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SPECIAL Interview

Materials Department, University of California, Santa Barbara

2008 Awardee Group Shares Views

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NIMS presented the "NIMS Award for Recent Breakthroughs in Materials Science for Energy and Environment" for achieving a remarkable breakthrough in materials science and technology at the NIMS Conference 2008.
The winner of the NIMS Award 2008 was the University of California Santa Barbara (UCSB) research team comprising Prof. Anthony G. Evans, Prof. David R. Clarke and Prof. Carlos G. Levi. As a group, they received a medal in recognition of work underpinning improvements in fuel efficiency of advanced aero and power turbines through materials innovation.

The Issue

The environment/energy issue has become an overarching global concern in establishing a sustainable society. "Environment and climate change" was one of the central topics at the G8 Hokkaido Toyako Summit in Japan (July 7-9, 2008). In order to reflect this international outlook, the 2008 NIMS Week, held on July 14-18 and organized by National Institute for Materials Science, was dedicated to the main theme of "Materials Science for Highly Efficient Use of Energy and Resources".

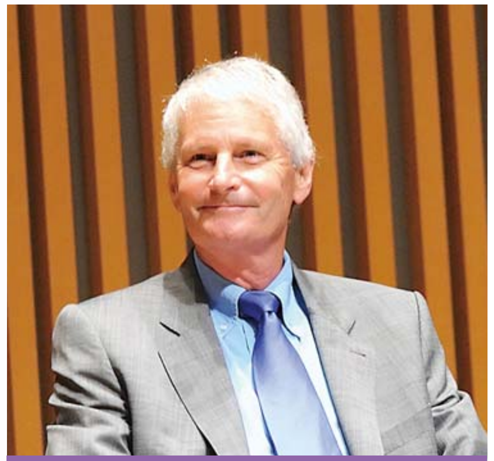
Over the past decade, the UCSB professors have led an international team that generated predictive performance models and guidelines for the development of new materials that provide thermal insulation and robustness, while also protecting the underlying nickel super-alloy from environmental degradation.

Prof. Evans is a leading light in the field of cutting-edge structural materials. The Briton has been the central figure in the drive to improve turbine engine efficiency through materials innovation, working in coordination with his UCSB colleagues Clarke and Levi, and clusters of researchers in various institutions. These efforts, supported by governmental as well as private industrial entities, have made possible major advances in materials technology over the past decade.

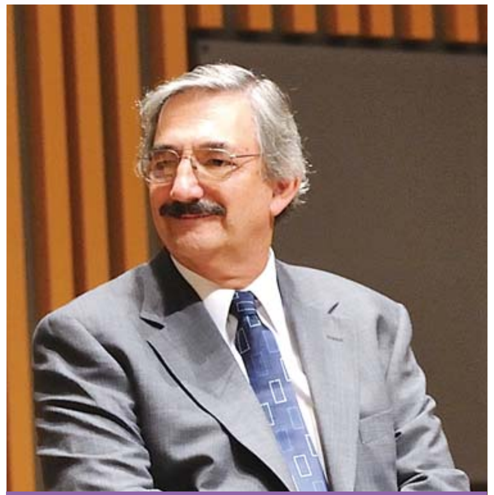
Since all aspects of the relevant material systems need to be studied, Prof. Evans asserted that a collaborative network was indispensable and thus the broader team has been truly multidisciplinary, with participants from materials science, solid mechanics, quantum mechanics, thermodynamics, thermal sciences and numerical methods.

A lucid explication was offered by Prof. Clarke, also a UK native, regarding the factors driving research on gas turbine materials. He explained that the work has always involved the pursuit of improved fuel efficiency for higher power and lower operating cost, augmented more recently by the need to reduce NOx and CO_2 emissions. From a fundamental perspective, the fuel efficiency of gas turbines for aircraft propulsion and power generation depends on the temperature of the combustion gases entering the turbine.

Understanding the behavior of materials under the extreme conditions prevailing in the gas turbine demands not only the contribution and integration of skills from multiple disciplines, but also requires approaching the problem from a systems perspective. A key role played by the NIMS Award team has been in providing this system approach and coordinating the integration of advances made by the broader research network. That the UCSB "dynamic trio" has been successful in producing remarkable results obviously backs up this perspective.



Professor, Materials Department,
University of California, Santa Barbara
Prof. Anthony G. Evans



Professor, Materials Department,
University of California, Santa Barbara
Prof. David R. Clarke

Professor, Materials Department,
University of California, Santa Barbara
Prof. Carlos G. Levi

In reflection of this stance, Prof. Levi elaborated that the researchers involved in the network have not only included multiple disciplines but also players from several countries in Europe as well as the Americas, including Prof. Levi's birthplace Mexico, and Asia, including Japan. He said that working in research teams, in addition to being effective from a technical perspective, is highly motivating because one continuously learns from colleagues and grows professionally more rapidly and effectively through these interactions. Key factors in developing these collaborations are not only that members of the team bring different talents to bear on the overall problem, but also that they have the right personal chemistry. A notable example is the longstanding collaboration between Professor Evans at UCSB and Professor Hutchinson at Harvard University, who have worked on numerous problems of advanced structural materials, including those of gas turbines.

Evolving Systems

Expanding on the systems approach, Prof. Levi remarked that, in general, the materials systems of interest are dynamic, and their useful life depends upon the manner in which the different components of the system evolve, as well as on the interaction between them as they respond to varying engine conditions such as thermal cycling.

