Summary of Proposal

Host institution name	National Institute for Materials Science
Head of host institution	Teruo Kishi
Center director	Masakazu Aono
Administrative director	Takahiro Fujita
Title of center project	International Center for Materials Nanoarchitectonics Project
Center name	International Center for Materials Nanoarchitectonics (MANA)
Project Summary	"Sustainable development" is the biggest issue for the 21st century of humanity. The most probable field of research that Japan can make significant contributions regarding this issue will be materials science. The center project is designed from the viewpoints of the essential importance of materials science and the necessity for an international cooperation in effectively promoting materials science. The purpose of the center is to develop innovative materials that contribute to sustainable development, based on a new technology system for materials development called "nanoarchitectonics", and offer them to the world. For this purpose, a multinational and interdisciplinary group of researchers is organized to conduct cutting-edge research in a relaxed international environment, and making up of total workforce of about 200 staff.
Research fields	**Main research field: Materials science** **Fused other research fields: Chemistry, Physics** Material is a base that supports the foundation of all fields of science and technology and is the area where Japan can best show its abilities. It is self-evident that industries and society of Japan will depend on materials in the 21st century, and it is also obvious that "sustainable development" is not possible without an innovation in materials. Materials science is actually the lifeblood for human beings. For the development of new materials required in the 21st century, the center will work to realize a paradigm shift in materials development through a new technology system for materials development that we call "nanoarchitectonics". Nanoarchitectonics is a technology system to arrange nanoscale functional structural units as a group of atoms or molecules in an intended configuration. The technology system is critical for practical applications of nanotechnology, beyond the stage of nanoscience. Nanoarchitectonics is also a typical interdisciplinary field that relates widely to such fields as materials science, physics, and chemistry.
Research objectives	The development of new materials required in the 21st century can not be realized without a paradigm shift in materials development. The center will realize the paradigm shift through "nanoarchitectonics", which is a new technology system to arrange nanoscale functional structural units as a group of atoms or molecules in an intended configuration. The research objective to be achieved by materials development based on nanoarchitectonics is: **"Development of innovative materials required for the realization of a sustainable society in the 21st century".** To be more specific, we set the following three objectives (issues to be studied intensively are shown as examples). **1) Development of innovative materials related to environment, energy**

	and resource **-** Superconducting materials (superconducting diamond thin film, etc.) **-** Battery materials (materials for solid state rechargeable batteries, etc.) **-** Catalysts (visible light active photocatalyst, etc.) **2) Development of innovative materials for nanoelectronics that lead to innovations in information and communication technology** **-** Quantum information device materials (novel quantum-bit materials, etc.) **-** Atomic electronics materials (materials for novel atomic switches, etc.) **-** Photonic device materials (quasi phase matching element material, etc.) **3) Development of innovative materials that enable the development of new technologies for diagnosis, treatment and renaturation.** - NT chip materials (nanopiller array, etc.) - Biomaterials (regenerative materials, etc.)
Outline of management	The center, as a basic principle, intends to establish the decision-making system that can support strong leadership of the center director, and therefore, it will give him the substantial authority of the center's operation in general. On the other hand, it is an important characteristic concerning managerial operation in the center that the center succeeds and develops the concepts through the International Center for Young Scientists (ICYS) program, which is now on operated by NIMS. Utilizing the experience gained from ICYS, the center will establish a research environment which is likened to a "melting pot", gathering excellent young researchers from various countries. The center aims to stimulate research and bring an innovation to the fundamental and basic field of materials science, respecting as much as possible the free thinking of young researchers, generated by the stimulation in the melting pot environment. The center also utilizes this melting pot environment to foster young researchers, positioning the center as a place to foster young researchers with tenure who will create the future for NIMS.
Researchers and other center staffs	Principal Investigators 27 (foreigners 10) ; Total Researchers 167 (foreigners 84) Total Staff at Core-Center 209 (foreigners 90) All achieved by 2011 Satellite: Univ. Tsukuba, Tokyo Univ. of Science, Cambridge Univ., CNRS, Univ. California (UCLA), Georgia Inst. Tech. Collaboration: Inst. Physics CAS (China), KAIST (Korea), Max Planck Inst., Charles Univ. (Czech), Univ. California (UCSB) etc.
Outline of research environment	We will take the following measures to arrange a research environment in the center: (1) establish an environment where researchers can devote themselves to research, enriching assistance related to various clerical procedures and assistance in experiments. Particularly at the center where half of the researchers come from abroad, we will develop a perfect system to manage the use of English as the official language so that foreign researchers can devote themselves to research without having to deal with a language barrier; (2) provide start-up research funds to researchers invited from external organizations so that they can launch their own laboratories immediately; (3) secure capable young researchers from all over the world by utilizing ICYS' accumulated recruiting know-how. We also secure researchers including graduate students through relationships with the University of Tsukuba, International Joint Graduate Schools and other institutions as well as enrich the content of research education; (5) develop a flexible salary system different from that of NIMS's main body, and establish a flexible compensation package to provide appropriate treatment for excellent researchers; (6) provide total space of approximately 10,000㎡ for the research activities at the center; (7) hold an international research conference once a year, to show that the center is one of the world's top-level centers in the material science field.
Outline of indicators for evaluating a center's global standing	We can cite such indicators as research outputs (number of papers accepted by renowned journals), ratio of researchers that are considered worthy of being named the world's top level researchers, the number of foreign researchers employed, the total amount of external funds obtained, the number of cooperative research projects with private sector corporations, the

	number of patents applied and granted, the conditions of patents exploited, the number of invited lectures, and conditions relating the number of academic society awards received. The ranking of the number of citations of papers in the field of materials science presented by ISI can be a strong indicator to evaluate research institutions, although it is not absolute. NIMS, of the host institution, now ranks 12th in the world for the number of citations of papers over the past 10 years in the materials science field; however, if taken statistics for the past 5 years, we rank 6th in the world, which obviously shows that the research activities in NIMS became remarkably active after it changed its organizational system to that of an independent administrative institution. We set the final goal to be the top-three of the world ranking (No. 1 in Japan) at the time of the ex-post evaluation, to get higher than the current rank, by leading the main body of NIMS, carrying out these objectives at the center in a radically accelerated manner. The rank order can be deemed sufficient to position NIMS as the world's top material research institute.
Securing research funding	It would be of particular note that we have acquired an average of one billion yen every year for the past 3 years as the total amount of external funds that were obtained for research by those researchers who are the principal investigators of the center. It is also worth of mentioning that we have allocated a total average of approximately 800 million yen to those researchers from operational subsidies. Both of these facts verify that we have reasonable direct costs to conduct world's top-level research. In 2007, we also succeeded in obtaining external funds from other MEXT projects, and therefore we believe we can keep the current level of average funds obtained, or it may exceed the current level.
Summary of host institution's commitment	The center in this concept has two aspects: (1) an advanced research implementation agency to conduct fundamental and basic research for materials, fusing fields with chemistry and physics, (2) an institution to foster researchers who create the future for material research, in an international and interdisciplinary atmosphere. Looking from the viewpoint of NIMS's main body, the center is expected to play two roles: to strongly lead NIMS in research and to provide NIMS with young researchers. Therefore, the center is definitely incorporated into the long-term strategies of NIMS's main body, and the activities are extremely effective for stimulating the whole of NIMS. For these reasons, we are willing to make efforts for the center's smooth operation to the fullest, including, for example, offering of human resources, allocation of research funds, supply of research space and transfer of administration authority to the center director.

Research Center Project

Host institution name	National Institute for Materials Science
Head of host institution	Teruo Kishi, President
Title of center project	International Center for Materials Nanoarchitectonics Project
Center name	International Center for Materials Nanoarchitectonics (MANA)
Project summary	Most technologies that support our society have been realized through the development of new materials. This has been true throughout the ages. For example, Edison's electric light bulb was realized using bamboo from Kyoto 100 years ago, information and communication technologies in the past 50 years have been supported by silicon, the recent development of blue-light emitting devices was achieved using a semiconducting GaN compound, new fertilizers and agrochemicals have played a critical role in enabling a large increase in food productivity. Furthermore, materials science is a field in which Japan can best show its abilities. It is also clear that Japan's many successes in key industries including automotive, electrical machinery, and electronics have been supported by its great ability to develop materials. Various technologies realized through the development of materials have brought about numerous benefits to humanity and contributed to improving welfare. However, several of these technologies are responsible for such serious problems as global warming and environmental pollution. In addition, rapid global industrial expansion, which is supported by technological development, is generating a new crisis -- a depletion of resources and energy sources. The 21st century is the period during which humanity, for the first time, has recognized the enormity and limits of the planet earth, and the future of humanity depends substantially on whether or not we can sustain development under the severe restrictions of energy, environment, resources and food. Serious problems caused by technologies can not be solved by abandoning technologies but only by further technological development. To solve the current global crisis, it is of critical importance to promote strongly cooperative research beyond national borders, thus concentrating the wisdom of scientists and engineers from across the world. Japan has the responsibility to assume a leading role in this endeavor. The concept of a world premier research center that we propose here is designed from the viewpoints of the essential necessity of materials and the importance of an international cooperative system for solving problems. The purpose of the center is to develop and offer new materials that contribute to a sustainable development. For this purpose, excellent researchers, especially young researchers who will create a future, will join the center from across the world and perform intensive research under an internationally-open environment, based on a new materials development system "nanoarchitectonics (see below)". National Institute for Materials Science (NIMS) is the most appropriate research institute to take the initiative for the center as the host institution. being continued to the next page ►►►►

Project summary (continued)	① World's top-level organization NIMS is one of the world's largest research institutes (see the table below) where basic research in materials is conducted comprehensively, and it has an international reputation for excellence based on its past research accomplishments, human resources, and facilities. We now rank 12th in the world for the number of citations of research papers in the past 10 years in the materials science field. However, over the past 5 years, we rank 6th in the world, which indicates that the research activities in NIMS increased dramatically after it changed to an independent administrative institution in 2001. We also have an excellent record for numbers of research papers, average impact factor, and other indices (see the figure).

