Microscopy Station, Nano Technology Innovation Center (NICe), SPring-8, and others can be considered to form an infrastructure that supports the Open Research Institute. In particular, from last year into the present one, we constructed a new Nanotech Foundry which can now be made available to researchers inside and outside of NIMS.

As one of good news from last year, MANA (International Center for Materials Nanoarchitectonics), was selected as a World Premiere International (WPI) Research Center, along with four traditional universities in Japan last September. Promotion of internationalization at MANA is expected to have the simultaneous effect of greatly opening NIMS itself, both domestically and internationally.

Where internationalization is concerned, the ICYS (International Center for Young Scientists), which NIMS launched in 2003, produced important results. This outcome also greatly contributed to the selection of MANA for the WPI project. The four "In" words – Independent, Innovative, Interdisciplinary, and International, which are the keywords for the operation of the ICYS, will also be the motto of NIMS in the future. In addition to the four "In" words, the ICYS is a "melting pot" where young scientists from various countries gather in an interdisciplinary, multicultural environment. In order to achieve dramatic progress as an international research center at NIMS, we want to expand this "melting pot" concept. The ICYS will remain in MANA at our Namiki Site, and a similar function will be established in the Sengen Site.

Collaboration with private corporations is also progressing steadily. The biweekly NIMS Evening Seminar program is on track, joint research and commissioned research are both increasing, and we are continuing to improve the technology transfer system for the results of basic research. Following on the Rolls-Royce Centre of Excellence for Aerospace Materials, which was established in NIMS to conduct research and development through international collaboration, we intend to put great effort into advanced research with a view to practical application.

In closing, I sincerely request that you continue to give us your guidance and support, and I would like to extend my very best wishes for a successful and rewarding year in 2008.

For Creating a More Open Research Institute

Based on the motto that "the true value of materials is in their use," NIMS strives to return the results of its research to society in various forms. We also make our world-class research facilities and equipment available to outside research institutes and researchers. Under the Materials Research Platform Concept, NIMS promotes transferring our technologies which are based on fundamendal and generic/infrastructural technology research and development, and activities intended to familiarize the larger society with NIMS and its work, including "open house" events and general tours.

Department of Materials Infrastructure

NIMS has been developing infrastructural technologies and opens our world top-level large facilities and cutting-edge equipments to the external joint users, for a break-through by the material analysis/measurement and manufacturing/engineering techniques. NIMS is also providing a lot of opportunities to the internal or external users/institutes to access our well-advanced facilities such as high voltage electron microscopes, high field magnets, contract beamline at SPring-8, Materials manufacturing and engineering support devices, and analysis support equipment. For being a leading institute in materials research and contribution for expanded use of new materials worldwide, NIMS engaged in efforts to expand and improve the intellectual infrastructure by constructing various types of materials databases in a planned manner and publishing information on materials which is necessary for the optimum selection of materials by researchers and engineers, for example by publishing materials datasheets and similar activities.

The Department of Materials Infrastructure includes the following stations.

1. High Voltage Electron Microscopy Station
2. High Magnetic Field Station
3. Beam Line Station
4. Materials Data Sheet Station
5. Materials Database Station
6. Materials Manufacturing and Engineering Station
7. Materials Analysis Station

The High Voltage Electron Microscopy Station (HVEMS) has been established for the research and development (R&D) of HVEMs and related instrumentation for nano-characterization and study of material systems, and for utilization by users including those who are not specialists of TEM. The focus of the R&D is the dynamic observation of materials on the atomic scale, improvement in spatial resolution, advanced spectroscopic characterization of materials and so on.

The High Magnetic Field Station is one of the world's leading NMR facilities, centralized the most advanced high field magnets such as the 930MHz high resolution NMR spectrometer. It has been open to Japanese and international researchers as joint and external user research facility since 1998. The magnets are now being used in a wide range of research, such as 3-dimensional structural analysis of proteins, recycling of steel slugs.

The Beam Line Station is engaged in research on methods of analyzing advanced materials and generation of new materials using synchrotron light. NIMS contract beamline, BL15XU (WEBRAM), in SPring-8 generates high flux high brilliance X-rays over a wide energy range of 2-30keV for the scientific and technological research of new and exotic materials. Combination of a high resolution powder diffraction station and a high resolution high energy photoemission spectroscopy station provides unique and powerful experimental methods for the advanced crystal structure and electron state analyses. BL15XU welcomes not only NIMS researchers but researchers of universities and laboratories from all over the world through the JST-Nanonet project.

The Materials Data Sheet Station obtains material property data and prepares structural material datasheets on creep, fatigue, corrosion, and the strength of space-use materials in order to improve the safety and reliability of mechanical structures. These results have been used in various types of standards, including the revision of allowable stresses in the "Technical Standard for Thermal Power Plant Equipment," the design of the Japanese H-IIA rocket, and others, and are also used in accident investigations and other fields. Since 2002, activity of materials datasheet the Materials Data Sheet Station has received certification for its Quality Management System under ISO 9001: 2000 for the preparation of materials datasheets and the closely-related activities of commissioned creep testing and accident investigation, and is working to improve the reliability of its data and its response to social needs.

