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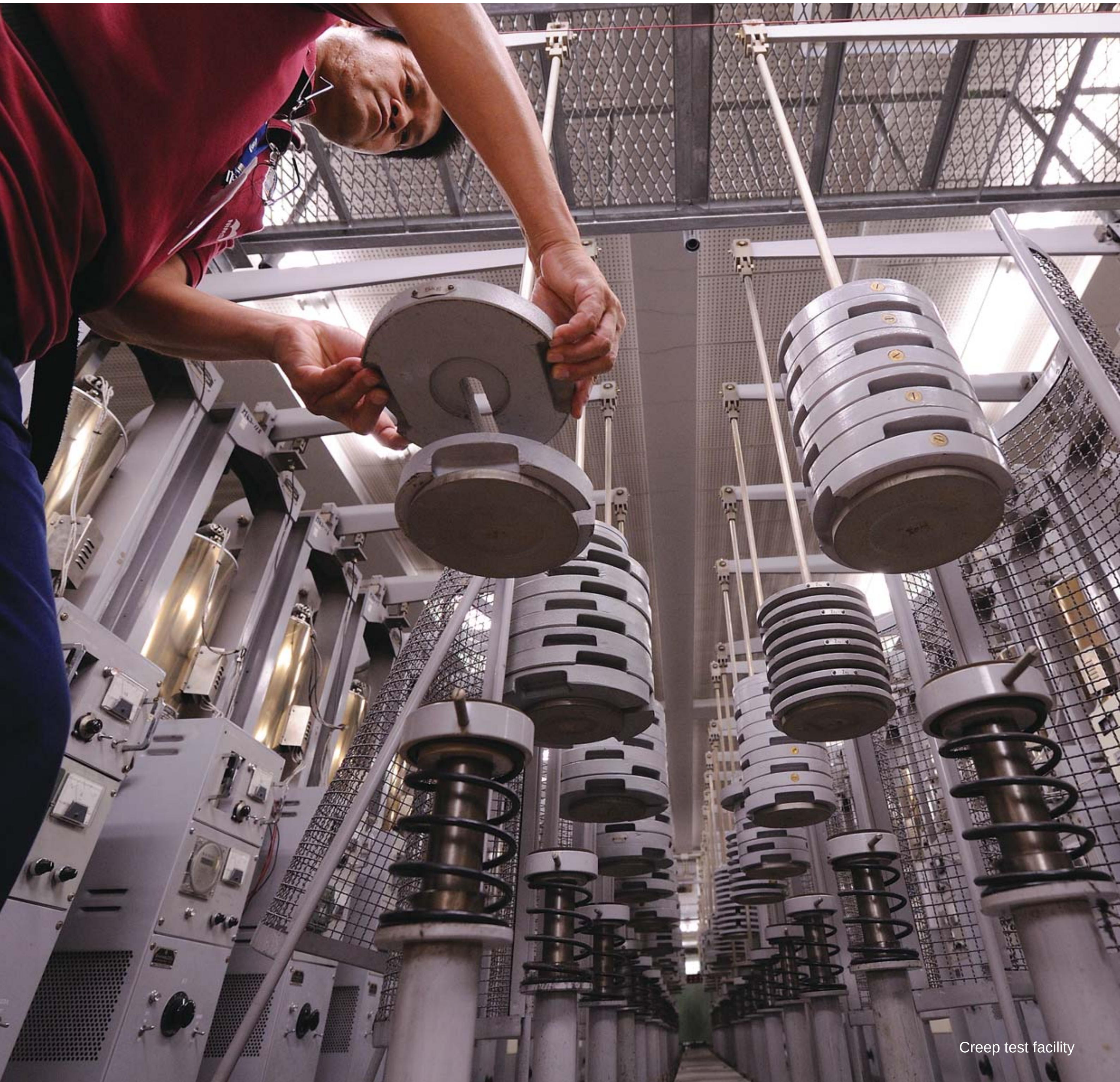
The Challenge of Global Warming

Dramatic Progress in Materials for Thermal Power Plant



Creep test facility

The Challenge of Global Warming

Dramatic Progress in Materials for Thermal Power Plant

Ensuring a stable supply of energy is an important challenge for every country. At present, coal-fired thermal power plants account for approximately 30% of all electric power generated in Japan. However, the fact that coal produces large amounts of CO_2 emissions is a serious problem. High plant efficiency is indispensible in solving this problem. Because Japan is a world leader in the development of heat-resistant high temperature materials to make the plant efficiency higher, we asked NIMS researchers to discuss trends in new thermal power technologies and the development of the high temperature materials for the practical application of those technologies.

The most effective approach to reduce CO_2 Emission

To the realization of A-USC plant

Adjunct Researcher **Masafumi Fukuda**
High Temperature Materials Center

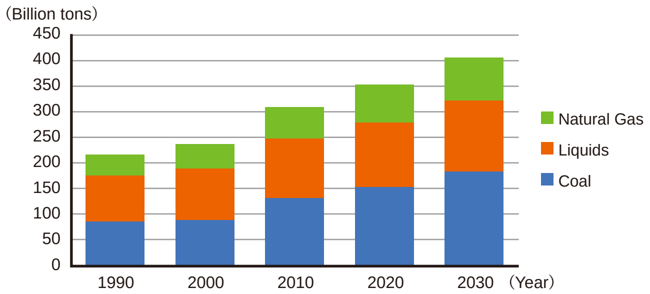
Aiming at Reducing CO_2 by Further Improvement in the Efficiency of Thermal Power Plants

As a fuel for thermal power plants, coal remains an easy-to-use supply, because of stable and abundant reserves which is large and geographically widely dispersed. The worldwide demand for coal is expected to reach double its current level by the year 2030. However, coal is also a fossil fuel and discharges CO_2 when combusted. According to forecasts of global CO_2 emissions, CO_2 emissions originating from coal combustion will account for approximately half of the total.

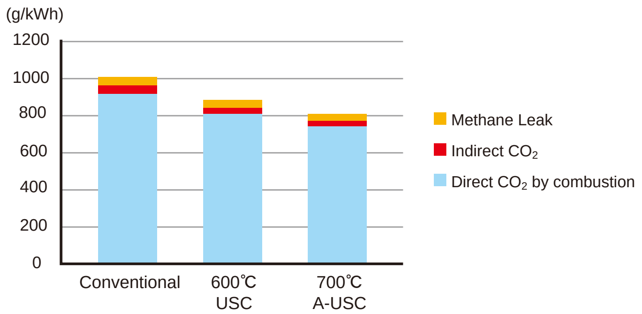
As NIMS adjunct Researcher Masafumi Fukuda explains, "How far we can reduce CO_2 emissions while using thermal power is a key issue. For this reason, research on ultra-supercritical steam condition (USC) power generation is underway worldwide, as this is a thermal power technology of high efficiency with low fuel consumption."

