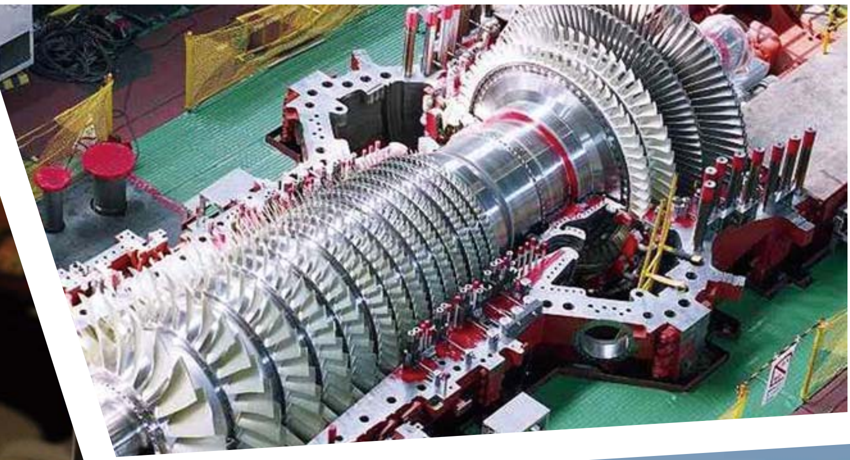
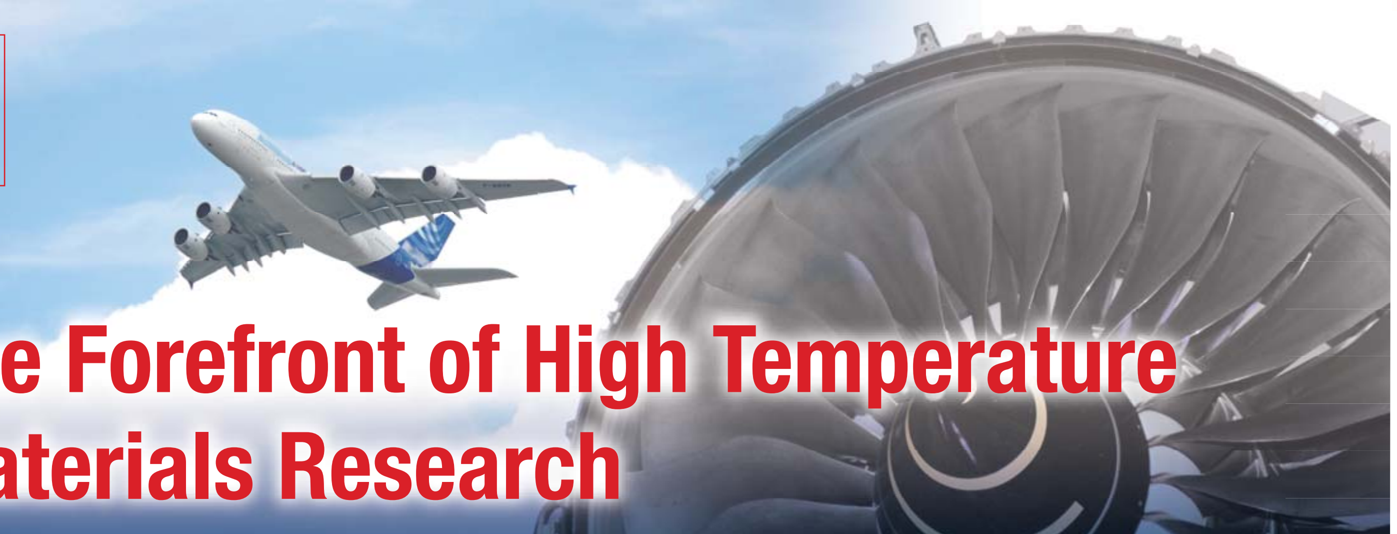
NIMS NOW International

2009. October

NIMS superalloys for cutting CO_2 emissions

Directional solidification furnace for single crystal casting





Special Feature

The Forefront of High Temperature Materials Research

The Japanese government announced that it will reduce its greenhouse gas emissions by 25% from the 1990 level by 2020 as a medium-term goal. One of the promising approaches to achieving this is to improve the efficiency of thermal power generation. For aeroengines, reducing fuel consumption is an important issue. The key to improving thermal efficiency as a solution to these issues is high temperature material technology that can produce materials with an excellent temperature capabilities.

NIMS superalloys that can help reduce CO_2 emissions

Hiroshi Harada
Managing Director, High Temperature Materials Center
(Director, The Rolls-Royce Centre of Excellence for Aerospace Materials)

Developing a superalloy that helps reduce CO_2 emissions from thermal power generation

One-third of the CO_2 gas emission in Japan is generated by thermal power plants. Thermal power generation is classified into coal fired power generation, oil fired power generation, and natural gas fired combined-cycle power generation, depending on the fuel used. However, there is a great difference in the amount of CO_2 emission per unit of power among these three systems; 1, 0.76, 0.53, respectively (Fig. 1). That is, CO_2 can be significantly reduced if coal fired power generation is replaced with natural gas fired combined-cycle power generation. The dissemination of renewable energy that can be harnessed from nature has just begun, and electric vehicles also require a supply of electric power. To stop the increase of, and even reduce, CO_2 emissions within the next ten years, shifting from coal fired power generation to natural gas fired combined-cycle power generation is a realistic approach, and probably the most effective one.

If the inlet gas temperature of gas turbines currently used for natural gas combined-cycle power generation (popular type: 1,100 to 1,300°C, thermal efficiency: 43 to 48% (HHV standard); latest type: 1,500°C, thermal efficiency: 52%) is raised to 1,700°C, thermal efficiency can increase to 56 to 60% (Fig. 2), resulting in a further reduction in CO_2 emissions as a consequence of less fuel being consumed. If an existing 1,250,000 to 1,350,000-kW class coal fired power plant is shifted to such an ultra efficient natural gas fired combined-cycle power generation, the CO_2 emission from a single power plant can be reduced by about 0.4% of the total emissions in Japan. This means there will be a 4 to 8% reduction if 10 to 20 power plants are switched. If this technology can be disseminated in overseas countries, where the efficiency of power generation is lower, great emissions trading benefits may be obtained.

High Temperature Materials Center has developed fifth-generation single crystal superalloys with world's highest temperature capability of 1100°C, new coating materials, and next-generation wrought superalloys for turbine disks. The center is also working with private companies to promote research into the practical use of these high temperature materials for 1,700°C ultra-efficient gas turbine combined-cycle power generation and high-efficiency cogeneration by combining them with the latest turbine cooling and other technologies. Besides, these developed superalloys are expected to help realize new power generation technologies, such as high-efficiency coal gasification combined-cycle power generation, a fuel whose deposits will last for 150 years (natural gas deposits will last for 60 years) and medium- and small-size high-temperature gas reactors (safer reactors), and improve their efficiency.

