NIMS NOW International

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Research on Next-generation Structural Materials

Constant stress creep machine in atmosphere

Research on Next-generation Structural Materials

– Building a Base for the Society of the Future

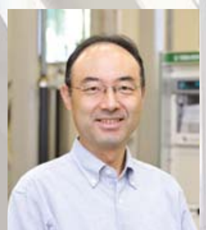
Leader, International Cluster for Structural Materials (iSM) **Takahito Ohmura**

Our secure, abundant social lives are supported by various structural materials, including metals, ceramics, polymers, and others. Because structural materials are so familiar and taken for granted, we frequently fail to realize the role they play. Nevertheless, progress in structural materials has been the driving force for the development of our society.

Today, when environmental problems are becoming increasing serious and a change in the basic form of society is demanded, heavy responsibility is placed on the structural materials which support society. In order to fulfill that responsibility, structural materials must achieve further evolution.

As the top runner in materials research, NIMS is devoting great effort to research on structural materials. In 2009, NIMS launched the International Cluster for Structural Materials (iSM) with the aim of establishing a new paradigm of structural materials research which frees itself from the conventional dependency on empirical rules, and contributing to the development of next-generation materials, by deepening collaboration between researchers that extends beyond differences in object materials, properties, and techniques, centering on young researchers who are involved in research on structural materials.

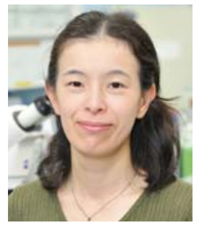
By promoting free debate in periodical colloquiums and other forums which bring together researchers from Japan and other countries and searching for the shortest route to realizing high performance materials, this project aims to contribute to building the base of a future society which is secure, safe, and sustainable.



Takahito Ohmura (Dr. Eng.). Graduated from the University of Tokyo, Graduate School of Engineering. Joined the National Research Institute for Metals in 1996. Previous positions include part-time Lecturer in the Faculty of Engineering, Chiba University 2001-2002 and Visiting Researcher at the University of California, Berkeley (USA) 2002-2003, among others.

iSM web site
http://www.nims.go.jp/nims-ism/english/

Development of High Corrosion Resistance Hydroxyapatite Coatings for Magnesium Alloy



Sachiko Hiromoto
Metallic Biomaterials Group, Biomaterials Center

Bioabsorbable metallic materials which can dissolve, absorb, and disappear as the affected parts are cured are demanded. Because magnesium is an essential element for the human body and also has high specific strength, application of magnesium alloys in bioabsorbable fracture fixing devices and stents is expected. However, with the existing magnesium alloys, poor corrosion resistance has been a problem.

We developed a hydrothermal treatment method for coating on magnesium with hydroxylapatite (HAp), on the surface of magnesium, and thereby succeeded in improving the corrosion resistance of the magnesium.

Fig. shows the anodic polarization curves of the HAp-coated and untreated pure magnesium in a simulated body fluid (SBF) and in a 3.5wt% NaCl solution, which is the concentration of sea water.

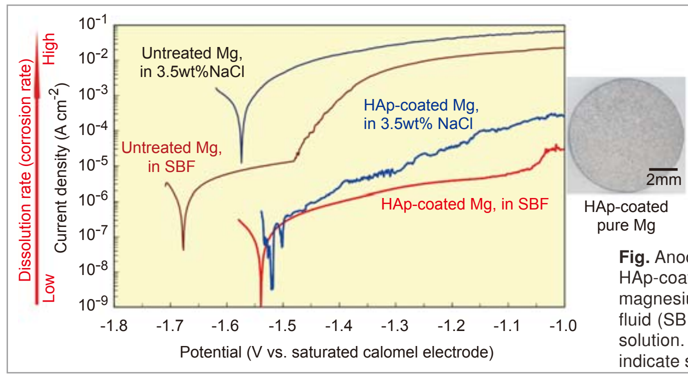


Fig. Anodic polarization curves of HAp-coated and untreated pure magnesium in a simulated body fluid (SBF) and in a 3.5wt% NaCl solution. Lower current densities indicate smaller dissolution rates.

The current density of the HAp coated specimen is lower than that of the untreated specimen in both the solutions, indicating that corrosion resistance is greatly improved by the HAp coating.

Further investigation of the influence of the morphology of HAp coatings on the corrosion behavior will contribute to the development of coatings with higher corrosion resistance. In addition, application of this HAp coating as an environment-friendly corrosion-resistant film for structural magnesium alloys can be expected.

Profile
Sachiko Hiromoto (PhD.). Completed master's course at the Waseda University Graduate School. Joined the National Research Institute for Metals (NRIM, now NIMS) in 1997, served as a visiting researcher at EPFL from 2003 to 2004, and was appointed to present position in 2009.

Development of Oxidation-resistant Coating which Retards Substrate Deterioration

Hideyuki Murakami
Coating Materials Group, Hybrid Materials Center

High efficiency in jet engines, gas turbines, and other internal combustion engines is an issue which is directly linked to the realization of a low carbon society. As is also clear from the theoretical thermal efficiency of the Carnot cycle*, higher operating temperatures are the most effective means of increasing efficiency. In fact, the combustion gas temperature at the inlet of gas turbines has increased by approximately 500°C in the past 30 years, and projects targeting 1700°C are now being launched.

Various technical development work is being carried out in order to maintain the life of rotor blades (nickel (Ni) based superalloy) used under these severe conditions. One such effort is research on oxidation-resistant coatings which prevent deterioration of the substrate material by oxidation. However, in high temperature environments, microstructural changes occur as a result of the mutual diffusion of the substrate and coating materials, and this has a negative effect on the high temperature properties of the substrate.

Therefore, we developed a novel coating technique in which an alloy of platinum (Pt) and iridium (Ir), which are platinum group metals, is coated by an electroplating method.

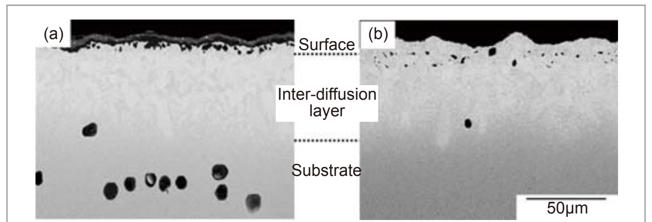


Fig. Cross sectional morphologies of specimens after exposed for 100 thermal cycles. Each specimen was developed by the electrodeposition of (a) Pt and (b) PtIr alloy (7μm in thickness) followed by the heat treatment at 1100 °C under vacuum. In the case of Pt-coated specimen (left), some voids are clearly shown in the substrate.

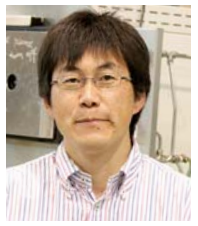
The **Fig.** shows cross sections of test specimens after 100 cycles of a process in which the specimens were heated in the atmosphere at 1125°C for 1 hour, followed by air cooling for 60 minutes, using specimens in which (a) Pt and (b) PtIr alloy were coated respectively on a Ni base single crystal superalloy by a plating method and subjected to vacuum heat treatment at 1100°C for 1 hour. In the Pt coated material, a large number of voids (holes) formed in the substrate material, but in contrast, with the PtIr alloy coating material, it is clear that voids were suppressed. This is attributable to the fact that addition of Ir suppressed mutual diffusion and is effective in prolonging the life of the substrate.

This research was carried out jointly with IHI Corporation.

Profile
Hideyuki Murakami (Dr. Eng.). Graduated from the University of Tokyo Graduate School. Joined NRIM in April 1991. Previous to present position, also a Visiting Researcher at the University of Cambridge (UK) from April 1992 to March 1994 and an Associate Professor at the University of Tokyo Graduate School from April 2002 to March 2005.

*Carnot cycle: Reversible heat cycle with the highest thermodynamic efficiency.

Manifestation of Toughness in Ultra-High Strength/ Low Alloy Steel in Low Temperature Region



Yuuji Kimura
Physical Metallurgy Group, Structural Metals Center

The basic performance of structural materials is to support large loads, in other words, strength. Recently, heightened expectations have been placed on the development of ultra-high strength steels with tensile strength exceeding 1500 MPa, with the aims of realizing next-generation steel structures and further weight reduction in transportation equipment for prevention of global warming by reducing CO_2. In particular, if it is possible to achieve high strength in steel by addition of only small amounts of alloying elements which are low in cost and have excellent recyclability, this will have a large economic merit.

On the other hand, the property of tenacity and resistance to breaking is called toughness. Toughness is an important index in the safe, secure use of structural materials. Until now, steels with strength exceeding 1500 MPa had low toughness, and consequently, their range of application had been limited.

