from Tsukuba, Japan to the world
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Special Features

Nanotechnology/Materials Research Supporting the Creation of a Sustainable Society

Development of Powerful, Large Displacement Actuator for MEMS using Shape Memory Alloy

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In recent years, many fields of technology have been characterized by progressively more advanced functions and greater convenience, which have been achieved by miniaturization and portability of devices. Consequently, the development of actuators capable of operating tiny parts has become increasingly important as a key technology for creating new products. In particular, in leading-edge micro-machines, adoption of MEMS (Micro Electro Mechanical Systems) has begun. Because MEMS are assembled while fabricating parts using the same methods as with integrated circuits for computers, new types of actuators which can be fabricated by the semiconductor manufacturing process are required.

A shape memory alloy thin film actuator which is developed by NIMS displays performance including a generated force more than 15 times greater and displacement more than 50 times greater than those of conventional piezoelectric elements, and can also generate greater force than any micro-actuator proposed to date. Because this shape memory alloy thin film is produced by a film production technique used with semiconductors, it has a different composition and structure from the shape memory alloys produced by casting which are already in practical use. < Continued on p.3

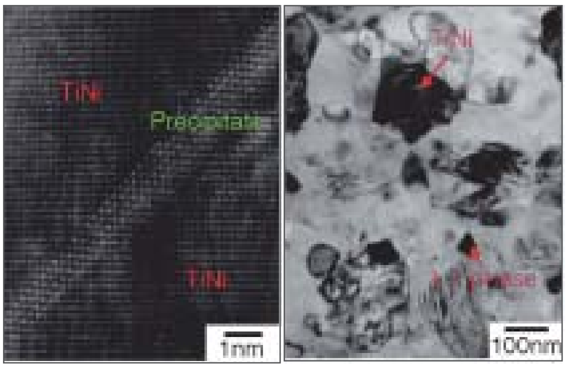

Fig. 1 (left) Precipitates in Ti-excess Ti-Ni alloy thin film (atomic image), and (right) structure of Ti-Ni-Zr alloy thin film.

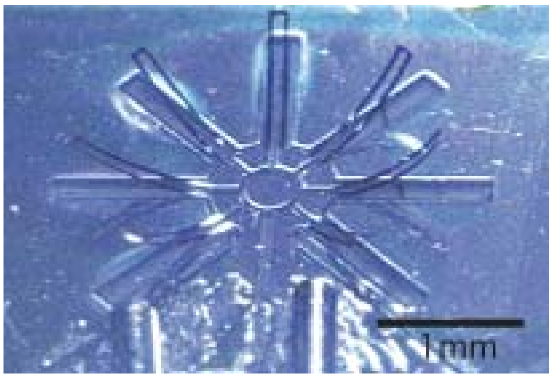

Fig. 2 Microgripper grasping microscopic object.

in this issue

NIMS News

NIMS Sponsors World Materials Research Institute Forum

Front row: speakers; back: NIMS representatives.

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A Practical Application of Carbon Nanotube Probe in Analytical Equipment

Jie Tang
Materials Physics Group
Materials Engineering Laboratory (MEL)

Carbon nanotubes (CNTs) are extremely small cylindrical tube-shaped carbon molecules with diameter of approximately 1 nm and length of about 1-10 µm. Potential applications of CNTs as an electron source in high-resolution analytical equipment and as high-resolution, long-life scanning probes have been expected, taking advantage of their excellent mechanical and electrical properties. For these purposes, a practically simple manufacturing process with good reproducibility combined with morphological controls is necessary.

In collaboration with the University of North Carolina at Chapel Hill (USA), we have succeeded in producing CNT probes with high reproducibility using an electrophoretic process (**Fig. 1**), opening the way to applications of CNTs in high-precision metrological equipment such as scanning probe microscopies (SPM). In the present research, CNT probes have been produced as tips of high-resolution atomic force microscopes (AFM) and as electron point sources (electron emitters).

The electrophoretic fabrication process has two key features in comparison with the conventional methods. Firstly, it is possible to produce CNT probes at low cost because no sophisticated setting is required (water is used as the solvent and fabrication is performed at room temperature in air). This process can also be scaled up and be automated. Secondly, the produced CNT probes are of high purity and are well aligned. It is also possible to control the probe length as desired.

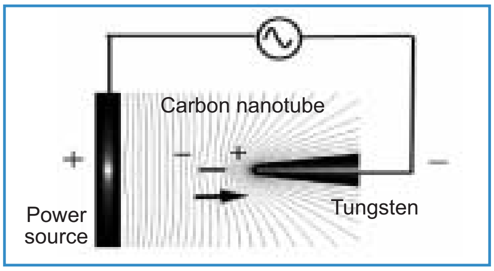

Fig. 1 Fabrication process of nanotube probes by electrophoresis.

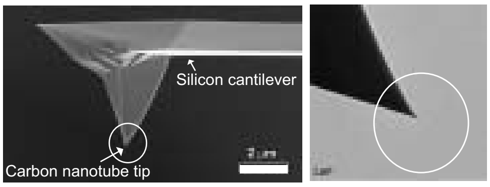

Fig. 2 CNT fabricated on a general-purpose AFM tip.