High Voltage Electron Microscopy Station: Dual ion beam interfaced high voltage TEM

High Magnetic Field Station: 930MHz NMR magnet

Beam Line Station: The large synchrotron radiation facility SPring-8

Materials Data Sheet Station: Long-term creep test machine

The Materials Database Station provides access to the world's largest database on materials over the internet. The NIMS Materials Database comprises the structural materials database, which is based on creep and fatigue datasheets, as well as databases on polymers, basic crystal structures, diffusion, pressure vessel materials, and others which were constructed by acquiring useful numerical data from the published scientific literature. These databases are useful not only in materials development, and optimum selection and use of materials for specific applications, but also in prediction and comparison of material properties, identification of materials (dictionary function), etc. As of the end of November 2007, the NIMS Materials Database had 33,518 registered users (Japanese: 24,684, users from other countries: 8,834) from 10,293 organizations in 110 countries around the world. This database is accessed more than 1 million times a month.

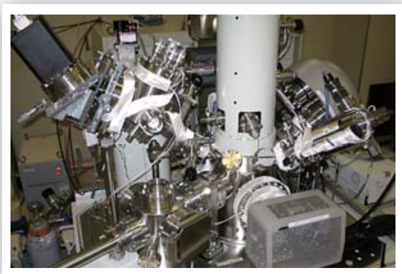
The Materials Manufacturing and Engineering Station was organized to support NIMS' world leading research as "Materials production (*Monozukuri*)". This station consists of "Material Engineering Section"(Sample Making Workshop, Mechanical Workshop, and Glass Workshop) and "Materials Manufacturing Section" (melting, forging, rolling, heat treatment).

In particular, the Materials Manufacturing Section is opened to external organizations including joint research for utilizing of the NIMS facilities with accumulated know-how based on the various advanced processing technologies for newly developed materials at NIMS.

The Materials Analysis Station has been developed a novel electron beam excitation ultra-soft X-ray microanalyzer, which is capable of high-resolution measurement of extremely low energy X-ray such as Li Kα, and helium glow-discharge mass spectrometer (He/GD-MS), which has extremely high sensitivities for gas forming elements. We have also carried out the developments of new analytical techniques suitable for the new materials. Through these activities, the Materials Analysis Station supplies more reliable analytical information to researchers in NIMS, and simultaneously, publishes the results as joint research to researchers outside NIMS. This station actively promotes the international standardization for the reliability and reproducibility of analytical results based on our research.

Materials Database Station: NIMS Materials Database

Materials Manufacturing and Engineering Station: Ultra-clean characteristics levitation smelting furnace



Materials Analysis Station: Ultrasoft X-ray microanalyzer

New User Facilities

The Innovation Support Program "Nanotechnology Network" was launched in fiscal year 2007 with a scheduled period of 5 years as a commissioned project of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The aim of this program is to provide nanotechnology researchers throughout Japan with opportunities to use the most advanced nanotechnology facilities/equipment, and thereby produce research results which contribute to technological innovation. NIMS participated in the 1st period project, "Nanotechnology Researchers Network Center of Japan", (Nanonet) (2002-2006). For the 2nd period project, NIMS has established a new organization, "NIMS Nanotechnology Support Network", for providing technical support services in 3 of 4 program areas, "Nano Fabrication," "Nano Characterization," and "Extreme Conditions." In the Nano Fabrication area, NIMS has established a "Nanotechnology Innovation Center (NICe)" to provide ultra-miniature processing technologies for a variety of materials ranging from silicon to compound semiconductors, oxides, magnetic materials, organic/polymer materials, biomaterials, and others. NICe has cleanrooms with total areas of approximately $200m^2$ and $400m^2$ with the capability to fabricate micro-electrode, fluid device structures, 3-dimensional nano-integration of photonic crystals and other advanced nano-materials. NICe also has a laboratory with an area of approximately $400m^2$ exclusively for research on organic and polymer materials, and biomaterials. Full-time staff members provide support for users. In Nano Characterization, staff centering on researchers specializing in electron microscopy provide support ranging from sample preparation to analysis using 3 of the world's most advanced electron microscopes, each with distinctive features. Support is also provided using precise crystal structure analysis, etc. by the high resolution powder diffraction method employing high brilliance, high parallelism monochromatic light, taking advantage of the features of the NIMS dedicated beamline, BL15XU, at the large-scale synchrotron radiation facility SPring-8. In Extreme Conditions, NIMS provides support in connection with nanostructural analysis/evaluation using 5 NMRs, beginning with the 930 MHz solid-state high resolution NMR magnet, which operates in the world's highest magnetic field, as well as other devices, in order to contribute to the development of nanomaterials and nanostructures by leading-edge analytical technologies utilizing various structural analysis/physical properties evaluation and measurement devices under advanced ultra-high field environments.

Cleanroom (focused ion beam processing device)

Organic/Biomaterial Laboratory

NIMS-Leica Bio-imaging Laboratory

Recognizing the importance of the encounter between "needs" and "seeds"

While the main focus of work at NIMS continues to be fundamental, generic, infrastructural technology research, NIMS also supports practical applications of "NIMS Seeds" by private companies.

There have various cooperative arrangements, including supply of samples, technical consulting, funded joint research, entrusted research, and others.