Fig. shows the temperature dependence of the impact absorbed energy of the developed steel. The author succeeded in greatly improving the impact toughness of 1800 MPa class steel by multi-scale microstructure control in the nano to micrometer range by simple thermomechanical treatment.

Inverse temperature dependence of toughness was also discovered, in which toughness increases as the temperature decreases in the temperature region of 60°C to -60°C. Although inverse temperature dependence of toughness has been confirmed previously in several cases, the appearance of this property in an ultra-high strength steel with a low alloy composition is a revolutionary discovery.

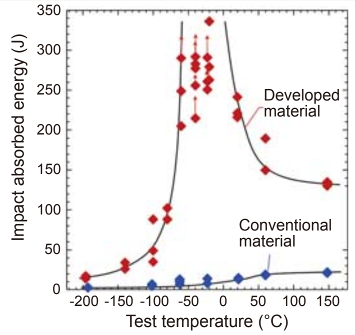
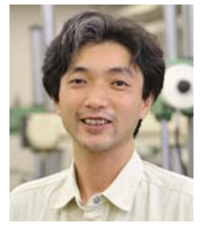


Fig. Relationship between test temperature and impact absorbed energy of a thermomechanically-treated steel with an alloy composition of 0.4%C-2%Si-1%Cr-1%Mo (developed material) and a quenched and tempered steel (conventional material). The arrows in the figure show test specimens which completely absorbed impact energy of 500 J without breaking.

Profile
Yuuji Kimura (Dr. Eng.). Senior Researcher. Served as Associate Researcher in the Kyushu University Faculty of Engineering before joining NRIM in 1999. Became a NIMS Senior Researcher in 2001 and was appointed to present position in 2009.

MPa: Unit of pressure. 1MPa = 10.197162129779283 kgf/cm^2

Elucidation of Mechanism of Gigacycle Fatigue and Establishment of Property Evaluation Method



Yoshiyuki Furuya
Fatigue Group, Materials Reliability Center

The author is engaged in research on gigacycle fatigue, mainly on high strength steels. With high strength steels, the central issue is how to evaluate and overcome internal fracture as the fatigue limit disappears due to internal fracture, as shown in **Fig. 1**.

Previous research revealed that an accelerated test using an ultrasonic fatigue testing machine (**Fig. 2**) is effective in evaluations of internal fracture. **Fig. 3** shows an example of the results of a gigacycle fatigue test. In the case of internal fracture, it can be understood that the results of the ultrasonic fatigue test and the results of a conventional fatigue test are in good agreement. Simultaneously with research on internal fracture based on this result, the author is also engaged in the development of applied technologies such as inclusion inspection using the ultrasonic fatigue test.

In recent years, the author has also carried out research on nonferrous metals, namely, titanium alloys and magnesium alloys, in cooperation with members of the Fatigue Group. In particular, in research on nickel (Ni) base superalloys, the author has taken up the challenge of new technical development in the development of an ultrasonic fatigue testing machine for high temperature use.

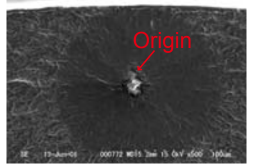


Fig. 1 Fractured surface of internal fracture

Fig. 2 Ultrasonic fatigue testing device

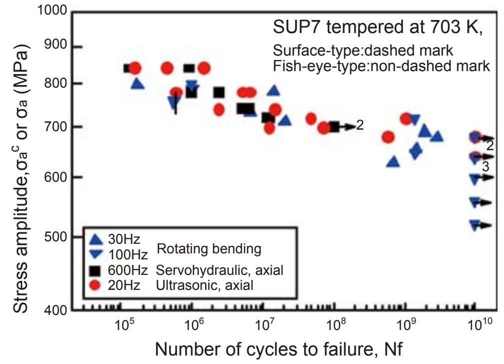


Fig. 3 Results of gigacycle fatigue test

Profile
Yoshiyuki Furuya (Dr. Eng.). Graduated from the Kyushu University Faculty of Engineering. Previous positions include Research Officer at NRIM (2000), NIMS Researcher (2001), and NIMS Senior Researcher (2005). Assigned current position in 2010.

Reliability Evaluation of Structural Materials for Low Temperature Use

Yoshinori Ono
Special Environment Group, Materials Reliability Center

When designing machinery and structures, it is important to understand in advance the properties which the materials being used will show in the use environment and how deformation and fracture may occur. For example, liquid-fuel rocket engines use liquid hydrogen (20K) and liquid oxygen (90K) as propellants, and convert the energy of the combustion reaction of these substances into thrust. In operation, many of the materials used in the engine parts are exposed to these low-temperature liquid fuels. Therefore, a good understanding of the low temperature properties of those materials and their deformation/fracture behaviors at low temperatures contributes to improving the reliability of rockets.

Our group has been proceeding the joint research on the structural materials used in liquid-fuel rocket engines with Japan Aerospace Exploration Agency. In this research, it was found that the high-cycle fatigue properties of a titanium alloy for engines show a characteristic temperature dependence in which these properties decrease at low temperature. Since tensile strength of the titanium alloy increases at low temperature, this is contrary to the empirical rule; high-cycle fatigue strength and tensile strength have a proportional relationship. The cause of the temperature dependence of the high-cycle fatigue properties was examined based on observation and analysis of the fracture surface, and it was found that fatigue fracture occurs accompanying twin deformation at low temperatures, as shown in **Fig.**.

At present, a more detailed study on the relationship between this type of fatigue fracture and the reduction of high-cycle fatigue properties at low temperature is in progress. Moreover, we have been investigating the methods for improving the high-cycle fatigue properties at low temperatures.

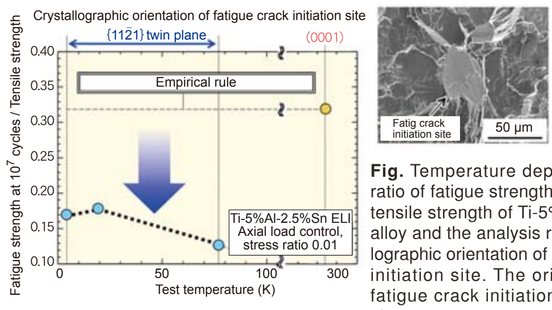


Fig. Temperature dependence of the ratio of fatigue strength at 10^7 cycles to tensile strength of Ti-5%Al-2.5%Sn ELI alloy and the analysis results of crystallographic orientation of the fatigue crack initiation site. The orientation of the fatigue crack initiation site is the slip plane at room temperature but becomes the twin plane at low temperature.

Profile
Yoshinori Ono (Dr. Eng.). Completed the second half of the doctoral course in engineering in the Kyushu University Faculty of Engineering in March 2001. Has worked at NIMS from April 2001 to the present.

ELI: Extra Low Interstitial.

Development of Nano-Micro Hierarchical Type Carbon Fiber Reinforced Polymer Based Hybrid Composite

Kimiyoshi Naito
Composite Materials Group, Hybrid Materials Center

Carbon fiber reinforced plastics (CFRPs) are currently used in the fuselages and wing structures of aircraft, and the amount used is increasing steadily. In the future, an expanded range of applications, which includes energy saving automobiles, is also expected. Thus, with material systems of these types, it is necessary to develop materials that can respond to more advanced and diverse requirements.

The conventional CFRPs show behavior in which stress increases linearly corresponding to increases in strain, and it is known that these materials reach fracture instantaneously at a certain limit value.

Therefore, the author developed a polymer based hybrid composite with a failsafe function, which is capable of bearing a load for a certain period even after loading exceeds the allowable load and fracture has begun (**Fig.**).

Concretely, this is a nano-micro hierarchical type carbon fiber reinforced polyimide matrix hybrid composite using a composite of a high modulus/high strength carbon fiber (micro level) and a nanostructure filled polyimide resin (nano level).

Future issues include optimization of the microstructure and composition of the interface of the hybrid composite and elucidation of the conditions for the maximum failsafe function and its failure mechanism.

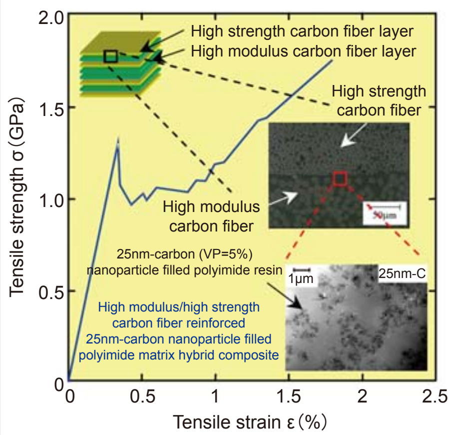
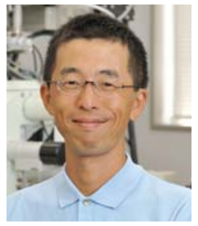


Fig. Microstructure/composition and stress/strain curve of nano-micro hierarchical type carbon fiber reinforced polymer based hybrid composite.

