from Tsukuba, Japan to the world

NIMS NOW International

National Institute for Materials Science

Vol.4 No.5 May, 2006

Special Features

Research Frontier

Development of Green Phosphors for White LEDs

- Realizing the General Illumination with Good Color Rendition -

Naoto Hirosaki,
Rong-Jun Xie
Nitride Particle Group
Nano Ceramics Center

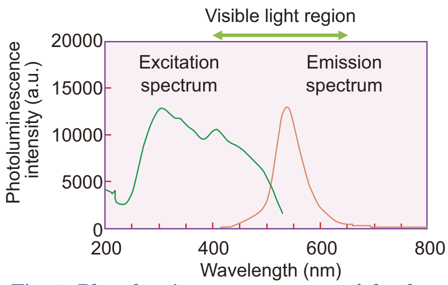

Fig. 1 Photoluminescence spectra of the developed green β-SiAlON phosphor.

Because white LEDs (light emitting diodes) have outstanding environmental features, including low power consumption, long lifetime, and no use of mercury, it is therefore expected that white LEDs will replace traditional fluorescent lamps for general lighting in the near future. Currently available white LEDs have a problem of low color reproducibility because they are constructed on the combination of a blue LED and a yellow phosphor, and thus are lack of green and red components. To solve this problem, we started to search for a novel green phosphor, and finally succeeded in developing a green β-SiAlON phosphor.

β-SiAlON is a solid solution of β-silicon nitride, and has been the object of research as a heat-resistant material. We have developed β-SiAlON as a green phosphor by doping Eu ions, its luminescence spectra being shown in **Fig. 1**. Because this phosphor can be excited by light with wavelengths of 300 nm-450 nm efficiently, it thus can be served as a green phosphor for white LEDs which use a near-UV LED or blue LED as a primary light source.

We have already developed SiAlON-based red and yellow phosphors. As shown in **Fig. 2**, together with the β-SiAlON green phosphor the SiAlON-based phosphors display intense green, yellow, and red colors under the blue-light irradiation, respectively. With the cooperation of Fujikura Ltd., we have succeeded in producing white LEDs with various color temperatures by varying the mixing ratio and the weight of these three phosphors (**Fig. 3**).

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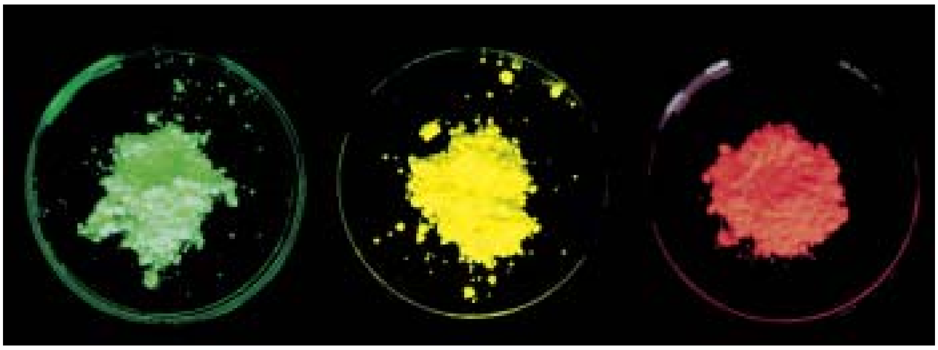

β-SiAlON α-SiAlON $CaAlSiN_3$

Fig. 2 SiAlON phosphors.

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NIMS Open House

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Regeneration Technique of Organs for Transplantation using *in vitro* 3-Dimensional Cell Culture Device

Ai Okamura,
Hideki Taniguchi
Biofunctional Materials Group
Biomaterials Center

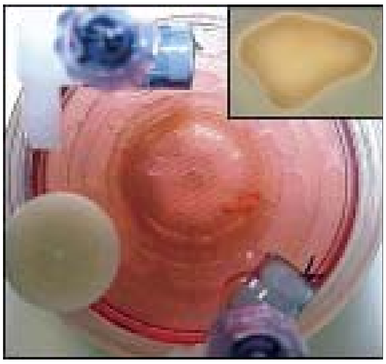


Fig. 1 Uniaxial cylindrical rotary cell culture device. The upper right shows a mass of cells formed after 10 days of culture.

Although organ transplants are performed to treat severe illnesses involving the liver, pancreas, and other organs, the inadequate number of donors is a serious problem. For this reason, a technique for *in vitro* creation of artificial organs with high-order functions equivalent to those of natural organs is considered necessary. Conventional methods of creating 3-dimensional tissue structures similar to the tissue and organs in the living body include a scaffold culture, stirrer culture, shaker culture, and others, but the structure and properties of the created tissue are different from those of natural organs. The fact that these tissues were unable to function adequately as artificial organs had been a remaining problem.