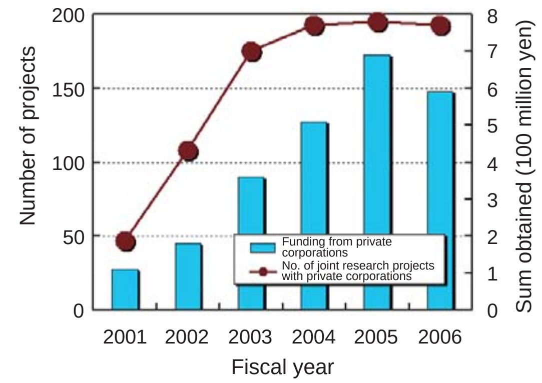
Joint research with private companies is increasing annually, and accompanying this, the funding provided to NIMS by companies is also increasing.

NIMS actively promotes to set up events which the "needs" of private companies are matched with NIMS "seeds." The aim of NIMS Evening Seminars is that researchers in industries and other external attendees can learn about the research work being done by NIMS researchers in face-to-face discussions. This program is widely open to interested parties outside NIMS and 48 sessions have been held with a total of 789 participants (as of December 2007).

In private seminars, NIMS and a company exchange information on mutual "seeds" and "needs" and search for concrete approaches to collaboration under a confidential agreement. We had already 36 of private seminars with 17 companies, and joint research and entrusted research have been materialized through these seminars.

The NIMS Forum is held once a year to introduce research results at NIMS. These events include oral presentations, poster sessions, and discussions of technology transfer.

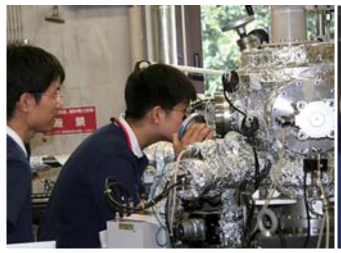
The scene at the 7th NIMS Forum



Coexistence with society

As part of the MEXT Science and Technology Week activities, NIMS opens its facilities to the public to introduce and to understand NIMS to the communities in April of each year. We contrive that the open house will be interesting opportunities for visitors to see the work being done by NIMS casually.

During the summer vacation period, NIMS conducts a Summer Science Camp for high school students from throughout Japan, a Mini-Doctor program for middle school students in Ibaraki Prefecture, and a Doctor Kid program for elementary school students in Tsukuba City. In winter, NIMS provides opportunities for children to visit its laboratories in the Tsukuba Science Workshop. NIMS believes that these activities including various unique materials experiments would generate interests in science and technology. And NIMS hopes to inspire and encourage those youngsters to be researchers in the next generation.



Summer Science Camp

Mini-Doctor Program

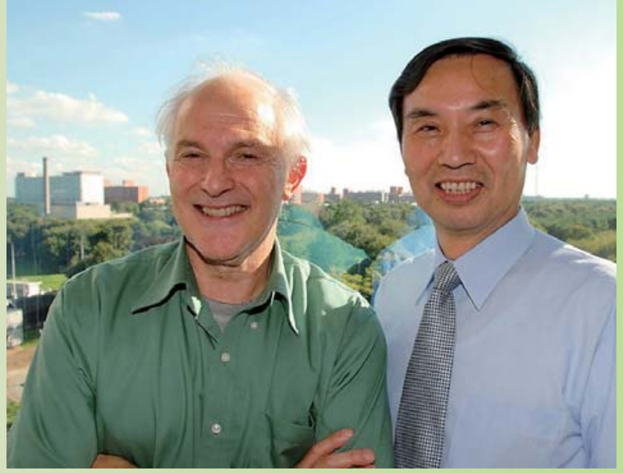
Doctor Kid Program

Tsukuba Science Workshop

SPECIAL Interview

Fostering Creativity and Serendipity in Scientific Research

Dr. Harold Kroto is one of the world's most eminent chemists. In 1985, while working with Dr. Robert Curl and Dr. Richard Smalley and students Jim Heath, Sean O'Brien and Yuan Liu investigating the chemistry that occurs in the atmospheres of cool red giant carbon stars C_{60} was discovered, a hitherto unknown form of the element carbon. Now known as buckminsterfullerene, or buckyballs, this material is finding increasing use in nanotechnology, solar cells and quantum chemistry. In 1996 Drs Curl, Kroto and Smalley were awarded the Nobel Prize for this discovery. Dr. Kroto has been an ICYS Executive Advisor since ICYS's foundation, and on a recent visit to NIMS in September, he spoke with Dr. Yoshio Bando about the creative process in scientific research.



Harold Kroto
Nobel Laureate in Chemistry 1996

Yoshio Bando
NIMS Fellow

Profile

Harold Kroto
Sir Harold Walter Kroto is an English chemist and one of the winners of the 1996 Nobel Prize in Chemistry. He spent most of his scientific career at the University of Sussex in England, where he did important work in phosphorous chemistry and molecular radio astronomy. He is currently a professor at Florida State University. An ardent advocate of science education, Dr. Kroto devotes a significant amount of his time and energy to promoting careers in science among young people. In 2001, he won the Royal Society's prestigious Michael Faraday Award, given to a scientist who has done the most to further public communication of science, engineering or technology in the UK. He is an ICYS Executive Advisor.

Yoshio Bando
Dr. Yoshio Bando is a NIMS Fellow and Director-General of the International Center for Young Scientists (ICYS) at NIMS. Dr Bando is also deputy-director of International Center for Materials Nanoarchitectonics, which has been recently established in October 2007. He is the recipient of numerous awards for his work with nanotubes and structural analysis using analytical electron microscopes. He has published over 400 original papers in international journals.