Profile
Kimiyoshi Naito (Dr. Eng.). Previously employed in the Mitsubishi Electric Corporation, Kamakura Works, Sagami Factory, Advanced Materials Engineering & Design Section. NIMS Senior Researcher in the Composite Materials Group, Hybrid Materials Center, NIMS International Cluster for Structural Materials (NIMS-iSM) from 2005 to the present.

Fabrication of Thin Foil of an Intermetallic Compound!

Masahiko Demura
Intermetallic Catalyst Group, Fuel Cell Materials Center



Intermetallic compounds, which consist of two or more metallic elements, have great potential and one can meet unpredicted but useful properties in a combination of elements. For example, Ni_3Al, one of our target materials, has a remarkable property that the strength increases with temperature, i.e. "the hotter, the harder". This anomalous hardening at elevated temperature, which could not be predicted from its constituent elements, Ni and Al, is a very attractive feature for heat-resistant structural materials.

We thought a foil of Ni_3Al would be an outstanding heat-resistant metallic foil. Heat-resistant metallic foils are used as container materials for high-temperature chemical reactors and converter materials for exhaust gas purification. Until now, the fabrication of intermetallic foils had been considered unrealistic due to the brittle nature of the compounds; that is, they are easily fractured during a rolling process, which process is low in cast and thus widely used to make metallic foils. In the case of Ni_3Al, there are two major obstacles to the rolling into the foil: the brittleness of the grain boundaries and the crystallographic anisotropy of the rolling deformability.

We first have discovered that directionally solidified (DS) ingots show an reasonable rolling deformability. The crystallographic directions of these DS ingots are aligned so that the brittle grain boundaries are removed out, which yields the reasonable deformability. Furthermore, we have discovered that there is an easy crystallographic direction for the rolling deformation in Ni_3Al: along this direction the material can be rolled very smoothly. With these two discoveries, we have succeeded in fabricating the thin foils of Ni_3Al by cold rolling for the first time in the world (**Fig.**). The foils have a smooth and crack-free surface with a metallic luster.

We are now starting a project in which we use this foil to make a high-temperature chemical reactor for hydrogen production. We are very pleased if you visit our web site for further information: http://www.nims.go.jp/imc/

Fig. Intermetallic Ni_3Al foil fabricated by cold rolling (thickness: 23μm).

Profile
Masahiko Demura (Dr. Eng.). Joined NRIM in 1995. Appointed NIMS Senior Researcher in 2005.

3D/4D Stereology

Yoshitaka Adachi,
Mayumi Ojima,
Naoko Sato
Basic Research Group, Exploratory Materials Research Laboratory for Reliability and Safety

Microstructure is characterized by *metric* properties such as length, area, volume etc. In addition, it should be also examined from *topological* and *differential geometrical* viewpoints such as Euler characteristics, genus, Gaussian curvature, etc. The targeted microstructures are morphology, crystallography, composition, and elastic-plastic strain of materials. An ideal microstructural analysis should be, therefore, performed at any desired magnification, from any desired direction, and at any desired time to examine both metric and topological characteristics.

For this, three-dimensional (3D) characterization seems to be very potential for topological and differential geometrical analysis. Here, 3D image is obtained by reconstructing serial sectioning images. Our group is engaged in work on not only 3D visualization, but also quantification of 3D image to correlate with transformation mechanism and accompanying mechanical properties (**Fig.1**).

On the other hand, we are also responsible for evaluation of stress and elastic strain in parallel with the development of a deformation/heating EBSD stage (**Fig. 2**). Hierarchical evaluation of elastic stress and strain in a microstructure is possible by complementary use with elastic strain measurement by a neutron beam technique and EBSD-Wilkinson method.

Coupling of modeling techniques with these 4D (3D plus time) analysis techniques is expected to result in a dramatic improvement in understanding of structural changes during deformation and heating.

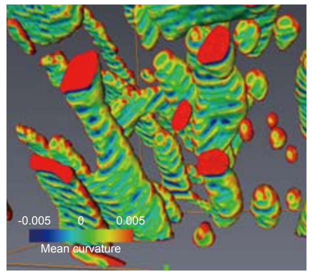


Fig. 1 Mean curvature map on 3D image of partially spheroidized pearlite.

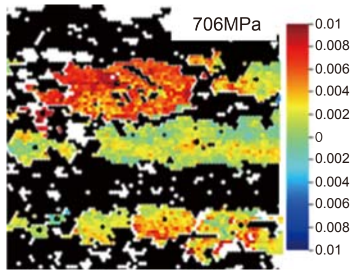


Fig. 2 Stress partitioning among ferrite grains in DP steel (in-situ EBSD-Wilkinson method during deformation).

Profile
Yoshitaka Adachi (Dr. Eng.). Appointed to present position as NIMS Principal Researcher in 2003. Since 2009, Joint Associate Professor in Kyushu University Faculty of Engineering, Advanced Nanomaterials Engineering Course (Kyushu-NIMS Joint Graduate School Program).
Mayumi Ojima (Dr. Eng.). Appointed as NIMS Postdoctoral Fellow in 2009.
Naoko Sato. Currently in the second half of the doctoral course in Kyushu University Graduate School (Kyushu-NIMS Joint Graduate School Program).

Serial sectioning: Polishing and observation are repeatedly performed. Obtained serial sectioning images are reconstructed using rendering software.

Establishment of Method of Predicting Structural Changes in Heat-Resistant Steels

Yoshiaki Toda
Heat Resistant Design Group, Structural Metals Center

The development of new high strength, heat-resistant materials and improved energy efficiency in thermal power plants are demanded in order to conserve energy resources and reduce CO_2 emissions. However, in the new development of heat-resistant materials, it is necessary to elucidate the microstructural changes which occur in the material after 100,000 hours (approximately 11 years and 4 months) at service temperature. Thus, development based only on experimental methods requires a large number of specimens and an extended period of time.

To address this problem, we are trying to establish a computational method of predicting the structural changes in practical heat-resistant materials.

For example, the precipitation sequences in the austenitic heat-resistant steel 18Cr-8Ni was predicted by the system free energy method (**Fig.**). With this approach, it was possible to predict the start of precipitation not only of $M_{23}C_6$ carbides, but also of the intermetallic compound σ phase after approximately 1-10 years from the basic physical parameters of the practical material by using energy theory.

In the future, the establishment of this prediction method is expected to enable efficient development of heat-resistant materials and easy optimization of the heat treatment processes for practical materials.

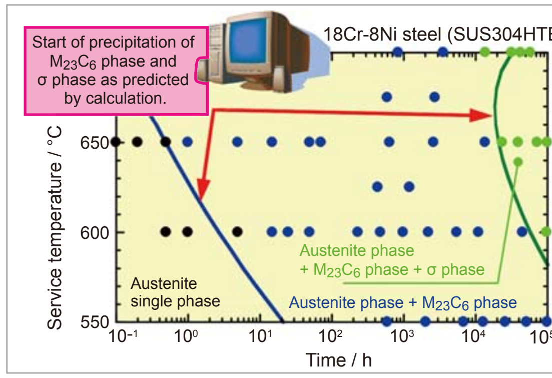


Fig. Isothermal precipitation diagram of 18Cr-8Ni steel. The blue and green circles show the conditions under which the $M_{23}C_6$ phase and σ phase were observed by electron microscope. The lines showing the start of precipitation of the respective phases predicted by the system free energy method accurately reproduced the experimental results.

Profile
Yoshiaki Toda (Dr. Eng.). Joined NRIM in 2000. Previous positions included NIMS Young Contract Researcher and NIMS Senior Researcher. Appointed as NIMS Senior Researcher in 2007. Dr. Toda holds a concurrent position as Visiting Associate Professor at Yokohama National University.

Microstructural Evaluation of Structural Materials by Analytical Electron Microscopy

Toru Hara
Advanced Electron Microscopy Group, Advanced Nano Characterization Center

In many practical materials, addition of many kinds of trace elements is one way to improve the required properties. A knowledge of the dispersion of these trace elements is important to elucidate the mechanism responsible for the functions and properties of materials and for obtaining guidelines for material design.

Observation by an electron microscope with analytical devices is widely used in observation of complex microstructures and compositional analysis of local regions. We are developing devices and techniques aimed at improving the functions and performance of energy-dispersive X-ray spectroscopy (EDS) of the transmission electron microscope (TEM) and research on their application.