To minimize physical damage to the cultured cells, in this study, we developed a method of forming 3-dimensional tissue structures, which is characterized by gradual assembly of the tissue, by floating the cells in the culture medium using a simulated low-gravity environment. The device used, as shown in **Fig. 1**, is a uniaxial rotary cell culture device with a horizontal axis of rotation which was developed by NASA in the U.S. and reduces the gravitational force applied to the cultured cells to 1/100 of terrestrial gravity. Using this device, it was possible to culture disassembled cells which had been isolated from fetal mouse liver. After 10 days of culture, liver tissue with a diameter of 500-1000 μm was successfully created in this *in vitro* process (**Fig. 1**). A detailed examination of the internal structure when the tissue was sliced revealed that the bile duct structure and blood vessel structure had been properly reconstructed (**Fig. 2**). Moreover, with longer culture period, the structure of the bile duct became larger in scale and more complex (**Fig. 3**). Although the liver tissue in the living body has a complex structure, in which blood vessels and bile ducts are included in the spaces between the liver cells, the structure of the liver tissue created outside of the body in this work exhibited an extremely close resemblance to the natural structure. The level of expression of genes and proteins which are distinctive features of liver cells and the presence/absence of high-order functions (ammonia metabolism, chemical metabolism, albumin secretion, glycogen storage) were analyzed, verifying that the artificial tissue takes a pattern similar to that of the liver in the living body. In the future, this new 3-dimensional culture technique is expected to find application not only in transplantation medicine, but also in animal experiment substitution methods and screening in the creation of new drugs.

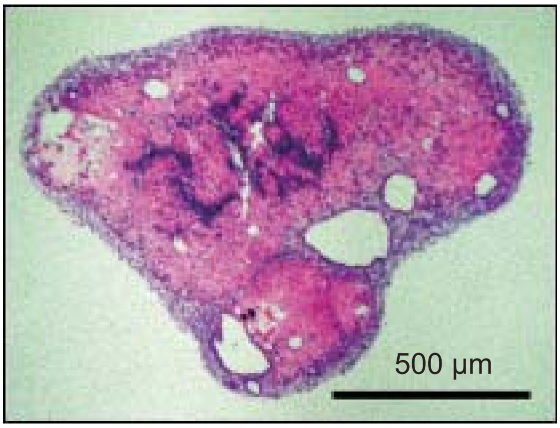


Fig. 2 Internal structure of sliced cell mass.

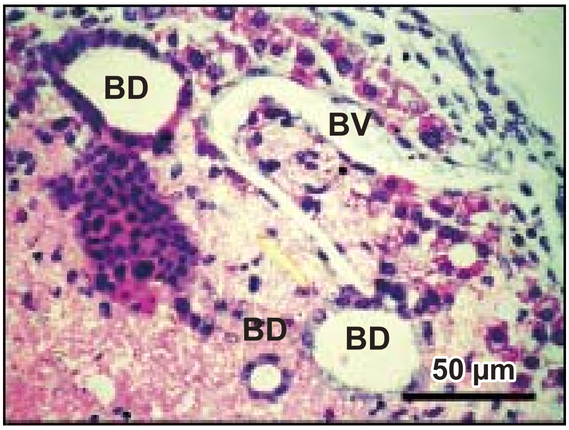


Fig. 3 Bile ducts (BD) and blood vessels (BV) had formed inside the cell mass.

NIMS News

NIMS Signs MOU with India's Vellore Institute of Technology

(February 24, NIMS) -- The NIMS' Biomaterials Center signed a memorandum of understanding (MOU) with India's Vellore Institute of Technology (VIT). Located in southern India between Bangalore, which is known as India's Silicon Valley, and Chennai (formerly Madras), VIT is a new university which was established in 1984 but has already produced many outstanding researchers and engineers in the fields of biotechnology and IT. VIT and the Biomaterials Center plan to promote exchanges of researchers and research information, joint research, and other activities in the field of biomaterials.

From the left, Dr. Hanagata (Senior Researcher, NIMS), Dr. Uchida, (Director, NIMS), Dr. Noda (Vice President, NIMS), Dr. Tanaka (Director-General, NIMS), Mr. Viswanathan (Chancellor, VIT), Mr. Sampath (Pro-Chancellor, VIT), and Prof. Sethumadhavan (VIT).

Photonic Rubber Sheet: Tunable Optical Properties when Elongated

- Elastomer Material Composed of Colloid Particles Displays Reversible Color Change -

Hiroshi Fudouzi,
Tsutomu Sawada
Wave Optics Group
Optronic Materials Center

In the jewel called precious opal, closely packed silica spheres with a consistent particle size form a regular array structure of optical wavelength. Although silica particles are colorless and transparent, the phenomenon of "structural color" can be observed in this type of opal due to selective reflection of a portion of the white light spectrum. Synthetic opals using this principle of coloration are already produced industrially as artificial gemstones. Recently, research has expanded to high-order functional materials and sensing devices which apply the structural color of synthetic opals.