Dr. Bando: Thank you for joining us today for this dialogue. I have two main themes I would like to address: the importance of serendipity in big accidental discoveries, and the subject of grasping the implications of unusual results and realizing their importance. What is most important attribute of the researcher – his or her attitude, for example?

Dr. Kroto: I always preface this by saying that in 1984-5, before we made the discovery of C_{60}, I was very happy and satisfied with my science, and proud of what I'd done in phosphorous chemistry and radio astronomy. I had made some important breakthroughs – not Nobel material, but I'd won awards for this work. I was a professor, quite happy with what I'd done and felt I'd had a successful career. I had no aspirations or ambitions for winning the most prestigious or famous prizes; I went into science because I was good at it, and it was a good way to earn a living, but it was not the most important area of interest for me. Art and graphics were what I found most satisfying.

So I didn't have the pressure that a lot of young people have today. Pressure to publish, to produce some sort of "important" results, to prove their worth. I see that everywhere, and I think it's destructive, in a lot of cases.

As for serendipity, I think that so many of the things I'm happiest with, the most important ones, came out of experiments and ideas which were on the back-burner, in the background – interesting to me, but not "obviously" very important. I think that's when serendipitous discoveries often turn up. If you think they're important, it is quite likely that other people do too, and they may have already done it.

Dr. Bando: Often a new discovery is the result of serendipity, and to become a product it can take a long, long time. In the case of fullerene, which is now starting to be exploited in Japan, it took over 20 years. In materials science, finding new materials can take a long time. So how does one deal with this kind of long time period, especially a pioneer who discovers a new material?

Dr. Kroto: This is a big problem. Again, C_{60} is a good example. It could make a massive contribution, especially in the semiconductor industry. Perhaps it already could have done, if it had been discovered 50 years ago when silicon transistors were in their infancy. Now billions of dollars, a colossal investment, has been spent on silicon chip infrastructure.

So where can C_{60} fit in? It requires a whole new way of thinking in molecular electronics to make products from it, and huge new investment, so it has to be an order of magnitude better than silicon, or else why would the industry bother? Unless there's a huge breakthrough, molecular electronics is going to be a tough sell.

It may start to make an impact in organic solar cells, in inexpensive, large-area electricity generation. If it can be printed, using printing technology, and be very inexpensive, it could be used to bring electricity to parts of the world that don't have it. Then it will start to make inroads.

But again, often breakthroughs come out of left field. They come about by letting young people do research on what they're interested in doing. So you must guard against being too focused in research. You have to have strategic, applied research on the one hand, predominantly this should be carried out by industry that is their job, and on the other, fundamental research, should be carried out mainly at universities. Furthermore effective ways must be found to ensure cross fertilization of ideas and development between the two cultures.

But what is happening now is that big companies are pulling out of research, finding it a better bet, less risky and more profitable, to let small, entrepreneurial research programs do the work, then cherry-pick the most successful ones. This is good to an extent, but I worry that companies are getting out of the large-scale research programmes and letting the little guys do all the risk-taking. This may be good in some cases but whether there will be important disadvantages remains to be seen.

How this will work in future I don't know, but in general, you have to give our bright young people the freedom to do something crazy – crazy in the sense that no one thinks it's important. C_{60} is a good example – Even I didn't think the original experiment that I proposed that led to the discovery was that important. I was pretty sure I knew the answer and it was something I wanted to check out at some point as I had proposed on several occasions that it could explain our earlier radioastronomy results. The experiment would also be a preliminary investigation to set up a more "obviously" exciting experiment.

Dr. Bando: Let's talk about the ICYS for a moment, and the fostering of young researchers. The ICYS is meant to foster an internationally attractive environment, inviting many young researchers from other countries, having all different specialties, and an atmosphere of freedom here. We feel that this atmosphere, which allows them to do autonomous research based on their own ideas, is best for fostering young researchers. What is your evaluation of the ICYS program?

Dr. Kroto: I've interviewed many researchers here, and I'm very impressed with the way they've presented their work, their enthusiasm and what they've accomplished. Their situation, their conditions are much different from mine when I was their age.

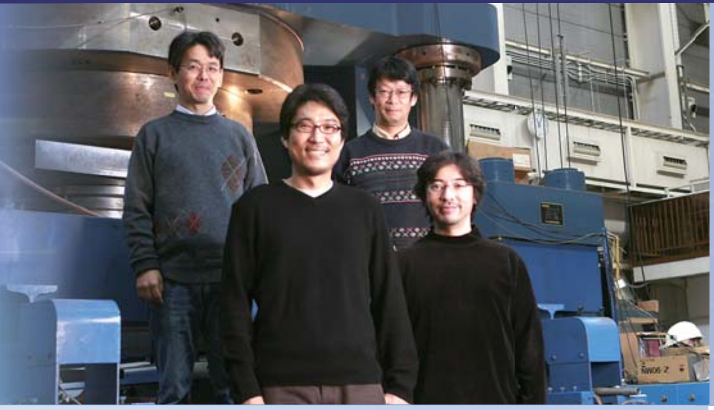
Referring back to my own experiences, something I always try to do with my students is to give them more than one project to work on – a major project, and then something a bit more adventurous, something they're particularly interested in, and that maybe doesn't matter so much if it doesn't work out.