USC refers to ultra-supercritical pressure power generation, meaning that the steam temperature and pressure are above the critical point for water. Japan is the leader in this field. A large number of USC plants were constructed in Japan before other countries, and 80% of the 20 USC plants currently in operation worldwide are located in this country.

At present, research on Advanced-USC (A-USC) is underway as a technology which further increases the efficiency of USC. The aim is to achieve higher efficiency in power generation by increasing the steam temperature of around 600°C in USC to more than 700°C in A-USC. This will make it possible to reduce coal consumption, and thus will make an important contribution to reducing CO_2 emissions.



World CO_2 Emission
(Source:International Energy Outlook 2009 by EIA)



Life Cycle CO_2 Emission

A-USC Projects in Progress around the World

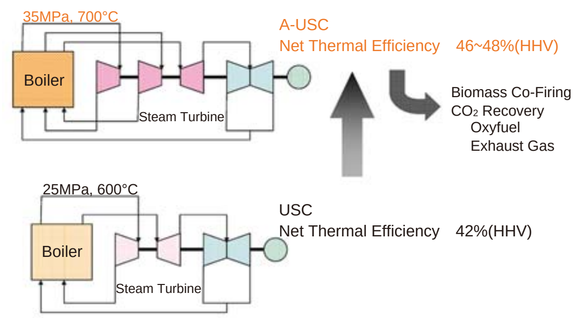
In realizing A-USC, materials which are capable of withstanding high temperature steam must be used. The candidates for this include nickel (Ni)-based superalloys and high temperature steel, which was developed by NIMS.

Ni-based superalloys are more expensive than the heat-resistant steels which have long been used. For this reason, it is considerable to apply Ni-based superalloys only in necessary parts, and to use heat-resistant steels in most other parts. NIMS has accumulated research on high temperature materials for use in power plants and similar applications over the course of many years as the world's leader in this field. NIMS is already engaged in research on boron-added high strength high temperature steels and other materials, assuming use in A-USC, and is finding a way for practical application.

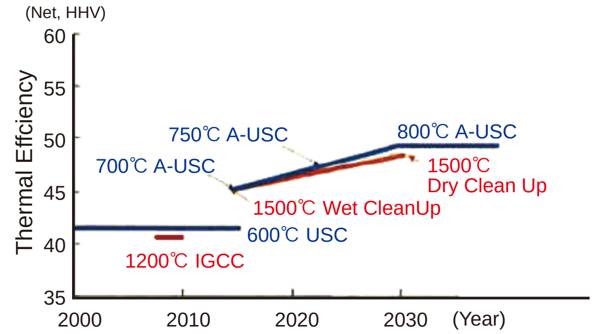
The manufactures of turbines and boilers, material makers, and various research institutes, including NIMS launched an A-USC project with the subsidy of Japan's Ministry of Economy, Trade, and Industry (METI). The work in this project includes system design for A-USC and the development of element technologies such as materials and manufacturing technologies. Plans also aim at the construction of an A-USC demonstration plant based on the results.

In Europe, a long-term material verification test is already underway in Germany, and in the United States, researchers are evaluating materials capable of withstanding 760°C class steam.

If Japan's outstanding USC technologies can be applied in thermal power plants in the United States, China, India, and other countries which are heavily dependent on coal for electric power generation, a calculation shows that CO_2 emissions can be reduced by 1.3 billion tons per year. This is an enormous amount, corresponding to Japan's total emissions of CO_2 at present. With A-USC, further reductions in CO_2 will also be possible. Assuming practical application can be realized by the targeted date of around 2020, followed by dissemination of this technology thereafter, a 10% reduction in the world's consumption of coal for thermal power generation is conceivable. Thus, A-USC is expected to have a major effect in reducing CO_2 emissions at the global scale.



A-USC (Advanced USC)



Thermal Efficiency

Perspectives on thermal power technology & its materials technology

Executive Research Scientist
Mikio Sato
Central Research Institute of Electric Power Industry (CRIEPI)

Considered from the viewpoints of "securing energy security" and "solving global environmental problems," the issues for thermal power technology are "improvement of thermal efficiency," "diversification of fuels," "expanded use of biomass-originated fuels," and "carbon dioxide capture and storage (CCS)."

In steam power generation in Japan, steam conditions have reached a pressure of 31 MPa and temperatures of the 600°C class, and we have entered an era in which net thermal efficiency (HHV base) of approximately 42% can be obtained. In gas turbine combined cycle power generation, net thermal efficiency (HHV) exceeding 50% has been achieved by adopting 1500°C class gas turbines. As a result of these trends, large expectations are placed on higher allowable heat resistance temperatures in materials, improved cooling technologies for hot gas path parts, and optimization of plant systems as a whole.

Among other challenges for thermal power technology, one which relates to materials technology is "diversification of fuels." In the future, the quality of fossil fuels will tend to decrease, for instance, the use of lower quality coal with considerable amount of ash and moisture will increase. Moreover, oil sand, oil shale, and other types of unconventional oil have high contents of heavy metals. Thus, the effects of the impurities in fuels will become an important issue accompanying higher temperatures in the service environment for materials.

Issues from the viewpoint of management and plant operation include "cost reduction" and "improved reliability." Development of materials technologies also plays a large role in these areas. While not saying that every problem can be solved simply by developing excellent materials, from my own perspective as a researcher who is involved with heat and combustion, reducing the restrictions related to materials allows us to have bigger dreams when considering improvement in the performance of power system.

Research on High Strength Ferritic Heat Resistant Steel

Group Leader **Fujio Abe**
Heat Resistant Design Group, Structural Metals Center

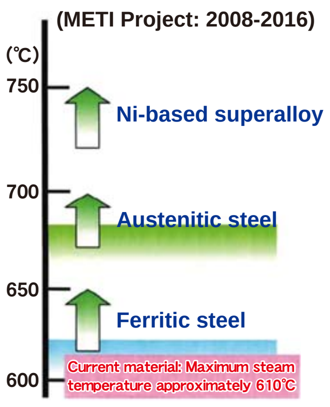
The performance of high temperature materials determines the efficiency of power plants

In coal-fired thermal power generation, coal is combusted in boilers, and heated water produce high temperature, high pressure steam. This steam passes through boiler tubes and is collected in a header, from which it travels through the main steam pipe to the turbine and is then used to drive the turbine-generator.