Enhancements in gas turbine efficiency have been realized through a combination of airfoil design, cooling engineering and the invention and implementation of novel, multilayer material concepts for thermal and environmental protection of the hot gas path components. These engineered multilayers are generally known as thermal barrier coating (TBC) systems, and are broadly used in the higher performance engines used for aircraft and power generation. They consist of a metallic underlayer that feeds the formation of a protective, thermally grown oxide layer, and a thermally insulating ceramic layer. The technical challenge in producing the next generation of such turbines is to extend the temperature capability and lifespan of these TBCs, which requires new compositions of matter and tailoring the architecture of the layers in the system.

Similar materials systems can provide sufficient operational flexibility to reduce undesirable emissions, especially when applied to combustors. Prior to the involvement of the UCSB-led group, implementation was empirical and progress slow. Research outputs from these efforts have been implemented by designers into simulation codes that enable systematic enhancements in turbine efficiency.

The fundamental insights gained through the efforts of this team have also led to the invention of new compositions of matter that combine thermal insulation with robustness within the extremely aggressive combustion environment in the turbine. TBC durability is curtailed by numerous failure mechanisms that lead to partial loss of the protective coating by spalling/delamination. These new materials promise increases in durability and temperature capability, and thus are expected to enable further advances in efficiency over the next several years.

UCSB Activities

Prof. Evans' current research interests include the performance and reliability of systems in a broad range of technologies, not only regarding energy and transportation but also information, communication and health. Currently he covers, in addition to materials for structural applications, systems with other functionalities (electronic, magnetic, optical and thermal) whose survivability depends on their ability to withstand stress without failure. Strong emphasis is placed on mechanics of interfaces and thin films, with applications to electronic packaging and high temperature coatings for metallic components in gas turbines.

According to Prof. Clarke, who stated that his field of specialty as an experimentalist had been expanded after starting work with colleagues at UCSB since the subject-matters covered were greatly interesting, his recent research has moved strongly toward structural materials, including a concentration on materials aspects and failure of TBCs. This TBC work includes development by the British scientist of techniques for non-destructive measurement of stress in solids using piezospectroscopy.

As for the overarching theme of Prof. Levi's research, which is the fundamental understanding of microstructure evolution emphasizing structural alloys and ceramics, the focus has been on the application of this understanding to the chemical and micro-structural design of coatings, composites and monolithic systems. Most of his current research concerns materials that would enable more efficient and environmentally cleaner energy and transportation technologies.

The three academics said that coming up with models, codes and simulations for engine manufacture and durability analyses took much doing, while the teamwork including contacts with other researchers—such as the personal links nurtured by Prof. Evans over the past decades with the aforementioned New England academic, Prof. Hutchinson, or the channel to NIMS with Professor Kagawa and more recently Dr. Hiroshi Harada– brought about synergistic effects in expanding the fruits of the overall research effort.

Although the UCSB thrust is supported by the government and its results available in the public domain, in-kind support from the engine division of General Electric and other companies shows the great confidence that industry has in the academic institutions involved. It was stressed as well that students benefit the most since not only can they inherit "philosophy" from participation in the team endeavors but also interact with industry scientists and cultivate potential sources of employment.

NIMS Award 2008 Medals
Made from Ni-free High Nitrogen Austenitic Stainless Steel by NIMS

Materials Analysis Station

Providing the Foundation for Materials Research

Chemical Analysis Section

Materials analysis techniques and analytical information are key technologies when performing characterization of materials, and are necessary and indispensable as research infrastructure for the development and improvement of materials. The Materials Analysis Station (MAS) works in close cooperation with all Centers and Stations in NIMS, supplying analytical information on a wide range of materials, providing education and support in connection with analysis, and performing maintenance and control of analysis equipment. The Materials Analysis Station is also actively engaged in efforts to establish international standard for analytical techniques based on these results with the aim of developing and implementing more reliable, accurate, and precise analytical methods.

Chemical Analysis Section

The work of the Chemical Analysis Section focuses on analysis to accurately determine the contents of various elements in materials. Its advanced analytical equipment includes the X-ray Fluorescence Spectrometer (XRF), Glow-Discharge Mass Spectrometer (GD-MS), Induced-Coupled Plasma-Optical Emission Spectrometer (ICP-OES), and Atomic Absorption Spectrophotometer (AAS). The group also uses the inert gas transport fusion/thermal conductivity method and combustion/infrared absorption method in analysis of gas-forming elements (H, N, O, C, S).

Because chemical analysis is an area where expert skills and experience are particularly important, the Chemical Analysis Section is working to improve techniques and ensure the transmission of techniques through external activities and other efforts. Details are introduced on the following page.

X-Ray Diffraction Section

The properties of materials differ greatly depending on their crystal structures. Accordingly, accurate determination of the crystal structure is one important type of evaluation in materials research. This Section is responsible for control of powder X-ray diffraction devices as common equipment, and also provides research support by identifying precise crystal structures by single crystal structural analysis. Because there are also cases in which it is difficult to determine the exact structure by powder X-ray diffraction alone, support by single crystal structural analysis sometimes holds the key to research achievements.

Surface and Micro Region Section

This Section uses electron beam and X-ray techniques to perform analysis of grain boundary precipitates and fine states, analysis of the surface and near-surface regions of devices and catalysts, and in particular, the analysis directly linked to the functions of new materials, and is also engaged in technical development of devices which will make it possible to cope with more advanced needs.

Because this group brings together bright experts who possess knowledge and experience not only in the field of analytical techniques, but also metal microstructures, electronic theory, and device technology, it is possible to provide reliable measurements and assured data analytical results backed up by expertise, thus realizing more advanced support.

Efforts for international standardization of analytical techniques

Because analytical techniques are the most important foundation for quality assurance, today, when international business is taken for granted, it is necessary to observe international agreements and certified procedures. Those internationally-recognized procedures are international standards.