I also like to see young people work on at least one project with someone else with conflating expertise, so they learn to share ideas and collaborate and learn to work in a team. This is the way to develop the synergy that leads to important advances.

Dr. Bando: At NIMS we want to become more attractive for international researchers. One problem is the language barrier, which we are working to overcome. What else should we look out for?

Dr. Kroto: Well, social and cultural things are important – it's important that people not feel isolated. Now you have the Tsukuba Express, a fast train into Tokyo, so that's not a problem. Japan has a lot of interesting history and cultural things going on all the time, so you should build on that. I love coming to Japan and visiting some of the great cultural centres. I particularly like Tokyo and I am sure the proximity to Tsukuba could be an attractive draw for young people. Perhaps the ICYS should organize one or two some group outings or research workshops in places which have historically important significance to promote science interaction as well as non-scientific cultural activities. Getting people out and doing some other things than science itself is extremely important, if you want to foster creativity in the science.

Synthesis of Deep Ultraviolet Light-Emitting Hexagonal Boron Nitride at Atmospheric Pressure



Opto-electronics Group, Optronic Materials Center
High Pressure Group, Advanced Nano Materials Laboratory†

Group Leader
Kenji Watanabe, Yoichi Kubota, Takashi Taniguchi†, Osamu Tsuda

We are studying materials that emit deep ultraviolet (DUV) light (wavelength: 200-300 nm). In recent years, the fields of application of new semiconductor light-emitting devices have expanded in traffic signals, large-scale color displays, lighting, optical recording devices, etc., as a result of the development of blue light-emitting diodes (wavelength: around 400 nm). Realization of DUV light-emitting devices emitting even shorter wavelength light of around 200 nm, which is our goal, will expand the fields of application, including decomposition of hard-to-decompose harmful chemical substances, water purification, sterilization, medical applications, etc.

Many of the semiconductors that are used as light-emitting materials are compounds composed of group III and group V elements in the Periodic Table. Hexagonal boron nitride (hBN) is similarly a compound that consists of the top elements in group III and group V. Because hBN has extremely good thermal and chemical stability, it has long been used as a heat resistant material or electrical insulator. However, owing to the difficulty of synthesizing high quality crystals of hBN, virtually no research had focused on the intrinsic light-emitting properties of this substance. In 2004, we succeeded in synthesizing high purity hBN single crystals and clarified the fact that hBN is a new light-emitting material that by nature emits high luminous DUV light with a wavelength of 215 nm under electron beam excitation. However, high-purity DUV light-emitting crystals were only obtained using an extremely special synthesis technology, namely, a high pressure and high temperature (HP-HT) synthesis method in the 4 GPa, 1500-1750°C region. Thus, the development of a more general-purpose synthesis method was critical to accelerate applied research on hBN.

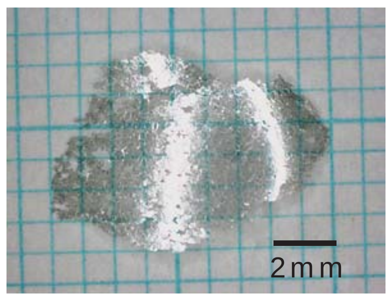
In the present research, we discovered that it is possible to synthesize high purity hBN crystals at 1 atm by a solution method using a nickel alloy-based solvent. In this solution method, the raw materials are dissolved in the solvent, and the solution is then gradually cooled, resulting in growth of crystals under the supersaturated solution. The obtained crystals are colorless and transparent (**Fig. 1**), and show high luminous DUV light emission comparable to that of the high purity single crystals previously obtained by HP-HT synthesis (**Fig. 2**). In order to use hBN in devices, it is necessary to grow the crystals on an appropriate substrate. In this research, we found that hBN crystals precipitate on a substrate placed in the solvent, suggesting the possibility of growing hBN crystals on the substrate directly from the liquid phase.

Development of the liquid phase growth technology discovered in this research should make it possible to supply a large area hBN substrate for gas phase growth, which is commonly used in the development of light-emitting devices.

K. Watanabe, T. Taniguchi, and H. Kanda, Nature Mater. 2004, 3, 404-409.

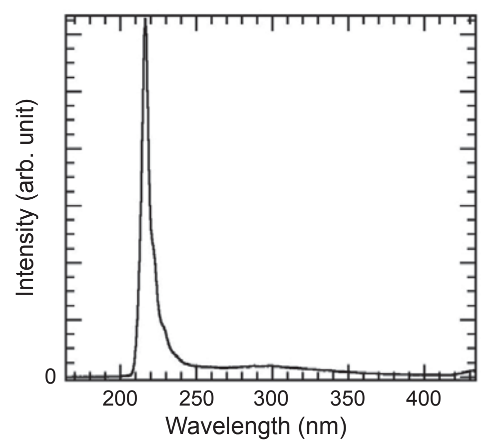
Y. Kubota, K. Watanabe, O. Tsuda, and T. Taniguchi, Science, 2007, 317, 932-934.

Fig.1



High purity hBN synthesized at 1 atm (polycrystal material consisting of crystals with a size of several 100μm).