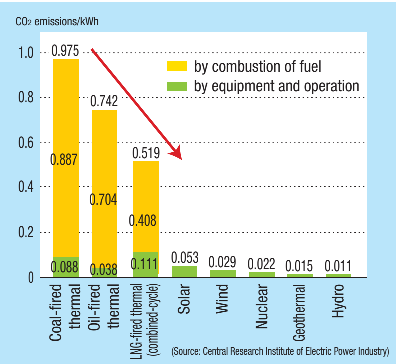


Fig. 1 CO_2 emissions by electric power source

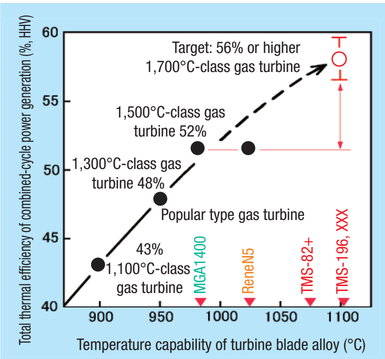


Fig. 2 Relationship between the temperature capability of superalloys and natural gas fired combined-cycle power generation efficiency

Research into practical use in jet engines

On the other hand, the CO_2 emission from airplanes, which is estimated to amount to 1 to 2% of Japan's total emissions, may rise to 5% or so depending on the future increase in demand. It is, therefore, very important to reduce CO_2 emissions by increasing the thermal efficiency of jet engines, and expectations for high temperature material technology capable of fulfilling these requirements are growing accordingly. The Rolls-Royce Centre of Excellence for Aerospace Materials, established in NIMS in 2006, is promoting joint research to put this technology to practical use. High Temperature Materials Center is also cooperating with the jet engine manufacturer. Jet engine technology was a field in which Japan was, and still is, lagging behind overseas countries in the postwar era. From the viewpoint of recovering the status of the domestic aeroengine industry, high temperature materials, which put Japan ahead of the rest of the world, are attracting great attention.

Materials development

Single crystal superalloy - World's highest temperature capability

Kyoko Kawagishi
(Associate Director, The Rolls-Royce Centre of Excellence for Aerospace Materials)
Toshiharu Kobayashi

Ni-base superalloys have a coherent structure consisting of two phases with close lattice parameters: a γ phase (fcc structure), which is a Ni solid solution; and a γ' phase ($L1_2$ structure), which is a Ni_3Al intermetallic compound (Fig. 1). Ni-base superalloys are designed as high temperature resistant alloy with precipitation hardening of the γ' phase, and are used for high-pressure turbine components in gas turbines that will be subjected to more than 1,000°C.

Ni-base cast superalloys have been used as gas-turbine blade materials, have the moderate strength among alloys. With the progress of the manufacturing process from conventional casting to directional solidification in which the grain boundary is parallel to the tensile axis, and to single crystal solidification without grain boundaries, superalloys have contributed to less grain boundary slip deformation or fracture at high temperature, and have improved high-temperature strength (Fig. 2). The temperature capability of single crystal superalloys increases with more addition of refractory elements such as W, Ta, and Re. For example, a typical alloy has the temperature capability of about 1,040°C (the temperature at which the alloy can withstand 1,000 hours of creep under a stress of 137 MPa).

We are the world's first group succeeded in developing single crystal superalloys having temperature capability higher than 1,100°C with our original alloy design program. The alloy, developed by our original alloy design, has larger lattice misfit of the γ and γ' phases by adding elements and finer interfacial dislocation network (Fig. 3). If the optimized amount of refractory elements such as Mo, Re, and Ru, having relatively large lattice parameter, are added to a Ni-base superalloy, these elements can partitioned more to the γ phase. Consequently, they replace with Ni in the γ phase, and the lattice parameter of the γ phase increases compared with that of the γ' phase. As the misfit between the two phases increases, the interface between them becomes strained, and the cubic γ' precipitate transforms into a plate-like structure, called a raft structure, during high temperature creep. The dislocation networks are mutually constrained in the interface between the γ and γ' phases to reduce the strain, and they finally become an interfacial dislocation network. The finer interfacial dislocation network works as a barrier for dislocation movement, and results in the prevention of deformation. [Zhang, et al., Acta Mater. 53 (2005), 4623]

We are now working for the further development of the new alloys, which have higher temperature capability aiming to 1,150°C, with better fatigue properties and oxidation resistance. [Kawagishi, et al., Mar. Sci, Tech, 25 (2009), 271]

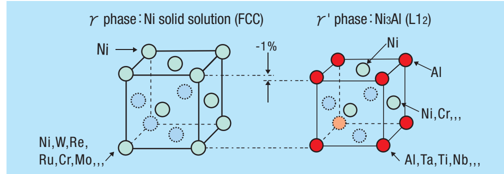


Fig. 1 Structures of γ and γ' phases

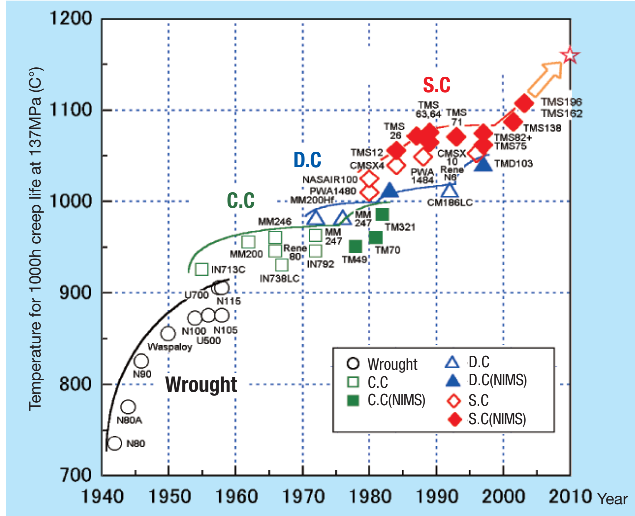


Fig. 2 Improving high-temperature capability of Ni-base superalloys

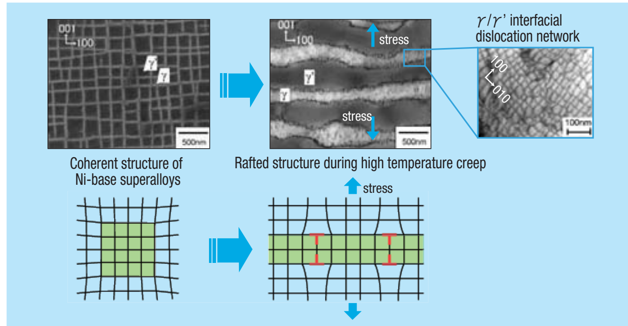


Fig. 3 Dislocation network on interface between γ and γ' phases

EQ coating - Both improved oxidation resistance and reduced interdiffusion

Kyoko Kawagishi
(Associate Director, The Rolls-Royce Centre of Excellence for Aerospace Materials)
Kazuhide Matsumoto

The most effective way to improve the efficiency of a gas turbine is to increase the inlet gas temperature of the turbine. One of the most important keys to this is the development of a thermal barrier coating (TBC) in addition to increasing the temperature capability of Ni-base superalloys. The basic structure of TBC has two layers — a ceramic top coat with low thermal conductivity, and a bond coat intended to prevent the substrate from oxidizing (Fig. 1).

Metallic coating containing much Al previously used as a bond coat causes mutual diffusion with the Ni-base superalloy substrate at high temperatures. A layer of precipitate, called a secondary reaction zone (SRZ), is formed in the interface between the bond coat and the substrate, which reduces the strength of the substrate.