As Japan's base in this field, the Materials Analysis Station is promoting international standardization, centering on two such activities, VAMAS and ISO.

VAMAS Activities

VAMAS stands for Versailles Project on Advanced Materials and Standards, and is an organization which sponsors and supports joint international research which is directly linked to "seeds," or pre-standards, that have the potential to become international standards. Among these activities, in TWA2 (Technical Working Area 2: Surface Chemical Analysis), the role of the Materials Analysis Station is not limited to domestic activities such as organization and operation of the TWA-2 committee in Japan. It is also playing a key role as a core organization internationally by dispatching committee members and proposing and participating in international round robin tests in which the testing and measurement data of the participating institutes are compared using common specimens.

ISO Activities

ISO, or the International Organization for Standardization, is an international organization headquartered in Switzerland with the mission of establishing and popularizing international standards. In ISO Technical Committees (TC), the Materials Analysis Station is continuing to make active contributions to TC-201 (Surface Chemical Analysis) and TC-202 (Microbeam Analysis).

As an object of analytical support by the Chemical Analysis Section, in recent years, quantitative analysis of trace amounts on the order of a rice grain or in thin film form has increased. In many cases, after obtaining information such as the types of coexistent elements and their semi-quantitative measurement by the FP/XRF (fundamental parameter) method, which is initially nondestructive, this group works as necessary to improve analytical results by combined use of wet methods such as the weight method, solution method, and other precision standard analytical methods. In any case, no on analytical method can answer every need, the group responds to the user's requests by selecting an appropriate analytical method.

Figure 1 shows a multi-gas/GD-MS device which enables ionization using He plasma. By using He gas in place of Ar gas as the discharge gas, it was possible to solve problems such as composite molecular ions, which are called argide ions (MAr^+) and cause spectrum interference, and inadequate ionization efficiency for elements with high energy potentials (>12keV). As a result, as shown in **Fig. 2**, many elements showed lower relative sensitivity factor (RSF) values in comparison with Ar glow discharge, and ionization efficiency was improved. In particular, high sensitivity analysis of gas-forming elements such as C, N, O, and others has become possible.

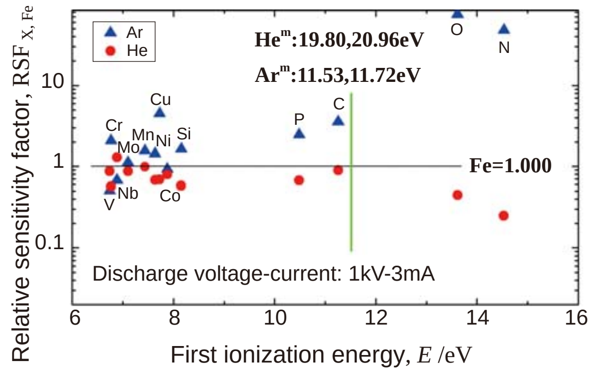
The Chemical Analysis Section is also studying application of the laser ablation (LA) method as a method of introducing specimens in the ICP. Because the sample undergoes ablation as a result of irradiation with a tightly focused laser, a specimen can be introduced in the form of a microparticle. As a result, it is expected to be possible to perform local analysis, chemical composition analysis and depth-direction analysis of microscopic regions, and obtain knowledge in connection with micro-segregation of analysis specimens.

Among external activities, the Chemical Analysis Section also participates in preparation and determination of the standard values of the Japanese Iron and Steel Certified Reference Materials (JSS) in the Standardization Center of the Japan Iron and Steel Federation. By performing quantitative analysis of standard substances by standard chemical analysis methods, the Section is working to pass on chemical analysis techniques. The Section is also promoting standardization of various analytical methods for silicon nitride and other substances in the Ceramic Society of Japan's Raw Materials Division, Analysis Committee. In the EU, the Waste Electronic and Electrical Equipment (WEEE) Directive in connection with recycling has come into effect, and the Directive on Restriction of Hazardous Substances (RoHS) regulates the use of designated hazardous substances (lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyl (PBB), and polybrominated diphenyl ether (PBDE)) in specified object products. The Chemical Analysis Section is also participating in joint experiments for the establishment of analytical methods and working to improve techniques in this connection.

Fig.1

Multi-gas/glow-discharge mass spectrometer

Fig.2



Relationship between first ionization potential (FIP) and relative sensitivity factor (RSF) for various elements

Cluster
Introduction of Interdisciplinary Clusters

Non-Destructive Evaluation Cluster

Improvement of safety and security is a universal goal of society. Nondestructive inspection and reliability evaluation techniques are key to securing the safety of structures and equipment, and also play an essential role in the formation of a sustainable, resource-saving society premised on long-term use of structures and other infrastructure. As one of our important missions, NIMS launched the “Non-Destructive Evaluation Cluster” in 2006, as an interdisciplinary unit whose activities extend beyond conventional research fields and organizational frameworks in order to promote and develop research on nondestructive reliability evaluation techniques. The aim of this Cluster is to develop and apply the techniques produced by our researchers, and thus contribute to society, with wide-ranging cooperation of universities and other research institutes.

(1) Development of research on materials reliability evaluation

The Non-Destructive Evaluation Cluster is engaged in basic research that goes a step beyond the conventional evaluation of defects by combining advanced nondestructive measurement techniques such as acoustic emissions (AE)*1 and laser ultrasonics*2 with research on material reliability, including metal fatigue, creep*3, and corrosion. This work, which is expected to be useful for evaluating the deterioration of material quality, includes elucidating the precursor phenomena that precede the actual occurrence of damage and the mechanisms responsible for damage. The Cluster is also promoting pioneering research themes by applying nondestructive measurement techniques to material processes such as plasma spray coating*4 and superplasticity*5, aiming at new developments in materials research. This research is expected to be useful for analyzing and improving process phenomena.