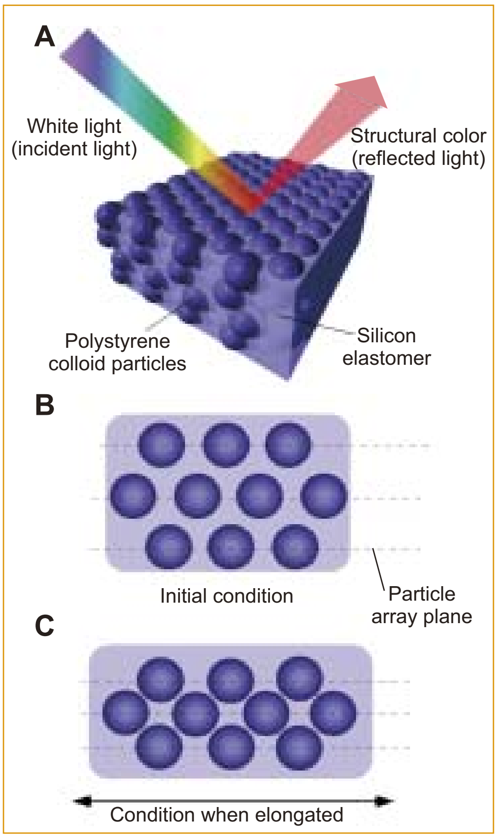


Fig. 1 Explanation of the principle of change in structural color due to deformation.

The authors previously reported a solvent sensing technique based on changes in structural color depending on the type of solvent (2004, Vol. 2, No. 2). In the present research, we developed a novel material which displays reversible change in the structural color under elastic deformation. As shown in **Fig. 1A**, this new material has a structure consisting of a regular arrangement of polystyrene particles and a silicon elastomer filling the interstices in the polystyrene. Due to Bragg diffraction, only designated wavelengths of visible light are reflected selectively from incident white light. Here, for example, when a specimen in its original state (**Fig. 1B**) is elongated in the horizontal direction (**Fig. 1C**), the spacing of the particle array plane is compressed in the longitudinal direction. When the periodicity of the array is changed in this manner, the wavelength produced by Bragg diffraction also shifts, resulting in a change in the structural color.

This new material has actually been used as a coloring layer which is coated on the surface of a rubber sheet. When the rubber sheet is tensioned in the horizontal direction, as shown in **Fig. 2**, the structural color changes from red (A) before tensioning to green (B) after tensioning. Within the range of elastic deformation, this structural color change is reversible and shows good reproducibility. The relationship between the amount of deformation and the Bragg diffraction wavelength can be observed in the relationship shown in C and D in **Fig. 2**. Application to a simple stress sensor (laid-open Japanese patent 2006-28202) which enables visual judgment of the intensity of tensioning and other devices utilizing this phenomenon is being studied.

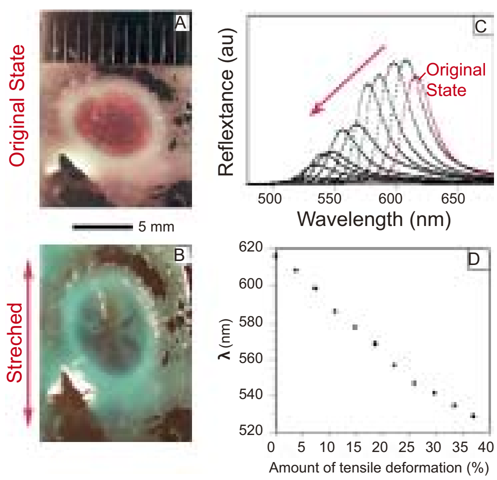


Fig. 2 Photonic rubber film coated on a fluoride rubber sheet which displays reversible color change when elongated. (A) Initial condition (red). (B) Color change when elongated in the direction (green). (C) Trend in reflection peak. (D) Relationship between amount of tensile deformation and peak wavelength.

For more details: http://www.nims.go.jp/Smart/fudouzi

NIMS News

ICYS Holds Workshop for Young Scientists

(February 27-March 1, Mishima) -- NIMS' International Center for Young Scientists (ICYS) held an International Advanced Materials Forum for Young Scientists (IAMF). Leading young researchers from 14 of the world's countries were invited to the event. Last summer, NIMS hosted the World Materials Research Institute Forum (WMRIF), where the problem of training of young scientists on a global scale was raised. The recent IAMF was planned as a response to this challenge. In addition to NIMS' researchers and ICYS Research Fellows, a total of 63 persons participated in the workshop, including a number of renowned researchers and persons recommended by the 14 institutes which participated in WMRIF and NIMS' sister institute, the University of California at Santa Barbara. The 3-day workshop was characterized by vigorous discussions on research topics related to nanomaterials, biomaterials, and a variety of other materials.