Since improving oxidation resistance is the main purpose of bond

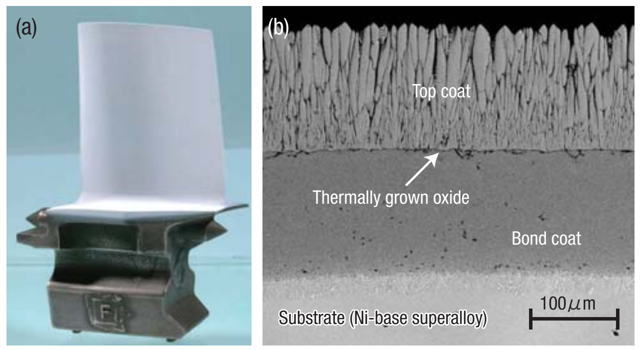
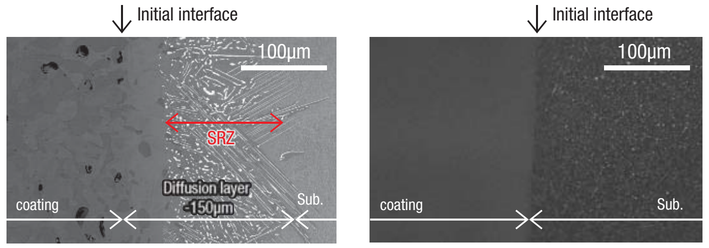


Fig.1 (a) Turbine blade with thermal barrier coating
(b) Cross-section of coating layers

coat, the problem of diffusion in the interface has been left unsolved.

High Temperatare Materials Center developed EQ coating (EQuilibrium coating), which uses a material in thermodynamic equilibrium with the substrate, as a new concept of fundamentally resolving this problem. [Kawagishi, et al., JOM (2008), 31] This epoch-making process is capable of reducing diffusion while maintaining oxidation resistance because the driving force of diffusion becomes zero by making the chemical potentials of the substrate and the coating material equal. Fig. 2 (a) shows a cross-section of a substrate and a conventional bond coat after they were maintained at 1,100°C for 300 hours. An SRZ consisting of plate-like precipitates is formed. On the other hand, the EQ coating shown in Fig. 2 (b) shows a much thinner diffusion layer even under the same condition and does not form any precipitates in the interface, so that the substrate does not lose its mechanical strength. We are also committed to research into a top coating process using electron beam - physical vapor deposition (EB-PVD), a equipment we originally designed. We are looking for optimum materials that have low thermal conductivity, high thermal expansion coefficient, excellent high temperature resistance, and high spalling resistance.

We developed a burner rig (Fig. 3) in order to evaluate the environmental resistance characteristics of coating materials and Ni-base superalloys. This device is capable of performing high-temperature oxidation and corrosion tests in combustion gas and controlling the corrosive atmosphere, enabling us to conduct tests under conditions that are closer to actual environments. We will develop a coating system that has higher durability while carrying out these evaluations.



(a) Conventional NiCrAl coating (b) EQ coating

Fig. 2 Cross-section of substrate bond coat interface after 1,100°C for 300 hours exposure.

Fig. 3 Specimens being tested at 900°C in combustion gas

Development of high-performance cast-and-wrought Ni-Co-base superalloys for turbine disks

Yuefeng Gu
Tadaharu Yokokawa

To improve the performance of jet engines, the heat resistance of turbine disk besides turbine blade must be improved because turbine disk is a component holding turbine blade. The materials for turbine disk are normally in wrought condition because of high requirements for mechanical properties mainly including of fracture toughness, creep and fatigue resistance.

Fig. 1 shows the history of the temperature capability development of turbine disk materials. Normally, heat resistance has been improved by adding alloy elements with solid solution strengthening or by increasing the volume fraction of γ'. U720Li is the alloy with the highest heat resistance and can be processed by conventional cast-and-wrought (C&W). The alloys with higher temperature capability than that of U720Li were normally processed by powder metallurgy (P/M) process route. The P/M process, however, is expensive because of high requirement for powder cleanliness and following thermal processes.

Recently, we developed a new kind of C&W Ni-Co-base alloy (TMW alloy) with the innovative concept of combining the characters of two kinds of γ−γ' two-phase alloys, Ni-base and Co-base superalloys (Fig. 2). The results from 50-kg ingots indicate that TMW alloys show excellent strength and forge-ability, and provide 50°C temperature advantage in 0.2%-strain creep performance over alloy U720Li, which may match with the materials processed by P/M route.

To put alloys into real practical applications, we try to manufacture the full-size pancakes with TMW alloys. By cooperating with Mitsubishi Materials Corporation in a NEDO project, we succeeded in making practical-scale pancakes (Fig. 3, with diameter of 440 mm and grain size of 10 μm) from TMW alloys by selecting suitable parameters for melting and forging. The evaluations of mechanical property of the pancakes indicate that TMW alloys provide 58 to 76°C temperature advantage in 0.2%- strain creep performance over alloy U720Li, which is higher than all existing C&W disk materials, and even equivalent with the latest P/M disk alloys (Fig. 4). [Gu, et al., Met. Mat. Trams. A, accepted for publication]

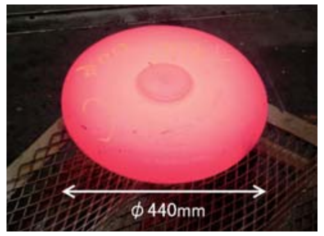


Fig. 3 Forged pancake manufactured through C&W process for real components (440mm dia.).

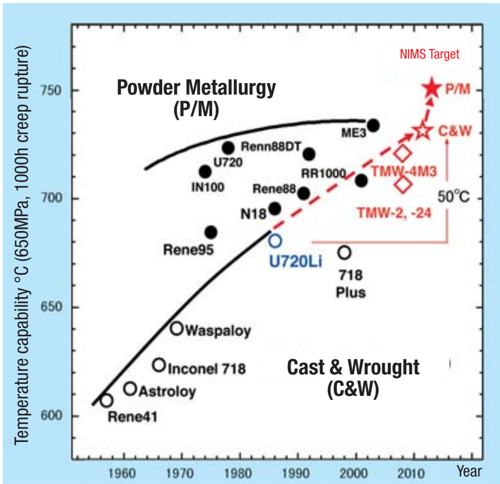


Fig. 1 Improvement in temperature capability of disk alloys.

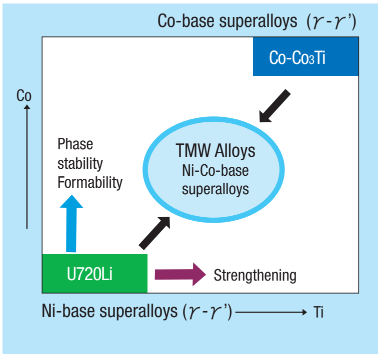


Fig. 2 Design concept of Ni-Co base superalloys.

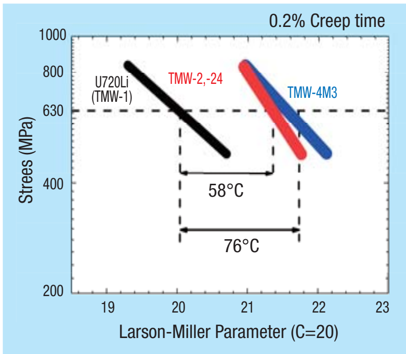


Fig. 4 TMW alloys have the world highest temperature capability in C&W alloys.