- Application of AE measurement to stress corrosion cracking (SCC)*6 testing
- Noncontact monitoring of ultrasonic fatigue tests by laser vibrometer
- Noncontact AE monitoring of process phenomena in plasma spray coating

The following themes are also under study:

- Remaining life evaluation of high-temperature materials by creep damage evaluation of high-Cr steels
- Monitoring of high-temperature deformation process for ceramics
- Nondestructive evaluation of damage, toughness (embrittlement), etc. of cryogenic materials
- Development of novel nondestructive sensors using quantumized devices, etc.

(2) Development and application of novel nondestructive techniques

As a social contribution, it is important to ensure that basic research on nondestructive reliability evaluation is linked to subsequent development and real-world projects. As part of this trend, in April 2008, a new research project on noncontact techniques for evaluating material quality was launched, based on past achievements in research on ultrasonic measurement, creep and other phenomena in high-temperature materials. In this project, the Cluster is focusing on evaluating coatings and nondestructive detection of changes in material quality in high-temperature structural materials by incorporating a new technique using terahertz*7 waves, in cooperation with materials and process researchers.

(3) Popularization and expansion of our techniques

To be useful for the safety and security of society, nondestructive techniques must be popularized and expanded. We believe that research links with external organizations and companies are an effective way of developing and popularizing our techniques in line with needs, in cooperation with research institutes and universities. As part of this effort, in April 2008, NIMS, AIST and JAXA concluded a trilateral research cooperation agreement, and started activities that extend beyond joint research and application of nondestructive techniques, to encompass educational activities such as holding international conferences (see next page).

“Interdisciplinary clusters” is a problem-solving type organization which enables flexible action to achieve various objectives, extending beyond organizational boundaries. As one of the Interdisciplinary clusters, the Non-Destructive Evaluation Cluster is a workshop type unit consisting of researchers who focus on developing and popularizing our techniques. Based on our mission of ensuring the safety of society, we hope that researchers from various fields will participate in our activities.

*1 Ultrasonic waves generated by microscopic deformations or cracks in materials.

*2 Noncontact inspection technique in which ultrasonic waves generated by local laser heating are detected with a laser interferometer.

*3 Phenomena in which materials under load in the elastic region undergo plastic deformation over time; creep is particularly remarkable at high temperatures.

*4 Method of producing a coating by blowing molten ceramic or metal particles carried by a high-temperature plasma gas onto materials.

*5 Phenomenon in which a material displays large plastic deformation up to fracture.

*6 Environmental cracking phenomenon caused by interaction of corrosion and stress.

*7 Waves of an intermediate wavelength between that of electromagnetic waves and light.

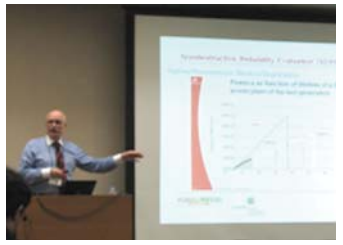
Topics

Research on Nondestructive Reliability Evaluation in Trilateral Cooperation by NIMS, AIST, and JAXA

At the signing ceremony for the trilateral collaboration agreement (April 18, 2008; at Tokyo Office of JAXA). From the left, Vice President Ono of AIST, President Kishi of NIMS, and President Tachikawa of JAXA.

In April 2008, National Institute for Materials Science (NIMS), National Institute of Advanced Industrial Science and Technology (AIST), and Japan Aerospace Exploration Agency (JAXA) agreed to wide-ranging research collaboration in connection with reliability evaluation technologies for materials and structures based on nondestructive evaluation techniques, with a scheduled duration of 2 years. The core of this effort is cooperation among the three organizations, and the overall objective of the project is to improve the safety and reliability of machinery and equipment, structures, and social infrastructure based on the high knowledge and technical development capabilities which the three organizations possess in the fields of materials and nondestructive measurement techniques.

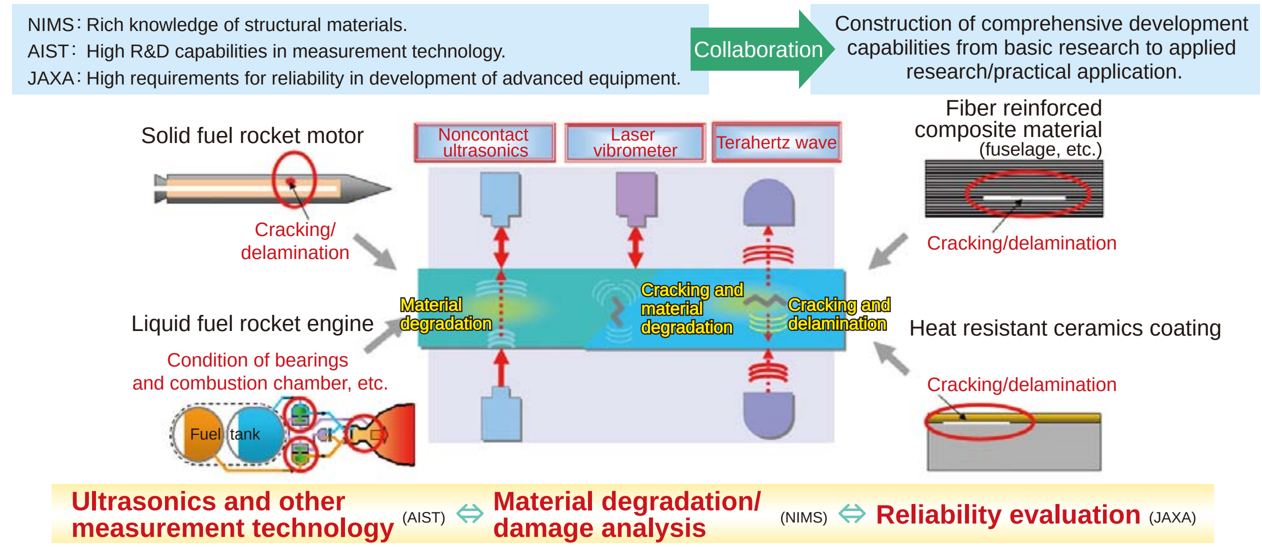
For nondestructive reliability evaluation, research and development will not be limited to detection of defects, but will also include techniques for detection and evaluation of the changes in material microstructure which precede the actual occurrence of defects. One aim is research and development and practical application of advanced technologies, including nondestructive measurement techniques which can be applied in extreme environments. In particular, through this collaborative project, the partners will grapple with issues by bringing together a wide range of capabilities in different fields, including materials reliability research and R&D on element technologies for measurement at each of the organizations, focusing on rockets and other space structures. Techniques for evaluating changes in material quality in extreme environments can also be expected to contribute to the development of materials, as illustrated in the following **figure.**