Table: Personnel composition in NIMS

Position		Number	
		Total	(Foreigner)
Permanent Employee	Researcher	400	(28)
	Engineer	49	(0)
	Administrative staff	100	(0)
	Subtotal	549	(28)
Post-doc. etc.		661	(150)
Guest Researcher		285	(44)
Total		1495	(222)

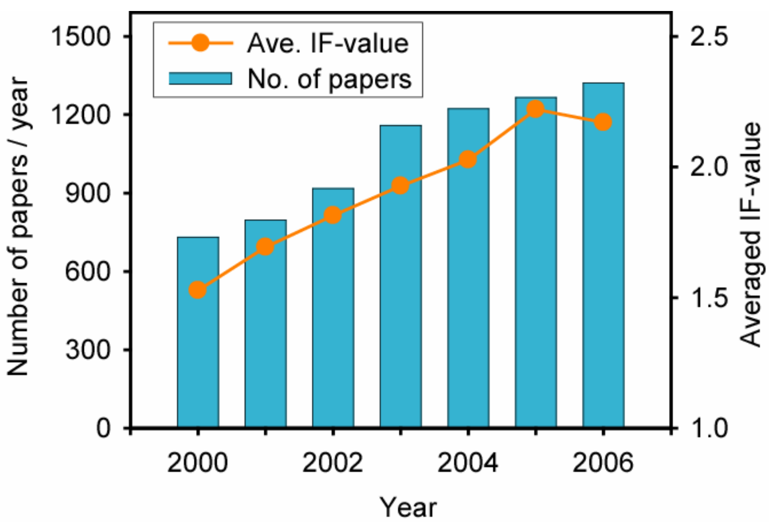
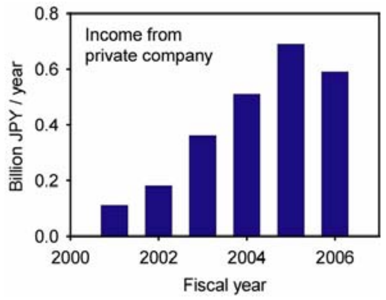


Figure: Number of papers and average impact factor of NIMS

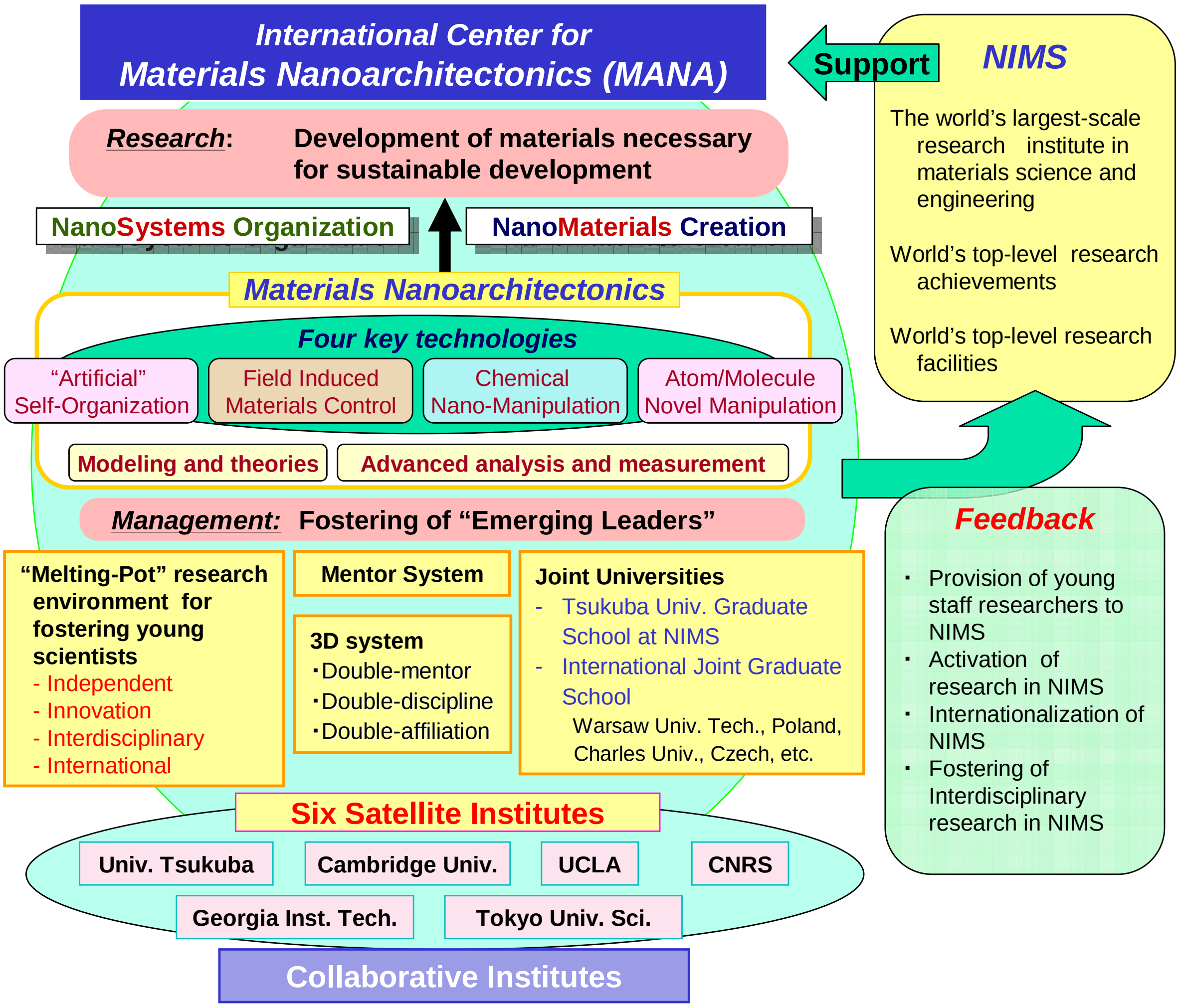
② Internationally-open management
We established the International Center for Young Scientists (ICYS) in 2003, and over the center's 5 year operation we have accrued a great deal of experience in the organization of an internationally-viable research environment including the organization of a multinational group of young researchers and in the use of English as the official language, as well as in realizing an interdisciplinary research environment.

Project summary (continued)	③ Cooperation with overseas research institutes We have various international cooperative relationships with key research institutes around the world. This includes summer schools that have been held regularly in cooperation with Cambridge University and the University of California for promotion of scientific exchange and fostering of young researchers. ④ Joint graduate school We have been actively fostering young researchers and developing cooperation with domestic and foreign universities through various activities including acceptance of graduate students by domestic and international Joint Graduate School Programs, as well as initiation of the University of Tsukuba Graduate School in NIMS (The Doctoral Program in Materials Science and Engineering of Graduate School of Pure and Applied Science, University of Tsukuba). Also, we offer "junior researcher" position for an excellent graduate student. ⑤ Technology transfer We have been active in industrial cooperation, to grasp social needs and to promote technology transfer, through various activities including establishing a "platform" system to conduct collaborative research with enterprises and holding evening seminars (every week) for researchers in companies (see the figure below for results of funding given from the industrial world).  Figure: Funding from industry Characteristics of NIMS in terms of performance and potential of research and development are as follows. ① Synthesis of materials Internationally first-rate research accomplishments and potential concerning synthesis and processing of materials (For example, the world's first diamond synthesis by plasma CVD method, discovery of Bi-Sr-Ca-Cu high-Tc superconductors, synthesis of superplastic ceramics). ② World's largest research facilities Various high-performance large-scale facilities relating to synthesis, structural observation and physical property measurements, which are without equal anywhere in the world (high magnetic field facility, high magnetic field 1 GHz NMR, ultrahigh-pressure synthesis facility, high-resolution high-voltage electron microscope, Nano Foundry, etc.) ③ Advanced nanotechnology Top-level performance and potential in research fields of nanotechnology relating to synthesis, control, processing, and structural and physical property measurements in nanoscale (synthesis and applications of various new nanotubes and nanosheets, atomic switch for integrated circuits, various advanced nanoscale measurement devices, etc.) being continued to the next page ►►►►