Design and analysis - High-accuracy alloy design program

Tadaharu Yokokawa
Dehai Ping
Michinari Yuyama

To design and develop the multi-component Ni-base superalloys efficiently, we have analyzed the behavior of alloy elements and microstructural evolutions at high temperature using electron probe X-ray microanalyzer (EPMA), 3D atom probe field ion microscope (3D APFIM), and other instruments. The basic data of alloy design parameters and theoretical simulations have been obtained. Also, the strengthing factors and failure mechanisms of the materials have been clarified.

Fig. 1 shows the partitioning ratios of the alloy elements derived from a chemical composition analysis of γ and γ' phases using EPMA. In general, the sizes of the γ and γ' phases of Ni-base superalloys are as small as 0.1 to 0.3 μm and, therefore, it is difficult to accurately analyze their chemical compositions. However, we can quantitatively identify the partitioning behaviors as well as temperature dependences for each elements, by strain aging on specimens and coarsening process of γ and γ' phases. [Yokokawa, et al., Scripta Mater, 49 (2003), 1041] In addition, we constructed the alloy design program (ADP) that capable of modeling the relationship among the chemical composition, microstructural and mechanical properties of an alloy such as lattice misfit, creep properties, and so on. ADP can precisely predict the creep rupture life under arbitral conditions of chemical composition, temperature and applied stress. It is playing a great contribution to the domestic and international collaboration research.

Fig. 2 shows the result of microstructural analysis of Inconel 718 by using a 3D APFIM. Inconel 718 is a precipitation-hardening Ni-Fe-base alloy consisting of γ (Ni), γ' (Ni_3Al) and γ" (Ni_3Nb), which can be used for high-pressure compressor blades, and so on. This was the first atomic level analysis for the microstructural evolution of compressor blades that have been used for tens of thousand of hours. It shows that γ' and γ" have formed a multi-layer structure of γ'-γ". This is in good agreement with the first-principles simulation result that this state is energy stable. [Geng, et al., Physicai Rev. B, 76 (2007), 224102]

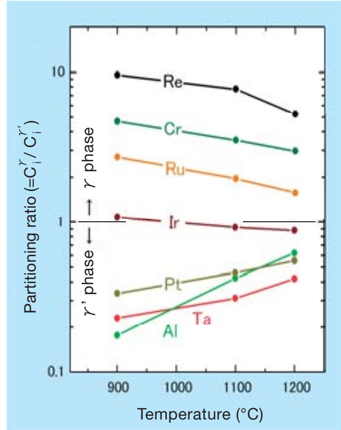


Fig. 1 Partitioning ratios of alloy elements into γ and γ' phases of Ni-base superalloys.

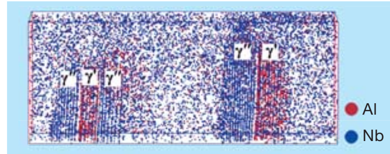


Fig. 2 Result of microstructural analysis of Inconel 718 by using 3D APFIM.

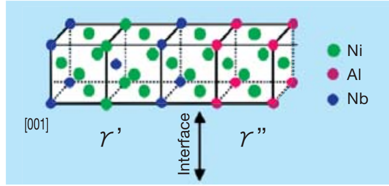


Fig. 3 Crystal structure model for γ'-γ" interface of Inconel 718 alloy.

Simulation Development of a virtual gas turbine

Tomonori Kitashima
Masafumi Fukuda
Tadaharu Yokokawa

The High Temperature Materials Center has achieved successful results in predicting the microstructures and mechanical properties of the superalloys using empirical formulae based on database, i.e. the so-called Alloy Design Program. We are currently developing a more theoretical approach using the phase field method that can predict the temporal evolution of microstructure morphology and its equilibrium state. The conventional phase field approaches have been used only for binary and ternary systems and consequently have made little contribution to the design of practical multicomponent superalloys. Our developed approach is capable of predicting microstructure changes of up to 8-element superalloys. Fig. 1 shows the simulated concentration distributions of Al and Re in the initial stage of γ' precipitation in the 8-element practical Ni-base superalloy TMS-75. This is the first time in the world that such a simulation predicts the change of microstructure morphology during the γ' precipitation in an 8-element system at the practical level, and it is expected to be a powerful tool for designing and developing superalloys. [Kitashima, et al., Acta Mater, 57 (2009), 2020]

We are also developing a virtual jet engine program (Fig. 2) integrating system and multi-scale material characteristics. In this program, damage states of components in gas turbines, are monitored to avoid a possible aircraft engine failure. In addition, the program also can simulate the engine performance, such as the propulsion efficiency and CO_2 emission rate. The virtual jet engine performs aerodynamic cooling and structural analysis calculations, while interacting with calculations of microstructure evolution and deformation in the engine components under the service conditions of jet engines. This is the first time in the world that calculations by both material and system simulations have been integrated. By 'running' the virtual jet engine, the effect of newly developed superalloys can be evaluated, which makes new alloys to be introduced into practical use more quickly.

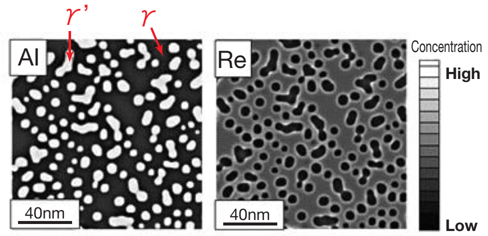


Fig. 1 Results of a simulation of the concentration distributions of Al and Re, and W in the initial stage of precipitation of the γ' phase in the 8-element practical Ni-based superalloy TMS-75.

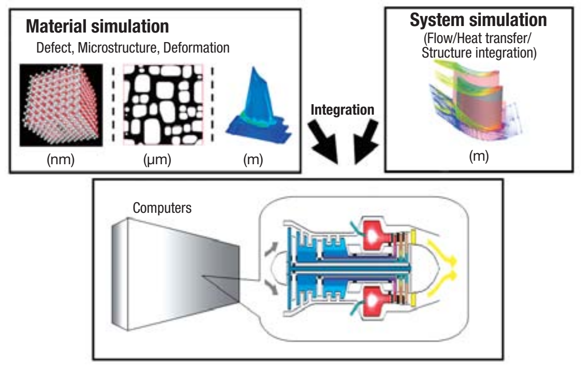


Fig. 2 Concept of a virtual jet engine integrating materials and system simulations.

Research for practical use

Efforts to put high temperature materials into practical use

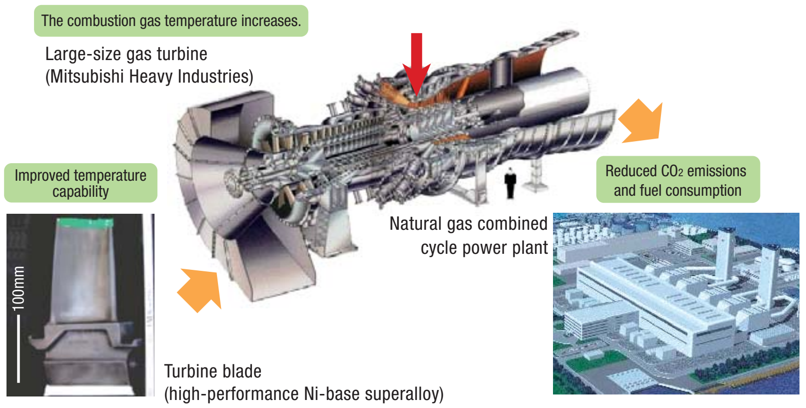
Junzo Fujioka
Yutaka Koizumi
Masao Sakamoto
Toshimitsu Tetsui

High Temperature Materials Center have developed to date Ni-base single crystal superalloys and Ni-Co-base wrought superalloys which have the highest temperature capability in the world. We are working with private companies to promote the practical use of these achievements in order to apply them to industrial gas turbines and aeroengines, drastically improve their working temperatures, and make a great contribution to reducing CO_2 emissions and fuel consumption.