Invited lectures by international researchers at the 1st International Symposium for NDRE. (left: Prof. Chimenti, right: Dr. Dobmann).

As a first step in these activities, The 1st International Symposium for Nondestructive Reliability Evaluation (NDRE) was held jointly by NIMS, AIST, and JAXA as a satellite symposium during NIMS Week in July of this year. For the future, lectures by leading researchers in this field at Japanese and international universities and research institutes are planned. Activities envisioning strengthening of international collaboration, including private companies, are also in progress.

Fig. Content of research and technologies to be developed in NIMS-AIST-JAXA collaboration in nondestructive reliability evaluation



Object parts and nondestructive evaluation techniques in trilateral collaboration

Ultra-High Strength Steel with Excellent Low Temperature Toughness

Physical Metallurgy Group, Structural Metals Center
Intense Research Group†
Progressive Materials Research Group††
Innovative Materials Engineering Laboratory

Managing Director
Yuuji Kimura, Kaneaki Tsuzaki, Tadanobu Inoue†, Fuxing Yin††

Although metals are ductile and tough at high temperature, they display a ductile-brittle transition, meaning they become brittle and fracture below a certain temperature. The property of being tough is called "toughness". Toughness can be evaluated in a simple method by applying impact to a notched test piece and measuring the energy necessary to cause fracture. This is termed "impact energy (vE)".

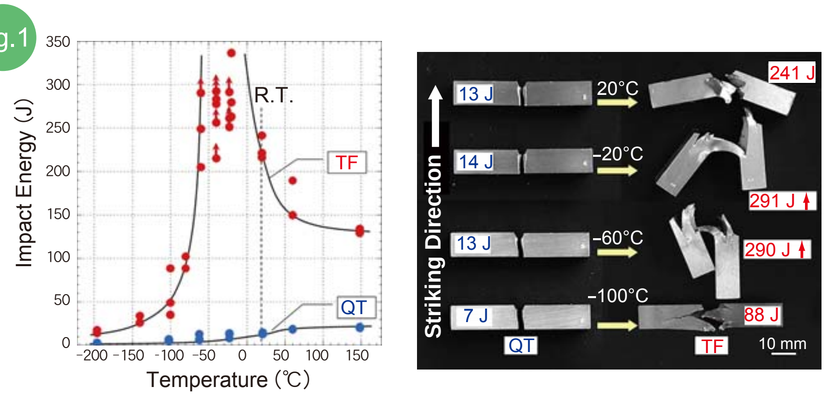
The basic function of structural materials is to support large loads (strength). In the design of structures, yield strength is important as an index of resistance to plastic deformation. Because steel can be manufactured at a relative low cost and provides a combination of high strength and excellent toughness, it is widely used in everyday products and structures. If the yield strength of steel is increased to more than 1800MPa (MPa: megapascal), its specific strength (strength/density) is greater than that of the high strength aluminum alloys used in aircraft, and a large weight reduction can be expected in transportation equipment. However, a trade-off relationship exists between strength and toughness. Conventionally, the toughness of ultra-high strength steels with yield strengths of 1500MPa and higher had been improved by the addition of expensive scarce elements such as Ni and Co in a total amount of 10-30wt% (high alloy steels). However, even in the highest grade of high alloy steels, toughness was low, showing a vE of 40J or less in materials with yield strengths of 1800MPa and higher. This limited the range of applications.

We succeeded in developing a steel which shows a vE approximately 6 times higher than that of high alloy steel at a room temperature yield strength of 1840MPa (**Fig. 1**) by controlling the metallic microstructure of a low alloy steel containing only small amounts of alloying elements (0.4%C-2%Si-1%Cr-1%Mo steel). Furthermore, we also discovered that this material displays an inverse temperature dependence of toughness, in that vE increases in the temperature region from 60°C to -60°C, where the conventional ultra-high strength steels show a ductile-brittle transition. This improvement in toughness is due to delamination, in which cracks branch off at basically right angles to the direction of impact. Several examples of inverse temperature dependence of toughness due to delamination have been confirmed to date. However, the discovery of this property in the low temperature region of an ultra-high strength, low alloy steel is epoch-making.

Delamination originates in a dense, fibrous crystal grain structure with an average short axis diameter of 0.26μm (**Fig. 2**). Focusing on the fact that the microstructure of quenched and tempered (QT) steels is fine, we obtained this microstructure through a simple thermomechanical treatment, in which QT material was deformed into a bar shape at 500°C. This technique is expected to contribute to realizing practical ultra-high strength steels.