Fig. 1 shows an STEM-EDS (scanning TEM-EDS) for quick observation of elemental distribution images. A silicon drift detector with a high acceptable X-ray counting rate was introduced at an early date.

The TEM shown in **Fig. 2** is the only transmission electron microscope in the world equipped with a microcalorimeter EDS, which is currently being developed independently by NIMS and co-workers. also has the world's highest energy resolution. This detector realizes the energy resolution more than 10 times higher than that of conventional detectors. This new detector enables separation and measurement of closely-clustered X-ray peaks, which had not been possible until now, and can measure the X-ray peaks of almost all elements separately.

Our aim is to realize high accuracy compositional analysis of nanoscale local regions, even in complex microstructures, using these devices.

Fig. 1 JEOL JEM2010F + EDS (Silicon drift detector)
Fig. 2 JEOL JEM2010 + Microcalorimeter EDS

Profile
Toru Hara (Dr. Eng.). Became a Researcher at NRIM in 1998 after Furukawa Electric Co., Ltd. and Teikyo University. Member of the Advanced Electron Microscopy Group of the NIMS Advanced Nano Characterization Center since 2006.

Results of the 1st International Cluster for Structural Materials Symposium

The 1st International Cluster for Structural Materials Symposium was held on April 26-27, 2010 with the cooperation of 8 Japanese scientific societies. This event was held with the aims of deepening discussion and interaction between the young researchers in the field of structural materials and persons affiliated with those societies and the industries, through an introduction of research on structural materials at NIMS.

In the poster session by postdoctoral fellows and graduate students, 5 prize-winning posters were selected. The prize winners and the contents of their presentations are introduced below.

Work Hardening from the Viewpoint of Stress partitioning

Mayumi Ojima Basic Research Group, Exploratory Materials Research Laboratory for Reliability and Safety

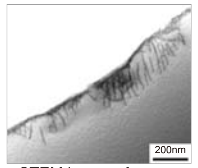
Our research group is promoting high accuracy 3D (3-dimensional) and 4D (dynamic) evaluation of deformation behavior with the aim of perfectly predicting mechanical properties in polycrystalline materials. At the symposium, we discussed that a work hardening mechanism of austenitic steels at elasto-plastic region in terms of stress partitioning, namely, heterogeneous deformation behavior among [hkl] family grains based on experimental results obtained by (1) in-situ neutron diffraction method during deformation, (2) in-situ electron backscattering method during deformation, and (3) TEM observation. As a result, it was shown that stress partitioning is the macroscopic factor in work hardening.

Profile: Mayumi Ojima— Doctor of Engineering. Graduated from the Graduate School of Science and Engineering, Ibaraki University. NIMS Research Assistant from 2006 to September 2009. NIMS Postdoctoral Fellow Researcher since October 2009.

In-situ Observation of Deformation by Nanoindentation in TEM

Zhang Ling Physical Metallurgy Group, Structural Metals Center

The *in-situ* nanoindentation in TEM technique was applied to correlate the force-displacement response of the material with direct images of the microstructural change. By indentation into a bcc single crystal of Fe-3% Si, the obvious pop-in behavior and change in slope on loading curves were found to be caused by change of deformation mode.



STEM image after test

Profile: Zhang Ling— Ph.D, graduated from School of Materials Science and Engineering, University of Science and Technology Beijing. Started research from 2007 as NIMS Postdoctoral Fellow Researcher.

Mechanism of Grain Growth of Ni-Co Base Forged Superalloy for Turbine Disks

Toshio Osada High Strength Materials Group, High Temperature Materials Center

Ni-Co superalloy is an alloy which was designed based on a novel concept proposed by the NIMS High Temperature Materials Center and currently holds the world record for the highest service temperature (>700°C) in a cast & wrought superalloy for turbine disks. In order to further improve its mechanical properties, we are trying to develop a technique for controlling the grain size by solution heat treatment. Focusing on the heat treatment technique in the γ/γ' two phase region, in this research, a new kinetic model for grain growth was proposed by arranging grain growth by both the Zener-Smith pinning model and LSW coarsening mechanism.

Profile: Toshio Osada— Doctor of Engineering. Completed the doctoral course in the Yokohama National University, Department of Energy & Safety Engineering. Research Fellow of the Japan Society for the Promotion of Science (JSPS) (DC2), etc. Has been a NIMS Postdoctoral Fellow Researcher since 2009.

Effect of Solid Solution Carbon on the Deformation Behavior of Steels

Kaoru Sekido Physical Metallurgy Group, Structural Metals Center

Nanoindentation technique was employed for analyzing a role of solid solution C upon the initiation of plastic deformation. Materials used are an ultra low carbon (ULC) steel and a Ti added interstitial-free (IF) steel, and each material has two conditions of low and high dislocation density. In the case of the low dislocation density, the critical load Pc corresponding to the initiation of plastic deformation was higher in ULC than that in IF. This result indicates that solid solution C makes higher friction resistance for the slip deformation. On the other case of the high dislocation density, both ULC and IF showed much lower Pc than that in the low dislocation case, and the difference between the two materials disappeared. The reason of this result could be that behavior of pre-existing dislocations with less effect by solid solution C is dominant for the slip deformation.

Profile: Kaoru Sekido— Doctoral student at the University of Tsukuba and a NIMS Junior Researcher since 2009.

Effect of Si on Microstructure of an Fe-Mn-Si-C Shape Memory Alloy

Motomichi Koyama Physical Metallurgy Group, Structural Metals Center

The purpose of this research was to clarify the "role of the essential element Si" in Fe-Mn-Si base shape memory alloys. The results were as follows: (1) the optimum Si content is 6 mass% regardless of the base composition, (2) the work hardening rate decreases when Si addition reaches 6%, increasing the critical strain for the onset of dislocation gliding. In other words, this work demonstrated that one role of Si is to reduce the work hardening rate, which suppresses "dislocation gliding" and promotes stress-induced ε martensitic transformation contributing to the shape memory property.

Profile: Motomichi Koyama— Doctoral student at the University of Tsukuba as a NIMS Junior Researcher since 2008.

NIMS – The Best Place for Young Researchers to Improve their Strength

Dr. Yoshinao Mishima

Professor, Tokyo Institute of Technology
President, The Japan Institute of Metals (JIM)

In April 2010, Prof. Yoshinao Mishima became the 59th President of the Japan Institute of Metals. In this interview, Prof. Mishima discusses NIMS as a place where young researchers in their 20s and 30s can improve their strength, and the role of NIMS as an "incubator."

——Japan is generally considered to be superior in materials research.

Certainly, we can say that Japan holds a leadership position at the global level. In functional materials, Japan has responsible for a succession of new discoveries and new materials. Likewise, in structural materials, Japanese researchers are doing outstanding research involving nanocontrol. Research on metallic materials is active and is producing results. The level of research is extremely high, and good conditions prevail. However, a better understanding on the value of these activities among the general public is needed.

——Perhaps a hero is needed?

For example, we need industries that use superalloys and other advanced materials in Japan. Because Japan doesn't currently have a large –scale aircraft manufacturing industry, they go to Lockheed in the United States. However, I think it would increase the presence of these materials if they were used in our own country.

Heroes are also needed, but perhaps more slow-but-steady efforts to publicize the interesting side of materials research are also necessary. We need to highlight what kinds of research we're doing, and for what purpose. . . . and I would like to see a process of our research produces results, and those results lead to the birth of a new industry. The best scenario would be a "success story" in which researchers create a wonderful new material that hasn't existed before, and product will be made from that material.

——What are your impressions of young researchers?

First, I think that the young researchers of today are great. The times have changed. Because hardware is advancing so rapidly, they understand a great many things. Researchers attempt to understand things from their fundamental nature using strict approach techniques such as the atomic probe, 3-dimensional analysis, structural simulation, the phase-field method, and observation at the atomic and molecular levels. As a result, their ideas go to places beyond the thought of old generation. This means that there's a possibility that novel materials will appear in principle. Concepts that would be impossible for older people, and the high accuracy of the data obtained, are making a great contribution.

——Some people are voicing concerns about their lack of interest in other fields.

Methods of education for doctoral students in universities need to be improved. The fact that students have a one-to-one relationship with a teacher when taking a degree means there's little "plus alpha" effect. I think that it's necessary to increase the depth of the outstanding top layer. In other words, the level of the top students is high, but the top layer is thin. For young researchers who have earned the degree, one reason why they either don't want to go overseas, or can't go, is the large burden of miscellaneous work imposed on them. They may want to go out and continue their training, but in the meantime, their friends are moving up the ladder. They have their hands full just dealing with the most immediate problems.