Project summary (continued)	There is no equivalent independent material research institute that possesses those three characteristics. In the center proposed here, we will promote such research that is difficult to perform in other institutions, by closely linking these three characteristics as well as developing a new technology system "nanoarchitectonics". Meanwhile NIMS will perform its duty as a comprehensive research institute for materials science, targeting all materials including metals, ceramics, organic polymers, composite materials, by using various approaches from various fields including materials science, chemistry, physics, biological science, and life science. We are planning to send NIMS's most experienced researchers from various fields to the center, as well as to invite there top level researchers from around the world, in order to conduct basic research for materials, combining the fields of materials science, chemistry and physics. The development of new materials required in the 21st century can not be realized without a paradigm shift of materials development. The center will realize the paradigm shift through a new materials development system that is named "nanoarchitectonics". "Nanoarchitectonics" is a technology system for arranging nanoscale structural units-- in other words, a nanostructure unit as a group of atoms and molecules-- in an intended configuration. This technology system can be roughly classified into two fields: "establishment of nanomaterials" and "establishment of nanosystems". A typical example of the former is one recent achievement of NIMS, where new composite materials consisting of nanosheets and heterogeneous substances were synthesized for the first time by soft-chemical layer-by-layer processing of nanosheets that were had been prepared in advance using a soft-chemical delamination technique of layered materials. With the enhancement of this method, it will be possible to synthesize various new materials that show unique functions. A typical example of the latter is the development of a nanoelectronics circuit. At present, challenging electronic devices are produced experimentally, using carbon nanotubes and functional molecules. In the "establishment of nanosystems", these devices are required to be integrated and linked as a system. This will open the new way to the development of innovative devices. On the other hand, key technology components in nanoarchitectonics are "artificial" self-organization", "field-induced material control", "chemical nanomanipulation", and "atom/molecule novel manipulation". In addition, theoretical and computational approach is quite important for conducting research effectively. Nanoarchitectonics is an exceedingly dominant method for realizing innovative functions and performance that keep up with complex requirements for materials. The center will make the best use of this technology with the aim of developing new materials that contribute to sustainable development. Namely, the goal of research in the center is the "development of innovative materials that enable new technologies required for the realization of a sustainable society in the 21st century", with a new paradigm of materials development based on nanoarchitectonics. To be more specific, we set the three objectives as shown below together with the main types of materials to be studied intensively. **1) Development of innovative materials related to environment, energy and resource** Examples: Superconducting materials (superconducting diamond thin film, etc.) Battery materials (materials for solid state rechargeable batteries, etc.) Catalysts (visible light active photocatalyst, etc.) being continued to the next page ►►►►

Project summary (continued)	**2) Development of innovative materials for nanoelectronics that lead to innovations in information and communication technology** Examples: Quantum information device materials (novel quantum-bit materials, etc.) Atomic electronics materials (materials for novel atomic switches, etc.) Photonic device materials (quasi phase matching element material, etc.) **3) Development of innovative materials that enable the development of new technologies for diagnosis, treatment and renaturation.** Examples: DNT chip materials (nanopiller array, etc.) Biomaterials (regenerative materials, etc.) To realize the paradigm shift in materials development and achieve the objectives of research, we will start the project, selecting form NIMS and other domestic and overseas institutes 22 principal investigators who have the most excellent abilities and careers. During the project, we will find additional principal investigators, including Asian (non Japanese) researchers, resulting in a final total of about 27. (Indeed, it has been decided that a distinguished Swiss researcher will join the center from 2008 if this proposal is accepted. Moreover, we will make efforts to increase the number of female principal investigators (although there is only one at the present stage.) Under the principal investigators, the center will arrange the lineup consisting of about 200 staff in total including technical staff, and select and organize excellent young researchers. Regarding managerial operation, the center will succeed and develop the concepts from the International Center for Young Scientists (ICYS) program, which is now being operated by NIMS. NIMS established ICYS in 2003 supported by the “Program for Fostering Strategic Research Centers”, a Special Coordination Fund for Promoting Science and Technology of the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Operating ICYS, where talented young multinational researchers gather to study independently in a “melting pot” environment with mixing of different research fields and different cultures, we have been conducting cutting-edge research and nurturing research leaders of the next generation, as well as promoting the internationalization of NIMS’s main body using a spillover effect. The basic concepts of ICYS are as follows: ① Research center consisting of multinational groups of young researchers ② Internationalized management using English as the official language ③ Promotion of interdisciplinary research in a “melting pot” environment with mixing of different research fields and different cultures ④ Research management that respects the ideas of individual researchers. ICYS has been given high marks for its activities, as receiving an “A” in a comprehensive evaluation using a 4-point scale “ABCD” in the interim assessment conducted by the MEXT. being continued to the next page ►►►►

Project summary (continued)	Utilizing the experience of ICYS, the center will establish a “melting pot” research environment, gathering excellent young researchers from various countries. The center will respect the novel and freewheeling ideas of young researchers as much as possible and the “melting pot” research environment will be an ideal incubation apparatus for such ideas. As detailed later, the center also utilizes this “melting pot” environment to foster young researchers, contributing to the main body of NIMS by providing young staff researchers. In addition to the basic concepts of ICYS, the center will adopt unique systems, such as the examples shown below, to thoroughly promote the integration of different fields and to foster young researchers. Mentor system: Principal investigators will be positioned as “mentors” and will decide the basic direction of research leading young researchers with, as far as possible, respect for their research ideas. 3D system (Double-mentor, Double-discipline, Double-affiliation system): Young researchers will belong to two organizations (center plus satellite or cooperative institute), have two disciplines and be led by two mentors. This rule aims to promote interdisciplinary alliances among different fields and to foster far-sighted researchers with an interdisciplinary background. Active cooperation with universities: The center will accept many graduate students, especially foreign graduate students, who can contribute to conduct the center’s research as junior researchers and to enrich the “melting pot” environment, by improving and expanding the University of Tsukuba Graduate School in NIMS and International Joint Graduate Schools with foreign universities as well as by utilizing other invitation programs for students. One of the characteristics of the center is that it will be definitely incorporated into the long-term strategies of the main body of NIMS, which is the host institution. The research objectives of the center are perfectly consistent with the mid-to-long term objectives of NIMS, and therefore, the center will play a principle role to lead the main body of NIMS by carrying out these objectives in a radically accelerated manner. We expect that, not only the center itself, but NIMS as a whole, can finally attain a top ranking position internationally. On the other hand, the center will also undertake a role to nurture research leaders of the next generation taking advantage of the center’s international and interdisciplinary atmosphere. We have decided that, if this proposal is realized, NIMS’s new staff researchers with tenure will be chosen, in principle, from young researchers of the center. Thus, the center will be positioned as an organization to supply human resources to the main body of NIMS. Therefore, it is quite important from the viewpoint of NIMS that the center undertakes the role of fostering of researchers in addition to the implementation of cutting-edge research. We should be able to activate the whole of research at NIMS, supported by these two actions of the center. The gathering of a multinational, multicultural and multidisciplinary group of young researchers under the leadership of world class principal investigators (mentors) is the most important part of the center’s structure. Formation of such a group is difficult within the main body of NIMS and this “melting pot” research system of the center will be a stimulating environment for scientific breakthroughs. (Illustration for the center organization on the next page)


International Center for
Materials Nanoarchitectonics (MANA)
Support
NIMS
The world's largest-scale research institute in materials science and engineering
World's top-level research achievements
World's top-level research facilities
Research: Development of materials necessary for sustainable development
NanoSystems Organization
NanoMaterials Creation
Materials Nanoarchitectonics
Four key technologies
"Artificial" Self-Organization
Field Induced Materials Control
Chemical Nano-Manipulation
Atom/Molecule Novel Manipulation
Modeling and theories
Advanced analysis and measurement
Management: Fostering of "Emerging Leaders"
"Melting-Pot" research environment for fostering young scientists
- Independent
- Innovation
- Interdisciplinary
- International
Mentor System
3D system
・Double-mentor
・Double-discipline
・Double-affiliation
Joint Universities
- Tsukuba Univ. Graduate School at NIMS
- International Joint Graduate School
Warsaw Univ. Tech., Poland, Charles Univ., Czech, etc.
Feedback
・ Provision of young staff researchers to NIMS
・ Activation of research in NIMS
・ Internationalization of NIMS
・ Fostering of Interdisciplinary research in NIMS
Six Satellite Institutes
Univ. Tsukuba
Cambridge Univ.
UCLA
CNRS
Georgia Inst. Tech.
Tokyo Univ. Sci.
Collaborative Institutes

(1) Research fields

The 21st century is, without doubt, the century where humanity, for the first time in its experience, recognizes the enormity and limits of the earth. The future of humanity depends on whether or not we can find a way to sustain development, under severe restrictions of energy, environment, resources and food. To solve this common issue for all humanity, the most dominant field of research that Japan can contribute will be in materials science. Materials form the basic foundation that supports all technologies, and is the area where Japan can best show its abilities. In fact, the many successes of Japan in key industries such as automotive, electrical machinery, and electronics have been realized by the development of materials. It is self-evident that industries and society of Japan will be depending on materials in the 21st century, and it is also true that "sustainable development" is not possible without an innovation in materials. Materials science is actually the lifeblood for human beings.

For the development of new materials that will be required in the 21st century, the center is working to realize a paradigm shift in materials research through a new materials development system named "nanoarchitectonics". "Nanoarchitectonics" is a technology system to arrange nanoscale structural units -- in other words, a nanostructure unit as a group of atoms and molecules-- in an intended configuration. This technology is critical for development of nanotechnology, beyond the stage of nanoscience. "Nanoarchitectonics" is also a typical interdisciplinary field that relates widely to such fields as material science, physics, and chemistry.