According to Dr. Abe, “In coal-fired thermal power plants, the total length of the large-diameter, thick section main steam pipe in one plant is 100-200 meters. The steam pipe itself is a large-scale structure weighing several hundred tons, and the material is exposed to high temperatures over a period of many years. It’s no exaggeration to say that. its heat resistance temperature, holds the key to higher operating temperatures in power plants.”

The main properties required in materials for main steam pipes are, firstly, high temperature strength, together with oxidation resistance to high temperature steam on the inner side of the pipe, and weldability. Moreover, low cost is also important because these materials are used in large quantity.

One particular problem in the main steam pipe which carries steam from the boiler to the turbine is thermal fatigue damage. Thermal power plants frequently switch between operation and a stopped condition. As a result, the pipes are subjected to fatigue due to the thermal expansion and contraction resulting from repeated heating and cooling. The material used in this part is ferritic heat resistant steel. In addition to its low cost in comparison with austenitic heat resistant steels and Ni-based superalloys, ferritic steel also has a low coefficient of thermal expansion, and thus can reduce thermal stress. Dr. Abe and his colleagues are grappling with the development of boron-added high strength ferritic heat resistant steels, which feature improved high temperature strength while taking advantage of the distinctive features of ferritic heat resistant steel, aiming at realization of advanced ultra-supercritical (A-USC) power generation.



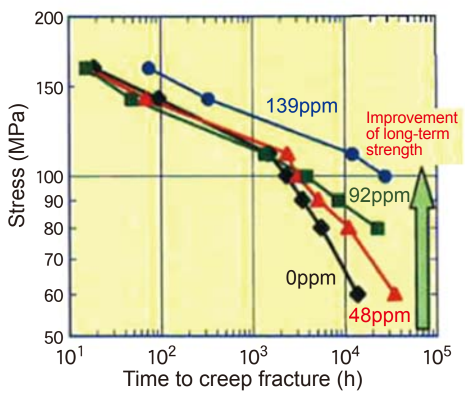
High temperature materials and their service temperatures.

High-strength NIMS-9%Cr Steel

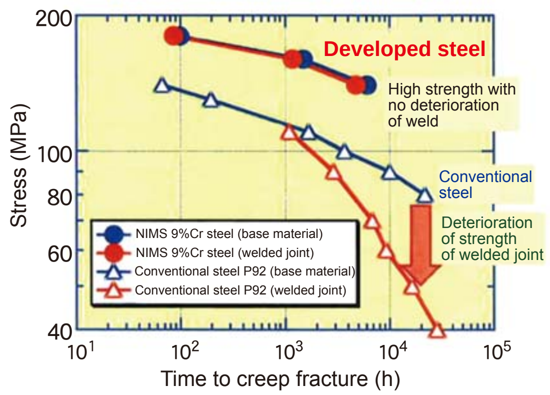
Pride in world-leading research on high temperature steels

In order to secure high temperature creep strength, which is the most critical property, Dr. Abe’s research aims at refinement of the size of precipitates in the material microstructure, and in particular, at stabilization and strengthening of the microstructure at and near grain boundaries, where strength tends to decrease. His research has revealed that reduction of the strength of the welding heat affected zone (HAZ) can be avoided by adding boron, and also clarified the mechanism. He has also shown that forming a protective oxide film of chromium on the surface by a preoxidation treatment is effective for improving oxidation resistance. Basic guidelines for alloy design have been established through this type of research. Future research will focus on verification of long-term properties aiming at practical application and research on manufacturing and processing technologies.

According to Dr. Abe, the No. 1 unit of an A-USC power plant is scheduled for construction in Germany in 2014. Although Europe will be the first to realize A-USC with this No. 1 unit, Dr. Abe expresses his confidence that “Japan continues to lead the world in research on heat resistant steels.” Thus, all countries involved in research on A-USC have high expectations for the material technologies in which Japan leads the world.



Improvement of the strength of high strength ferritic high temperature steel by boron addition.



Deterioration of welds in high strength ferritic high temperature steel and conventional steel.

Creep Life Prediction and Prevention of Deterioration of Weld Strength

Group Leader
Masaaki Tabuchi
Creep Resistant Materials Group
Materials Reliability Center

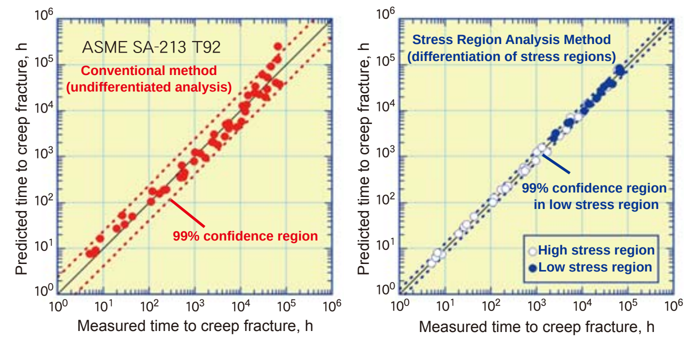
Station Leader
Kazuhiro Kimura
Materials Data Sheet Station

Research on creep properties contributing to high accuracy in material life prediction

The life of thermal power plants is generally considered to be 30-40 years. To ensure reliability, NIMS is engaged in research from various angles, assuming the conditions under which materials are actually used.

One such effort is research on creep properties. Creep is the phenomenon in which objects gradually deform with the passage of time as a result of external force. In creep tests, the stress which causes creep fracture is measured over a span of 100,000 hours (approximately 11 years and 5 months) at the service temperature of the material. The allowable tensile stress is obtained from the long-term test results and used in design. In such long-term creep tests, the amount of deformation in 1 hour is only about one hundred-thousandth %. Research on the dynamic changes in this nanoscopic world can be considered a so-called “dynamic-nano” challenge.

In actuality, in research on high temperature materials which are to be used in high efficiency USC thermal power generation, the danger of overestimating the creep strength of the ferritic high temperature materials had been pointed out.



Comparison of measured values and results of creep life prediction by the conventional method and Stress Region Analysis Method. The width of the confidence region is narrow with the developed method, showing that its predictive accuracy is high.