——Do you have any comments about NIMS?

Since NIMS became an Independent Administrative Institution, various innovations have made it easier to understand. When I participated in the external evaluation of NIMS about a year and half ago, I had the impression that the researchers, and particularly the young people just above the post-doc level, are making great efforts. This made me think that NIMS has a mission which is different from that of both universities and companies, and that is to train the human resources who will be the core of materials research. NIMS is the ideal place for researchers who are in their latter 20s to 30s to improve their strengths. I hope that NIMS will become an "incubator" that sends out trained people to various fields.

——You've said that NIMS should establish its "brand."

I think it will be good if people who leave NIMS are active in various fields. NIMS is one necessary gate on the road to success for researchers. Speaking of my own specialty, which is steel, steel and nanotechnology appear to be unrelated, but in fact, this isn't true. If I may say so, the true worth of NIMS can be seen in the dramatic improvement in the properties of iron and steel materials which has been achieved using nanotechnology.

Profile

Born in Tokyo in 1949. Graduated from the Tokyo Institute of Technology Department of Metallurgical Engineering in 1973, and completed his master's degree in Metallurgical Engineering at the Tokyo Institute of Technology Graduate School in 1975. Completed the doctoral course in materials science at the University of California, Berkeley in 1979. Became an Assistant Professor of the Tokyo Institute of Technology Precision and Intelligence Laboratory in 1981 and an Associate Professor in the same school in 1989. Appointed to present position as Professor of the Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology in 1997.

Control of Grain Boundary Chemistry and High Temperature Properties in Structural Ceramics by Cation Doping

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Keijiro Hiraga (Group Leader)
Fine-Grained Refractory Materials Group,
Nano Ceramics Center

Oxide polycrystals such as alumina (Al_2O_3) and zirconia (ZrO_2) are used as heat-resistant materials, oxygen sensors, and other applications which take advantage of their features of heat resistance, high strength, and ionic conductivity. Conventional techniques for development of the engineering ceramics are grain refining to nanosize, dispersion of second phase particles, formation of composites (*1), and so on. On the other hand, our recent research has revealed that various physical/chemical properties of ceramics, such as high temperature mechanical properties, and the microstructure can be drastically changed by doping of a small amount of metallic ions (cations) to high purity oxides.

For example, the high temperature flow stress and tensile elongation of the tetragonal zirconia polycrystal (TZP) are sensitively influenced by the doping of a small amount of cations at the doping level of 0.1 to several mol %. The ductility of TZP can be significantly improved by optimizing the amount of cation dopant and the synthesis process.

Fig. 1 shows the relationship of flow stress (y-axis) and strain (x-axis) under tensile deformation at an initial strain rate of $1x10^{-4}$ s^{-1} (constant crosshead speed) at 1400°C. In undoped TZP, elongation to failure of only 1.4 times the original length can be achieved. In contrast, in TZP doped with germanium (Ge) and titanium (Ti), the flow stress is only 1/4 that of the undoped TZP, and the elongation exceeds 10 times the initial length (1000% of nominal strain). Conversely, by the doping of cation species such as barium (Ba) which improve resistance to deformation (require large flow stress), heat resistance can be improved. This effect has also been confirmed in oxides other than TZP.

High-resolution transmission electron microscopy observation and chemical analysis at local portion (EDS (*2)) have revealed that doped cations tend to concentrate in the vicinity of the grain boundaries of ceramics (grain boundary segregation) in various cation-doped oxide ceramics, as shown in **Fig. 2**. Our research also confirmed that the structure and composition of the grain boundary nano region can be changed, and diffusivity and grain boundary energy (*3) can be accordingly controlled by the cation doping. The grain boundary diffusion and grain boundary energy influence the flow stress and accumulated damage at grain boundaries (cavities) in high temperature deformation, and therefore, the cation-doping can contribute to control of high temperature deformation.

This cation doping effect is a characteristic phenomenon of ceramics, and in particular, is effective in control of the high temperature matter transport phenomena such as sintering, phase transformation, microstructure development, and high temperature deformation. Recently, we have succeeded in reducing the sintering temperature of yttrium oxide (Y_2O_3) with low sinterability by several hundred degrees and refining the grain size of this oxide by optimizing the doping technique.

The doping effect is an extremely unique phenomenon, in which macroscopic properties of structural ceramics are controlled by the nanostructure in the vicinity of the grain boundaries. The elucidation of the basic principle, which exists between grain boundary nanostructure and material properties, is expected to be helpful in the design and development of ceramic materials in the future.

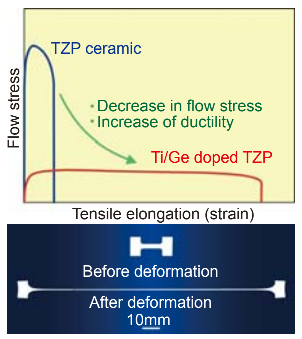


Fig. 1
Top: Changes in the high temperature deformation behavior of TZP by doping with Ti^{4+} and Ge^{4+} (schematic), and **bottom**: Photo of the sample showing tensile elongation exceeding 1000%.

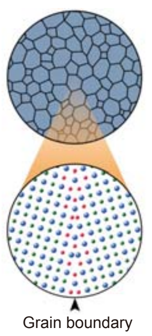
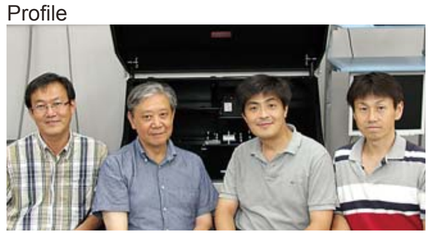


Fig. 2 Schematic illustration showing grain boundary segregation of doped cations. Owing to the segregation of the dopant cations, a unique chemical bonding state forms in the grain boundary nano region, and the grain boundary diffusivity and grain boundary energy accordingly change.

*1 **Particle dispersion/formation of composites**: Techniques in which small amounts of second and third phases different from the matrix are dispersed in the matrix, or composites are produced by mixing other phases in amounts which may be as large as that of the matrix.
*2 **EDS**: Energy-dispersive X-ray spectroscopy is an analytical device used for the elemental analysis and chemical characterization of a sample. In an electron microscope, characteristic X-rays generated from a specimen by electron beam irradiation are measured by an energy-dispersive spectrometer.
*3 **Grain boundary energy**: In comparison with single crystals, polycrystals, in which grain boundaries exist, have a higher energy state. The grain boundary energy is given by the excess energy per unit area of grain boundary. Grain boundary energy is related to the stability of grain boundaries, etc.

Profile



Hidehiro Yoshida(second from right)
(Dr. Eng.) After serving as Fellow Researcher at Japan Society for the Promotion of Science(JSPS) and Research Assistant at Graduate school of Frontier Sciences, the Univ. of Tokyo, joined NIMS in April 2004. Senior Researcher at NIMS from 2008.
Koji Morita(right)
(Dr. Eng.) After serving as Fellow Researcher at JSPS, joined NRIM in April 1997. Senior Researcher at NIMS from 2008.
Byung-Nam Kim(left)
(Dr. Eng.) Joined NRIM in March 1998 after served as Research Assistant at Tokyo Metropolitan Univ, and the Unv. of Tokyo. Visiting Researcher at Univ. of Pennsylvania in 2003. Senior Researcher at NIMS from 2006.
Keijiro Hiraga(second from left)
(Dr. Eng.) Joined NRIM in April 1978. Group Leader of Fine-Grained Refractory Materials Group, and also Guest Professor at Division of Materials Chemistry of Graduate School of Engineering, Hokkaido Univ.

Nanostructures of Grain Boundaries in Structural Ultrafine Grained Metallic Materials

Seiichiro Ii
Structural Functions Research Group,
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Virtually all practical metals and ceramics consist of many single crystals, and are therefore called polycrystalline materials. In order to elucidate the properties of polycrystalline materials, it is necessary to unravel the mysteries of the "grain boundary", which is the interface where pairs of crystals join.

The vast majority of structural materials which are practically used are polycrystalline materials. Grain boundaries essentially exist within these polycrystalline materials. In general, the grain boundaries in metals and ceramics act as obstacles to dislocations (*1) in plastic deformation, and thus are important for understanding the mechanical properties of the material, such as strength, toughness, etc. In recent years, many researchers have been positively used grain boundaries to improve strength and toughness.

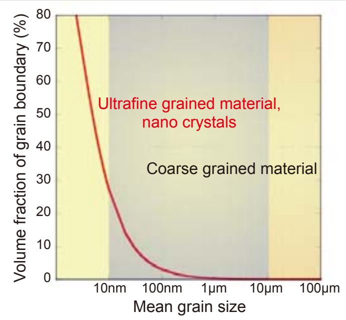

Fig. 1 Relationship between mean grain size and volume fraction of grain boundary. In this figure, we assume a thickness of the grain boundary is 1nm.