The CNT-AMF probes (**Fig. 2**) that are produced in this work offers high resolution in comparison with the general-purpose AFM probes. The new probes also have high durability and thus can have longer service life.

The CNT probes produced by electrophoresis are also suitable for use as electric field-induced point electron emitters (**Fig. 3**) with high emission current density and excellent stability. These CNT tips can be operated in relatively low vacuum in comparison with contemporary field-induced electron emitters.

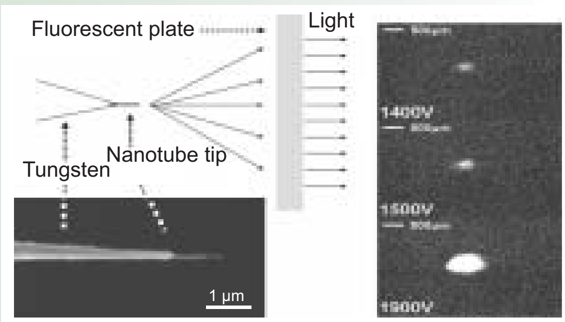

Fig. 3 Experimental setup with nanotube electron emitter and electron emission image.

The electrophoretic fabrication process developed in this research can be utilized to produce a variety of nanodevices and the technology can be applied for mass production when needed. Initiative efforts to commercialize the process are underway.

The ultimate purpose of the present research and development project is to establish controllable methods of producing new nanostructured probes for analytical nano-device applications. We are also exploring the possibilities to extend the applications into the field of biomedicine.

For more details: http://www.nims.go.jp/kisobussei/index_e.html

MOU with Germany's Max Planck Institute for Chemical Physics of Solids

Front row (from left): Prof. Dr. Grin, Managing Director of MPI-CPfS, and President Kishi of NIMS; Back: Dr. Schwarz of MPI-CPfS, and Dr. Mori and Dr. Nishimura of NIMS.

(April 11, Dresden) -- The NIMS' Advanced Materials Laboratory (AML) and Max Planck Institute for Chemical Physics of Solids (MPI-CPfS) concluded a memorandum of understanding (MOU) for joint research on the development of novel functions in network materials. MPI-CPfS has achieved the some of the world's most impressive results in research on the chemistry and physical properties of covalent-bonded network materials and intermetallic compounds, while AML has succeeded in diverse discovery/synthesis of new network materials and intermetallics different from MPI-CPfS, and is also engaged in research on their physical properties. Considering the high potential of both institutes, fruitful research through joint studies which take advantage of the mutual strengths of the two institutes is expected in the future.

For more details: http://www.nims.go.jp/amlaml/english/

Evaluation of Properties of Silicon Single Crystal Nanowire for Application to Microdevices

Hiroshi Suzuki, Hiroshi Araki, Masahiro Tosa
Micro-Nano Component Materials Group
Materials Engineering Laboratory (MEL)

An extremely wide range of applications is conceivable for silicon (Si) nanowires, including not only nanosize semiconductors, but also components for medical use and submicron-size nano-machines, such as coils, nano-tweezers, nano-arms, nano-shafts, and nano-motor parts. If the size of these wires exceeds 50 nm in diameter and several millimeters in length, their manipulation becomes possible by incorporating a manipulation device in a general scanning electron microscope (SEM) or optical microscope, and the assembly process is simple. At present, with research and development on nanowires in countries around the world oriented toward micro-semiconductors, development of applications for a cm class long nanowire developed by the Materials Engineering Laboratory is considered an urgent task in worldwide competition in advanced technical development. We are therefore attempting to clarify the thermal, electronic, and mechanical properties of this long Si nanowire and control its composition, and are engaged in applied research on micro- and nano-machine systems.

Two types of Si nanowires can be fabricated. One grows to a length of several mm or longer. Manipulation of this nanowire is easy, making it suitable for measuring thermal and electrical properties in one piece units. The second Si nanowire can be fabricated at low temperatures of about 300 ℃ or less. Therefore, application aimed at reducing damage to the substrate and application to various LSI substrates is expected.

A jig device is being produced for measurement of the material properties of nanowires fabricated as the first step toward application to micro-devices. The **figure** shows a photograph of a nanowire (diameter: 100 nm) which was set on the surface of a micro-measurement jig device created by micro-processing using an LSI lithography process. This measurement device is capable of evaluating the thermal conductivity of a single nanowire. A micro-material tester is also being constructed, making it possible to measure the material strength properties of nanowires using a micro-manipulation prober with a strain gauge for micro-stress measurements mounted on its tip.

If this type of system for accurately evaluating material physical properties in one nanowire unit can be established, expansion of a wide range of applications to micro-devices can be expected.