Dr. Kimura investigated the mechanism of strength reduction accompanying long-term use under high temperatures, and carried out a study aimed at achieving higher accuracy in long-term creep life prediction methods. He focused on the fact that the mechanism of creep deformation is different in the high stress region and low stress region, leading to the proposal of a “Region Splitting Analysis Method” (Please see NIMS NOW, June/2008.) in which creep life is analyzed in these respective regions. This method has been praised as a technique which enables high accuracy life predictions. As a result, the allowable tensile stress in design standards has been revised to include this method.

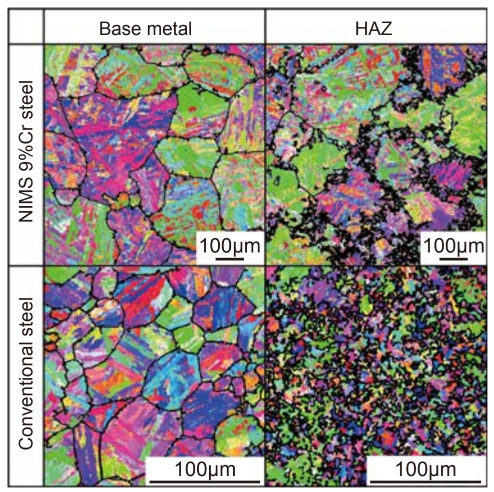
Expressing his strong motivation in this connection, Dr. Kimura said, “The results of research at NIMS, which has continued for many years, are a shared national asset. In the future, we will continue to actively study new techniques such as the Region Splitting Analysis Method.”

Preventing deterioration of creep strength in welds by controlling grain boundaries

Recently it is reported that there are some cases in which creep voids (small cavities) were discovered in the welds of ferritic heat resisting steel in thermal power plants that had been in operation for many years.

When steel is welded, the creep strength of the heat affected zone (HAZ) is deteriorated. This occurs because the grains are refined by the weld thermal cycle. In addition, creep voids are easily formed at grain boundaries due to the effect of multi-axial stress condition in HAZ. This phenomenon is called Type IV damage.

Dr. Tabuchi has been involved in research on the mechanism of Type IV damage at grain boundaries, in which he investigated the microstructures and creep damages in HAZ, and performed a dynamic analysis of creep voids. He found that it is possible to suppress the formation of a refined microstructure by diffusional transformation, by a method in which boron is added to the ferritic heat resistant steel, and simultaneously, the nitrogen content is held to a low level. This makes it possible to suppress deterioration of creep strength in welds. Dr. Tabuchi commented that, “With progressively higher efficiency in thermal power plants, it is becoming even more important to secure the long-term strength of welds. Welds are a key factor contributing to improved reliability in the plant as a whole.” From this viewpoint, materials research plays a large role in supporting stable long-term operation.



Grain boundary structures for HAZ and base metal of the boron-added NIMS 9%Cr steel and conventional steel.
(In the boron-added NIMS 9%Cr steel, grains are not refined in HAZ.)

Evaluation of the Degradation Behavior of Magnesium Alloy in the Body

Metallic Biomaterial Group,
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Graduate School of Dentistry, Tohoku University[†††]

Akiko Yamamoto,Yoko Shirai[†],Toshiji Mukai[††],Yoshihide Shimizu[†††]

Metallic materials have been used in bone fixation devices, stents,[*1] and similar medical devices which become unnecessary after the tissue surrounding the implant has healed. Therefore, it is desirable for these devices to be biodegradable in order to eliminate for the secondary surgery to remove them. However, only ceramic and polymeric materials are developed as biodegradable materials so far, which are inadequate to substitute metallic materials because of their insufficient mechanical properties..

In recent years, magnesium (Mg) and its alloys are highly expected to be used as biodegradable metallic materials, because Mg is an essential element in the body and it is decomposed by reaction with water. Nevertheless, the degradation behavior and mechanism of Mg and its alloys in the body had not been elucidated, and very little data of their biocompatibility is available. Therefore, we implanted pure Mg and the WE43 alloy[*2] in the area near a rat tibia (shinbone) and investigated its degradation behavior.

Figure 1 shows examples of micro X-ray CT images of the pure Mg specimen on 1st and 56th after implantation. A cavity was observed around the specimen on Day 1, which seems to be formed by hydrogen generated accompanying the degradation of the Mg exceeding its diffusion rate into the blood. **Figure 2** shows the transition in the volume of the cavity obtained from micro X-ray CT images and the residual amount of the specimen (residual ratio). In the case of pure Mg, the volume of the cavity was the largest on Day 1 and decreased thereafter. On the other hand, in the case of WE43 alloy, the volume of the cavity on Day 1 was smaller than that of pure Mg, but over time, it became virtually the same as that of pure Mg. However, in the both case, the cavity had disappeared by Day 56. On Day 56, the residual ratio of the pure Mg specimen was smaller than that of the WE43 alloy, showing that the larger degradation rate of pure Mg. These results revealed that the degradation behavior of Mg alloys in the body differs with the kind of alloy. Furthermore, the results of the implantation test showed a good correlation with the results of an immersion test in a simulated body fluid performed previously at NIMS, demonstrating that it is also possible to estimate biodegradation behavior in the body from *in-vitro* tests.

Based on these results, the authors plan to conduct research to further clarify the biodegradable behavior and biocompatibility of Mg alloys in the body. At the same time, we will also conduct research and development on Mg alloys for medical applications in order to optimize their mechanical properties and biodegradation rate.

*1 Stent: A tube-shaped medical device made of a metal mesh. Stents are inserted inside tubular organs such as blood vessels and the biliary ducts and used to expand constricted parts.

*2 WE43 alloy: A Mg alloy containing 4 wt% of yttrium and 3 wt% of rare earth elements. Because the rare earth elements have difficulty on their separation, these elements are used in a mixture.

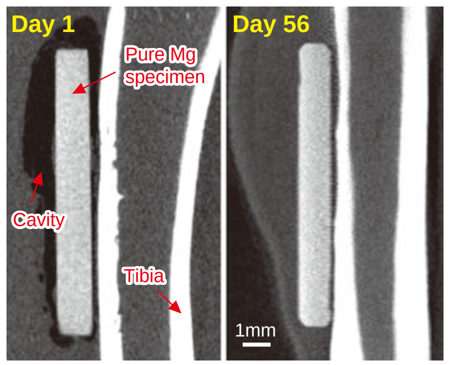


Fig.1 Examples of micro X-ray CT images of pure Mg specimen on 1st day and 56th day after implantation in rats. On Day 1, a cavity was observed around the specimen due to hydrogen gas generated by degradation of the specimen. However, by Day 56, the cavity had disappeared. The shape of the tibia is different because the images were taken from different rats.