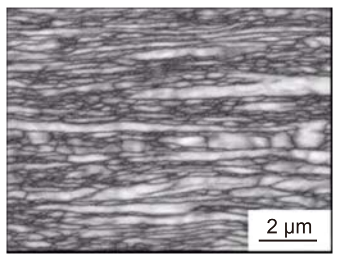
Y. Kimura, T. Inoue, F. Yin and K. Tsuzaki, Science, 320, 1057-1060 (2008).

Fig.1



Left: Relationship between the impact energy (vE) and testing temperature of normally quenched and tempered (QT) material and developed material (TF). Right: Appearance of V-notch test pieces after the impact test. The red arrows in the figure show test pieces which did not fracture completely, but rather split in a manner like bamboo. The room temperature yield strength of the QT and TF materials is 1470MPa and 1840MPa, respectively.

Fig.2



Crystal grain structure of the developed material.

Ultrafast optical nanoswitch

Inorganic "nanopeapods": gold nanoparticles periodically embedded in twinned galium oxide nanowires

National Tsing Hua University, Taiwan†
International Center for Materials Nanoarchitectonics (MANA)

Prof. Li-Jen Chou†
Principal Investigator
Dmitri Golberg

Over the years, the large surface-to-volume ratio and low-structural dimensions of inorganic oxide nanowires have attracted the attention of researchers working in the field of nanoscale photonic devices. Through the strengthening of the International Cooperation between ICYS-MANA and the team of Prof. Li-Jen Chou of Tsing Hua University the significant breakthrough was accomplished - a design of a novel optical nanoswitch.

The device is a metal-insulator heterostructure made of twinned Ga_2O_3 nanowires and discrete gold nanoparticles that are periodically embedded along the twin boundaries. The novel nanostructures are referred as "peas in a pod" or "peapod" inorganic nanomaterials, because of their resemblance of a common plant eaten as a vegetable. They were formed through a reaction between gallium and silica with gold as a catalyst during simple thermal annealing at 800ºC under a process known as vapor-liquid-solid (VLS) growth.

The microscopic views of a novel nanoachitecture at low- and high-magnifications are illustrated in **Figures 1a and 1b**. Discrete gold nanoparticles of 10-20 nm in dimensions are clearly visible along the twinned boundary of a gallium oxide nanowire. In order to perform dedicated opto-electrical measurements a multi-probe electrical circuit consisting of multiple microfabricated gold electrodes embracing an individual nanostructure was designed, as shown in the inset to **Fig. 1a**, and its performance under various combinations of separately biased gold electrodes was exploited.

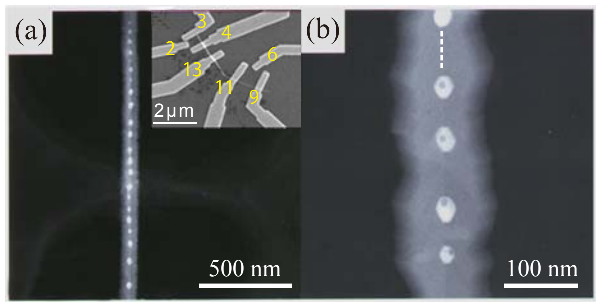
When excited by light from a Nd:YAG laser with a wavelength of 532 nm, strong photoabsorption by the device was observed with an extremely quick photoresponse. A maximum photocurrent of over 100 pA and an on/off photocurrent ratio as high as 500 were recorded, as shown in **Figure 2**. We attribute the regarded photoresponse to the pronounced surface-plasmon resonance effects which are described as follows.

Under laser illumination the surface plasmon polaritons (SPP), resulting from coupling of surface plasmons with light, are generated at the interface of the gold and gallium oxide, consequently, the electromagnetic field of SPP decays exponentially into the interior of Au-Ga_2O_3-Au junctions. The electrons generated by the surface plasmon resonance (SPR) effect drift to the Ga_2O_3 barrier and tunnel to the counter electrodes. The overall device photoresponse is determined by the generation rate of the electrons which are not in thermal equilibrium with the Au nanoparticle lattice under high electric fields and their tunneling rate through the gallium oxide nanowire barrier. Thus, the photocurrent response of the device is proportional to the pumping laser power. Because the frequency of switching is controlled by the pumping light source, a novel ultrafast optical system through the integration of the nanoarchitecture into the active light source, such as laser transistor can now be constructed.

We are also confident that the proposed relatively simple synthetic approach can also be used to create optoelectronic devices with numerous and diverse functions, particularly for nanoscale optoelectronics.

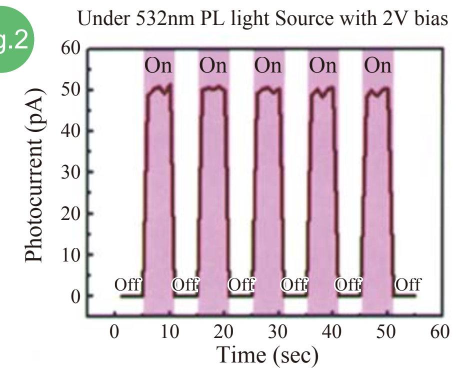
This accomplishment was published in Oct. 2008 issue of *Nano Letters*, Vol. 8, p. 3081, as a **Cover Image Paper**, and was highlighted by *Nature Photonics*, Vol. 2, June 8, 2008, page 330.