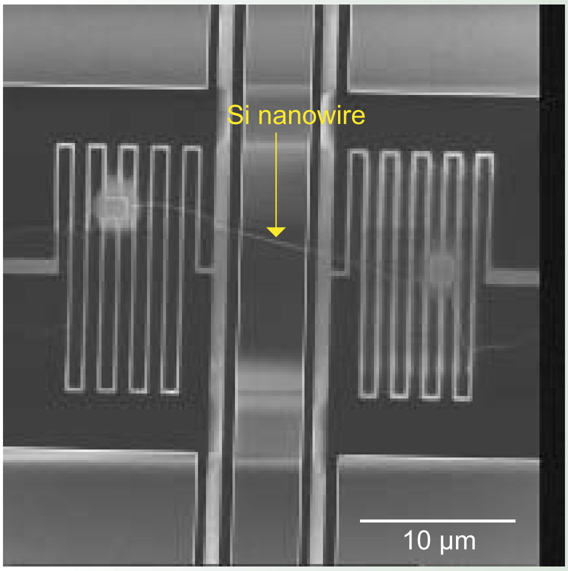

Fig. Micro-jig-device for measurement of thermal conductivity, with a Si nanowire mounted.

For more details: http://www.nims.go.jp/nanofab/

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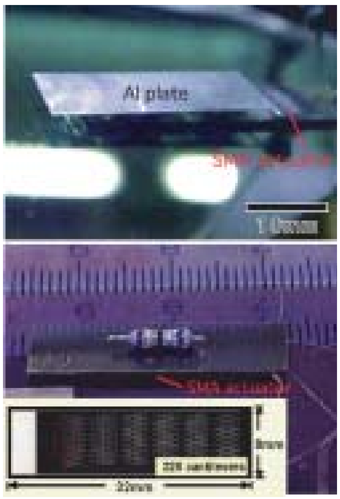
Development of Powerful, Large Displacement Actuator for MEMS using Shape Memory Alloy



Micro-conveyor transporting aluminum plate.

Legged robot carrying resistance. The lower figure shows the mask pattern. (The robot walks like centipede using 220 legs made from SMA thin film.)

Fig. 3 Example of micro-device using shape memory alloy (SMA) thin film (result of joint research with Tabata Laboratory, Kyoto University).

Figure 1 (left) shows the microstructure of a Ti-excess Ti-Ni shape memory alloy thin film. It was found that fine precipitates with a thickness of 1 nm form in the thin film material. These do not form in cast materials in TiNi alloys which are responsible for the shape memory effect. **Fig. 1** (right) is an example of a Ti-Ni-Zr alloy. In the cast material, the grain size is as large as 50 µm, and the material is brittle, making it unsuitable for practical use. However, in the thin film, the grain size has been reduced to approximately 200 nm. Control of this nanometer order microstructure made it possible to realize high mechanical properties and a shape memory effect not obtainable in cast materials. The **Fig. 2** and **Fig. 3** show a micro-machine which was fabricated on an Si substrate using the shape memory alloy thin film developed at NIMS. The legs of the legged robot confront the problem of easy breakage because devices of this type had been fabricated from Si until now. No breakage occurred in the legged robot shown here because the shape memory alloy thin film with excellent mechanical properties was used in the legs. (With this alloy, breakage does not occur even under deformation exceeding 50 %.) We are now engaged in research and development aiming at practical application of shape memory alloy thin film actuators in cooperation with universities and industry.

For more details: http://www.nims.go.jp/Smart/eng/index_e.html

Creation of Quasicrystal-Reinforced Magnesium Alloy

—New High Strength Mg Alloy—

Alok Singh
Light Materials Group
Materials Engineering Laboratory (MEL)

An-Pang Tsai
Institute of Multidisciplinary Research for Advanced Materials
Tohoku University

One effective response to environmental problems is reduction of auto body weight with the aim of improving fuel efficiency and reducing exhaust gas emissions. The development of lightweight, high strength materials is indispensable for this. However, we are now reaching the limits of existing materials and methods. The authors are therefore conducting a research to create a new type of material which possesses a combination of light weight and high strength by a simple method based on the new concept of quasicrystal dispersion, thus responding to environmental needs by dramatically improving material performance.

In research on quasicrystals, we showed that a quasicrystalline phase and an Mg phase coexist in Zn-Mg-Y alloys and were able to obtain a structure in which quasicrystals were dispersed in the Mg matrix using a conventional casting method. Because quasicrystals have a comparatively high melting point and do not display periodicity, they have the distinctive feature of being hard and brittle in comparison with ordinary compounds. However, we believed that it should be possible to produce a quasicrystal-reinforced Mg alloy with high heat resistance by skillfully controlling the microstructure.

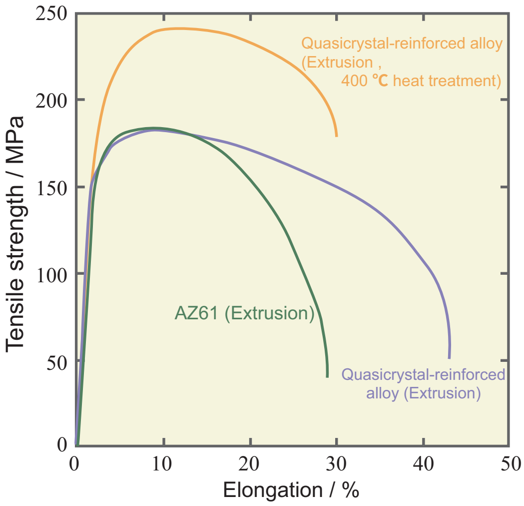


Fig. 1 Curves of tensile test at 200 ℃ on quasicrystal-reinforced Mg alloy ($Mg_{93}Zn_6Y_1$) and AZ61 produced by extrusion.