Success in Self-Assembly of Concentric Quantum Double-Ring

Takaaki Mano, Takashi Kuroda,
Kazuaki Sakoda, Nobuyuki Koguchi
Quantum Dot Research Center

Nanometer-scale semiconductor quantum nanostructures manifest unique properties, depending on their shape. With progress in crystal growth techniques, a variety of structures such as quantum wells, quantum wires, quantum dots, and others have been proposed and realized, and some have already been applied to the devices. The authors were the first in the world to propose a self-assembly method of fabricating quantum dots, which was termed "droplet epitaxy," and have been pursuing research up to the present. In the present work, we succeeded in natural formation of a complex concentric quantum double-ring structure by simply irradiating arsenic (As) atoms on a liquid metal gallium (Ga) particle (droplet).

Experiments were performed using a conventional molecular beam epitaxy system. In this process, first, nanometer-sized hemispherical Ga droplets are formed by supplying Ga atoms to the substrate surface (**Fig. 1(a)**). With the previous technique, an extremely intense As molecule beam is irradiated on the droplet, which causes instantaneous crystallization into gallium arsenide (GaAs), resulting in the formation of a pyramidal nanocrystal. However, in the present research, the migration of Ga atoms from the droplet was enhanced by irradiating an As molecule beam approximately 2 orders weaker than in the previous technique. Crystallization into GaAs at two locations, mainly on the edge and the outside of the droplet, was obtained by a proper balance of the migration of the Ga atoms and the strength of the incident As molecule beam. As a result, concentric quantum double-rings with excellent circular symmetry were formed (**Fig. 1(b)**).

In order to investigate the properties of the formed concentric quantum double-ring, the light-emission properties from a single concentric quantum double-ring were studied and compared with the results of a theoretical analysis. Electronic states existing locally in each ring (inner and outer rings) was predicted theoretically, and two peaks of light emissions corresponding to these electronic states were successfully observed in the actual measurements (**Fig. 2**). This suggests that the two rings function independently as separate quantum dots. In the future, it is expected to be possible to realize two quantum bits which can be applied to quantum computers by using this structure.

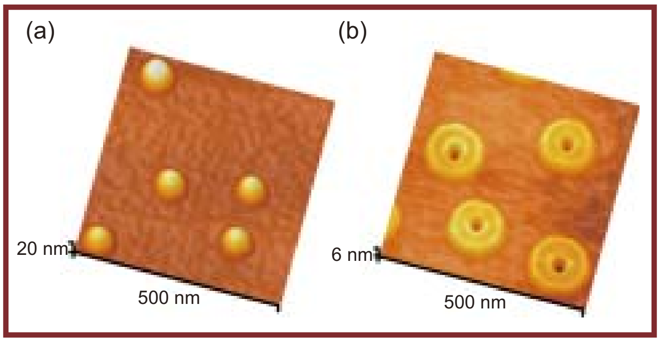


Fig. 1 Atomic force microscope (AFM) images (500 nm x 500 nm) of (a) Ga droplets and (b) GaAs concentric quantum double-rings. The vertical axes correspond to 20 nm for (a) and 6 nm for (b).

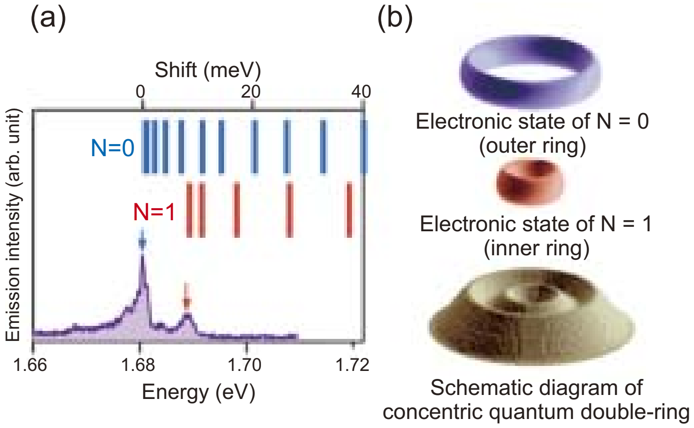


Fig. 2 (a) Light-emission spectrum and (b) results of theoretical analysis of electronic state of a concentric quantum double-ring.