Fig.1



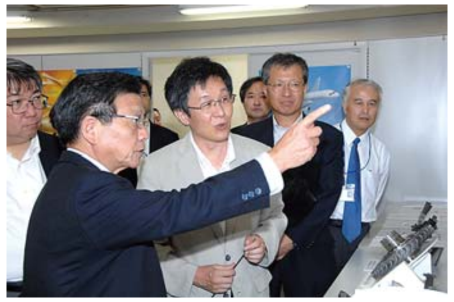
High-angular dark-field TEM images at low- (a) and high- (b) magnifications of an individual nanoarchitecture comprising of periodic and discrete Au nanoparticles embedded along the twin boundaries of a Ga_2O_3 nanowire. The location of the regarded twin boundary within a gallium oxide nanowire is marked with a dashed line in (b). The inset in (a) displays an electrical circuit with numerous Au electrodes embracing an individual wire.

Fig.2



Photoresponse behaviour of a device made of an individual nanoarchitecture during illumination-on and off cycles using a 532 nm laser line.

Minister and Vice Minister of MEXT Visit NIMS


Mr. Suzuki at High Temperature Materials Center


Mr. Yamauchi at Structural Metals Center

(Sep. 4-5, 2008) Minister Tsuneo Suzuki of Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT) visited the NIMS Sengen Site on September 4, 2008, and Vice Minister Toshio Yamauchi also visited on the following day.

The President of NIMS, Prof. Teruo Kishi, gave an overview of NIMS, including recent research outcomes and the International Center for Materials Nanoarchitectonics (MANA), which was established about a year ago under the World Premier International Research Center (WPI) Initiative sponsored by MEXT.

Both Mr. Suzuki and Mr. Yamauchi toured the High Temperature Materials Center, which is engaged in collaborative research with Rolls-Royce, the Structural Metals Center, which is developing high performance structural materials, and the Nanotechnology Innovation Center, which opened last April.

(* The Cabinet title in this article is from the time of visit.)

NIMS Advisory Board


Advisory Board meeting

(Aug. 6-7, 2008) The NIMS Advisory Board meeting was held on August 6-7 at the Okura Frontier Hotel Tsukuba with attendance of eminent international experts in the field of materials science. After reviewing the current conditions, five Advisors, the Chairperson, Prof. Humphreys of the University of Cambridge, Prof. Suresh of MIT, Prof. Schlapbach of the EMPA, Prof. Van de Voorde of Delft University of Technology, and Prof. Dauskardt of Stanford University gave frank advice to NIMS on new fields in which it should become involved (polymers, materials related to nuclear power, materials related to the environment and energy, simulation techniques, etc.), strengthening of cooperation between groups, the necessity of benchmarks in each field, and other matters. The results of the meeting are expected to be compiled, including issues pointed out by Prof. Ruhle of the Max-Planck Institute for Metals Research and Prof. Wang of the Institute of Physics, Chinese Academy of Sciences, who gave advice separately due to various circumstances.

NIMS expands research cooperation with Korean Institutes

Nano Korea 2008 opening ceremony

(Aug. 27-29, 2008) Prof. Teruo Kishi, President of NIMS, gave the Keynote Address on the topic of "Japan's R&D Strategy for Nanotechnology, Materials and NIMS Activity" at Nano Korea 2008 on August 27, which was held near Seoul, Korea.

On the following day, Prof. Kishi visited the Korea Institute of Science and Technology (KIST) and the Korea Institute of Materials Science (KIMS) and signed on comprehensive research cooperation agreements with both institutes with the aim of further expanding international cooperation with research institutes in Korea. Prof. Kishi also gave talks and exchanged views on research activities with his Korean counterparts, and toured the facilities at the two institutes. On August 29, he visited the Korea Advanced Institute of Science and Technology (KAIST) for an exchange of views on cooperation as sister institutes and toured the facilities of the National Nanofab Center in KAIST. He also visited the Korea Research Institute of Standards and Science (KRISS), where he discussed future cooperation. Thus, during this visit, Prof. Kishi further deepened future cooperation by exchanges with several key institutes in Korea.

NIMS Signs an MOU with Chalk River Laboratories


Dr. W. Kupferschmidt, Vice President & General Manager of AECL (second from the right) is shaking hands with Dr. K. Sakurai, Group Leader of the Quantum Beam Center, NIMS.

(Aug. 13, 2008) The NIMS Quantum Beam Center signed an Memorandum of Understanding for research collaboration on X-Ray physics and industrial radiography with Chalk River Laboratories, Atomic Energy of Canada Limited (AECL), Ontario, Canada.

The two institutions agreed to promote exchanges of researchers, information, publication of results of the research, and implementation of cooperative research. AECL is responsible for research and development of Canada deuterium uranium (CANDU) nuclear reactors. Both sides understand the significance of novel advanced X-ray technologies for nondestructive examination.

NIMS Concludes an International Joint Graduate School Agreement with Stony Brook University


From left: Prof. L. Martin, Dean of the Graduate School, Dr. H. Murakami, NIMS Chief Researcher, Prof. S. Sampath, Director of the Center for Thermal Spray Research

(Sep. 12, 2008) NIMS concluded an international joint graduate school agreement with Stony Brook University (one branch of the State University of New York). Stony Brook University is among the most prestigious state universities in the United States, and is famous for the development of MRI, which led to the award of the Nobel Prize to Prof. Lauterbur.

Prof. Sanjay Sampath has been an important bridge between the University and NIMS, and has had close research exchanges with the NIMS Composites and Coatings Center in the past. In 2006, MOUs were also concluded with the Sensor Material Center and the Optronic Materials Center. Based on this cooperation agreement, Stony Brook graduate students are expected to do research work at NIMS.