Figure 1 shows the results of a tensile test of a $Mg_{93}Zn_6Y_1$ alloy at 200 ℃ after extrusion at 250 ℃. (Extrusion is a process in which a material is introduced into a container and then forced out through an opening by applying strong pressure; it is used in manufacturing bars, pipes, shapes, wire, tubes, and other products with specified shapes.) For comparison, the **figure** also shows the results with a commercially-available extrusion material, AZ61 (industrial Mg alloy with a composition including 6 wt.% Al and 1 wt.% Zn; commonly called AZ61). Both specimens fractured after a constant elongation following the maximum tensile strength. The as-extruded quasicrystal-reinforced alloy showed a maximum tensile strength similar to that of AZ61, but from **Fig. 1**, it can be understood that the reduction in tensile strength following this maximum was smaller, indicating resistance to softening. The quasicrystal-reinforced alloy also displayed higher tensile strength when subjected to heat treatment at 400 ℃. A transmission electron microscope (TEM) image of this specimen after the high temperature tensile test is shown in **Fig. 2**. A condition in which numerous fine quasicrystals, which appear black, are dispersed in the matrix Mg grains can be observed. The quasicrystal grain indicated by the arrow exists on the boundary between two Mg grains with different orientations and has stopped the growth of the Mg grains by a pinning effect. In general, the strength of crystal grains decreases as grain size increases. Because the phenomenon of softening at elevated temperatures has its origin in the growth of Mg grains, it is considered that quasicrystals prevent this high temperature softening phenomenon by impeding grain growth. Furthermore, it is thought that the above-mentioned 400 ℃ heat treatment also caused an improvement in the high temperature strength of the new alloy by stabilizing the quasicrystals in grain boundaries. In the first stage, dispersion strengthening by quasicrystals was confirmed. We are now also producing high strength quasicrystal-reinforced Mg alloys using only casting, without employing secondary processing such as extrusion.

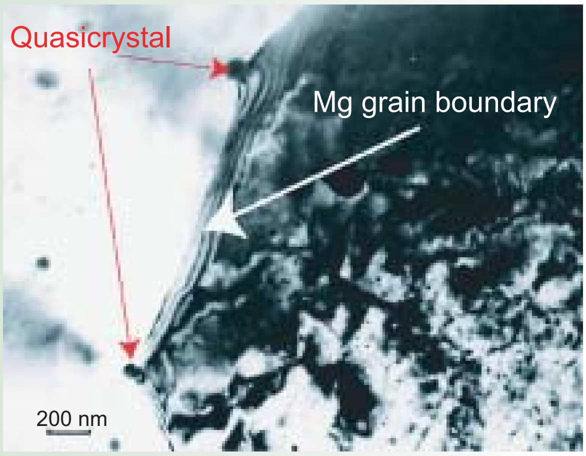


Fig. 2 TEM image of extruded quasicrystal-reinforced Mg alloy after tensile test at 200 ℃ following heat treatment at 400 ℃.

This research was carried out as a joint research project with Messrs. Akira Katoh and Makoto Watanabe of Toyota Motor Corporation.

For more details: http://www.nims.go.jp/kohikyodo/index-e.html

NIMS News

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NIMS Sponsors World Materials Research Institute Forum

(June 6-7, Tsukuba) -- NIMS recently sponsored the World Materials Research Institute Forum (Session I), which was attended by representatives from 11 of the world's leading materials research institutes of 9 countries. Each of the institutes gave presentations, which covered a wide range of topics, including governmental policies for materials research in each country, the missions and distinctive features of operation of each institute, procurement of research funding and policies on fund allocation, cooperation with industry and universities, differences between the institutes and universities, policies for training young scientists, international standardization relating to materials, future directions in materials research, and the ideal form of international cooperation. After active debate, the conference concluded with the passage of various resolutions. A different group of research institutes have been invited to Session II, which is scheduled for July 27.

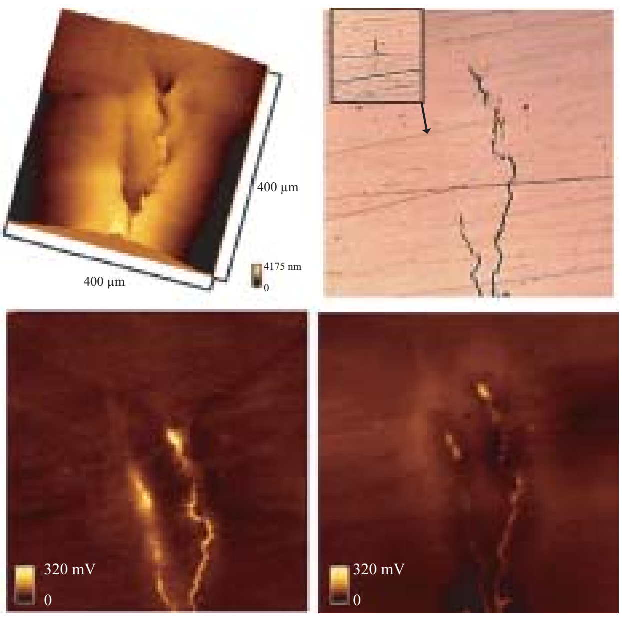
In-Situ Observation of Hydrogen Distribution in Vicinity of Cracks