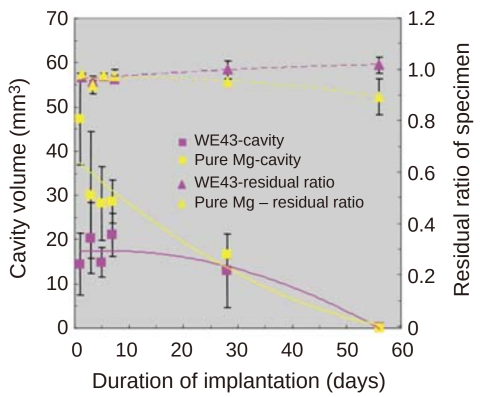
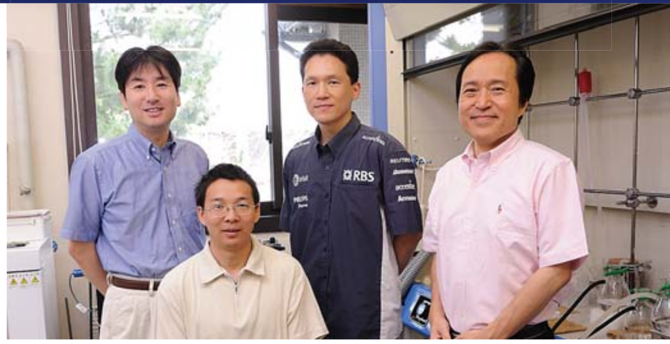


Fig.2 Cavity volume and residual metal ratio obtained from the micro X-ray CT images in the *in-vivo* implantation test. The cavities formed in the initial period of implantation gradually decreased and had disappeared by Day 56. The residual ratio of WE43 is slightly larger than 1.0 on Day 56, because it includes corrosion products formed on the specimen surface.

Ultra-High Speed Filtration of Organic Molecules Realized by Nano Membrane



Functional Thin Films Group,
Organic Nanomaterials Center
First-Principles Simulation Group 1,
Computational Materials Science Center[†]

Managing Director Managing Director
Izumi Ichinose, Xinsheng Peng, Yoshimichi Nakamura[†], Takahisa Ohno[†]

The permeation rate of liquids through porous membranes increases in inverse proportion to the thickness of the membrane. In other words, if the thickness of a membrane can be reduced by half, the permeation rate (flux) per unit of surface area and unit of time will double, resulting in savings in the time and energy necessary in separation. For example, ultrafiltration (UF) membranes which are capable of removing bacteria and viruses are generally polymer membranes with holes 2-200 nm in size, and their thickness is normally several 10 μm. If this membrane thickness can be reduced to several 10 nm, high speed, high capacity treatment should become possible. The problem is that this kind of ultrathin membrane must possess the mechanical strength to withstand a large flux. Creating a tough porous ultrathin film with the strength to withstand a large pressure differential is no simple task.

We discovered that a high strength nano membrane comparable to strong, tough polymer membranes of nylon and similar substances can be manufactured if a protein called ferritin is used. In addition to enabling high speed permeation of water, this membrane blocks water-soluble organic dye molecules. When the developed membrane was compared with commercially-available UF membranes (and nanofiltration membranes), it was found that filtration can be performed at a rate approximately 1000 times faster with organic molecules having a width of 1.5 nm or larger.

The developed membrane has a uniform thickness in the range of 30-100 nm and is a freestanding membrane which can be picked up with tweezers. It has a densely packed structure (**Fig. 1**) formed by mutual chemical bonding of ferritin, which is spherical in shape and has a diameter of 12 nm. The interior of the membrane contains numerous crevices through which water and small organic molecules can permeate at high speed. On the other hand, large organic molecules cannot pass through the narrow flow path (2.2 nm or less in diameter) formed by 3 ferritin molecules in the overall flow channel. The fact that this kind of water flow path is formed in the interior of the membrane was also confirmed by scanning electron microscope (SEM) observation of the cross section of the nano membrane (**Fig. 2**). The permeation rate of water through a nano membrane with a thickness of 60 nm reaches 9000 L/h·m²·bar. When calculated from this value using a fluid dynamics model, the effective thickness of the membrane was estimated at 5.8 nm or less. Moreover, it can be conjectured that water is affected by large viscous resistance only when passing through the narrow flow paths between three ferritin molecules.

Because harmful substances such as viruses can be removed from water if a nano membrane of this type is used, it is considered an extremely promising filtration membrane for water purification and medical applications. This achievement will contribute to the development of water treatment membranes and separation systems with good energy efficiency.

*This research was reported in the Nature Nanotechnology. (X. Peng, J. Jin, Y. Nakamura, T. Ohno and I. Ichinose, Ultrafast permeation of water through protein-based membranes, Nature Nanotechnology, 4 (6), 353-357 (2009)). A portion of this research was carried out as a JST-CREST Research Project "Macroscopic Properties of Liquids in Interfacial Nanopores" (Research Representative: Izumi Ichinose).

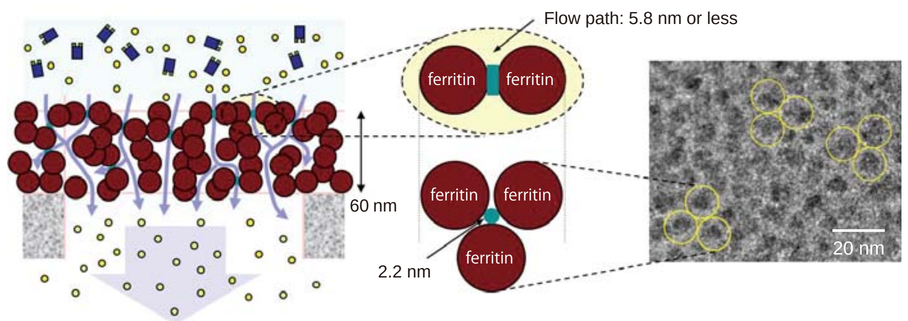


Fig.1 Nano membrane composed of ferritin and its structure. The membrane blocks molecules with a width larger than 1.5 nm.