2008 Industry-University-IAI Technology Exchange Fair "Matching Seeds and Needs"


Poster Exhibition of Nanotechnology Innovation Center

(Oct. 1-3, 2008) The 2008 Industry-University-IAI Fair was held recently at the Tokyo Big Sight International Exhibition Center, sponsored by the Nippon Kogyo Shimbun, Ltd. and cosponsored by a group of five Independent Administrative Institutions (IAI) led by NIMS. The aim of the event was to match "seeds" with the potential for development to practical "needs" by transferring research results and technologies to industry, finding partners for joint research, and other cooperative activities. This year's fair was the 5th in a series, and attracted a large number of participants including governmental research organizations, organizations involved in science and technology, universities, and R&D venture businesses, in fields such as nanotechnology, information technology, energy and the environment, biotechnology, and others. Representing NIMS in the seminar session on "Meeting the Challenge of a Low Carbon Society" held by the cosponsors, lectures were given by the High Temperature Materials Center on "Realizing the World's Highest Power Generating Efficiency" and the Materials Research for the Environment and Energy unit on "Development of Materials for the Environment and Energy at NIMS." The NIMS booth also presented recent research achievements by the Materials Manufacturing and Engineering Station, Nanotechnology Innovation Center (NIMS Center for Nanotechnology Network), Innovative Materials Engineering Laboratory, Materials Reliability Center, and Optronic Materials Center. In the future, these types of cooperation are expected to contribute to numerous technical innovations and the creation of new industries.

(Cover photo: NIMS Booth at the Fair)

Introduction of New Vice President

Comments on Appointment

I was appointed Vice President of NIMS on August 1. I have been focusing my work on science and technology administration as a member of the government's Science and Technology Agency, then the Ministry of Education, Culture, Sports, Science and Technology (MEXT) for many years. When I was Director of the Planning Division of the National Research Institute for Metals (one of the predecessors of NIMS) about 20 years ago, I was involved in the discovery of new superconducting materials, promotion of the Multi-Core Project, and the facility relocation from Tokyo to Tsukuba. Recalling those days, I have a real feeling that NIMS has been transformed into a completely different research institute as an Independent Administrative Institution (IAI). I am familiar with Tsukuba Science City through various experiences in the past, including the Tsukuba Center for Institutes (MEXT), Ninomiya House (International Residence for Researchers), and the Tsukuba Space Center (JAXA). However, this will be the first time that I've actually lived in Tsukuba City, so I'm really looking forward to it.

I want to become familiar with this new organization as quickly as possible and devote my efforts to the further development of NIMS.

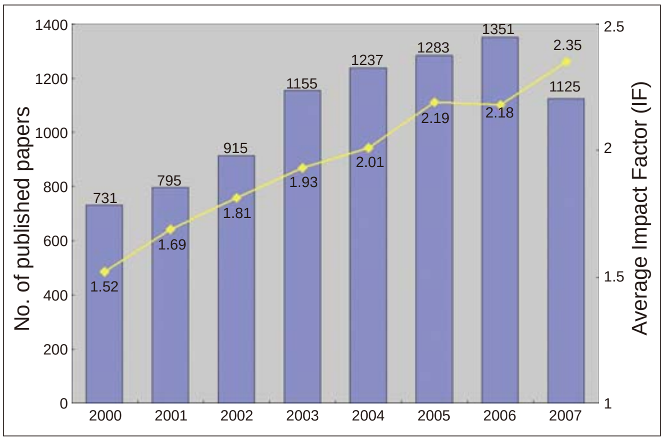
Ryo Kimura

Mr. Kimura graduated from the Department of Electronic Engineering, Tohoku University in 1973 and joined the Science and Technology Agency in 1974. During his career, he has served as Director of the Power Reactor Development Division, Director of the Department of International Affairs of the Japan Science and Technology Agency (JST), Director of the General Affairs Department of the National Space Development Agency of Japan (NASDA), Director of the Administration Division of the Cabinet Satellite Intelligence Center (CSICE), Executive Director of the Japan Atomic Energy Research Institute (JAERI), and Director General of the National Institute of Science and Technology Policy (NISTEP). He was appointed Vice President of NIMS on August 1, 2008.

Citation Index Ranking Climbs to 4th

NIMS's Citation Index (CI) for papers in the field of Materials Science in Thompson Scientific's Essential Scientific Indicators (ESI) for September 2008 has increased by 5.4 times since 2000, before NIMS became an Independent Administrative Institution (IAI). Over this period, NIMS's world ranking has risen dramatically, from 31st to 4th.

In 2007, the number of papers (SCI papers) published in scientific journals by NIMS researchers listed in ESI was 1125, and the average Impact Factor (IF) of the journals which carried these papers was 2.35, for an increase of 0.83 in the past 7 years. These results show that NIMS researchers are steadily producing research results, and at the same time, these achievements are being published in journals with higher impact.



Analysis based on Web of Science database provided by Thompson Scientific.

Mr. Yamkate of DSS visits NIMS

(Sep. 12, 2008) Mr. Pathom Yamkate, the Director-General of the Department of Science Service (DSS), Ministry of Science and Technology, Thailand and six other members visited NIMS, and met with Dr. Tetsuji Noda, the Vice President of NIMS. The DSS is a Thai government agency which provides various services such as laboratory assessments and accreditations, testing and analysis of raw materials, human resource development programs, technical transfer, and support to private companies. During the meeting, the DDS members showed keen interest in nanomaterials characterization and measurement. After an introduction of both organizations, they toured the laboratories of the Nanoceramics Center, Bio-Organic Facility, and Sensor Materials Center.

Mr. Pathom Yamkate (Left) and Dr. Tetsuji Noda shaking hands after the meeting.

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