NIMS News

(March 8-10, Tsukuba) -- The 4th NIMS International Conference on the theme of "Photonic Processes in Semiconductor Nanostructures" was held at the Tsukuba International Congress Center, "Epochal Tsukuba," over a 3-day period. As core materials for optical telecommunications technologies and quantum information processing technologies, high expectations are placed on the future potential of semiconductor nanostructures, especially photonic crystals and quantum dots with structures controlled with nano precision, and devices combining these types of materials. Much research is currently underway in this area.

The aim of this conference was to contribute to the future development of research through mutual discussions by the world's leading researchers in this field. Keynote lectures were given by Prof. Hiroyuki Sakaki of the University of Tokyo and Prof. Eli Yablonovitch of UCLA, followed by presentations by NIMS researchers and 26 invited speakers from 8 countries, as well as poster presentations. Including the speakers, more than 200 persons participated in this event, which featured spirited discussions of recent research results.

World's First Discovery of Water-Free Soap Film - "Dried Foam Film"

- Opening the Way to Ultra-Thin Self-Supporting Film Fabrication -

Izumi Ichinose
Director General
Organic Nanomaterials Center

Jin Jian
Functional Thin Films Group
Organic Nanomaterials Center

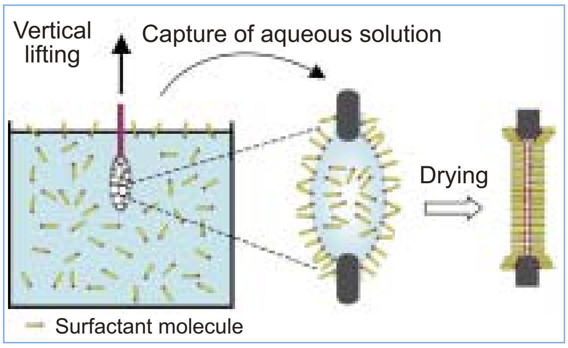


Fig. 1 Dried foam film formation process.

When a wire frame is immersed in soapy water and then lifted out of the solution, a soap film is formed. In scientific terminology, this is called a foam film. When blown on hard, this film becomes the common "soap bubble" which vanishes sometime.

Soap films maintain a film-like form due to the action of surfactant molecules. These molecules contain a hydrophobic component which resists dissolution in water and a hydrophilic component which is soluble in water, and have the property of collecting at the interface between water and air. In a soap film, these surfactant molecules align so that a thin film of water is sandwiched between surfactant molecules on both sides, with the hydrophobic component of the surfactant facing outward.

A soap film, which is essentially a flat film of water, becomes progressively thinner as it dries. With proper control of temperature and humidity, it is possible to form a thin film with a thickness of the 10 nm order. However, when the water content is exhausted, the film vanishes. Conventionally, this has been explained by suggesting that the soap film is maintained by the surface tension of water. (Surface tension is a force which attempts to minimize the area of a surface.)

We produced soap films in a frame several μm in size, and in the course of research on their structures using an electron microscope, discovered for the first time in the world that several surfactant molecules produce soap films which remain intact even when completely dried (**Fig. 1**). In other words, in the micron region, water was not an essential structural element for maintaining the soap film. In spite of the fact that the dried soap film (dried foam film) is extremely thin, having a thickness equivalent to only 2 molecules (approx. 3 nm), we discovered that it displays thermal stability at temperatures of 150 ℃ and higher. In observation with a scanning electron microscope (SEM), the film revealed transparency similar to that of a lace curtain, which is attributed to its thinness (**Fig. 2**).

This dried foam film is a new form of molecular film which can be obtained by a simple operation, and its discovery may provide a production technique for various kinds of ultra-thin self-supporting films. By appropriate design of the surfactant molecules, we are fabricating dried foam films with larger areas and greater stability, aiming at wide-ranging application as nano-separation membranes.

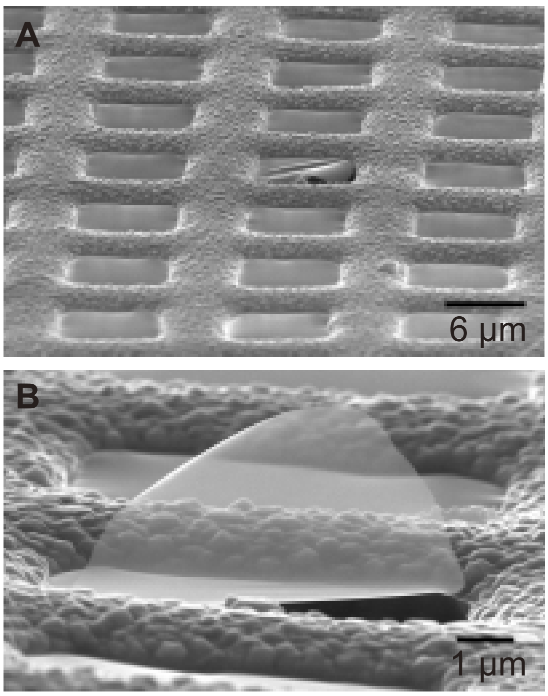


Fig. 2 (Upper) SEM image of dried foam film formed on copper mesh. (Lower) enlargement of part peeled from mesh.