1 Joint research into materials for 1,700°C power generation gas turbine with Mitsubishi Heavy Industries, Ltd.

At present, the highest turbine inlet temperature of a natural gas combined cycle power plant is 1,500°C, and its thermal efficiency is 52% (HHV standard). However, if this temperature is raised to 1,700°C, the thermal efficiency will increase to 56 to 60%. It is estimated that the total CO_2 emissions of Japan will decrease by about 4% if half of the existing coal fired power plants are replaced with such natural gas combined power plants with a thermal efficiency of 56%. The key to realizing a 1,700°C large-size gas turbine is technology that can make the turbine blades withstand a higher temperature. The High Temperature Materials Center and Mitsubishi Heavy Industries, Ltd. jointly developed a single crystal alloy characterized by its excellent creep strength and thermal fatigue strength, achievable at a lower cost than the currently available alloys, and made prototypes of blades for actual turbines. We are continuing research and development to put this alloy into practical use around 2015.

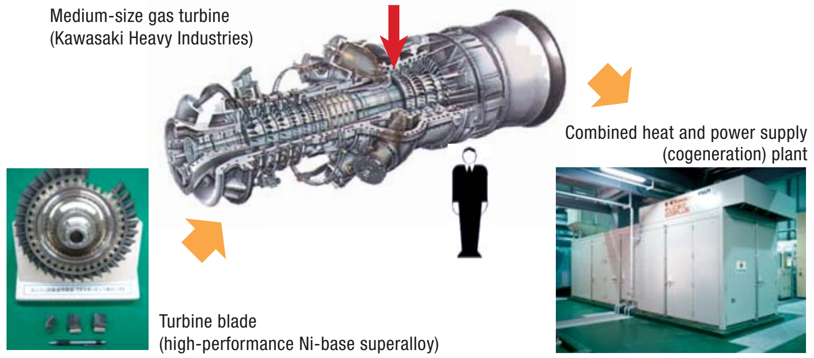
■ Research into practical use of high-performance Ni-base single crystal alloy for large-size gas turbine blades for natural gas combined cycle power generation



2 Joint research into material for medium- and small-size power generation gas turbines with Kawasaki Heavy Industries, Ltd.

An increasing number of plants, office buildings, hotels, hospitals, and local air conditioning facilities are introducing a cogeneration (combined heat and power) system, which is designed to collect heat from gas turbine emission gas in waste recovery boiler and supply both electric power and heat (steam or hot water). In connection with the medium- and small-size gas turbines used for cogeneration systems, improving the heat resistance of turbine blades is an important issue to increase power generation efficiency and the electric power ratio. An operation test was successfully conducted with turbine blades manufactured from the alloy developed jointly by the High Temperature Materials Center and Kawasaki Heavy Industries and mounted on an actual engine.

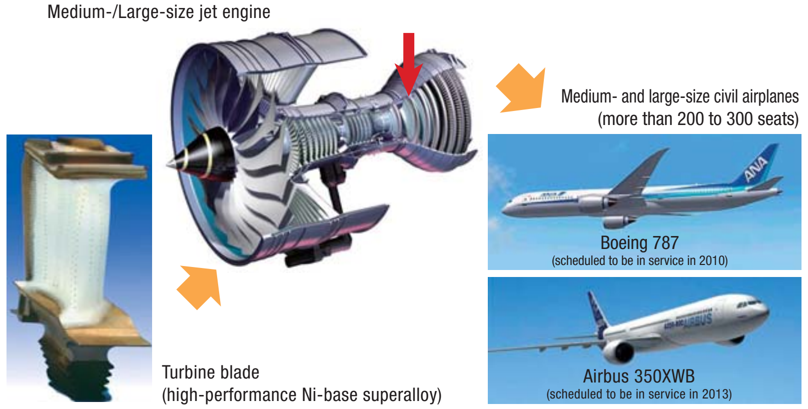
■ Research into practical use of high-performance Ni-base superalloy for medium-size gas turbine blades for cogeneration



3 Joint research into material for large-size aeroengines with Rolls-Royce, plc.

The fuel cost of airlines accounts for about 10% of their total cost and about 30% of their operation expenses. Reducing the specific fuel consumption (SFC) of aeroengines is a very important issue from the viewpoint of reducing CO_2 emissions, preventing global warming, and cutting down on operation expenses. The High Temperature Materials Center is developing with Rolls-Royce (RR) a highly heat-resistant Ni-base single crystal superalloy to be used for the hottest area (turbine blades) of jet engines for large civil airplanes. This development project aims to produce an alloy that has the world's highest temperature capability of 1,150°C, about 100°C higher than the currently used alloys. We are committed to this research to actually use the alloy for RR engines around 2012. RR estimates that raising the temperature capability of turbine blades by 40°C will increase SFC by about 1% and cut down on operating costs of international flight by 1 million US dollars per airplane per year. If this domestically developed material is used for turbine blades which have traditionally used materials developed in overseas countries, it will be an unprecedented accomplishment for Japan.

■ Research into practical use of high-performance Ni-base single crystal alloy for turbine blades of medium- and large-size jet engines for civil airplanes



4 Joint research into material for small-size engines of business jet airplanes with Honda R&D Co., Ltd.

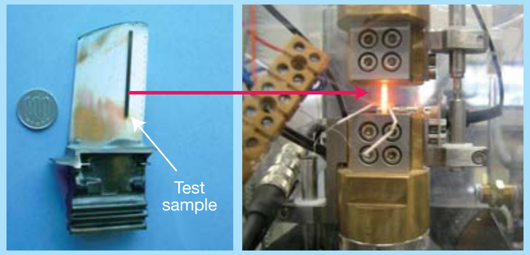
Improving the performance of small-size airplanes, such as business jets whose demand is expected to increase in the future, require an improvement in fuel consumption efficiency and weight reduction by simplifying the engine structure. To this end, the cooling structure around the turbine must be simplified, and the temperature capability of the material is required to be increased. The High Temperature Materials Center and Honda R&D Co., Ltd. are developing a heat-resistant alloy for small-size jet engines.


Honda
HF118 turbofan engine

5 Accident investigation

We are cooperating with the Japan Transport Safety Board of the Ministry of Land, Infrastructure, Transport and Tourism to investigate the causes of airplane engine accidents from a neutral standpoint and preventing the same type of accidents. Besides, in terms of material development, we are investigating the material deterioration and damage mechanism of the high temperature and high-pressure components such as turbine blades and actually used in airlines, and using the obtained data to develop more reliable alloys.