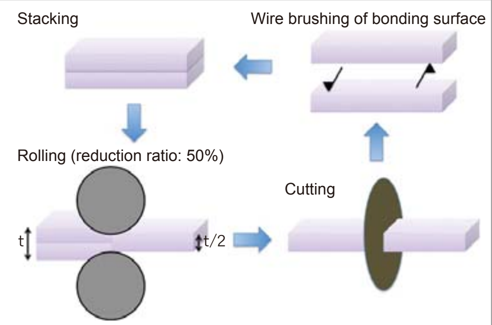

Fig. 2 Schematic diagram of the accumulative roll-bonding process.

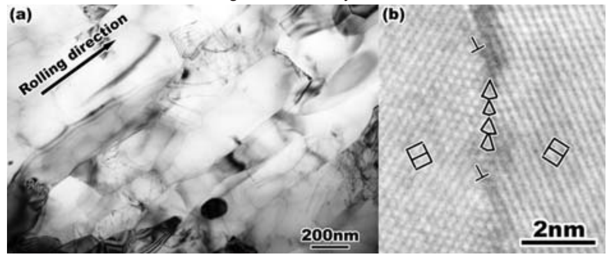

Fig. 3 (a) Microstructure of ultrafine grained commercial purity Al produced by a SPD process (accumulative roll-bonding process) and (b) the grain boundary structure of the material in (a).

One example of this research field is efforts to improve important properties of structural materials, such as strength and toughness, by grain refinement of the grain size of metallic materials to less than 1μm by the severe plastic deformation (SPD) process, in which plastic strain (*2) exceeding an equivalent strain of 4 is applied to the bulk material. Many researchers in all over the world have attracted much attention to this process.

In ultrafine grained metallic materials produced by the SPD process, the role of the grain boundaries in those materials is extremely important because the volume fraction of grain boundaries, increases dramatically as a result of this process (**Fig. 1**). In order to clarify the role of grain boundaries in various properties, it is first necessary to understand micro and/or nanostructure of the grain boundary itself.

Therefore, we are engaged in research with the aim of clarifying the atomic structure of the grain boundaries in ultra-fine grained metal materials utilizing the transmission electron microscope.

Fig. 2 shows schematic illustration of the accumulative roll-bonding process, which is one of typical SPD process. This process can apply unlimited plastic strain to the materials. **Fig. 3** shows (a) the microstructure and (b) the atomic structure of the grain boundary in ultrafine grained commercial purity aluminum (1100Al) produced by this process.

In (a), it can be seen that the distinctive microstructure consists of fine grain elongated along the rolling direction. Additionally, because the microstructure is formed with the mechanical working, i.e., plastic deformation, a large number of dislocations can be also observed in the grain interior.

Fig. 3 (b) shows representative results of observation of the lamellar grain boundary, which is parallel to the rolling direction. The atomic arrangement around the grain boundary was investigated, and this grain boundary atomic structure was determined. The results clarified the fact that the atomic structure of the grain boundary in ultrafine grained materials can be considered based on the concept of "structure unit(*3)", as same as coarse grained materials. On the other hand, we also confirmed that dislocations which bear deformation exist at the locations indicated by the "⊥" marks. It was concluded that this is a characteristic feature of the grain boundary structure in ultrafine grained materials formed by deformation processes.

At present, the authors are attempting to elucidate the essential nature of the physical properties in ultrafine grained materials by systematically clarifying the nanostructure of the grain boundaries which exist in ultrafine grained materials.

*1 **Dislocation**: The boundary between the regions where slip deformation does and does not occur in crystalline materials. Generally, dislocations are line defects, and plastic deformation proceeds by movement of dislocations.
*2 **Plastic strain**: The residual strain (elongation, compression and shear etc.) remaining in a material after plastic deformation in which stress is applied to the object material, and having removed that stress. This affects not only the microstructures but also various properties of the material.
*3 **Structure unit**: A characteristic atomic structure at the grain boundary. This is one of basic concept used in the discussion of grain boundaries.

Profile

Seiichiro Ii (Dr. Eng.)
Completed the doctoral course in the Graduate School of Science and Technology, Kumamoto University. Previous positions include postdoctoral fellow at the University of Tokyo and Kyushu University, and Assistant Professor and Associate Professor at Sojo University. Joined NIMS in October 2008 and is currently a NIMS Senior Researcher.

Biocompatible Coronary Stent Controlling Cell Response by Polymeric Matrix and Drug

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Ischemic heart disease, which includes angina pectoris and myocardial infarction, is the second largest cause of death among Japanese, and occurs because the blood vessels become constricted or blocked. This type of disease is treated by performing an operation in which a net-like metal tube called a stent is used to expand the constricted blood vessel and maintain the flow of blood.

At present, drug-eluting stents (DES), in which a mixture of drug and polymer material is coated on the stent surface, are used to prevent restenosis. Restenosis is a condition in which the expanded blood vessel becomes constricted once again, and occurs due to excessive replication of the smooth muscle cells which form blood vessels. However, with the commercial DES, there is an increased possibility of "stent thrombosis" after placement of the stent because the drug and the polymer responsible for slow release of the drug inhibit not only the replication of the smooth muscle cells, but also the replication of the endothelial cells which form the lining of blood vessels, or endothelialization. Therefore, as shown in **Fig. 1**, the development of a coronary stent, which has the property of uniquely suppressing replication of smooth muscle cells, while promoting endothelialization (coating of the vascular surface by endothelial cells) without formation of clots after stent placement, had been desired.

To dissolve this problem, first, we developed a polymer matrix, in which gelatin is chemically crosslinked with citric acid, as a scaffold for endothelialization and a polymer matrix for drug release.

By controlling the crosslink density, the polymer matrix show highly expected properties for a DES, i.e., endothelialization and antithrombogenicity,. We then incorporated Tamibarotene (Am80) in the polymer matrix, which uniquely suppresses the growth of smooth muscle cells, and succeed in the development of an Am80 eluting stent by coating this material on the stent surface.

This stent releases nearly 80% of the Am80 in the first 1-2 weeks after implantation, when the inflammatory response is strongest, and continuously releases Am80 for an extended period of 8 weeks, thus displaying desirable drug-release behavior. As shown in **Fig. 2**, when the Am80-loaded drug eluting stent was left for 2 weeks in the coronary artery of a pig, satisfactory endothelialization was observed, without formation of clots. This experiment also showed that the restenosis rate was extremely low in comparison with that of the commercial bare metal stent.

The coronary stent developed in this work offers superior effectiveness and safety in comparison with the DES currently in use. At present, in cooperation with the University of Tokyo Hospital and Nipro Corporation research and development aiming at clinical use are in progress.

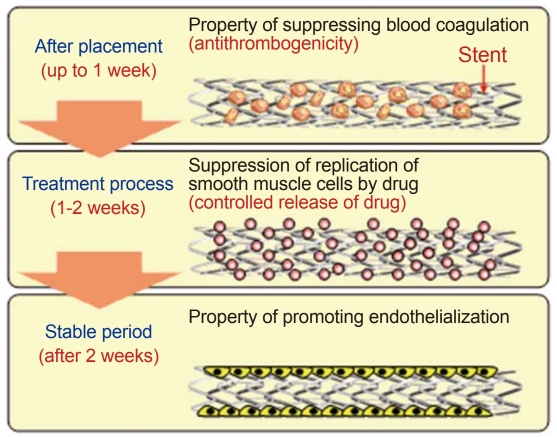

Fig. 1 Required properties for coronary stents

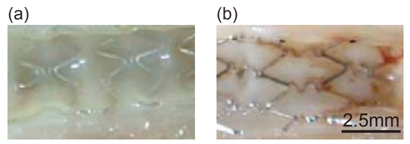

Fig. 2 (a) Appearance of blood vessel cavity 2 weeks after placement of the developed coronary stent in a pig coronary artery, showing no formation of blood clots (thrombosis) and satisfactory endothelialization, and (b) appearance when a commercial stent was used, showing considerable formation of blood clots and almost un-observed endothelialization. The reddish-black areas in (b) are clots that formed inside the blood vessel (scale bar at lower right: 2.5mm).