Fig.2

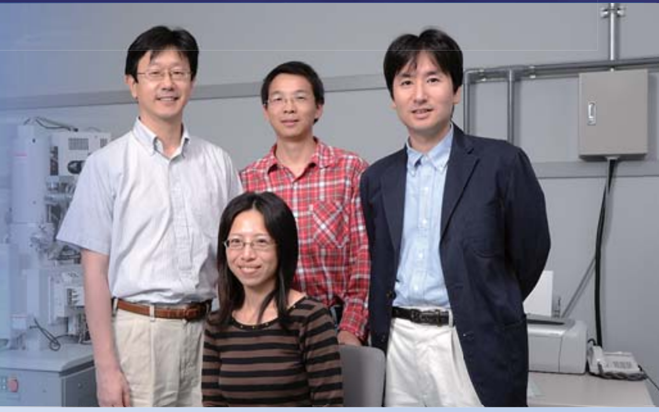


Example of room temperature light emission spectrum of hBN under electron beam excitation. A strong emission peak can be observed at a wavelength of 215 nm, indicating extremely high crystallinity.

Research Highlights

A Novel Technique for Production of Nanoscale Inorganic Free-Standing Films

- A Simple Process using a Soap Film -



Functional Thin Films Group,
Organic Nanomaterials Center
Advanced Device Materials Group,
Advanced Electronic Materials Center†

Managing Director
Yutaka Wakayama†, Jian Jin, Xinsheng Peng, Izumi Ichinose

Free-standing films which separate gases or liquids are a key structural element in biosensors and separation membranes. In miniaturizing or achieving high performance in these devices, the size (thickness) of the free-standing film must be on the submicron order. In general, photolithography is used in the manufacture of ultra-thin inorganic free-standing films. Although this is the most suitable method for manufacturing free-standing films having complex shapes, the processes of deposition, patterning, etching, and others must be repeated a number of times.

High expectations are focused on nano thickness free-standing films as separation membranes for refining bioethanol and reducing global warming gases. However, for these purposes, the development of a simple, low-cost manufacturing process with a low environmental impact is necessary.

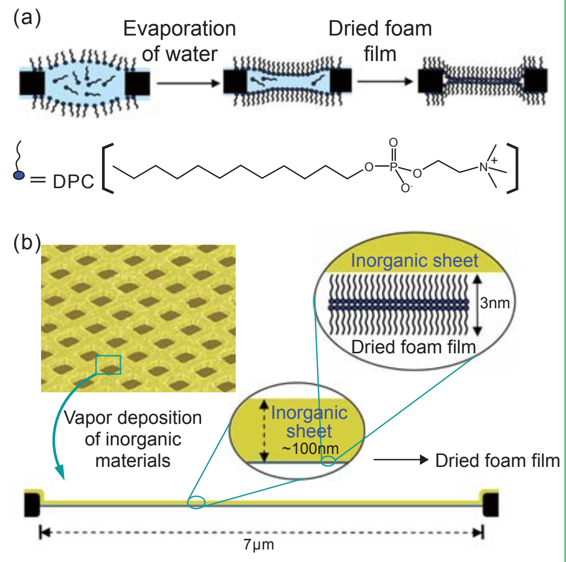
We discovered that a soap film (dried foam film) stable even under high vacuum can be obtained from an aqueous solution of a designated surfactant molecule. In the present research, we developed a simple process for producing inorganic free-standing films in holes of micron order arranged on a substrate using this type of dried foam films.

In the process, an aqueous solution of surfactant molecules is deposited in pores arranged in a regular pattern, and an ultra-thin soap film is formed by drying this solution (**Fig. 1(a)**). A variety of inorganic materials can be deposited on this film by sputtering, electron beam physical vapor deposition (EBPVD), or thermal deposition , and the surfactant molecules can be removed by rinsing with water if necessary. We demonstrated that homogeneous free-standing films on the order of 1-100 nm can be obtained with carbon and silicon by this operation (**Fig. 1(b)**). **Fig. 2** shows an optical microscope image and scanning electron microscope (SEM) image of a silicon free-standing film with a thinness of 50 nm which was formed by EBPVD. From the diffraction pattern, it can be understood that a homogeneous amorphous silicon thin film has been formed. With this method, it is possible to produce free-standing films of metals (Pt, Fe, In), half-metals (Te), and compound semiconductors (CdSe). Multilayer deposition of multiple inorganic materials is also possible.

Because this method provides an extremely simple production process for inorganic free-standing films, use as a substitute for photolithography in a wide range of research and development situations can be expected.

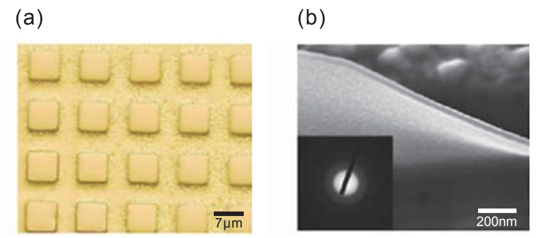
J. Jin, Y. Wakayama, X. Peng and I. Ichinose, Nature Mater. 2007, 17, 886-891.

Fig.1



(a) Formation of a soap film (dried foam film) of dodecylphosphocholine (DPC) in micron order pores.
(b) Vapor deposition of an inorganic sheet on the dried foam film.

Fig.2



(a) Optical microscope image of an ultra-thin silicon free-standing film with thickness of 50 nm. The free-standing film was formed in square pores.
(b) SEM image of the cross section of the silicon free-standing film and its electron diffraction pattern.