The photo on the right shows an example of evaluation conducted on a damaged turbine blade. A test sample almost the size of a matchstick (1 × 2 × 40 mm HWL) is taken from turbine blade actually used in airlines and subjected to a mechanical test at high temperature (about 1,000°C) to evaluate the deterioration or damage to the material. ▶



Turbine blade
Compact type high temperature testing machine

We succeeded in developing a new alloy that is intended to apply to 1,700°C-class gas turbines.

Chief Researcher,
Materials & Strength Laboratory,
Takasago Research & Development Center
Technical Headquarters,
Mitsubishi Heavy Industries, Ltd.
Ikuo Okada

Since 2004, we have been working to develop element technology for 1,700°C-class high-efficiency gas turbines as a national project. Improving the heat resistance of turbine blades is one of the most important issues to deal with, and this requires the development and application of an excellent Ni-base single crystal alloy. We have been receiving the full guidance and support of researchers of the High Temperature Materials Center, NIMS, which is one of the leading authorities, in this field. We finally succeeded in developing a new alloy combining outstanding high temperature characteristics, such as high creep rupture strength. The development of each element technology is steadily progressing. We expect that our new alloy will help realize high-efficiency combined power generation at 1,700°C, reduce CO_2 emissions, and consequently help to resolve global environment problems.

"Engine full of dreams" created by high temperature materials

Senior Manager,
Development Group,
Aircraft Engine R & D Center
Honda R & D Co., Ltd.
Yoshihiko Wajima

Nowadays, hybrid vehicles are gaining popularity in the automobile industry, and, as such, environmental performance is rapidly drawing wide attention. This is the case with the world of aircraft engines, and expectations for reduced fuel consumption and emissions are growing year by year. The key to high performance to fulfill these expectations is the evolution of materials. The evolution of materials for turbines, which can directly improve the performance of engines, in particular, is the focus of attention, and the research group of the High Temperature Materials Center, NIMS, has played the leading role in the development of these materials and succeeded in developing attractive materials. As the responsibility of an engine manufacturer, we will cooperate closer with the center to create "engines full of dreams" that exceed the industry's expectations and put NIMS materials, the core of such engines, into practical use.

Patent licenses

Shoichiro Mori

The High Temperature Materials Center is promoting the practical use of NIMS high temperature materials in a wide range of fields by granting many private companies license of patents. We applied for 13 domestic patents and 13 overseas patents for single crystal alloys, disk alloys, and coating materials from 2004 through 2008.

Fig. 1 and 2 show the number of patents we were granted and patent royalties received from 2004 through August 2009. The constant increase in the number of granted patents reflects the strong interest in these materials of many jet engine and gas turbine manufactures and alloy manufacturers. The recent rapid increase in the patent royalties received shown in Fig. 2, indicating that developed materials are being shifted from the stage of prototyping to the stage of practical use. So, patent royalties are expected to further increase.

These situations show that NIMS high temperature materials are attracting much attention as promising technical solutions to the issues of CO_2 emissions and rising fuel costs through the improvement of energy efficiency. These materials are expected to be put into practical use in a wider range of fields in the future.

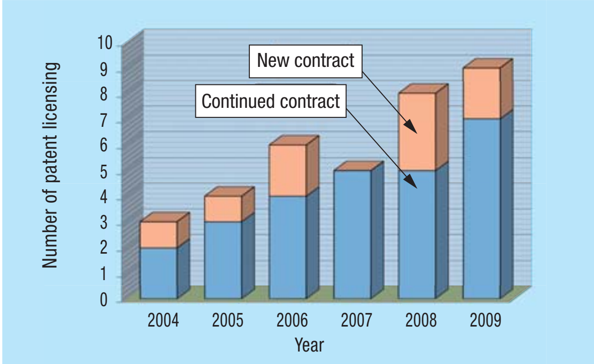


Fig. 1 Change in number of granted patent licensing

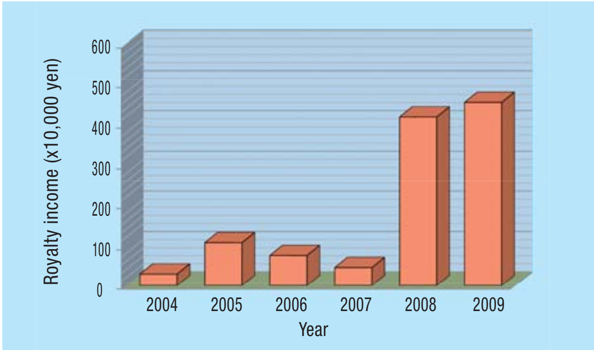


Fig. 2 Change in royalty income

Staff at the High Temperature Materials Center

FACE フェイス interview

NIMS' research on high temperature materials is well-known as among the world's most advanced, as NIMS researchers have succeeded in developing superalloys with the world highest temperature capabilities exceeding 1100°C. The day when the very first flight by a new type of aircraft using the superalloy developed at NIMS in its engines is just around the corner. We asked the Managing Director of the High Temperature Materials Center, Dr. Hiroshi Harada, about the future possibilities of ultra-high temperature materials.

Original Ideas Create Next-Generation Ultra-High Temperature Materials

Hiroshi Harada

Managing Director, High Temperature Materials Center

Director, The Rolls-Royce Centre of Excellence for Aerospace Materials

Please explain the current work of the High Temperature Materials Center.

The research of the High Temperature Materials Center can be broadly divided into two types. One is basic research, which aims at improvement of the temperature capability of materials by controlling their composition and microstructure. The second is practical research, which we are carrying out in cooperation with engine makers and others in order to ensure that the materials which we develop are actually used. Many of the superalloys which are currently targeted for practical application have already reached the stage where use in turbine blades and disks for gas turbines and jet engines will be possible by around 2015. For example, the thermal efficiency of natural gas-fired thermal power plants can be greatly improved by using superalloys with higher inlet gas temperatures. As a result, it is generally thought that CO_2 emissions can be reduced to less than half the level of coal-fired thermal power plants. This was once a dream, but it is steadily becoming a reality.

What is important for the development of new materials?

The Center is endeavoring to propose original ideas and novel concepts. As the temperature capability of superalloys increases, fresh ideas which are different from those of the past are also necessary. Our strength is that everyone can produce the next idea, and we also have the total capabilities to realize those ideas.

It had been thought that the temperature capability of single crystal nickel-base superalloys can be increased if the lattice constants of pairs of crystals, γ phase and γ' phase, are matched. However, in actuality, we discovered that the temperature capability decreases if the lattice constants are too close to each other. We tried imparting a difference of about 0.5% to the lattice constants and found that this produces an appropriate level of stress between the crystals, causing self-induced changes in the morphology of the microstructure which strengthen the material. As a result, we succeeded in developing a new superalloy with the world's highest temperature capability. Proposing and demonstrating new ideas that can change existing concepts is one of the great pleasures of research. Because this alloy also has the potential to make a useful contribution to society by reducing CO_2 emissions, this is very challenging work.

For the future, there is an idea of using high melting point materials other than nickel as the base metal in order to dramatically increase the service temperature. The development of a material that can be used as-is without cooling at the inlet gas temperature of 1700°C in high efficiency power-generating gas turbines and jet engines might well win the Nobel Prize!

In research, is there anything difficult or hard work in particular?