Profile

Motoki Inoue (upper left) (Pharm. D.) NIMS postdoctoral fellow researcher.
Tetsushi Taguchi (upper, second from left) (Dr. Eng.) Joined NIMS in 2002. Also, researcher at NanoBio Area of MANA.
Yasuyuki Katada (upper, second from right) (Dr. Eng.) Joined NRIM in 1981. Retired after served as Group Leader, Station Leader, and General Manager at Human Resources Development Office.
Yuji Miyahara (upper right) (Dr. Eng.) After serving as researcher at Central Research Laboratory at Hitachi, Ltd., joined NIMS in Oct. 2002. Group Leader at Biomaterial System Group, Managing Director at Biomaterials Center, and also researcher at NanoBio Area of MANA. *Professor at Tokyo Medical and Dental University from Sep. 2010.

Investigating the Electronic State of Iron-based Superconductors

Taichi Terashima
Nano-Quantum Transport Group,
Exploratory Nanomaterials Research Laboratory

Superconductivity is the phenomenon in which electricity flows with zero resistance in solids at low temperatures approaching absolute zero (–273.15°C). However, if this phenomenon can be achieved at temperatures as close as possible to room temperature, the range of applications will be expanding correspondingly. The recently-discovered iron-based superconductors, which contain iron and arsenic, display superconductivity at a comparatively high absolute temperature of 55K (approximately –218°C) and may become a powerful rival to the copper oxide high temperature superconductors which are currently being developed.

Because superconductivity occurs when the conduction electrons which are responsible for conducting electricity form pairs, a knowledge of the state and nature of the electrons in iron-based superconductors is indispensable for elucidating the mechanism by which the iron-based superconductors exhibit high temperature superconductivity. This knowledge is also important for obtaining guidelines for searching for new superconductors which manifest superconductivity at room temperature, which is the ultimate goal.

We have taken up the challenge of this research by measuring the de Haas-van Alphen (dHvA)* oscillation using the high field magnets of the NIMS High Magnetic Field Station. We recently succeeded in measurement of the iron-based superconductor KFe_2As_2 and clarified its electronic state in detail.

The specimen used in this measurement was small, with a size of only 1mm. In order to transport the specimen into the measurement environment, which was under a high magnetic field and at a cryogenic temperature near absolute zero, the specimen was inserted into the detection coil and attached to the end of a 3.5 m long bar called a probe (**Fig. 1**). In order to detect the weak magnetic signal from the specimen, the detection coil was wound many 1000 times with extremely fine (diameter: 0.02 mm) copper wire.

The upper right part of **Fig. 2** shows an example of the measured dHvA oscillation. When the frequency components included in this oscillation were investigated, it was found that they comprised three frequency components corresponding to electrons with different properties. These were named ε (epsilon), α (alpha), and ζ (zeta) (see lower part of **Fig. 2**).

The same measurement was performed numerous times with different temperatures and magnetic field directions. When the results were compared with theoretical calculations called electronic structure calculations, it was found that the experimental results were remarkably different from the theoretical calculations. This result showed that the interactions between the electrons in this substance are far stronger than under normal conditions and the electrons are in a strongly correlated state. This is crucial knowledge for elucidation of the mechanism of iron-based superconductivity and the search for additional high temperature superconductors.

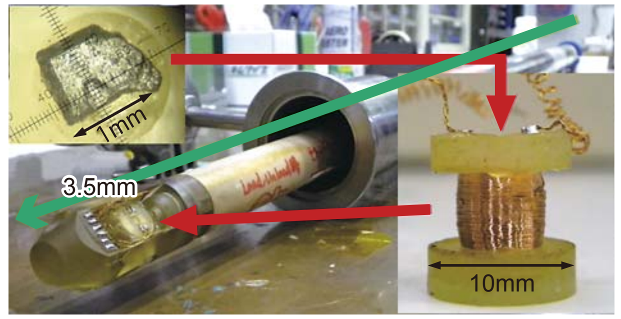

Fig. 1 Probe (total length: 3.5 m) for transporting the specimen into the high magnetic field, cryogenic temperature measurement environment. The insets show the specimen (upper left) and detection coil (lower right).

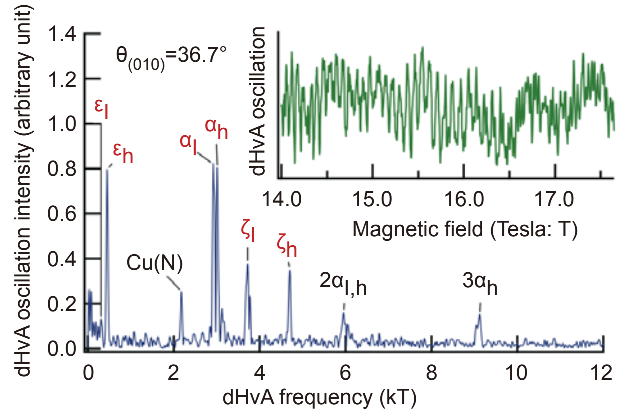

Fig. 2 dHvA oscillation (inset, upper right) of the iron-based superconductor KFe2As2 and its Fourier transform. The measurement temperature was an absolute temperature of 0.08K (–272.65°C). Three frequency components (ε, α, ζ) can be observed. 2α and 3α, etc. are harmonics. It should be noted that the peak marked Cu(N) is the signal from the copper wire in the detection coil and is unrelated to the specimen.

This research was carried out as joint research under the Japan Science and Technology Agency (JST) special research project on superconductivity, by NIMS, the National Institute of Advanced Industrial Science and Technology (AIST), Chiba University, and Kobe University. These results were published in the English-language edition of the Journal of the Physical Society of Japan (May 2010). The paper was selected in Papers of Editors' Choice.

* **dHvA oscillation**: In physical science, electronic states are studied using a mathematical virtual space called "wavenumber space". dHvA oscillation is an experimental technique for determining the distribution of electrons in wavenumber space. In measuring dHvA oscillation, a high magnetic field, cyrogenic temperature, and high quality specimen are necessary.

Profile

Taichi Terashima (Dr. Sci.) Joined NRIM in April 1993. Visited National High Magnetic Field Laboratory, USA, from Oct. 1997 to Sep. 1998. Senior Researcher at Nano-Quantum Transport Group, Exploratory Nanomaterials Research Laboratory at NIMS from Apr. 2010.

Results of NIMS Conference 2010

Led by the NIMS Innovative Center of Nanomaterials Science for Energy and Environment (ICNSEE), the NIMS Conference 2010 attracted a total of 550 audiences and featured spirited debates.

The NIMS Conference 2010 was held at the Tsukuba International Congress Center, Epochal Tsukuba from July 12 to July 14, focusing on the theme "Challenges of Nanomaterials Science: Towards Solution of Environment and Energy Problems." As the winner of the NIMS Award, Prof. Jean Marie Tarascon of the University of Picardie Jules Verne (France) was selected for major achievements in improvement of the capacity, life-length, and safety of lithium ion cells. Using a materials science approach, Prof. Tarascon has achieved numerous results in the development of lithium ion cells, ranging from electrodes and electrolytes to total systems, and thus has made an extremely important contribution to the development of lithium ion secondary cells, which have now reached practical application and grown to an enormous market scale. (See p.15 for a Special Interview with Prof. Tarascon.)

Prof. President Yoshifumi Yasuoka (left), Executive Director of the National Institute for Environmental Studies (NIES), Chair of the NIMS Award Selection Committee, with Prof. Jean Marie Tarascon (center), winner of the 2010 NIMS Award, and Prof. Sukekatsu Ushioda, President of NIMS.

In the Keynote Lecture, Prof. Akira Fujishima, President of Tokyo University of Science, discussed the principle and applications of TiO_2 photocatalysts, together with numerous examples of practical applications such as the purification effect, cooling effect, etc., particularly utilizing the super-hydrophilicity and oxidation decomposition reaction of organic matter of these photocatalysts. Following the Keynote Lecture, Prof. Sukekatsu Ushioda, President of NIMS, introduced highlights of research at NIMS and the ICNSEE, Prof. Prashant Kamat of the University of Notre Dame (US) presented a lecture on cutting-edge efforts in the development of new types of photovoltaic cells, centering on quantum dot photovoltaic cells, and Prof. Takahisa Ohno, Managing Director of the ICNSEE, introduced simulation technologies for understanding and control of interfacial phenomena in nanomaterials. As a representative of the industrial world, Dr. Keiichi Kohama of Toyota Motor Corporation, who is a Group Leader in the Toyota Battery Research Division, mentioned the expectations placed on high performance secondary cells. Finally, Dr. Sebastian Fiechter of the Helmholtz-Centre Berlin for Materials and Energy (Germany) introduced light-induced water splitting and the application of graphene substrates to secondary cells and fuel cells.