FACE フェイス interview

Dr. Inomata, who is a NIMS Fellow, began his career in the research and development center of a private corporation, later became a university professor, and is now engaged in research at NIMS, and thus is a researcher who has experience in all three areas of industry, academia, and government. The subject he was assigned when he began work at the laboratory of an electrical company was development of high performance rare earth permanent magnets. Following this, however, he himself determines the research topics and commercialized all of these, including magnets. His achievements include soft magnetic materials of amorphous alloys, the world's first GMR head, and others as well as the permanent magnet. After working in the company, he carried out fundamental research related to spintronics at a university, and he is now involved in research on half-metals, which will be the key material to spintronics.

Koichiro Inomata NIMS Fellow

Dreaming of Half-Metals, the Key Material for Spintronics

You've had experience in the private sector, a university, and now at NIMS. What differences have you noticed in these environments?

In a private corporation, the mission is commercialization. This means that the research topic itself must assume that the results can be used for something. Where new materials are concerned, it is normally necessary to develop new applications. For this reason, I visited the user departments in the company and sometimes conducted joint development of devices with other companies, and the developed materials were commercialized after the application was determined. Based on this experience, I acquired an attitude of carrying out fundamental research while developing an image of the future device. This was also useful after I moved to the university, for example, in preparing application documents for external funding. In the second year, CREST (Core Research for Evolutional Science and Technology) was selected, and we were able to start a laboratory. I've also kept this attitude at NIMS.

I believe you started research on half-metals after moving to the university?

I also did a little work on the subject while I was in the private sector, but my full-scale research began after I moved to the university. The half-metals are characterized by a band structure, and have a gap that acts as a metal with respect to up-spin and as a semiconductor with down-spin. For this reason, only upward spin can exist at the Fermi level. In 2003, we were able to observe TMR (Tunneling Magneto-Resistance) for the first time using a Co-based Heusler alloy. The ratio was around 18% at room temperature, but we have now increased this to 220%, which is the world's top level. Fundamentally, TMR can be expected to have an infinitely large ratio. However, our target for the time being is 1000%. We want to realize this and develop practical applications in the form of devices.

What kinds of devices are possible with this half-metal?

Electronics use a semiconductor electrical charge device, MOSFET, but this type of device will be unusable because a tunneling current will leak even when the device is off, as its gate length becomes progressively shorter in near future. In fact, MOSFET (CMOS) devices are nearly reaching their limit of capability. Since this problem is caused by using electrical charge, it does not occur when spin is used. The technology that surpasses CMOS is called "Beyond CMOS," and CMOS using spin (spin MOSFET) are truly "Beyond CMOS". The half-metals are indispensable for the development of spin MOSFET. If the spin MOSFET can be developed, it will be possible to create nonvolatile logic, memory, and other elements. DRAM and SRAM using semiconductor devices lose memory when the power is off. To avoid this, for example, in logics, circuits are incorporated in each system, it will be possible simply to rewrite the circuit by making nonvolatile devices. This will realize a reconfigurable nonvolatile logic, and would have enormous impact throughout the world. Application of half-metal technology to readout heads for terabit class ultra-large capacity HDD can also be expected.

What is your attitude toward promoting materials research?

Simply creating a new material normally doesn't mean that it can be used immediately in the real world. This is because the cost of new materials is high. Because new materials should offer features that don't exist in conventional products, depending on the case, I myself must develop new fields of application and new markets by conceiving applications which take advantage of those features. Even if I don't actually do this myself, it is necessary to find a key person who can do it and carry out this work jointly with that person.

What is your message to young researchers?

First, question whether the research you're doing now is really enough. Ask yourself, and then decide what you want to do. Talking about baseball games, don't be satisfied with a single, be determined to hit a double. In other words, I want young people to take on the challenge of research with the hurdles set a little high. It's also important to study the fundamentals widely while you're young and your minds are flexible. I think that research involves an integration of technical capabilities and planning capabilities. Even if you have a good topic, you won't be able to create good results without technical capabilities. Conversely, even with technical capabilities, you can't do good research without good ideas. While you're young, cultivate a spirit of challenge in taking on new problems, and develop your technical capabilities as completely as possible. As you're accumulating experience, you'll be able to see the future yourself, and you'll conceive new topics and also master planning capabilities.

Finally, what is your dream?

To perfect half metals, and to see this with my own eyes. Beyond that, I'll leave the more distant future to the young people.

NIMS NEWS

NIMS President Kishi receives the Barkhausen Award 2007

(Dec 7, 2007) Prof. Teruo Kishi, President of NIMS, received the Barkhausen Award 2007 at an award ceremony held at the Fraunhofer Institute for Non-Destructive Testing (IZFP), Dresden branch, of Germany's Fraunhofer-Gesellschaft on December 7. Prof. Heinrich Barkhausen (1881-1956) was an eminent German physicist who is known for discovering the Barkhausen effect, and also taught many researchers, including from Japan. The award which bears his name is given for outstanding research achievements in interdisciplinary work involving physics, materials science, and electrical engineering. The award to Prof. Kishi recognized his research in "the development and practical application of a non-destructive evaluation method for materials utilizing inverse analysis of acoustic emissions," to which Prof. Kishi devoted great energy while at the University of Tokyo. The award ceremony began with melody of stringed instruments. After an explanation of the content of the award and a brief outline of Prof. Kishi's career, a memento commemorating the award and monetary prize were presented. Prof. Kishi himself gave a 40 minute memorial lecture on his research, and concluded his address with an introduction of NIMS before a number of distinguished guests.