In power-generating gas turbines and jet engines, the turbine blades and turbine disks are key parts which are subjected to the highest temperatures and stress. Therefore, in research aiming at practical application, it is indispensible to investigate a variety of properties, including high temperature creep, fatigue, oxidation, and corrosion. These kinds of structural components using superalloys must have all-round performance at an extremely high level.

Development requires time, and teamwork and patience are essential. To improve teamwork, it is advisable to set large, easy-to-understand targets that everyone can share. In Japanese baseball, the national high school championship is the ultimate goal, and in our field, the target is to create a true Japanese engine. NIMS is currently engaged in research collaboration with Rolls-Royce. It is hoped that this will lead to the development of a 100% Japanese-made civil jet engine in the near future.

Do you have any advice for young researchers?

Superalloys. When I had just joined the National Research Institute for Metals (NRIM, one of the predecessors of NIMS), I was fascinated by smart-sounding names containing the word "SUPER" and by the beauty of microstructures. Then, I immediately fell in love with superalloys. Even though that was more than 30 years ago, my feelings have never changed. I believe that my colleagues also share these feelings and we love it so much, therefore, we have been able to work patiently in this field.

There are also booms in materials research, which seem to come and go with a cycle of several years to around 10 years. But there's no need to follow fads. Discover the work that you really should do and devote yourself to it, then you'll find and feel a following wind. I guess thinking that way would be alright. With high level of interest in CO_2 reduction and energy problems in recent years, I feel that, after a long interval, a following wind is now blowing in favor of the superalloys and us.

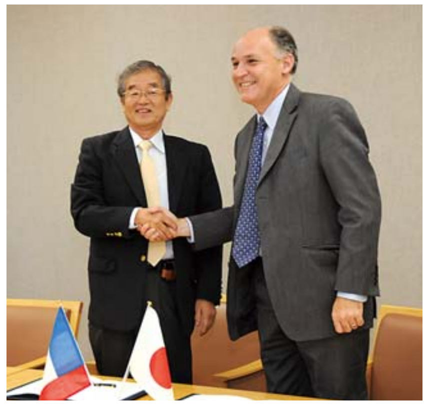
Dr. Sophonpanich of Thailand's Minister of Science and Technology (MOST) Visits NIMS

Dr. Sophonpanich (left) and Dr.Fujioka at High Temperature Materials Center

(Oct. 7, 2009) A Thai delegation of 20 persons headed by the country's Minister of Science and Technology, Dr. Khunying Kalaya Sophonpanich, visited NIMS. Dr. Sophonpanich showed keen interest in NIMS' efforts on materials research and its many achievements since becoming an Independent Administrative Institution (IAI), asked how NIMS made such remarkable progress at the meeting with Prof. Sukekatsu Ushioda, President of NIMS, and Senior Advisor Masaki Kitagawa.

Dr. Sophonpanich toured High Temperature Materials Center, which is engaged in the development of ultra-heat resistant alloys such as single crystal alloys for turbine blades in gas turbines for electric power generation and jet engines for aircraft. NIMS is a world leader in the development of these high temperature materials, which are making an important contribution to CO_2 reduction and improved fuel consumption. Dr. Sophonpanich congratulated the Center on hearing that the NIMS single crystal material, which is the result of joint research with Rolls-Royce, is scheduled for use in jet engines, and also asked with great interest what other foreign countries are developing single crystal alloys.

Establishment of NIMS/Saint-Gobain Center of Excellence for Advanced Materials



Prof. Sukekatsu Ushioda, President of NIMS, and Mr. Pierre-Andre de Chalendar, CEO of the Saint-Gobain Group (right), shaking hands at the signing ceremony.

(Oct. 2, 2009) NIMS and France's Saint-Gobain Group signed a memorandum of understanding (MOU) for the establishment of the "NIMS/Saint-Gobain Center of Excellence for Advanced Materials". The signing ceremony was held at NIMS' Sengen site on October 2, 2009. Mr. Pierre-Andre de Chalendar, Chief Executive Officer (CEO) of the Saint-Gobain Group, and Dr. Sukekatsu Ushioda, President of NIMS, attended the ceremony and shared their mutual pleasure on the deepening of their relationship and expansion of their ties through joint research collaboration.

Saint-Gobain's Vice-President of R&D and Innovation, Dr. Didier Roux, and Dr. Yukichi Umakoshi, Vice-President of NIMS, signed another collaboration research agreement in the field of thin oxide films, which follows an agreement on combinatorial materials signed in November of last year.

The new Center will manage these research projects and will explore future mutual research projects. These new projects will target material technologies for more comfortable and energy efficient homes and buildings. It will also coordinate joint seminars, workshops and research exchanges between Japan and other Saint-Gobain research centers around the world.

The NIMS/Saint-Gobain Center of Excellence for Advanced Materials is NIMS's third collaborative organization with a leading private-sector company, following the Rolls-Royce Centre of Excellence for Aerospace Materials and the NIMS-Toyota Materials Center of Excellence for Sustainable Mobility.

Prof. Lindqvist, Director of the Nobel Museum, Visits NIMS

Prof. Lindqvist (right) listening to an explanation of nanotubes by Dr. Dmitri Golberg, a MANA Principal Investigator

(Oct. 2, 2009) A mission headed by Prof. Svante Lindqvist, Museum Director of the Nobel Museum and President of the Royal Swedish Academy of Sciences, visited the NIMS' World Premier International Research Center for Materials Nanoarchitectonics (MANA). After a general explanation of MANA by MANA's Chief Operating Officer, Prof. Yoshio Bando, the group toured the respective facilities in the fields of nanobiotechnology, nanomaterials, and nanosystems, and showed deep interest in the explanations of their work by the MANA researchers.

In the afternoon of the same day, Prof. Lindqvist spoke about "Why is there no Nobel Prize for technology and engineering?" at the Tsukuba International Congress Center, hosted by the Science Academy of Tsukuba and co-hosted by NIMS and others. At the question-and-answer session following his lecture, Prof. Lindqvist gave thoughtful replies to the numerous questions and opinions on the content of his talk with Dr. Leona Ezaki, who is a Nobel Laureate and currently President of the Science Academy.

NIMS NEWS

NIMS New Partnerships

METU, Turkey

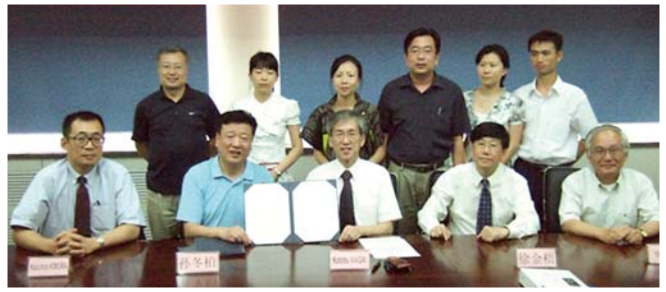
(from left) Dr. Kakisawa, NIMS Senior Researcher, Prof. Dursunkaya, Prof. Kagawa, NIMS Managing Director, Prof. Ozturk, Prof. Dericioglu.

(Jun. 22, Ankara) The Hybrid Materials Center signed a Memorandum of Understanding (MOU) on research cooperation with the Department of Metallurgical and Materials Engineering, Middle East Technical University (METU),Turkey. METU is founded in 1956 to contribute to the development of Turkey and Middle East countries, located at Ankara.