On the 2nd and 3rd days of the Conference, eight organized sessions related to the environment and energy materials were held. A large number of participants engaged in spirited discussions could be seen at every venue. In particular, non-Japanese participants were a strong presence in the lecture audiences, giving a real feeling that the NIMS Conference has taken root as an important international conference. Contributing to sustainable global development by breakthroughs in materials technology is a mission of the ICNSEE and of NIMS as a core institution in this field. We are confident that the NIMS Conference 2010, which attracted a total of 550 audiences, will serve as a trigger for the fusion of different fields, close cooperation among industry, universities, and Independent Administrative Institutions (IAI), and development/exchanges of human resources which are demanded in order to fulfill this mission.

Keynote Lecture by Prof. Akira Fujishima.

The scene at an organized session.

Taking Up Challenges with Passion and Open Communication

Prof. Jean-Marie Tarascon

Université de Picardie Jules Verne

Upon receiving the NIMS award 2010 for his enormous contributions to the development of lithium-ion secondary batteries and related areas, Prof. Jean-Marie Tarascon talks about the importance of open communication and passion for research.

— Can you provide us with a general overview of your research activities?

Throughout my 15 years in the U.S., including my time at Bell Labs and Bellcore, my research focused on the synthesis and characterization of new compounds, concentrating at the early stage on superconducting materials and then on electrode materials for energy storage. At that time, our effects were directed towards the development of the $LiMn_2O_4$/C Li-ion battery with advances in formulating new electrolyte composition (presently commercialized under the brand name "LP30") and in applying proper surfaces coating to prevent Mn dissolution for increased battery lifetime. It is during this period as well that we developed the plastic Li-ion battery technology based on the identification of a thermo-fusible, mechanically robust polymeric system.

I have been for more than 15 years now conducting research at the Laboratory of Reactivity and Chemistry of Solids (LRCS) and teaching at the Université de Picardie Jules Verne, both in Amiens, always working on materials for Li-ion batteries but shifting from bulk to nanomaterial and introducing the concept of sustainability in the hunt for new electrode materials. Li-cobalt-based oxide is much used as a positive-electrode material for lithium batteries, but earth resources in Co are somewhat limited, and in 50 years from now you don't want the automotive industry to cope with the same issue as it does today with the shortage of fossil fuels. So there was a demand for the development of new materials and the building of new concepts. For such reasons we looked at new inorganic or organic compounds for lithium batteries made via eco-efficient processes, such as sulfates or carboxylates.

I am also involved in a research network at the European level called ALISTORE, a center uniting 21 European laboratories and 14 European industries whose main emphasis is devoted to battery research as well. Throughout my research career, NIMS has always been recognized for its famous research areas of ceramics, metallurgy and especially hydride materials / hydrogen storage. In fact, one of my colleagues at the LRCS had been trained at NIMS as a post-doc fellow. Visiting Tsukuba this time gives me an opportunity to touch on another dimension of various NIMS expertise dealing with the field of energy storage.

— Could you provide us with your overall research thrust as to materials or compounds?

We are pursuing research on two fronts. The common denominator is sustainability. We need to look at materials made of low cost and abundant elements. Our favorites are iron, titanium, and manganese-based compounds, which are commonly used materials for electrodes. However, making these materials requires high temperature operation (1000°C) which indirectly leads to the generation of carbon dioxide. Therefore, organic electrodes and the use of natural resources and biological processes are being scrutinized. Although biological processes are attractive, they are slow and not easy for reproducible results, especially for large-scale production. However, our team is made of "amateurs" at biological processes; we have been trained as materials scientists.

That is the reason why we are looking to produce a bigger team with people who have been trained in biology, having competency and able to interact. For this, we are setting up a center in France for networking researchers, covering everything from basic research and technology transfer to industrial research. Our lab itself has some 60 people, with 25 being permanent researchers.

— Does your time at Bellcore help you with your work even today?

In the beginning it was dealing with superconductors, though we were told to do what we wanted, just be No. 1 in that area of research, but after the big earthquake in California around 1990, we were asked to concentrate our research efforts on batteries due to back-up battery failures seen after the earthquake.

The main thing was that there was a change in goals, and we were asked to focus on solving our company's battery research issues as well as scouting the research field so as to pursue relevant research. I gained much experience writing proposals, planning projects, learning how to sell and present the work I was doing as well as how to motivate people. It was fun, exciting - and luckily, it led to successful research results too. Being able to pursue cross-disciplinary work, interact with other experts, like people who knew about polymers because they had worked on coating polymer cables at Bell, showed the great value of open communication as it led to the development of plastic Li-ion technology.

— Do you have any advice for materials researchers?

They should experiment more; they should not shy away from traveling and changing research interests, meet people, having more discussions and communication, and constantly sharing their excitement about their research. For me, when one is pushing forward with research, the driving force is being passionate about it. I feel lucky because I found a passion for research and I hope young scientists especially can do the same.

Profile

After doing postdoctoral research at Cornell University, he joined Bell Labs and Bellcore. He is now a professor at Université de Picardie Jules Verne, and also member of the French Academy of Sciences.

Learn By Doing!
A Series of Mid-Summer Experience-based Learning Programs at NIMS

This summer, as in previous years, a series of experienced-based learning programs for children were held at NIMS. Students from elementary school to the high school level enjoyed a variety of programs, and all concerned gave NIMS high marks for making this rich experience possible.

Summer Science Camp 2010
July 28-30, Sponsor: Japan Science and Technology Agency (JST)

The participants were 16 high school students from all parts of Japan, who enjoyed exchanges with NIMS researchers over a 3 day period. The students were actively involved in lectures, having prepared for these sessions in advance, and were ready to ask detailed questions. The researchers who responded were instinctively enthusiastic in advising this talented group of future scientists.

Tsukuba Science Lab
August 6, Sponsor: Tsukuba City

It is a project for elementary school students living along the Tsukuba Express rail line, and is intended to encourage a better knowledge of the attractive nature and science and technology of Tsukuba City. This year, a total of 32 students were fascinated by their first experiences of scientific experiments and equipment.

Tsukuba Science Casting Workshop
August 10, Sponsors, International Congress Center Tsukuba Epochal, JTB Business World Tokyo

It is a new project launched this year, in which high school students from the Ibaraki Prefecture visit various research centers in Tsukuba and gain experience closer to actual research. At NIMS, 13 participants did "research" on the research at NIMS in experiences beginning with the use of an electron microscope and heat treatment of metal.

Chibikko Hakase (Little Doctor) Program
August 24, Sponsors: Tsukuba City, Tsukuba Board of Education

This program is an experiment event for elementary and junior high school students in which NIMS cooperates every year. This year NIMS offered three courses, "Let's Learn About Shape Memory Alloys," "The Mysteries of Metals," and "Superconductors – Story from a Very Cold World." Total of 59 children were brimming with interest in the demonstrations of the researchers who conducted these courses.

Hello from NIMS

Antonio Sanchez Torralba (Spanish)
NIMS postdoc, ICYS-Sengen
(since Dec.2007)

When I arrived in Japan at the end of 2007, I was planning to stay in NIMS for only 4 months, but then ICYS kindly offered me a position, despite my background in biochemistry, and I ended up staying for almost three years now. My work is theoretical or, more precisely, computational, so I am very grateful for this chance to experience the wonderful computer resources in NIMS and off-site, as well as for the support of many people, specially those at the First Principles Simulation Group I. Mafalda, the great Argentinian cartoon character by Quino, complained once that "urgent matters do not leave time for important ones". I think she would not complain at NIMS. At least, not too much. Foreign staff always get invaluable support with administration and what would otherwise be opaque regulations to us.

[Hanami with colleagues from the First Principles Simulation Group]

[Japanese street signs]

One of my hobbies in Japan is to wander the streets of any major city and to collect pictures of warning signs. Unlike the signs in other countries, usually threatening and promising untold suffering or punishment in bleak official language, Japanese signs are full of color and even respect. True, in one or two occasions I have experience hardly concealed forms of unwelcoming nationalism, but in general Japanese people and life are just like one would expect from their street signs: orderly and polite, inventive and accepting. And there is always more than meets the eye for the interested *gaijin*!

Announcement: The 10th NIMS Forum
Date: October 20th (Wed) ,2010 Site: Tokyo International Forum Hall B-7 http://www.t-i-forum.co.jp/english/index.html

NIMS plans to hold NIMS Forum, as follows, to present the results of advanced research at NIMS and encourage matching of those results with the needs of business. As the 10th NIMS Forum, this year's event marks an important milestone, and will feature nearly 100 poster presentations from various units. The oral sessions (lectures) will focus on content explaining the recent trends in research at each Center.
Online registration will start at end of September 2010.
For details, please see http://www.nims.go.jp/nimsforum/. (Only in Japanese)

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