—Aiming at Fundamental Elucidation of the Cause of SCC Accidents—

Hiroyuki Masuda, Hideki Katayama
Corrosion Analysis Group
Materials Engineering Laboratory (MEL)

We believe it is a well-known fact that stress corrosion cracking (SCC) of stainless steels has become a problem in nuclear power plants and other industrial facilities. Although much research has been done on this phenomenon, the mechanism of cracking is still unknown. Various explanations have been advanced, including theories involving anodic dissolution and hydrogen embrittlement, but the actual mechanism has remained unclear because the dissolution process and distribution of hydrogen could not be observed in-situ.

The target in the present work was SCC caused by sea salt particles. SCC caused by sea salt is a problem in atomic power plants and chemical plants because these facilities are frequently sited near the coastline. When pitting at room temperature was observed using test pieces in which cracks had been induced by the conventional U-bend method, we discovered an unbelievable phenomenon in which corrosion occurring only at the crack tip, and as if the crack grew under completely room temperature conditions. The occurrence of corrosion limited to the crack tip indicates that some electrochemically base substance exists in this area. We therefore developed a new test method (which is the subject of 2 patent applications) in which small droplets of a liquid are deposited on the sheet to enable continuous observation of crack growth and the potential distribution at the nano-scale.



(a) Immediately after test (b) After 16 days

Fig. Optical micrograph (upper right) of surface crack and SKFM image. The upper left shows the profile image. In the potential distribution image (bottom), the bright parts show base potential. The upper center shows an enlarged view of the crack.

The **figure** shows an optical microscope image of the vicinity of the crack tip produced by the new test method and a super Kelvin force microscope (SKFM) image in which it was possible to obtain simultaneously a profile image and surface potential distribution image over a wide area. This type of SKFM image was obtained by the method which was developed by the authors and is the only one of its kind in the world. In the optical micrograph, the area indicated by the arrow shows a location where an extremely small discontinuous crack has occurred. As can be understood from the profile image on the left, this corresponds precisely to the tip of a slip deformation area. The surface potential distribution shows that an area of low potential in comparison with the surrounding level of approximately 300 mV existed around the crack tip immediately after completion of the test. This decrease in potential was judged to be the cause of the corrosion at the crack tip at room temperature. When the specimens were allowed to stand in air, the potential distribution changed with time, eventually becoming uniform, as can be understood by comparing **Fig. (a)** and **(b)**. It can be thought that the potential was reduced by the formation of a new plane due to slip deformation. However, the decrease in potential in this manner was no more than 100 mV in the experiment, and the magnitude of the potential drop at the crack tip far exceeds this value. As the cause of this potential drop at the crack tip, it is thought that hydrogen generated by the cathodic reaction migrated together with the slip deformation, and as a result, hydrogen compounds formed at the tip of the slip deformation.

We are continuing to elucidate the mechanism of SCC by an unprecedented attempt to trace the changes over time in the corrosion rate, slip displacement, and the potential distribution.

For more details: http://www.nims.go.jp/fusyoku/index_e.html

NIMS Holds Workshop with University of Pennsylvania, U.S.

Vice president Koinuma's address.

(April 18-20, NIMS) -- NIMS and the University of Pennsylvania (Penn) held the 1st NIMS/ICYS-Penn Materials Workshop over the 3-day period. This event was planned and held by the discussion between President Kishi of NIMS and Prof. Klein, Director of Penn's Laboratory for Research on the Structure of Matter (LRSM) on ways of achieving higher activity in exchanges of young researchers from the two institutes.

From the LRSM side, eight enthusiastic young faculty members under Prof. Klein participated in the event, while a total of 100 researchers from the NIMS side participated. Research presentation sessions covered a wide range of fields, including photonics, computational science, carbon nanotubes, and supramolecular materials, and were characterized by spirited discussions. The next workshop in the series is to be held in Philadelphia, Pennsylvania.

For more details: http://www.nims.go.jp/icys/

Failure Analysis of a Nozzle-Guide Vane in Cooperation with an Airline Company

Rudder Wu, Makoto Osawa, Hiroshi Harada
High Temperature Materials Group (High Temperature Materials 21 Project)
Materials Engineering Laboratory (MEL)

In the High Temperature Materials 21 Project, the research aim is to apply the Ni-base superalloy developed at NIMS to hot-section engine parts in cooperation with Japanese and foreign jet engine makers, thereby ensuring effective use of this material in increasing engine efficiency, reducing CO_2 emissions, and improving fuel efficiency. In parallel with these efforts, with support from the New Energy and Industrial Technology Development Organization (NEDO), new collaborations with airline companies, who are in the position of engine users, have been initiated. In this article, a case of such collaborated research is briefly explained.