NIMS News

President Kishi Receives the 47th Honda Memorial Award

(May 12, Tokyo) -- President Kishi of NIMS was honored recently with the Honda Memorial Award, which is the most prestigious award given to persons who have made distinguished contributions to the progress of scientific culture based on outstanding achievements in research related to metals and their peripheral materials. The award to Prof. Kishi was given in recognition of achievements over the course of many years in research on nondestructive evaluation of materials and research on evaluation of the reliability of structures.

President Kishi (left) at the Award Ceremony.

Discovery of Giant Light Transmission Effect at Hydrogenated Diamond Surface

- Expected to Lead to the Development of Ultra-High Sensitivity UV Sensors -

J. Alvarez
International Center
for Young Scientists (ICYS)

M. Y. Liao, Yasuo Koide
Optical Sensor Group
Sensor Materials Center

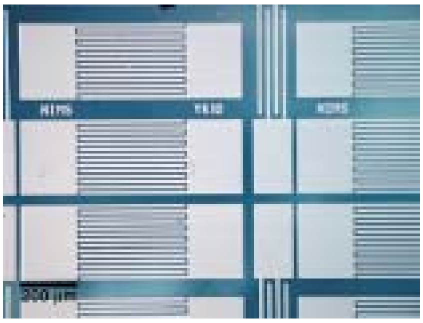


Fig. 1 Diamond UV sensor fabricated on the hydrogen-terminated surface.

Our group is developing research in which diamond semiconductors are applied to ultraviolet (UV) sensors with the aim of practical application and industrialization. In order to respond to global environmental problems and realize a safe, secure society, it is extremely important as research challenge to develop highly-sensitive, compact sensors which can detect fire, hazardous substances, and other dangers quickly. However, a current issue is that conventional optical sensors also respond to the wavelength range of sunlight. For this reason, it is required in new optical sensors to detect "wavelengths which are not included in sunlight," and "deep UV, which is the wavelength of the fluorescent light generated by flames and hazardous substances." Deep UV (DUV) refers to UV rays with wavelengths lower than 280 nm, which are included in the spectrum of sunlight but do not reach the earth's surface because they are absorbed by the ozone layer.

In the present research, we fabricated a metal electrode with a interdigitated-finger structure on the epitaxial single crystal layer of a boron-doped p-type diamond semiconductor with hydrogenated surface, and trial-manufactured a UV sensor with a metal/hydrogenated diamond/metal-type junction structure (**Fig. 1**). We discovered that this device manifests a "giant photoconductivity effect," displaying a photocurrent 10^7 times larger than the dark current in irradiating DUV (wavelength: 220 nm) at an applied voltage as small as 0.4 V. This device has a photocurrent gain which is 1000 times larger than the ideal photocurrent assuming the quantum efficiency of 100%. Because the giant photoconductivity effect is not observed at surfaces from which the hydrogen has been removed, it is understood to be a characteristic phenomenon of the hydrogenated surface. Furthermore, since the discrimination ratio between DUV (208 nm) and visible (630 nm) light is approximately 7 orders of magnitude (**Fig. 2**), this new device displays the world's highest level of performance in low-voltage detection of weak DUV, at 10^{-12} W/cm² (1 picowatt/cm²). In the future, application to the development of ultra-high sensitivity/DUV sensors can be expected.

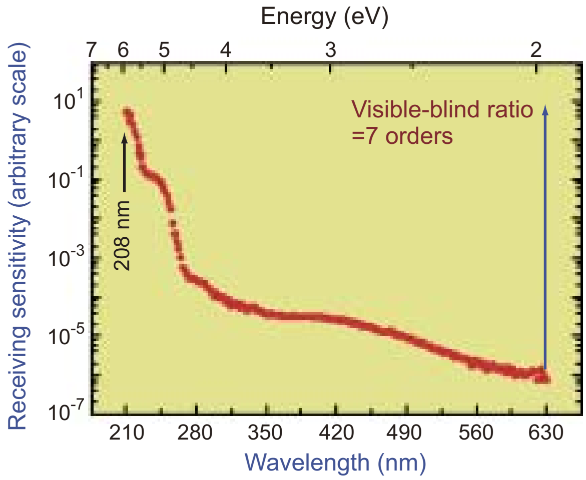
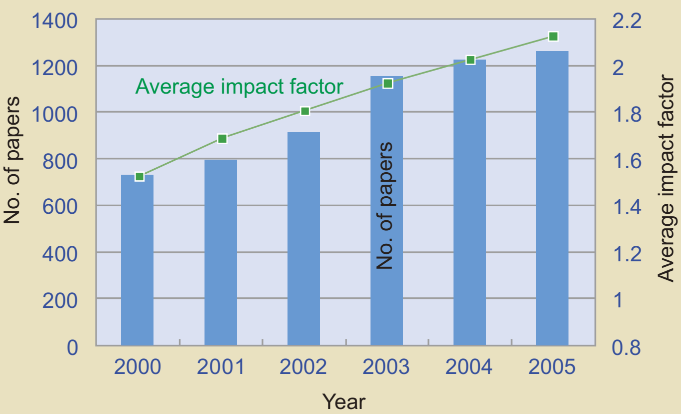