(2) Research objectives

a) Research Objectives

The development of new materials required in the 21st century can not be realized without a paradigm shift in materials development. The center will realize this paradigm shift through "nanoarchitectonics", which is a new technology system for arranging nanoscale functional structural units, such as a group of atoms or molecules, in an intended configuration. The research objective to be achieved by materials development based on nanoarchitectonics is:

"Development of innovative materials required for the realization of a sustainable society in the 21st century".

To be more specific, we set the following three objectives (issues to be studied intensively are shown as examples).

1) Development of innovative materials related to environment, energy and resource

Examples:
Superconducting materials (superconducting diamond thin film, etc.)
Battery materials (materials for solid state rechargeable batteries, etc.)
Catalysts (visible light active photocatalyst, etc.)

2) Development of innovative materials for nanoelectronics that lead to innovations in information and communication technology

Examples:
Quantum information device materials (novel quantum-bit materials, etc.)
Atomic electronics materials (materials for novel atomic switches, etc.)
Photonic device materials (quasi phase matching element material, etc.)

3) Development of innovative materials that enable the development of new technologies for diagnosis, treatment and renaturation.

Examples:
DNT chip materials (nanopiller array, etc.)
Biomaterials (regenerative materials, etc.)

b) Research plan

As stated at the beginning of this document, requirements for new materials to realize new technologies required in the 21st century are advancing, and the development of new materials that can respond to such requirements can not be realized without a paradigm shift in material development. Our research center aims to realize this paradigm shift through a new technology system that is named "nanoarchitectonics".

Prior to an explanation of "nanoarchitectonics", we would like to confirm the appropriateness of the vision that nanoscale structural control is important to create new functions, which has been accepted widely, regardless of whether it is macro structural material, micro electronic device material, inorganic materials, organic materials, or biomechanical materials. Through a remarkable development over these recent 20 years in nanoscience and nanotechnology, it was verified in many instances that new functions can be created by controlling structures at the nanoscale.

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It was hoped that that dreamlike development would be awaiting us in the future of remarkable developments in nanotechnology. However, recently a question has arisen relating to whether nanotechnology is really developing as expected. The question arose coincidentally by the recent recognition that a sort of breakthrough is inevitable for the practical use of nanotechnology, beyond the nanoscience level. Such a breakthrough will be made by pioneering a new technology system for creation of a new function of the whole unit, by arranging individual nanostructual units that have useful functions in an intended configuration. Such a technological system is called "***Nanoarchitectonics***".*

* Note: The word "***Nanoarchitectonics***" in this context was first used at the First International Symposium on Nanoarchitectonics Using Suprainteractions (NASI-1) for which Dr. Aono (Prospective Center Director) served as chairman. The second symposium, NASI-2, was held in Los Angeles and chaired by Professor Jim Gimzewski of UCLA (one of the chief researchers of this research center), and the third symposium NASI-3 is scheduled to be held in Cambridge and will be chaired by Professor Mark Welland of Cambridge University (also one of the chief researchers of this research center).

"Nanoarchitectonics" is a technological system to arrange nanoscale functional structural units as a group of atoms and molecules in an intended configuration. The purpose is to produce a new function of the whole unit through concerted interaction between nanostructures, so it is needless to say that fundamental research in the related materials science field is included. Nanoarchitectonics can be roughly classified into two fields, "NanoSystem Organization" and "NanoMaterials Creation" (See Figure 1). A typical example of the "NanoSystem Organization" is the development of a nanoelectronics circuit. Challenging electronic devices are produced experimentally, using carbon nanotubes, functional molecules, etc., but the practical use is impossible without a technology to integrate and link these devices into a system. A typical example of the "NanoMaterials Creation" is synthesis of a new material that does not exist in nature by combining and laminating heterogenous substances with "nanosheets" that were obtained by chemical exfoliation from a layered material. With the enhancement of this technique, it will be possible to synthesize various new materials that show interesting functions.

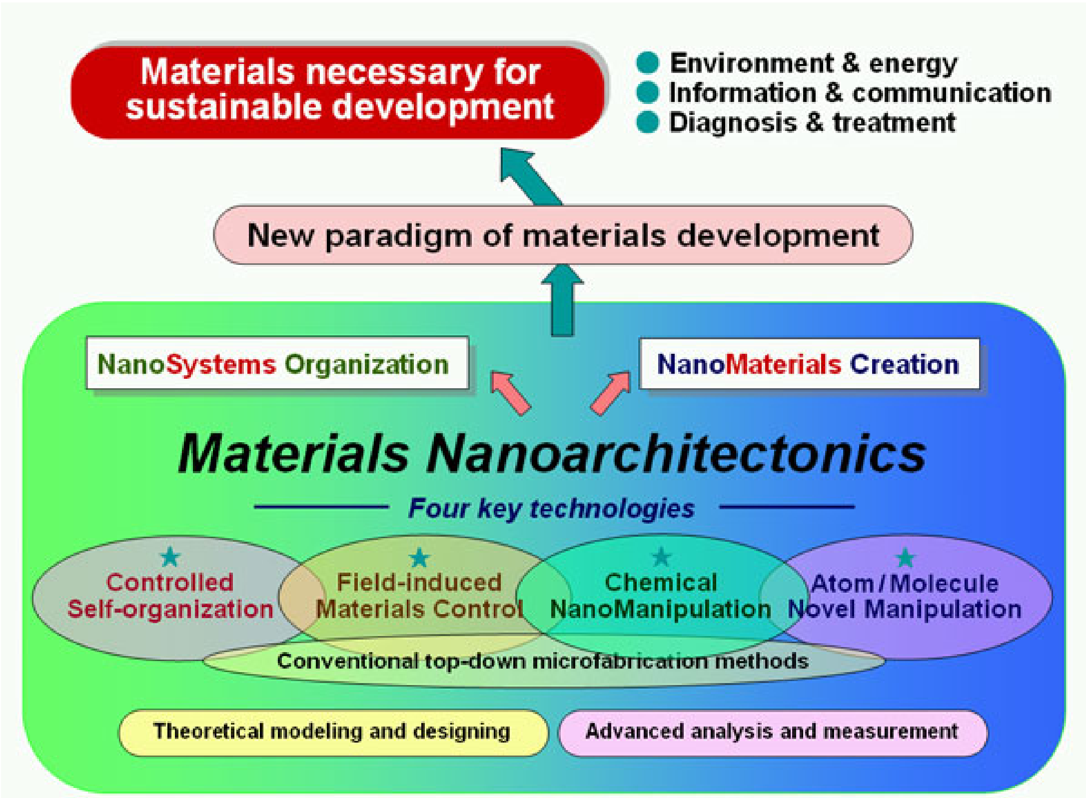

Figure 1: New paradigm in material development through materials "nanoarchitectonics"

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Technologies used in nanoarchitectonics can be roughly classified into 4 techniques: (1) atom/molecule novel manipulation; (2) chemical nanomanipulation, (3) field-induced material control; and (4) "artificial" self-assembly and organization ("artificial" means "controlled" or "guided"); see Figure 1. In addition, theoretical and computational approach is quite important for conducting research effectively. The capabilities and features of each technique are illustrated in Figure 2, using actual examples (all of these examples are selected from the world's first research of their kind performed at NIMS).

Novel atom/molecule manipulation is a method to control the configuration or the coupling state of individual atoms and molecules using proximity probes including scanning tunneling microscope (STM) and atomic force microscope (AFM). This method has excellent advantages unsurpassed by other methods, in terms of arbitrary operation on single atoms and molecules, although there is a disadvantage in terms of time consumption when handling a number of atoms and molecules. However, it is thought to be better to use the advantages of this method and overcome the disadvantage, rather than abandon this method because of its disadvantage. This disadvantage may be conquered by massively parallel use of probes combined with self-organization of materials. Chemical nanomanipulation is a method to control nanoscale substances by skillfully utilizing chemical equilibrium states and non-equilibrium states in a liquid or solid phase, temporally and spatially. This method enables nanomanipulation of various substances. Field-induced materials control is a method which uses changes in physical states dexterously through the intervention of electric fields, magnetic fields, electromagnetic fields (light, X-ray), and stress fields. Such efforts have been made conducted to date, but the research center will actively endeavor to pioneer new methods. To cite an example, NIMS found that the positions of molecules which are able to move relatively freely on a substrate can be immobilized by X-ray irradiation with a wavelength specific to those molecules, after arranging the molecules in an intended configuration. "Artificial self-assembly and organization is at the opposite end of the above atom/molecule novel manipulation. The latter is an artificial method to forcibly manipulate individual atoms and molecules, but this method relies on interactive forces specific to atoms and molecules. Hence, diverse effective nanoarchitectonics may be realized by the successful combination of both methods. Many studies in this research center will be related to the task of combination.