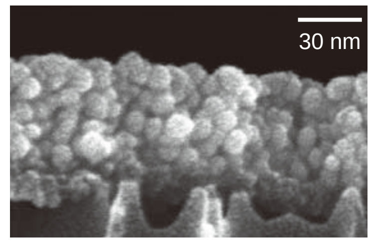
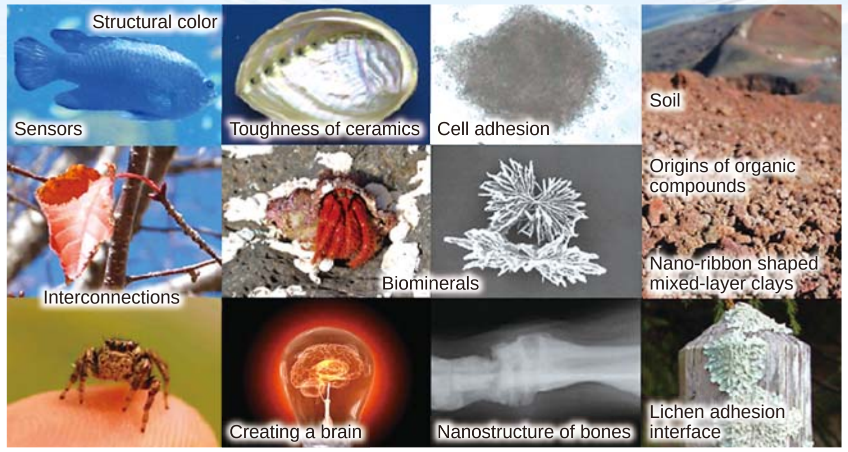


Fig.2 Scanning electron microscope (SEM) image of the cross section of the nano membrane.

Learning from Nature

Living organisms have realized superb high efficiency microstructures that enable energy conservation by creating substances with low environmental loads by processes which are free of waste. We believe that these processes hold important hints for nanotechnology and can lead to breakthroughs in the development of low environmental load technologies.



Outline of the research topics being studied by Cluster members

The theme of this Cluster is “Learning from Nature.” The Cluster was launched in September 2008 with the objectives of probing the foundations of these natural processes and pioneering a new materials science through a network of researchers in different fields. At present, 13 researchers are involved in work in this Cluster. Among other activities, the Cluster is engaged in collaboration aiming at a fusion with the agricultural field and holds workshops with eminent scientists from around the world.

◆ Research Topics ◆

Development of novel strain sensor using structural color

The vivid color of Morpho butterflies and jewel beetles is called structural color and originates in the periodical structure of the body surface. The cobalt blue of tropical fish, blue damselfish, is one of the structural colors. In addition, the blue dameselfish can change its structural color by controlling the periodical structure of body surface.

Creation of high toughness materials

The mother-of-pearl layer of the abalone shell is 95% calcium carbonate by volume, but in spite of this composition, several thousand times the energy of ordinary calcium carbonate is necessary to destroy it. The aim is to develop novel lightweight, high reliability materials by elucidating the mechanism of high toughness in this shell, which possesses a combination of strength and toughness.

Low temperature synthesis of ceramics

The aim in this area is to synthesize nanostructured ceramics at low temperature by a solution process, mimicking the creation of inorganic matter such as shells and bones by living organism. Cluster researchers are also investigating special microstructures such as hierarchical structures using fish scales.

Development of reversible adhesion technology

Flies, spiders, leaf beetles and lizards have the ability to attach and detach easily to the trunks and leaves of trees and even flat window glass. On the other hand, deciduous trees possess a superb circulation system, in which they spontaneously shed their leaves and recycle them as nutrition. The aim is to develop technologies which enable easy attachment/detachment by researching these kinds of natural mechanisms.

Creating a brain

In order to transfer the sophisticated information processing functions in a neural network to a different material system, we are exploring nanoscale measurements of molecular and ionic signal transfer through living neurons. A paradigm shift in a computer architecture is expected as a result of research on “creating a brain”.

Creating artificial bone by biological process

Bone has a nanostructure in which inorganic apatite nanocrystals and organic collagen molecules are regularly aligned with each other. This nanostructure is produced by bone forming cells by control of the surrounding conditions and supply of raw materials. The aim in this research area is to reproduce this kind of excellent nanostructure in living bodies by mimicking these conditions.

Intercellular adhesive

In the pancreas and liver, information is exchanged between cells by a bonding of pairs of cells by the intercellular adhesive proteins called cadherins (calcium dependent adhesion molecules). The aim of this research is to develop an intercellular adhesive which temporarily joins transplanted cells, and then is eliminated after cadherin forms.

Development of materials with novel functions

We are focusing on an ordinary substance which exists in abundance at the earth’s surface, namely, the layered clay minerals. The aim is to create ultra-low environmental load materials, materials for safety, security, and comfort, hybrid materials, and high performance materials using morphology control technologies and hybridization control technologies which mimic, technologize, and utilize the mechanisms geologically (geomimicry).

DDS contribute to future medical techniques in more than just a transporter

Tokyo University **Prof.Kazunori Kataoka**
Dep. of Materials Engineering, Graduate School of Engineering

For more than 30 years, Prof. Kazunori Kataoka—the third NIMS Award recipient—has been engaged in research into the use of polymeric nanomaterials to deliver drugs to target sites within the body. Today, drug delivery systems (DDS) are being developed for applications beyond therapeutic drug delivery; examples include vectors to deliver genes or probes. And five types of cancer therapy are currently undergoing clinical testing. On the occasion of NIMS Award, he talks about the history and the future of DDS.

What prompted you to start researching drug transport using polymers?

My initial motivation came in the late 1970s around the time of my doctoral studies, when my teacher, who was one of the leaders of polymer synthesis, suggested me that polymer materials had the potential for medical applications. At that time, the only medical applications where polymers were used were artificial organs, materials biocompatible with blood, or antithrombotic materials. This marked the start of my research in this area. The term DDS was already known, I also realized that blood clots might be less likely to form if we combine PEG (polyethylene glycol) on cell surface. When I read a paper that wrote "Combining PEG onto a protein reduces antigenicity and enables long-term presence in the blood", It led me to think that a drug attached to a PEG-polyamino acid copolymer and formed into micellar structures might not be recognized as foreign and so could remain in the blood for long periods. I therefore shifted my focus to DDS research.

Was it difficult for a materials researcher to move into the medical field?