Prof. Kishi shaking hands with the host of the award ceremony.

NIMS signs Sister Institute Agreement with EMPA

(Oct 29,2007) Professor Louis Schlapbach, the President of EMPA (Eidgenössische Materialprüfungs- und Forschungsanstalt, Switzerland) and Professor Teruo Kishi, the President of NIMS signed Sister Institute Agreement at the Sengen site of NIMS. The collaborative agreement aims to provide the modalities for scientific and technical cooperation in materials science and technology between EMPA and NIMS and intends to facilitate the exchange of scientific and technical knowledge services and the augmentation of scientific and technical capabilities.

Prof. Schlapbach and Prof. Kishi shaking hands after the signing.

Visit from Singapore for possible collaboration with NIMS

(Oct 23,2007) Mr. Kenneth Tan, Executive Director and Mr. Kelvin Ho, Assistant Director, of Economic Development Board, Singapore and Dr. Joshua Kuma, Director of M3TC (Minerals, Metals & Materials Technology Centre), National University of Singapore accompanied by Ms Nanami Kasasaki, Centre Director (Industry), Tokyo Centre of Singapore Economic Development Board visited NIMS and met Dr. Masaki Kitagawa, the vice president of NIMS. They exchanged information for the possible collaboration between NIMS and M3TC.

From left; Dr. Joshua Kuma, Dr. Masaki Kitagawa, Mr. Kenneth Tan, Mr. Kelvin Ho, and Ms Nanami Kasasaki

Dr. Carmen Huber and Dr. Zakya H. Kafafi, National Science Foundation visit NIMS

(Oct.29,2007) Dr. Carmen Huber, the Program Director and Dr. Zakya H. Kafafi, Director, Division of Materials Research, National Science Foundation (NSF), visited NIMS. They met Professor Teruo Kishi, the President of NIMS, Dr.Tetsuji Noda, the Vice President of NIMS. After the introduction of NIMS and International Center for Materials Nanoarchitectonics (MANA), they had a laboratory tour at Nanotechnology Innovation Center, International Center for Young Scientists (ICYS), and High Magnet Field Station.

Dr. Nobutaka Hanagata, Manager of Bio-Organic Materials Facility, Nanotechnology Innovation Center explains the equipments.

Lights Up! The Christmas/New Year's Illumination

As an annual tradition at NIMS, both Christmas and New Year's lights were twinkled during the holiday season, displayed on the north wall of the main building at the NIMS Sengen Site. This event, which has become widely known in Tsukuba City, was begun in 1993 by the former National Research Institute for Metals (a predecessor of NIMS), and celebrated its 15th anniversary this year.

Designs for the illumination are submitted every year by 6th graders of the Tsukuba City Takezono West Elementary School, which is in our neighborhood, with the theme "Draw your dream on the sky." We received more than 100 entries this year. The school children and their parents were invited to the "Lights Up Ceremony" on December 7, and were excited to be the first witnesses of this year's design.

NIMS also cooperated in a local holiday event "The Tsukuba Mini Forest of Light" this year.

Everyone at NIMS is very glad that we could deepen the relationship between NIMS and local communities through these events.

Christmas Illumination

Size: 8m (width) x 16m (height)

No. of light-emitting diodes (LEDs) used: approx. 4000

Christmas Illumination period: 17:30 on December 7 to 24:00 on December 25, 2007

New Year's Illumination (A mouse/this year's zodiac* on Hagoita**) period: From 0:00 on January 1 to 24:00 on January 7, 2008. (shown on the cover)

*The Oriental Zodiac which originated in China is used to indicated years, months, days, times and directions. The 12 Zodiac animal signs are (in order) the mouse, ox, tiger, rabbit, dragon, snake, horse, sheep, monkey, rooster, dog, and boar.

**Hagoita is an artistic racket with beautiful drawing on it, which is used by children to play games using the hagoita and shuttlecock on New Year's day.

Hello from NIMS

Dynamic Interactions

Having moved from a busy UK life to sleepy Tsukuba, I had resigned myself to trying out a quieter lifestyle. Besides a good working environment, what more could I ask for?

Fast-forward a year, and my week at NIMS is very lively. There is plenty of work, and wedged in between the research activities are sports sessions, an ikebana class, two difficult Japanese language sessions (nevertheless very useful) and occasionally a fascinating Japanese culture class. Weekends are more sedate, but I regularly find time for visiting Tokyo to meet friends, explore a new neighbourhood, or search through second-hand bookstores. I especially enjoy travelling to different parts of Japan and Asia and experiencing local customs.

I find the researcher support services in Tsukuba and NIMS exceptional in their effort to assist foreigners and introduce them to different aspects of the Japanese lifestyle. Learning more about Japanese culture has inspired my everyday work and informed my relationships with my Japanese friends and colleagues; it is something I will always treasure. That, and being able to make good sushi.

[Visiting Kinkaku-ji, Kyoto with my colleagues (from left; Chamini, me and Pedro)]

Milica Todorović (Republic of Serbia)
NIMS Postdoctoral Researcher Junior
(September 2006 – September 2009)
First-Principles Simulation Group (1),
Computational Materials Science Center

[At the top of Mt. Tsukuba, NIMS CMSC Trip]

National Institute for Materials Science

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