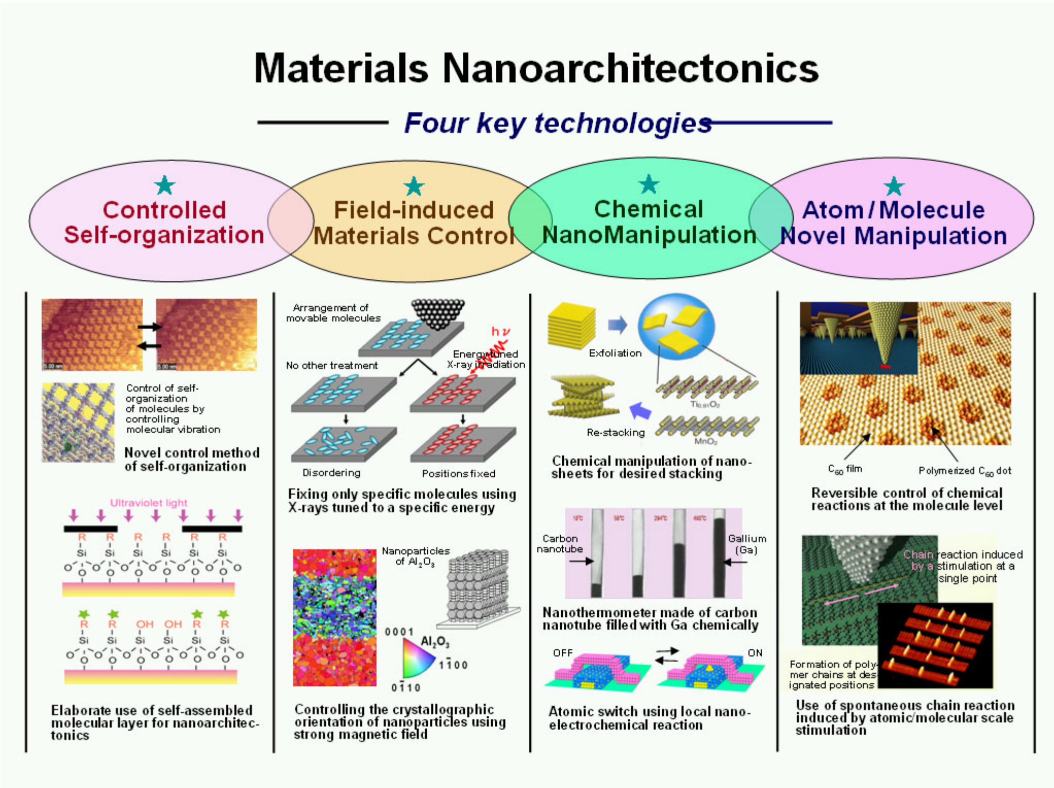

Figure 2: Illustration of materials nanoarchitectonics

Making full use of the above nanoarchitectonics concept, the center will endeavor to realize a new paradigm shift in material development. It would be difficult to achieve such a study based on nanoarchitectonics, if it were not conducted in a research institute above a certain size endowed, which possesses excellent human resources, experience and facilities. Thus, NIMS is a highly appropriate research institute for promoting such studies. This will be detailed in the following paragraph.

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To realize the above-mentioned paradigm shift in materials development and to achieve the above-mentioned research objectives, we will start the project, selecting form NIMS and other domestic and overseas institutes 22 principal investigators who have the most excellent abilities and careers. During the project, we will find additional principal investigators including Asian (non Japanese) researchers resulting in final number of about 27. (Indeed, it has been decided that a distinguished Swiss researcher will join the center from 2008 if this proposal is accepted. Moreover, we will make effort to increase number of female principal investigator though it is only one at the present stage.) Out of 22 principal investigators, 14 investigators are from NIMS, the host institution, and 8 investigators are from external institutions. Regarding the 8 investigators from external institutions, 5 investigators are from abroad and 3 investigators are from Japan. 7 of 22 principal investigators are foreign national investigators. 16 of the 23 principal investigators are internationally known top-class investigators (asterisks denote these people). Figure 3 illustrates how these principal investigators will be involved in the establishment of the new paradigm shift in material development through nanoarchitectonics as well as in the research stated in the above 1) to 3) research objectives.

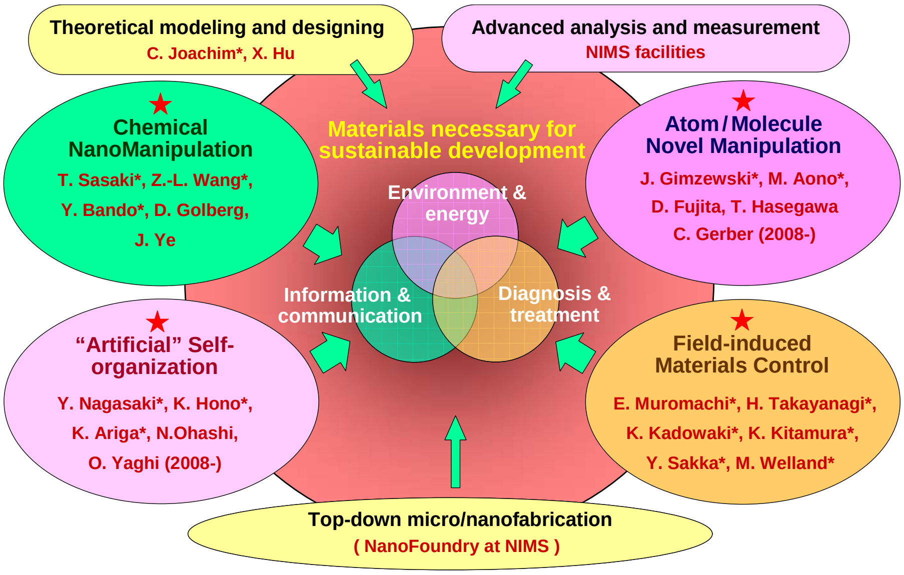

Figure 3: Research Implementation System

c) Past results

Past results of NIMS, the host institution, are summarized as follows, concerning results necessary to form a world premier research center.

<Material synthesis>

In terms of materials synthesis and control, NIMS has achieved excellent results and gained experience that is unsurpassed anywhere in the world, and which has been nurtured over many years. The following shows examples of this.

1) First successful fabrication of diamond thin films by plasma assisted chemical vapor deposition
2) Ultrahigh-pressure synthesis of single-crystal diamond
3) Discovery and structural identification of bismuth oxide high-temperature superconductors
4) Growth of single-crystal dielectrics of the world's largest size and highest quality, A venture company which was founded on this research has grown to become an enterprise with a capital of 281,000,000 yen (as of July 2006)
5) Basic research and practical use of an excellent electron emission material of single-crystal lanthanum hexaboride
6) Development of various super-heat-resistant alloys, the development of "super steel", which is unparalleled by any other in the world
7) Development and practical use of coiled wire fabrication technology of high-temperature superconducting materials
8) Discovery of the cobalt oxide superconductor
9) Development of super high-speed plastic ceramics

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10) Production of the superconducting diamond films
11) Construction of various nanostructures by means of manipulating atoms and molecules since the inauguration of the Aono Atomcraft Project under the ERATO program organized 18 years ago
12) Discovery and application of atomic switches resulting from atomic and molecular manipulation
13) Formation of conductive polymer chains at desired locations by chain polymerization
14) Development of memory with bit density greater than 100 Tb/in^2 by using C_{60} molecules
15) Development of a nanothermometer using carbon nanotubes
16) Discovery and use of metal oxide nanosheets with useful functions
17) Realization of semiconductor quantum dots, of which even the internal structure is controlled, by droplet epitaxy

<The world's largest research facilities>

We are equipped with a series of large high-performance facilities related to structural observation and measurement of material properties that are unique in the world. The following shows examples.

1) World's strongest magnetic field generator
2) Ultra high-voltage, high-resolution transmission electron microscopes
3) World's highest-frequency nuclear magnetic resonance (NMR) spectrometer using the strong magnetic field generator
4) Ultrahigh-pressure generator that can be used even for the fabrication of artificial diamond
5) Exclusive beamline at the synchrotron radiation facility (SPring-8)
6) High-current metal ion beam generator

<Advanced nanotechnology>

We hold records achieved by a series of unique high-level nanotechnology-related research facilities relating to nanoscale synthesis, control, process and measurement of materials. The following shows examples.

1) Synthesis of various novel nanotubes
2) Synthesis of novel nanosheets
3) Construction of atomic switches
4) Synthesis of functional supramolecules
5) Development of multiprobe scanning probe microscope (nanotester)
6) Development of scanning tunneling microscope that works at extremely low temperatures, in strong magnetic fields, and in ultrahigh vacuum
7) Development of computational science including the development of a new "order N" method

There are no other equivalent independent material research institutes that are equipped with these three attributes. We suggest that a world premier research center promoting nanoarchitectonics-related research, that would be difficult to implement at other institutions, can be created by integrating these three characteristics.

(3) Management

i) Prospective center director

Name:	Masakazu Aono (63 years old as of 1 Oct. 2007)
Current Affiliation:	National Institute for Materials Science (NIMS)
Position Title:	Fellow Coordinating Director of Key Nanotechnologies Field
Specialties:	Nanoscience, nanotechnology, nanoelectronics, surface physics and chemistry

<Brief Biography>

Masakazu Aono obtained his doctoral degree from the University of Tokyo in 1972, and was subsequently a research staff member of the National Institute for Research in Inorganic Materials (NIRIM) until 1986, during which time he spent two years (1978-1980) as a visiting professor at the University of Wisconsin, USA. He moved to the Institute for Physical and Chemical Research (RIKEN) in 1982 and organized/managed the Surface and Interface Laboratory until 2002 as the chief scientist at the laboratory. From 1996 to 2005, he was concurrently a professor of Atomic Precision Technology at Osaka University. In 2002, he assumed his present position at the National Institute for Materials Science (NIMS).