At the medical engineering research facilities of Tokyo Women's Medical College, which I had been in and out of since my graduate student days, the researchers and graduate students came from engineering (chemistry, materials, mechanical, electrical), pharmacy, and medicine backgrounds and were working towards the development of artificial organs, DDS, or antithrombotic devices. The facilities were truly interdisciplinary, and stimulating. When people from different backgrounds work together on research, you get a situation where one plus one can equal three or even four. It is really important to have structures in place to facilitate good collaboration when engaged in cutting-edge research. The field of nanotechnology is very much an interdisciplinary platform.

What is the recent development in this field of research?

DDS are not simply carriers that are used, for example, to introduce substances into tissues to change intracellular transfer pathways or to detect intracellular pH and change in form. Therefore, they have recently been described as "nanodevices." Our initial objective was to use polymer micelles to deliver anticancer drugs in a targeted fashion, thereby reducing side effects. However, we soon thought of using electrostatic interactions to insert a DNA electrolyte into polyion complex micelles and, by the mid-1990s, had realized that this could be used to transport genes instead of viral vectors. Moreover, DDS could also be used as a diagnostic if we inserted a probe.

What are the prospects for the future?

There are many possibilities. We are using the phenomenon of increased capillary permeability to concentrate DDS-delivered drugs at cancer sites, but maybe we can design other systems to allow drugs to pass through. Another possibility is to develop "theranostics" that combine both diagnostic and therapeutic components. They would work by checking whether the drug had been delivered to the target site and whether it was effective. Small interfering RNAs (siRNAs) and microRNAs (miRNAs) have been discovered recently. They cannot pass through cell membranes, but we might be able to develop them into drugs if we could identify vectors to effectively transport these nucleic acids. Yet another possibility is to develop a method to selectively attack cancer stem cells. Also, if we can be creative about transport methods, we may be able to re-visit some developmental drugs that were discontinued because of strong side effects. The advantage with polymers is the ability to build multifunctionality into a single molecule. I want to learn from nature to develop polymers with even greater functionality.

Do you have a message for young researchers?

They say that the hardest part of any mountain climb is when you are 80% of the way to the top. With research as well, it is important to focus on your goal and stick it out to the end. There is no need to think of basic and applied research as separate things. It is necessary to make an image-training of thinking about application even when you are in the process of making something of fundamental importance.

FACE フェイス interview

The NIMS Creep Data Sheet Project has accumulated creep data on high temperature materials for many years, and the reliability of these data are highly regarded internationally. Hideko Miyazaki of the Materials Data Sheet Station, who operates the thermocouples used in creep tests, recently received the Prize for Creativity of the Minister of Education, Culture, Sports, Science and Technology (MEXT) for "Improvement of the operating system of R-type thermocouples used in temperature measurements." We asked Ms. Mizayaki how she operates such a huge number of thermocouples on a daily basis, and what particular efforts she is making in this connection.

Hideko Miyazaki
Senior Engineer, Materials Data Sheet Station

Strict temperature control in creep tests is the result of steady work and accumulated innovations.

First, could you explain the thermocouples used in creep tests?

Creep tests are performed to investigate the rate of deformation of materials over extremely long periods. The test conditions are limited to only two factors, temperature and stress. Strict temperature control is indispensable for improving the accuracy of tests over long periods exceeding 100,000 hours. A temperature sensor called an R-type thermocouple is used in temperature control in creep tests. In this type of thermocouple, a platinum wire and platinum-rhodium alloy wire are cut to lengths of about 1 meter, the tips of the wires are welded together, and the resulting thermocouple is covered with an insulating tube and vinyl tube. When the tip of this thermocouple is placed in direct contact with the test specimen, a thermo-electromotive force is generated in the thermocouple by the temperature difference with a reference temperature junction. The test temperature is measured electrically from this value.

A thermocouple card is prepared for each thermocouple, and the every history of the thermocouple is recorded in detail from the beginning. In repairs after a test, the oxides on the surface are removed by performing conductive annealing for 15 minutes. The tip which was in contact with the specimen is then cut, the wires are rewelded, and the insulating tube is set on the thermocouple.

After this, the thermocouple is calibrated using, as a standard, a reference thermocouple which is traceable to the national standard. Because the electromotive force of a thermocouple will decrease due to gradual deterioration if the thermocouple is used for a long period of time, thermocouples are calibrated before use in a creep test in order to confirm their thermo-electromotive force.

How have you improved the operation of thermocouples?

The most important improvement was to ensure repair and calibration process after every test. Then, it became possible to guarantee that quality is always the same as good as new. Efficiency in repairing this enormous number of thermocouples has also improved. The materials which are cut off during repairs are collected and recast, but this recycling could also be extended by approximately three times compared with the past. As a result of improvements of these, it is possible to secure traceability to the national standard even with repeated use, and it has become possible to maintain strict control of the test temperature.

At a glance, a thermocouple without a cover and identification number is simply a wire. Therefore, care is necessary in order to avoid mistakes during repairs. Calibrations must also be performed in individual units. This work is time-consuming, as only 8 thermocouples can be calibrated in one day. Nevertheless, this work cannot be omitted. The rules requiring that a temperature equilibrium must be maintained for one hour after a thermocouple is inserted into the calibration furnace, and at least 30 minutes must be spent in extracting the thermocouple, are strictly observed so as to maintain calibration quality.

In your routine duties, when do you feel that your work is particularly rewarding?

When I calibrate a thermocouple after repair and obtain virtually the same value for electromotive force, I always feel anew that the thermocouple is a wonderful temperature sensor. I'm also happy when we've maintained strict temperature control and get a good creep curve.

NIMS has established stricter standards for temperature control in its creep tests than those specified in the JIS standard. Our engineers must carefully watch several hundred creep test machines every day, without rest, but precisely for this reason, the creep data sheets issued by NIMS have an extremely high reputation, not only in Japan but also in the international scientific community. In fact, we still have a large amount of valuable data that has not been published, which I hope that many researchers will be able to use in the future.

Do you have any advice for young researchers and engineers?

In my job, I repeat the same work every day. At a glance, this might not seem exciting, but continuing work properly in the specified manner contributes to outstanding research results. Change the things that require improvement, and respect those that should be respected. That's the "power of continuity."