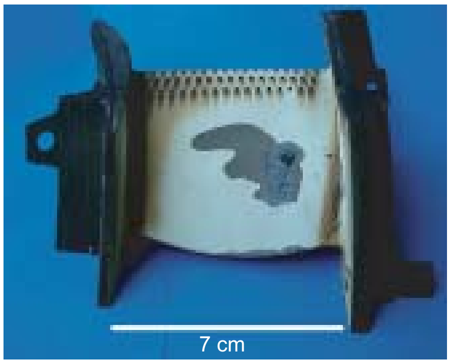


Fig. 1 High temperature, high pressure 1st stage nozzle-guide vane of a typical modern jet engine which suffered high-temperature degradation.

The turbine inlet gas temperature of advance jet engines reaches a maximum of 1500-1600 ℃ during a period of approximately 2 minutes in takeoff. The nozzle-guide vane (non-rotating static blade) which redirects the flow of combustion gas, the turbine blade which is driven by the gas flow and rotates at high speed under high temperature conditions, and certain other parts are manufactured from Ni-base single crystal superalloy with a melting point of around 1350 ℃. Since modern jet engines are operating above the liquidus temperature of the substrate alloy, these parts are cooled by internal air cooling, and thermal barrier coating (TBC) on their surfaces to prevent melting of the substrate. Although turbine components degrade gradually by repeated takeoffs and landings, flight safety can be ensured if such a degradation is discovered or well-monitored before parts suffer severe damage, or in the very early stages of damage assuming damage does occur, and the parts are replaced or repaired.

However, in rare cases, conditions may also arise in which parts suffer unexpected damage and it is necessary to elucidate the cause. **Figure 1** shows the high temperature, high pressure 1st stage nozzle-guide vane of a typical engine which suffered this kind of unexpected early-stage damage. In the simplified schematic diagram of a typical jet engine shown in **Fig. 2**, the rotors and stators in high temperature, high pressure parts of the engine are designated, from left to right, as 1st stage, 2nd stage, and 3rd stage components. In the High Temperature Materials 21 Project, the cause of damage in this nozzle-guide vane was analyzed by cross-sectional microstructure observation and chemical composition analyses. As a result, it was found that oxidation had proceeded at the interface between the ceramic coating and the underlying metallic coating (also known as an oxidation-resistant bond coat), due to the increased surface temperature of the turbine blade above the designd value; thus, causing spallation of the ceramic coating. Under this condition, the temperature of the exposed metallic coating and the substrate Ni-base single crystal superalloy increased greatly during takeoff, which resulted in thermal fatigue. This nozzle-guide vane has now been modified to enable safe use by further strengthening the surface air cooling (termed film cooling).

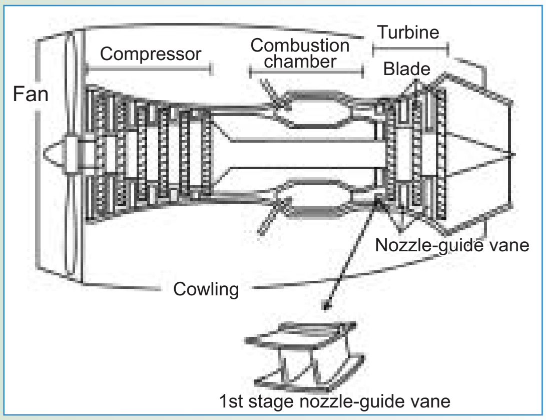


Fig. 2 Conceptual diagram of jet engine and position of nozzle-guide vane.

In addition to this example, the High Temperature Materials 21 Project has also analyzed various other engine components of different types. This research has not only contributed to ensure safety in aircraft, but has also become extremely useful for the understanding of the service conditions and mechanisms of damage in actual engine components, thus, reflecting this knowledge in the development of new alloys.

For more details: http://sakimori.nims.go.jp/htm21-e.html

Hello from NIMS

■ My Family Life in a Natural and Scientific City ■

Zhi-Quan Liu (China)
Research Fellow (Jul. 2002 - Mar. 2006)
In-Situ Characterization Group
High Voltage Electron Microscopy Station (HVEMS)

[With family in spring 2005]

Hello. I am a Research Fellow in the High Voltage Electron Microscopy Station of NIMS. My family came to Tsukuba about three years ago, and we live a pleasant life here.

At the time of our arrival, my 4-year-old son said Tsukuba is the countryside, since he could only see many tall, wild trees and few high buildings. This is the natural aspect of Tsukuba, as my wife once described in her newspaper article. The city looks more like a big garden with various trees, flowers, and greenbelts that show their multicolored beauty in all the seasons. Therefore, we delight in taking a walk in the parks or along the sidewalks during our spare time to enjoy the varied natural scenery. Another unique feature of Tsukuba is its scientific atmosphere, which has benefited from the gathering of several tens of institutes covering a wide range of research fields. Visiting these institutes on their public open days is always exciting for my family. New knowledge about subjects including space-

Observation of Terahertz Oscillation in Bismuth-Based High Temperature Superconductor

Huabing Wang
International Center for Young Scientists (ICYS)

Takeshi Hatano
Nano Quantum Electronics Group
Nanomaterials Laboratory (NML)