<Outstanding Research>

Dr. Masakazu Aono is highly recognized worldwide for his many distinguished research results over 35 years in the fields of surface science, nanoscience, and nanotechnology. His research is characterized by originality for making epochal advances and by surprising results. The research is outlined in Appendix 2. The research, the research results achieved, and his qualities as a project leader are detailed below:

① Development of a unique electron emission material

In one of the research projects early of his career, he disclosed, for the first time, the reasons why lanthanum hexaboride (LaB_6), which is widely used today in electron microscopes and electron-beam lithography machines as an electron emitter, has an abnormally low work function (~2.3 eV). Based on this result, and jointly with his colleagues and the firm (DENKA), he developed it into a commercial product, "LaB_6 single-crystal electron emitter", and released it to the world market.

② Development of ion scattering spectroscopy

He invented a new method of ion scattering spectroscopy, which facilitated analysis of structures of solid surfaces (not only the outermost layer but also the second and third layers), namely Impact Collision Ion Scattering Spectroscopy (ICISS) and its developed form, coaxial ICIASS (CAICISS). CAICISS was developed into a commercial product by an industrial firm (Shimadzu Corporation) and was awarded the New Industrial Products Award for the annual top ten chosen by the Nikkan Kogyo (Daily Industry) Newspaper.

③ Aono Atomcraft Project

In 1989, he organized the Aono Atomcraft Project of the ERATO program led by the Japan Science and Technology Agency (JST) and conducted a study to develop nanostructures by means of atom manipulation through probes of a scanning tunneling microscope (STM), thus taking the initiative in today's development of nanotechnology (which was almost 18 years ago).

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④ Leading nanoscience and technology research

Through consecutively presiding over the projects of the CREST, SORST, and ICORP programs led by JST, he has accomplished various outstanding results in the fields of nanoscience and nanotechnology. For example, one of the accomplishments is development of a multi-probe type STM which uses two, three, and four probes, instead of one, to enable measurement of electrical conductivity of a nanostructure by using each of the probes as a nano electrode contacted with any given point of any given nanostructure ("Nanotester"). Another example is the invention of an atomic switch which operates by controlling movement of a small number of atoms, which has already progressed to a stage of practical study conducted jointly with an industrial firm (NEC). (NEC has launched a study using its manufacturing line in Sagamihara for manufacturing the programmable ICs using an atomic switch.) Further, having developed a technology which can induce chain polymerization by simple application of a stimulus to one point on a monomolecular film forming one polymerized molecular chain (conductive pi-conjugated polymer chain) at any position, he is now working on a study of a new type of switching device and photon generating device by utilizing the technology. Most recently, he developed the technology to enable elemental analysis of nanostructure, which appears in an STM image through combination of synchrotron X-rays and STM.

<Awards and Honors>

For his creative research, Dr. Aono is highly credited worldwide, and he has been named a Fellow of the American Vacuum Society (USA) and the Institute of Physics (UK), and was awarded the Surface Science Society of Japan Prize, the Minister of Science and Technology Award, the Minister of Education, Culture, Science and Technology Award, and a number of other awards. He has chaired several international conferences, participated in the operation of more than 30 international conferences as an organizational committee member, etc, and has been invited to more than 130 international conferences.

<Personality as a Project Leader>

Dr. Aono has experience and a good record in organizing and operating a large number of research projects, part of which has already been mentioned above. Furthermore, through his experience and excellence in many international collaborative research projects, such as the international collaborative research project between UK and Japan under JST's International Cooperative Research Project, he has built a strong network of contacts across the world. He is also devoted to the education of young students as he was a professor of Osaka University for nine years. Currently he is serving as a Fellow of NIMS, the host institute of this research center, and is concurrently the Coordinating Director of key nanotechnological fields and the Managing Director of the NanoSystem Functionality Center, having a great reputation for excellence in NIMS. He actually served as the key person in the establishment of the Second Midterm Plan of NIMS which started in 2006. More importantly, Dr. Aono has wide and profound knowledge both of fundamental and applied material science, whose recent activities are focused on the development of materials science.

ii) Prospective administrative director

Name: Takahiro Fujita (55 years old as of 1 Oct. 2007)
Current Affiliation: National Institute for Materials Science (NIMS)
Position Title: General Manager, Integrated Strategy Office

1977 Master of Engineering, University of Tokyo
1977 NKK Corporation
1987 Master of Science, Virginia Tech
2001 National Institute for Materials Science

After an engagement in R&D work at a private firm, he had ten years of experience as the head of its research planning division and personnel division. Therefore, he is well versed in technology management and personnel policies. Having two years experience of study in the U.S, he has a good language skill and is internationally-minded. Since his appointment to the Institute in 2001, he served as Manager of the Integrated Strategy Office, Deputy-Director-General of the International Center for Young Scientists, General Manager of the Public Relations Office, and General Manager of the International Office. Currently he is serving as General Manager of the Integrated Strategy Office, which controls the overall management of the institute, and which has contributed greatly to the establishment and improved operation at this Institute since its incorporation as an independent administrative institution. Because of his distinguished management capability and good track record in the planning and coordination division, combined with distinguished language skills and international sensibility, he is very well suited to serve as the head of the administrative division of this international center.

iii) Composition of administrative staff

Starting in 2003, NIMS has about five years experience in research, using English as the official language of ICYS activities. Therefore, it has the advantage of being able to perform both efficient and international administrative operation by making the best use of its experience and know-how acquired in ICYS. All the documents regarding, for example, office routine regulations, purchase of items, and official trips are today already available both in Japanese and English. As a result, an environment of supporting documentation is close to perfection so that foreigner researchers can devote themselves to their study without a language barrier.

Based on the experience in ICYS, we will establish three groups including planning, general affairs, and technical assistance for efficient operation of the administrative division with the use of English as the official language. Further segmentation of the administrative division into planning group, personnel group, general affairs group, accounting group, supplies group, etc. would adversely affect improvements in efficiency and would impose inconvenience especially to foreigners. It is important to establish an administrative system where each person can handle clerical work as widely as possible.

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- **Planning Group:** Responsible for operations regarding employment and planning, such as recruiting, as well as employment of young researchers such as postdoctoral researchers, regular performance evaluation of researchers, holding of symposiums, and public relations as well as publication. Run by about five staff members under the supervision of the planning group leader (a middle-ranking researcher of NIMS)

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- **General Affairs Group:** Responsible for general affairs, accounting, and clerical work regarding researchers' attendance record, payroll, official trips, and purchase of supplies. Run by about 15 staff members under the supervision of the general affairs group leader (assign a NIMS employee who has good experience with ICYS). Especially, with the aim of reducing clerical work for researchers, we will hire about 10 secretaries, who will carry out all the clerical work for researchers. The secretaries hired as staff members of the general affairs group must have English language skills equivalent to a TOEIC score of 850 points or more. In addition, five administrative staff will join to the center from NIMS.

- **Technical Assistance Group:** Responsible for technical assistance work such as maintenance and control of shared devices used in the center, services in response to requests from researchers, and research assistance. A system will be established so that routine experiments can be conducted by technicians as much as possible. For this purpose, approximately 15 persons who are former NIMS's researchers (retirement people with a Ph.D degree) with good research backgrounds and English speaking proficiency are employed at the final stage for establishment of a system capable of high-level technical assistance. In addition, five technical assistants will join to the center from NIMS.

iv) Decision-making system

The center, as its basic principle, intends to establish a decision-making system that can support strong leadership of the center director. In addition, the center intends to minimize the number of meetings in its operation so that the researchers can devote themselves to their studies.

Principal investigators meeting: The principal investigators meeting will be held on a regular basis (about once every month) and will be led by the center director. Matters concerning center operation in general wil be discussed and reported under the full leadership of the center director. Also, the principal investigators must clearly communicate the intentions of the center director to all the young researchers and graduate students concerned.

Advisors: The center will take advice on the management and other issues from knowledgeable outsiders.

v) Allocation of authority between the center director and the host institution's side

・ Concretely describe how authority is allocated between the center director and the host institution's side.

Director of the center: The director of the center will be given authority over the center's operation in general. In other words, the center director will have authority in employment, renewal of contracts, payroll, research expenses, and space allocation for researchers including senior and young researchers of the center, etc. who are invited to the center, except for those who are enrolled in the main body NIMS. His authority also includes employment and renewal of contracts administrative staff members of the center, except for those who are enrolled in the main body NIMS.

President: The president, as the responsible person of the host institute, supports the center operation to the fullest extent, while respecting the authority of the director over the operation of the center. However, upon some situations such as receipt of any advice from the Steering Committee and NIMS Executive Board, the president can make personnel changes to the center director, principal investigators invited from external organizations, etc. Further, according to need, he must take various additional measures necessary for the center operation including, for example, improvement of the experimental space and additional assignment of NIMS researchers.