NIMS NEWS

The 3rd World Materials Research Institute Forum

(Jun. 21-25, 2009) The 3rd World Materials Research Institute Forum (WMRIF) was held at National Institute of Standards and Technology (NIST) in Washington D.C., USA. The aim of this meeting, which is held every 2 years, was to hold a "summit conference" of the heads of the world's leading materials research institutes and provide a useful platform for realizing more efficient research and development by sharing the problems which research institutes face in operations and planning. The 1st WMRIF was held in Tsukuba, Japan in 2005, hosted by NIMS, and was followed by the 2nd meeting in Berlin in 2007, which was hosted by Germany's Federal Institute for Materials Research and Testing (BAM: Bundesanstalt für Materialforschung und -prüfung).

The 3rd WMRIF participants

The next WMRIF is to be held in China in 2011 at the Institute of Metal Research (IMR), and will be hosted by the Chinese Academy of Sciences (CAS).

Prof. Kyoji Tachikawa, NIMS' Distinguished Emeritus Scientist receives the "ICMC Lifetime Achievement Award"

(Jun. 28-Jul.2, 2009) NIMS' Distinguished Emeritus Scientist, Professor Kyoji Tachikawa was recently awarded the "ICMC Lifetime Achievement Award" for 2009 by the International Cryogenic Materials Conference (ICMC).

The award was given in recognition of Prof. Tachikawa's achievements of a lifetime in advancing knowledge of cryogenic and superconducting materials. The Award Ceremony was held as part of the International Cryogenic Engineering Conference and International Cryogenic Materials Conference (ICEC/ICMC) in Arizona, United States from June 28 to July 2.

Prof. K. Tachikawa at the awarding ceremony

Prof. Tachikawa joined National Research Institute for Metals (NRIM:one of NIMS predecessors) in 1962 then served as Head of the Processing Research Section and Director of the Tsukuba Laboratories. He has been involved in research on superconducting materials, and accomplished a large number of outstanding research achievements, beginning with the development of the bronze process, which became a practical method of producing wire materials of Nb_3Sn, and has also trained many younger scientists. Prof. Tachikawa is one of the scientists who laid the foundation for research on superconducting materials at NIMS.

NIMS WEEK 2009

(Jul. 21-24, 2009) NIMS WEEK 2009 was held recently over a four day period at the Tsukuba International Congress Center, Tsukuba Epochal, on the theme of "Nanobio-materials and technologies for breakthrough in future medicine."

NIMS President Ushioda (left) and Dr. K. Kataoka at the NIMS Award ceremony

As part of the event, the NIMS Award 2009 was presented to Prof. Kazunori Kataoka of the University of Tokyo, School of Engineering, Department of Materials Engineering, for "Development of Functional Nanodevices for Drug and Gene Delivery." This drug delivery system, which carries drugs to targeted cells in the body by binding the drugs to macromolecule, has already demonstrated excellent effectiveness in the treatment of cancer, and clinical trials are in progress (see Special Interview).

Materials research based on the fusion of nano and bio-technologies requires a multi-disciplinary team including specialists in biology, medicine, chemistry, physics, electronics, materials engineering, etc.

At NIMS Week 2009, we are confident to successfully provide a wealth of opportunities for attendees to exchange views and ideas with reserachers in other fileds as well as to discover starting points of new joint research.

The 6th Japan-UK-US Nanotechnology Students' Summer School

Participants at CNSI, UCLA

(Jul.27–Jul.31,2009) The 6th NIMS/MANA – Nanoscience@Cambridge – UCLA/CNSI Nanotechnology Students' Summer School was held at the University of California, Los Angeles (UCLA). The participants, included 10 students from Nanosystem Institute (CNSI), UCLA , 9 students from Cambridge Nanoscience Center, the University of Cambridge, 9 students from NIMS, presented the results of their own recent research.

Last year, UCLA/CNSI joined the summer school program, marking the full-scale start of a three-institution school. The participating students not only deepened their knowledge of advanced nanotechnology, but also experienced the cultures of the United Kingdom and United States and deepened their friendships with the young scientists from those countries through the science program, a 3-way beach volleyball tournament and a festival hosted by the UCLA students. The 7th summer school in this series is planned to be held at the Cambridge Nanoscience Center at the University of Cambridge next summer.

The 1st US NIMS Venture "NIMBUS Technologies LLC"

NIMS has certified NIMBUS Technologies LLC (Seattle, U.S.) as a NIMS authorized venture.

In order to develop businesses in the United States utilizing the results of research, an American company, NIMBUS Technologies LLC, was established in June, 2009 by NIMS Fellow, Dr. Kenji Kitamura and CEO, Mr. David Bowes. The head office of the company is located in the Kennedy Building, #101, 4348 9th Ave. NE, Seattle, WA.

NIMBUS will be mainly responsible for commercializing medical infrared light sources and terahertz light sources which are being developed jointly by NIMS, the University of Washington, and the Pacific Northwest National Laboratory (PNNL).

Kennedy Bldg, Seattle

NIMS new partnerships

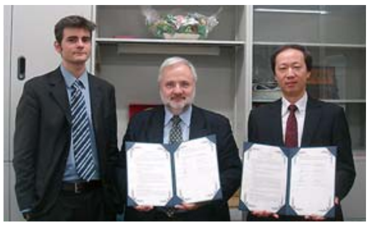
Belgorod State University, Russia

(July 23, 2009) The NIMS Structural Materials Center concluded a memorandum of understanding (MOU) for research collaboration with the Centre of Nanostructural Materials and Nanotechnologies of Belgorod State University in Russia. The joint research under the MOU will focus on "Nanostructural Control of Metallic Structural Materials." Actual research activities are already underway as joint research (April 2009 to March 2011) with Russia under a bilateral exchange project sponsored by the Japan Society for the Promotion of Science (JSPS).

From left: Senior Researcher, Dr. Yuuji Kimura, Managing Director, Dr. Kaneaki Tsuzaki, and Dr. Andrey Belyakov from Beogorod State Univ.

The Institute for Bioengineering of Catalonia (IBEC), Spain

(July 24, 2009) The NIMS Biomaterials Center and the Institute for Bioengineering of Catalonia (IBEC), which is located in Barcelona, Spain, recently signed a memorandum of understanding (MOU) on "Research and development of biomaterial surface technology and biosensors for cell function control and diagnosis." The IBEC was established by the government of Catalonia, the University of Barcelona, and the Polytechnic University of Cataloni. In the future, the two centers plan to positively promote exchanges of human resources and information, and will cooperate in research and development of materials for regenerative medicine and sensor materials.



From left: Dr. Abel Riera, Managing Director, IBEC, Dr. Josep A. Planell, Director, IBEC, and Dr. Yuji Miyahara, Managing Director.

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