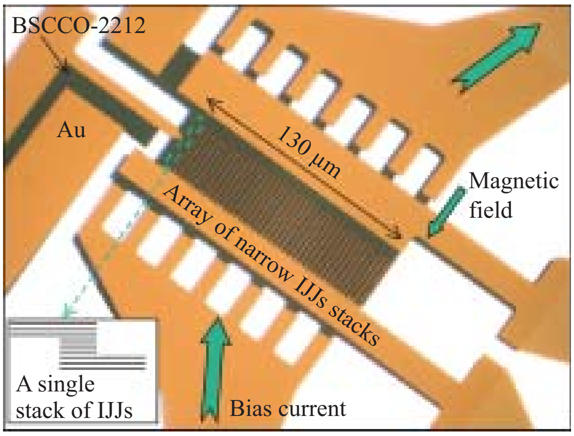


Fig. 1 A Device integrating 40 stacks of intrinsic Josephson junctions (IJJs) with sizes of 1 μm x 30 μm. (Because each stack contains 60 junctions, a total of 2400 IJJs are integrated in this device.)

Defined as a waveband from 0.3 THz to 30 THz and lying between microwave and infrared, the terahertz region has attracted much attention due to various possible applications in material science, spectroscopy, astronomy, medicine, security inspection, ultra-high speed telecommunication, etc. Although the exploitation of terahertz waveband has advanced rapidly since the beginning of the 21st century, it is not as quick as it should be, mainly due to the lack of general-purpose sources. At present, most terahertz light sources are either pulsed ones or very bulky. If compact, lightweight, and energy-efficient monochromatic continuous wave (CW) light sources can be developed, even faster progresses in the applications can be expected.

In this connection, superconducting devices based on the so-called a.c. Josephson effect have been considered because voltage-controlled oscillators can be made of them (a voltage of 2 mV corresponds to 1 THz), and they are energy saving elements too. However, the output from one Josephson junction is small, being on the nanowatt order. This means that it would be necessary to use a large number of such elements and coherently combine the radiations from them.

In 1988, a new type of bismuth-based high temperature superconductor was discovered at NIMS. In such a material superconducting layers interleave with non-superconducting ones, and the period of crystalline translational symmetry is 1.5 nm. As two neighboring superconducting layers and the non-superconducting one between them form a Josephson junction, in a piece of the Bi-based superconductor there will be many junctions in series. In such a device, all of the junctions can be phase-locked to each other. Consequently, resonant behavior with high intensity output can be expected, just like that in lasers.

A device has been designed with a narrow width and long depth in order to synchronize the junctions stacked in array form. Using double-sided fabrication method, 40 stacks were integrated as shown in **Fig. 1**. When a magnetic field is applied parallel to the layers, flux lattices are formed whose movement can be regulated by the edges of this narrow-width device. **Figure 2** shows the device properties by looking at the current-voltage characteristics. These results confirm that the height of the device's current step increases linearly as an increasing number of junctions switch to the voltage state, i.e. an oscillation state, and thus shows that a resonant oscillation state is realized internally in the device. Resonance power achieves a level of several tens of microwatts. Moreover, it is possible to increase integration by approximately 2 orders, and the prospects for developing tunable CW THz sources are now clear.

For more details: http://www.nims.go.jp/nanomat_lab/index_e.htm

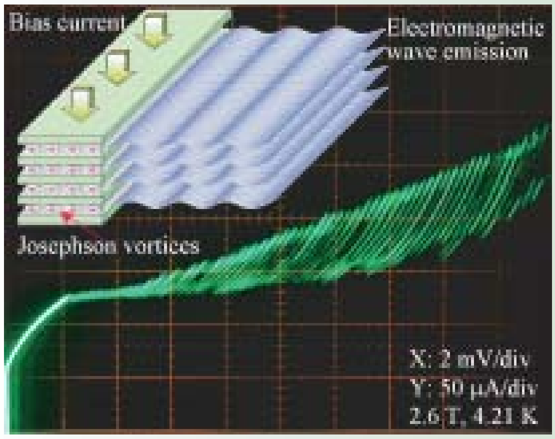


Fig. 2 Current-voltage characteristics of the device showing resonant oscillation. (The inset is a conceptual diagram of the ideal operation of a device in which the flux lattice is aligned with the device edges; as a result, all the junctions oscillate in synchronization, producing THz light.)

flight, geography, manufacturing, etc. can be learned through games and activities, which are extremely attractive to children.

My family is satisfied with living here, and we had a newborn baby last year. All of us love this natural and scientific city —Tsukuba.

[With colleagues at New Year 2005, front right]

Nature of Tsukuba

Hydrangea Lacecap
- Sengen Site -

Raspberry
- Namiki Site -

Dragonfly (Calopteryx atrata Selys)
- Hanamuro River -

Photos by M. Yoda

Introduction of New Directors

(May 1, NIMS) -- NIMS has promoted the appointment of outstanding international researcher to research management position and this time, two international researchers were newly appointed as Associate Directors.