(4) Researchers and other center staffs

i) The "core" to be established within the host institution

a) Principal Investigators (full professors, associate professors or other researchers of comparable standing)

	numbers		
	At beginning	At end of FY 2007	Final goal (Date: month, year)
Researchers from within the host institution	14	14	16 (1.10.2011)
Foreign researchers invited from abroad	4	4	7 (1.10.2011)
Researchers invited from other Japanese institutions	3	3	4 (1.10.2011)
Total principal investigators	21	21	27 (1.10.2011)

b) Total members

	Numbers		
	At beginning	At beginning	At beginning
Researchers (Number of foreign researchers among them and their percentage)	90 (56 / 40 %)	90 (56 / 40 %)	90 (56 / 40 %)
21 (7 / 32 %)	21 (7 / 32 %)	21 (7 / 32 %)	27 (10 / 37 %) (1.10.2011)
69 (24 / 40%)	69 (24 / 40%)	69 (24 / 40%)	140 (74 / 53%) (1.10.2011)
Research support staffs	17	17	17
Administrative staffs	20	20	20
Total number of people who form the "core" of the research center	177	177	177

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ii) Collaboration with other institutions

The center intends to promote effectively top world-level research that is appropriate to the world's center of substance and material research. At the same time, with the aim of fostering young researchers on the international level, it will collaborate actively with domestic and foreign research institutes. The center establishes two kinds of affiliates which are satellite institutes and collaborative institutes. The satellite institutes will serve as center's branches. On the other hand, based on the MOU agreement, the collaborative institutes carry out collaborative research and personnel exchange with the center.

Recently, NIMS has successfully organized the World Materials Research Institute Forum for global networking of materials institutions. Learning from this, the center will organize a World Nanotechnology Research Institute Forum and make efforts in global networking and global research collaboration in the field of nanotechnology and nanomaterials. Moreover, by participating in "Nanotechnology Network Japan Program (MEXT Innovation Support Program)" in which NIMS is deeply involved, the center will strengthen domestic network with Japan's nanotechnology related institutes.

Satellite Institutes: Research institutes to which principal investigators invited from external organizations belong are referred to as the satellite institutes. By December, 2007, the center plans to set up satellite institutes at the University of Tsukuba, University of Cambridge, UCLA, Georgia Institute of Technology and CNRS. The satellite institutes will play an important role in conducting research and are expected to be bridgeheads of the center.

・**University of Tsukuba:** Professor K. Kadowaki and Professor Y. Nagasaki are world leading researchers on superconductivity and organic chemistry, respectively. Their two satellite laboratories are set up in the University of Tsukuba with the intention of complementing the center's research activity and they will be bridgeheads of the center for the University of Tsukuba. Each of the laboratories will have stationed a few young researchers who are hired by the center to conduct research.

For the purpose of human resources cultivation, NIMS has already set up a Doctoral Program in Materials Science and Engineering at the Graduate School of Pure and Applied Sciences, University of Tsukuba. The center will accept many graduate students who can contribute to the research of the center as the junior researchers, utilizing this collaboration system with the University of Tsukuba.

・**Tokyo University of Science:** Professor Takayanagi, who is a world distinguished researcher of superconducting devices, will join the center, conducting the superconducting-device related research. NIMS is not very strong in this field. This satellite will be a bridgehead of the center to conduct joint research with the Tokyo University of Science.

・**University of Cambridge:** Professor Mark Welland, as Director of Interdisciplinary Research Center in Nanotechnology (IRC) of UK, is a world leader in nanoscience as well as in nanotechnology, especially with a focus on superfine processing by using an electron beam and creation of nanostructures. He has also served as a scientific adviser to the UK Prime Minister. He will join the research activities at this center with regard to the study of nanostructure fabrication. This satellite will play an important part in conducting the research of the center and will be a bridgehead of the center for the University of Cambridge.

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・**UCLA:** Professor James Gimzewski is very well known as the researcher who has established the foundation of today's nanoscience and nanotechnology at the IBM Zurich Research Laboratory immediately after the invention of the scanning tunneling microscope. After moving to UCLA several years ago, he launched a study concerning fusion of nanotechnology and biotechnology and has performed ingenious research including his recent invention of a desktop size fusion device. He participates in the center's research concerning manifestation of new functions of nanostructures and their measurement, playing an important role in the project. This satellite will be a bridgehead of the center for UCLA.

・ **Georgia Institute of Technology:** Professor Z. Wang is an outstanding researcher in the field of nanotechnology, who is ranked among the world's top 25 by having a total number of article citation of over 15,000. In particular, his discovery of the ZnO nanobelt has drawn attention as a new material applicable in piezoelectric elements and in biosensors (total cited numbers: 1,519 times). This satellite will contribute to the project mainly in the electronic materials field and will be a bridgehead of the center for the Georgia Institute of Technology.

・**CNRS:** Professor Christian Joachim is the leading authority who has clarified the electronic states of nanostructures, especially the electronic state of functional molecules, by means of first-principle calculations. On the other hand, by organizing a group consisting of experimentalists and theorists, he is now devoted to the realization of single-molecule devices. He is expected to join this research center for theoretical study of new nanostructure functions, leading the theoretical research. This satellite will be a bridgehead of the center for CNRS.

Collaborative Institutes: These institutes are expected to serve as sites for collaborative research with the center as well as exchange and training of young researchers. Among about 130 institutes in Asia, Europe, North America, East Europe, etc. with which NIMS already has MOU agreements, approximately 30 major institutes including, for example, Institute of Physics, Chinese Academy of Science (China), KAIST (Korea), Max Planck Institute (Germany), Charles University (Czech), and UCSB (U.S.) are serving as the collaborative institutes. It is further planned that MOU agreements will be signed with an additional 10 institutes by December, 2007 and with a further additional 20 institutes by December, 2008.

Overseas Offices: With the aim of strengthening overseas collaborations of the center and NIMS, overseas offices will be set up in UCSB, University of Washington and others. They are expected to conduct recruiting and investigation into the current research trend overseas. In particular, they will play roles in obtaining US-governmental funds from organizations such as DARPA and NSF and will also serve as liaisons for foreign personnel, for foreign enterprises, and for collaboration with overseas universities.

(5) Research Environment

i)

The following factors are required to establish an environment where researchers can devote themselves to their research: 1) to develop a clerical work support system, so that paperwork for business trips or the purchase of supplies can be promptly processed in support of the researchers' work; 2) to provide researchers with sufficient technical staff for the maintenance of equipment, services in response to requests from researchers or assistance in experiments; 3) to minimize the frequency of conferences for the improvement of communication; 4) to provide assistance to researchers and their family for their life in Japan when necessary. Since half of the researchers at the center will come from abroad, we will develop a system to manage the use of English as the official language so that foreign researchers can devote themselves to research without having to deal with a language barrier.

Clerical work support system in English: Through five years' experience at ICYS, a clerical work support system using English as the official language has been implemented, so we will allocate those experienced people to the center as clerical staff, and we will hire new non-permanent staff under the experienced clerical staff. English proficient secretaries will be hired under principal investigators to handle clerical services in response to requests from researchers (10 secretaries by the end of December 2007, and 20 in total by the end of March, 2008).

- **Make paper work bilingual**: All documents such as forms will be in Japanese and in English, so that the burden of paperwork on researchers will be reduced. Further, translators and/or interpreters will be on the staff to support foreign researchers. In addition, English education will be given to both young researchers and senior Japanese researchers and to clerical staff to improve their English capabilities (operation to make all documents bilingual will be completed by March 2008).

- **Assistance for daily life**: We will improve the support system for foreign researchers and their families to set themselves up for living in Japan, such as housing search, medical care, education and job search for the spouse to eliminate various barriers that foreigners encounter when they come to Japan. Full-time staff will be hired (October 2007).

- **Patent specialist**: For the convenience of foreign researchers to make patent applications in Japanese, we will hire English proficient patent specialists.

- **Providing sufficient technical staff and facilitating access to equipment**: We will establish a system where researchers can use freely the latest large-scale international level research equipment owned by NIMS (High Voltage Electron Microscopy, High Magnetic Field Magnet, Spring-8 dedicated beam line and Nano Foundry) for their research, by provision of sufficient technical staff. Further, we will promote shared use of other advanced equipment. We will also provide researchers with sufficient assistance, such as research assistants, who will undertake routine experimental procedures. For those technical staff and others, we are going to hire about 15 people including researchers retired from NIMS (total 15; 5 by the end of December 2007, another 5 by March 2008 and 5 by the end of December 2008). In addition, five technical staff will join the center from NIMS.

ii)

We will provide start-up research funds to researchers invited from external organizations so that they can launch their own laboratories immediately. We will grant a start-up fund of about 200,000 dollars to principal investigators invited from external organizations who conduct their research at NIMS. Those principal investigators who work in satellite research institutes will be allocated an annual research fund of 100,000 dollars. Young researchers such as post-doctorates will be allocated a start-up research fund as necessary to an amount of up to 100,000 dollars. On average, one principal investigator will conduct research with a group of 6 young researchers including 2 post-doctorates, 2 NIMS researchers and 2 junior researchers (graduate students).

iii)

Securing highly capable young researchers including post-doctorates is vital to the operation of the center in view of human resource development. Fortunately, we have been able to, in the ICYS project, select about 50 highly capable young researchers from about 25 countries, out of 1000 applicants from about 70 countries. By utilizing ICYS' recruiting know-how accumulated to date, we will secure capable young researchers. Further, we will promote securing graduate students and provide them with sufficient research guidance.

Securing young researchers including post-doctorates

- **International open recruiting:** We will conduct international open recruiting through international publications such as "Nature" and by the recommendation from the principals of more than 130 research institutes which NIMS is affiliated with. Young researchers refer to those who obtained their Ph.D within the last 10 years. Asian countries such as China, India, etc. will be promising counties from which to recruit excellent young researchers and students. In addition, we will make our best effort to employ female young researchers and students.