Fig. 2 Optical response characteristics of diamond UV sensor.

NIMS News

NIMS Research Papers Exceed 1,200 for the 2nd Consecutive Year



Note) The analysis presented in this article was based on the Web of Science database provided by Thomson Scientific; as the type of literature, the search was limited to "article."

In 2005, NIMS researchers published a total of 1,226 papers in scientific journals listed in Essential Science Indicators, which is compiled by Thomson Scientific. Since NIMS was established, our number of published papers has continued to increase steadily, and in fact has grown by 73% over the last 6 years. The average value of the impact factor (IF) of the journals where NIMS papers were published in 2005 was 2.13, for an increase of 0.6 over the same 6-year period. These results show that the number of research products by NIMS researchers is constantly increasing, and at the same time, these NIMS research results are also being carried in more influential journals.

Masaki Kitagawa, Ph.D.

Appointment of New Vice President

(April 1, NIMS) -- Dr. Masaki Kitagawa, former Executive Chief Scientist of Ishikawajima-Harima Heavy Industries Co., Ltd., was newly appointed Vice President of NIMS, succeeding Dr. Koinuma.

Dr. Kitagawa earned his Ph.D. at the University of Illinois (1972; Theoretical and Applied Mechanics Department, Champaign-Urbana, Ill. USA). He received his BS from the Mechanical Engineering Department of Kyoto University (1965), and was a Fulbright Travel Grantee, Research Assistant, and Research Associate at the University of Illinois (1967-1972). He worked as a Research Engineer at Ford Motor Company (1970) and as a Post-Doc Researcher at the Argonne National Laboratory (USA) (1972-1973).

From 1973 to 1990, he worked as a Researcher specializing in high temperature materials at the Research Institute of Ishikawajima-Harima Heavy Industries. Co., Ltd. Japan (IHI). From 1990 to 1994, he served as the Head of the Structural Materials Research Department at IHI, and from 1994 to 1998, as General Manager of the Research Promotion Department at IHI's Research Institute. From 1998 to 2005, he served as Director-General (Technology) and Executive Chief Scientist, Technology Development Division of IHI.

Dr. Kitagawa is the recipient of numerous important awards from major technical societies including the Japan Society of Mechanical Engineers, Society for Materials Science Japan, Iron and Steel Institute of Japan, and Japan Welding Institute, as well as a Commendation from the Ministry of State for Science and Technology-Persons of Scientific and Technological Merit, (for Research on life assessment and residual life assessment technology of high temperature components). He was appointed Vice President of NIMS in 2006.

Appointment of New Fellow

(April 1, NIMS) -- Dr. Koichiro Inomata, former Professor of the Tohoku University Graduate School of Engineering, was newly appointed as a NIMS Fellow.

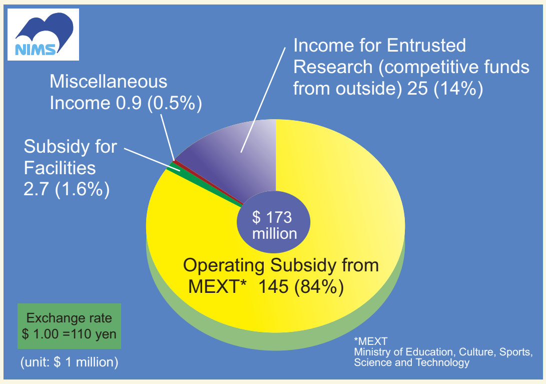
Dr. Koichiro Inomata

Doctor of Science. Completed the doctoral course in the Department of Physics, Graduate School of Science, Tokyo Metropolitan University (1970) and joined the R&D Center, Tokyo Shibaura Electric Co., Ltd. (current Toshiba Corporation) (1970). Appointed Professor, Dept. of Materials Science, Graduate School of Engineering, Tohoku University (2000), and now is a Team Leader in the JST-CREST Project since 2001. Named a NIMS Fellow in April 2006.