Dmitri Golberg
Associate Director
Nanosynthesis Group
Nanomaterials Laboratory (NML)

This group is involved in the full range of research on inorganic nanostructured materials from synthesis to structural observation using leading-edge electron microscope technology and measurement of physical and chemical properties. The object nanostructured materials include metals, semiconductors, and insulators as a whole, while states encompass a wide range, including nanotubes, nanowires, nanorods, nanocones, nanoparticles, and nanocables. Thus far, in addition to nanostructured materials with layered structures, such as graphite, boron nitride, we have also succeeded in synthesizing structured nanomaterials which do not form layers, such as silicon, magnesium oxide, cubic gallium nitride and so forth.

Our current priorities are the design of various electro-optical devices consisting of various synthesized nanomaterials and the development of an on-demand fabrication technology for them. We envisage that the practical applications of these electro-optical devices will include high precision nanomachines, adsorbents and sensors for various gases, nanothermometers, nanowire joints, rectifiers, field effect transistors, field emission electron guns, nanoswitches, nanomagnets, laser oscillators, and polarizers.

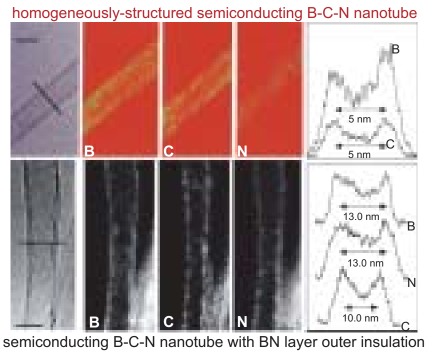
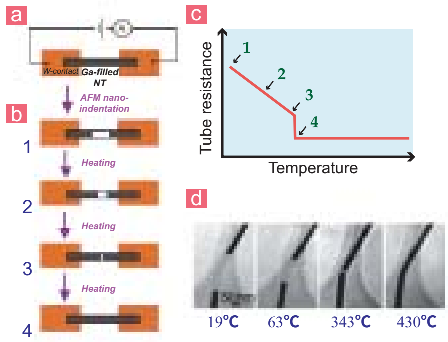


Image of element distribution of B-C-N multiwalled nanotube by energy filtering electron microscope and the corresponding TEM images. In the example in the upper row, B, C, and N are distributed homogeneously in all tube layers. In contrast, in the lower row, phase separation has occurred, and B and N have concentrated at the outer walls while C has concentrated at the inner walls.



Temperature nanosensor and electrical nanoswitch fabricated from a carbon nanotube containing enclosed liquid gallium. (a) One Ga-encapsulating carbon nanotube is bridged between the electrodes and (b) a void in the Ga is produced by an AFM tip. As the temperature rises, the void is gradually constricted until the two liquid Ga columns finally join at a certain temperature. (c) shows the temperature dependence of electric resistance in line with stages marked in (b). (d) illustrates how the two liquid Ga columns approach and join while the temperature is changed in the electron microscope.

For more details: http://www.nims.go.jp/nanomat_lab/index_e.htm

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Photocatalysts have attracted much attention in recent years as next-generation low environmental impact purification materials and photo-chemical energy conversion materials. However, the photocatalysis materials now in practical use, such as TiO_2, only display activity in ultraviolet light, limiting their range of applications and expansion of market scale. Our group is engaged in research and development of new photocatalysts which respond to visible light by band edge engineering of oxide semiconductors. We are also challenging high efficiency and selectivity of the photocatalysis materials in decomposing hazardous chemicals by controlling surface structure as well as hybridizing with nano- or micro-porous absorbent materials. Furthermore, mechanism of the photcatalytic reaction is under investigation experimentally and theoretically, to establish guidelines for development of highly efficient materials. Our objective is to develop environmental benign purification materials capable of efficiently decomposing/removing various hazardous organic substances which exist in the living environment, and also contribute to the fundamentals of solar-chemical energy conversion by photocatalytic water-splitting.

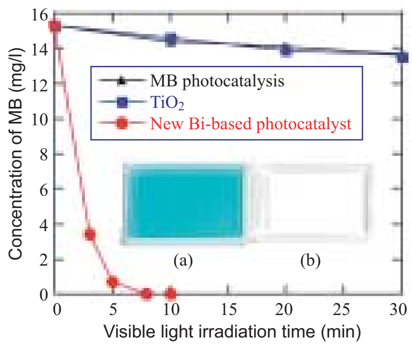

Fig. 1 Decomposition of methylene blue (MB) by new Bi-based photocatalyst under irradiation with visible light. Photo (a): Before irradiation. Photo (b): After irradiation with visible light for 8 minutes.

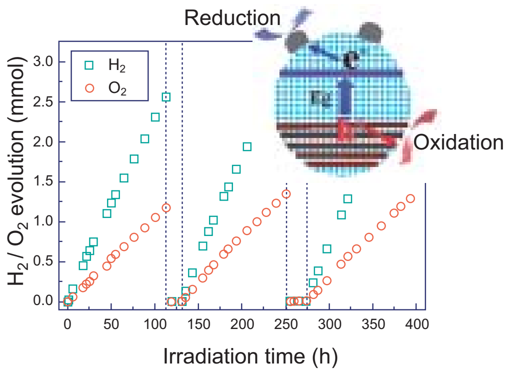

Fig. 2 Decomposition of water by newly-developed nanocomposite material.

For more details: http://www.nims.go.jp/photocatalyst/home.htm

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