The signing ceremony was held at METU, and the two sides agreed with 5-years research cooperation aimed at the development of high performance hybrid composites, and plan to promote joint research and exchange of researchers and information.

The both expect much research achievements from their collaboraton by this agreement.

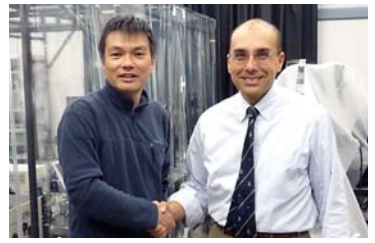
USTB-NCMS , Beijing



(front row, from left) Dr. Kimura, NIMS Station Leader, Dr. DongBai Sun, USTB Vice President, Dr.Nagai, NIMS-iSM Manager, Dr. JunWu Xu, USTB President

(Jul. 11, 2009) The NIMS International Cluster for Structural Materials (NIMS-iSM) and China's National Center for Materials Science, University of Science & Technology Beijing (USTB-NCMS) signed an MOU for "Cooperation in Basic Research on the Microstructure and Mechanical Properties of Structural Materials." USTB-NCMS is now in the process of constructing a large-scale National Center for evaluation of structural stability in China, and intends to study medium-and long-term collaboration in basic research linking structures and materials under specific topics such as creep, corrosion, fatigue, databases, and others by cooperating in basic research on material reliability, which is an area in which NIMS has a long history of impressive achievements. The Chinese side displayed strong interest in the signing ceremony, which was held at USTB with the University's President Xu in attendance.

University of Padua, Italy



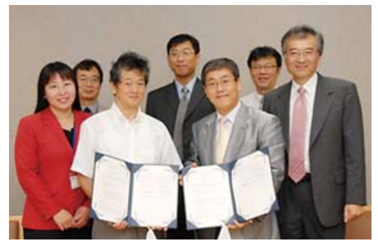
Prof. Giovanni Mattei of the University of Padua (right) and NIMS Senior Researcher, Dr. Yoshihiko Takeda

(Sep. 1, 2009) The Department of Physics, University of Padua and the Quantum Beam Center signed a Memorandum of Understanding on research and development of functional optical nanomaterials by advanced ion beam technology.

The University of Padua is the second oldest university in Italy, founded in 1222, and is where many great scientists such as Galileo Galilei and Nicolaus Copernicus taught or studied.

This collaborative research proposal had been discussed since the two met at an international meeting (IBMM 2008) in Germany last September. The institutions will start to exchange researchers and information to promote their research.

Hanyang University, Korea



(Center two) Dr. Halada, NIMS Managing Director and Prof. YoungDo Kim, Dean of Hanyang Univeristy

(Sep. 4, 2009) The NIMS Exploratory Materials Research Laboratories for Reliability and Safety and the Department of Materials Science and Engineering, Hanyang University, which is located in Seoul, Korea, signed a memorandum of understanding (MOU) on "Development of Intelligent Materials Systems". The Department of Materials Science and Engineering at Hanyang University is a leading Korean institution in materials research and has attained outstanding achievements in the fields of thin film technology, carbon nanotube related materials, functional metal oxides, and nanoparticle systems.

In the future, the two institutions plan to promote academic exchanges of both personnel and information, and will cooperate in the research and development of materials including new composite nano-materials and new applications. This cooperative venture will also exploit the intellectual and equipment resources of both institutions more effectively.

NIMS Group Leader Wins the Experimental Feynman Prize for 2009

(Oct. 5, 2009) The Foresight Institute in the United States selected Dr. Oscar Custance of NIMS' Advanced Nano Characterization Center, together with Designated Lecturer Yoshiaki Sugimoto and Associate Professor Masayuki Abe, both of the Osaka University's Graduate School of Engineering Science, as the winners of the Foresight Institute Experimental Feynman Prize in Nanotechnology for 2009.

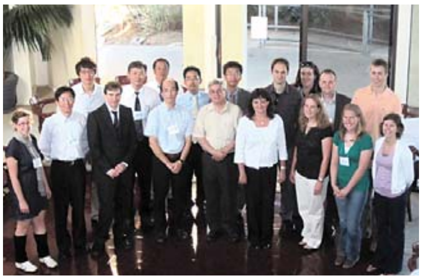
(from left) Dr. Yoshiaki Sugimoto, Dr. Masayuki Abe and Dr. Oscar Custance

This award recognized their works in developing techniques for the manipulation and chemical identification of individual atoms at surfaces of semiconductors using atomic force microscopy at room temperature.

Although a number of the world's most distinguished researchers have won the Foresight Institute Feynman Prize in the past, this year award is the first one given to scientists at research institutions in Asia. The award ceremony is scheduled to be held in California (USA) in January of next year.

The 1st NIMS-UCSB Workshop at UCSB

(Aug. 25-26, 2009) The NIMS-UCSB First Annual Workshop was held recently at the University of California, Santa Barbara. A total of 8 persons from NIMS participated, including Dr. Yutaka Kagawa, Coordinating Director of the NIMS Materials Research for Reliability and Safety Field. Seven researchers from UCSB participated, along with one researcher from a private company and one from another university. Lectures topics included hybrid materials, heat resistant metal materials, new measurement technologies, and non-destructive evaluation, and the presentations were followed by lively discussions. This workshop provided an opportunity for the participants to gain a better understanding of the research work of their counterparts. Beginning with the 2nd Workshop, which is scheduled to be held during the next year, concrete research topics will be selected and most appropriate methods of promoting joint research will be discussed, with the aim of carrying out joint research which takes full advantage of the strengths of the two sides.



All participants at UCSB

Hello from NIMS

This past summer, I was very privileged to have the opportunity to intern at NIMS. Before going to Japan, I had never travelled on my own to another country, and the fact that I was able to work at a renowned research institute on my first independent foreign excursion was simply amazing.

While at NIMS, I worked in the 1D Nanomaterials Group under the exceptional direction of Dr. Jie Tang, Dr. Jun Ma, and Dr. Han Zhang. More specifically, I performed research on coating carbon nanotube fibers with insulating polymers - PMMA and polyphenol, in particular - by dip - coating and electropolymerization. Brought to the frontier of scientific research and with an immense wealth of resources available to me, I gained a great deal of invaluable knowledge and hands-on experience at NIMS.

Perhaps what left the greatest impression on me, however, was my experience meeting numerous people from around the world. NIMS truly embodies the ideal spirit of scientific research a community spirit that is a culmination not only of researchers' fervor for science, but also of researchers' desire to share their own scientific and cultural knowledge with others. It is for this very reason, I came to realize that NIMS has been able to contribute so much to the scientific world. It is for this very reason that I enjoyed my time at NIMS so very much.

Victoria X. Yu (USA)
1-D Nanomaterials Group
Exploratory Research Laboratory
2009/06/16 - 2009/09/10

[In a yukata at the Ninomya House in Summer]

NIMS NOW International 2009.Vol.7 No.8

National Institute for Materials Science

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To subscribe, contact:
Mr. Tomoaki Hyodo, Publisher
Public Relations Office, NIMS
1-2-1 Sengen, Tsukuba, Ibaraki, 305-0047 JAPAN
Phone: +81-29-859-2026, Fax: +81-29-859-2017
Email: inquiry@nims.go.jp