Budget for FY2006

(April 1, NIMS) -- The budget necessary for research and development and other tasks is comprised of an operating subsidy and a subsidy for facilities provided by the Japanese government each fiscal year, and other research funding provided by external organizations. An outline of incomes in the budget for FY2006 is shown right.

For more details: http://www.nims.go.jp/eng/about/whatsnims.html



Special Features Research Frontier

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Development of Green Phosphors for White LEDs

The color rendering index (Ra) of the new LEDs hits 82-88, and is superior to that of the existing white LEDs and fluorescent lamps (Ra is a value showing color reproducibility; 100 is the base value, and fluorescent lamps have a value of 80). Thus, these LEDs have satisfying performance as a light source for natural color lighting. As the power consumption efficiency of white LEDs is more than double than that of ordinary light bulbs, and the energy efficiency is also higher, it is thus anticipated that such white LEDs will commercialize soon.

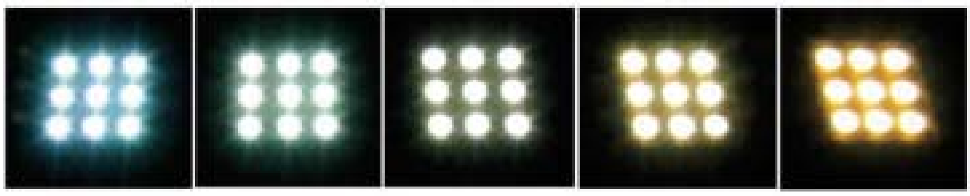

Fig. 3 White LEDs fabricated using three developed SiAlON phosphors.

Our Trip to Kansai

Jan Labuta (Charles University, Czech Republic)
International Joint Graduate School Program
(September 2005-September 2006)
Supermolecules Group, Nanoorganic Center

[Having a great time in Kyoto]

Hi there! It is our pleasure to share with you our experiences from the Kansai trip. We are all international Ph.D. exchange students under the NIMS Joint Graduate School Program. Our travel group was very multicultural. There were four students from the Czech Republic (Petr Janeček, Jan Houfek, Jan Labuta, and Břetislav Šmíd), one student from Slovakia (Natália Hajduková), one from Australia (Dandan Sun), one from Poland (Michal Wozniak), and our two Japanese guides from the NIMS International Affairs Office (Dr. Tadashi Ozawa and Dr. Tomoaki Hyodo).

Our three-day trip began in Tsukuba. On the first day, we took the Shinkansen bullet train from Tokyo to Fukuyama, where we visited the second largest steel works in Japan (JFE Steel's West Japan Works Fukuyama District) and its research center. It was fascinating to see how the results of scientific research are applied in industry. On the second day, we went to SPring-8, the largest synchrotron facility in the world, and on the third day, we visited a Japanese company called Kyocera. At all of these places, we received an interesting introduction to their work, and were impressed by the high level of Japanese scientific research and industry.

Petr Jan L. Michal Jan H. Tadashi Břetislav Natália Dandan

[Encountering Japanese history (Himeji Castle)]

Of course, we also enjoyed many sightseeing spots in Kyoto, Nara, and Himeji. In particular, Himeji Castle is one of the most beautiful castles in Japan. It was a great opportunity to get an insight into ancient Japanese culture. Our next stop was in Kyoto, where we visited several shrines and temples, including the famous Golden Pavilion (Kinkakuji). Next, we headed to Nara to see other parts of Japan's cultural and spiritual heritage. There we had an opportunity to admire a big statue of Buddha in the world's largest wooden building, all surrounded by beautiful nature. It was especially exciting to feed and pat freely the deer roaming in the nearby park. We tasted Okonomiyaki (vegetable pancake) and other regional dishes and discovered that sushi is not the only cuisine in Japan. It was a new experience for all of us to travel by Shinkansen; long distances can seem amazingly short. We appreciate what NIMS gave us, and want to take this opportunity to thank them for the chance to see what a wonderful country Japan is.

NIMS News

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NIMS Open House

(April 19-20, 23, NIMS) -- NIMS opened its facilities to the general public and received a total of 508 visitors, which far exceeded last year's number.

In spite of an unpleasant rain on April 20th, when Sengen site, Namiki site, and Sakura site were open, this was a major event which featured various open laboratories and areas where visitors could see demonstrations and enjoy a first-hand experience of NIMS' activities.

In addition, a Special Program was held at the Sengen Site and Namiki Site on April 23, and these sites also set a new record of 678 visitors.

Glass processing.

Making inscriptions on brass plate.

NIMS National Institute for Materials Science

PUBLISHER
Dr. Hisao Kanda

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