- **Multi-national young researcher group**: Through ICYS activities, we have proven that the international environment created by young multi-national researchers from different fields, cultures and races (at ICYS, this kind of international environment is referred to as a "Melting Pot") is vital to both the research activities and human resource development of young researchers. Therefore, the center will also establish young multi-national researcher groups in different fields. We will hire about 60 post-doctorates from more than 20 different nations (total of about 60: 30 by March 2008 and another 30 by March 2009).

Application method and recruitment:

Applicants will propose a three year research plan in the application form. We will conduct the selection by weighing originality of the research plan and potential of the candidate as a researcher through two steps; screening of the application documents and interviewing (about 5% is assumed as the ratio of successful applicants). Applicants will be invited to the center for an interview, and have a one hour interview from which we will decide if the applicant will be accepted (the recruitment committee will consist of about 6 principal investigators headed by the center director as the committee chair). The employment period shall be two years, but renewal of the contract for another year may be granted after appraisal of the results. The reason we limit the employment period to 3 years at maximum is because we give priority to career improvement of post-doctorates and alike so that we can promote recruitment to NIMS' research staff.

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Securing the junior researchers (graduate students)

Graduate School of University of Tsukuba: At the Doctoral Program in Materials Science and Engineering, Graduate School of Pure and Applied Sciences, University of Tsukuba, which is jointly managed by NIMS and University of Tsukuba, we have made extensive efforts towards internationalization such as the implementation of an entrance examination in English since April 2004, the year we accepted the first students. As a result, the majority of doctorial course students at present come from abroad. By extending this system, we will secure capable graduate students from foreign countries such as China and India and make them conduct research as the junior researchers. Upon creation of the center, instructors at University of Tsukuba and instructors at the Doctoral Program in Materials Science and Engineering will take charge of the master's course program by supplementing each other, and an English curriculum will be prepared in a manner that allows students to take all the requisite courses in English. Further, we will provide a world-class research assistantship to all the graduate students as NIMS junior researchers, so that we can provide an environment in which students can concentrate on their studies and research without worrying about their tuition or the cost of living.

- **International Joint Graduate School:** By expanding the International Joint Graduate School Program which NIMS already has with Charles University in Czech and Warsaw University of Technology in Poland, we will allow capable graduate students to participate in research under the supervision of principal investigators at the center.

- **Human resource development of young researchers:** Fostering capable young researchers under the world's top class principal investigators is one of the remarkable features of the center. For that purpose, at the center, we will further expand the activities at ICYS.

- **Fostering in the Melting Pot:** We will develop an international environment where capable multi-national youths gather at one center from around the world, and develop their talents by receiving stimulation there. For that purpose, we will assemble about 60 post-docs of different nationalities from more than 20 countries in one place.

- **Mentor system:** In order to enhance independence of young researchers who obtained their Ph.D within the last 10 years, top world-class principal investigators will become their mentors and give advice regarding their research while respecting the researchers' own initiatives. Through the five year experience in ICYS, this mentor system proved to be quite effective for young researchers to enhance their independence, widen their research scope and show creativity.

- **Foster human resources by 3D system:** A human resource development called 3D system will be established to enhance independence of young researchers and develop extensive interdisciplinary knowledge and experience. The 3D system stands for <u>D</u>ouble-mentor, <u>D</u>ouble-discipline and <u>D</u>ouble-affiliation; meaning: Research guidance by more than one mentor to enhance independence, having more than one discipline to strengthen interdisciplinary background knowledge, and multiple affiliations to strengthen an independent spirit. We will carry out fostering of young researchers by utilizing satellite institutes as well as with the cooperation of overseas' cooperating organizations because the 3D system cannot be achieved by NIMS alone. We will also use the 3D system to promote human resource development of the junior researchers (graduate students) who belong to the center.

- **Career development:** As a result of the abovementioned human resource development at the center, we will not only hire young researchers as permanent staff researchers at NIMS, but we will provide also them an associate professor's position or alike in research institutes either in Japan or abroad, to further their career development.

iv)

As mentioned previously, through the ICYS project NIMS has experienced research work using English as the official language, and therefore we have already trained clerical staff and have accumulated know-how. In using English as the official language, the keys for success lies in the improvement of the clerical staff's English proficiency, rather than of researchers' English proficiency, and the preparation of paper work materials in English. In Japan, bilingual documentation and communication in English and Japanese are effective. At the center, about 5 clerical staff members who have experience in ICYS will participate in the plan. To make English the official language, we will prepare the following items:

- **Life in NIMS:** We will make a booklet "*Life in NIMS*" (approx. 30 pages) with full information on procedures for coming to Japan as well as on life in Japan. We will partially revise a booklet made for ICYS.
- **NIMS Research Guide**: We will make a booklet about information on NIMS research activities (approx. 50 pages). We will partially revise a booklet made for ICYS.
- **Bilingual documentation of various paper works:** We will make bilingual documentation of paper work for business trips, purchase of supplies, salary, regulations and others (approx. 100 pages). ICYS has already prepared such documentation, so we will revise those.
- **Principal investigators meeting:** The meeting will be held once a month in English.
- **Intranet:** The office communication through the Internet in the center will be done bilingually in English and in Japanese.

v)

At the center, we will develop a different salary scale from that of NIMS's main body, and will establish a flexible compensation package to secure excellent researchers and to provide them appropriate treatment. We will expand the system, which we have implemented in ICYS, including an annual salary system.

Annual salary system: Salary system for fixed-term principal investigators invited from external organizations or fixed-term young researchers such as post-doctorates will be an annual salary system. Because an annual salary system has already been introduced in ICYS, we will make full use of the experience. Annual salaries of the fixed-term principal investigators invited from external organizations will be in a range of 80,000 to 180,000 dollars, depending on their performance. Salaries of the fixed-term young researchers such as post-doctorates will be more than ca. 40,000 dollars, and will be assessed by their performance.

Assessment of the salary and renewal of contract: The center director shall evaluate research performance of young researchers to determine their salary for the next year. Salary shall not be based on seniority but on research performance, so as to be able to generate differences of more than about 50% in bonus among researcher of the same age group based on their performance.

Performance evaluation committee: The committee evaluates the research performance of young researchers once each year (the center director chairs the committee, and several principal investigators are included). They will assess the renewal of contract, salary and research budget for the next fiscal year.

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The center evaluation committee: We will set up a center evaluation committee which consists of external experts (about 8 people, about 50% of whom are foreigners. An external expert will be appointed to act as chair) to evaluate the management of the center and research activities. At the same time, they will conduct performance assessments of the center director and principal investigators. The NIMS president will determine the annual salary of the center director after receiving a report from the center evaluation committee. The term of a principal investigator shall be 5 years, with a mid-term assessment in the 3rd year. Moreover, those who have shown excellent performance at the 5-year assessment will be allowed an extra five year of affiliation. For purposes of rejuvenation, about 1/4 of the principal investigators in total shall be replaced 5 years after the establishment of the center, to introduce new research fields, and to prevent the center from becoming inflexible.
However, salaries for researchers who belong to the center and are affiliated to NIMS shall be borne by NIMS, according to the results of the assessment from the center.

vi)

Space of the center: For the research activities at the center, NIMS will provide total space of approximately 10,000㎡.

Space for experimentation: We will provide office space and laboratory rooms in the Nano Biomaterial Research Building only for young researchers, including post-doctorates, who conduct their research independently (about 4,000 ㎡ in total). We will provide approximately 1/2 of that as experimental space. We will provide necessary and sufficient space to principal investigators invited from external organizations.

Single-occupied office and cafeteria: We will provide young researchers with a single-occupied office (approx. 12㎡) where they can devote themselves to research and to have a comfortable living environment. Also, to realize an ideal Melting Pot environment, we will put all the office rooms together in one place, and secure enough space for casual talks, including a cafeteria. At the center, we will utilize single occupied offices which are currently used by ICYS, and additionally will prepare approximately 10 rooms to cover shortfalls.

Research equipment: We will secure world's top-level advanced facilities with high commonality (for example, next-generation ultra high resolution electron microscope), in cooperation with NIMS in a well-planned manner.

vii)

To show that the center is one of the top world-level centers in the material science field, we will hold an international research conference once a year (a conference with 300 attendants). Furthermore, we will hold workshops as needed to provide leading world researchers in this field with opportunities to exchange information. Also, every summer we will open a summer school to foster young researchers.

viii)

The most remarkable feature of the center will be not only that the center sends excellent leading world research results generated by top world-level principal investigators and subordinate young researchers, but that the center is a human resource development center where young researchers will be fostered and improve their careers to become future leaders. It is also a feature of the center that it respects young researchers' fresh and innovative ideas, as well as those of principal investigators. To realize these features, the proportion of foreigners among young researchers shall be more than 50%. Our strength lies in the 5-year experience of the ICYS project, which we can improve and extend for further development, for example, research management using English as its official language and know-how in human resource development for young researchers.

We have to keep the following points in mind to create an internationally attractive research environment:

- **Use English as the official language**: By eliminating the language barrier, we need to establish a system where foreign researchers can do all their works without the need for understanding Japanese.

- **Ensure independent research activities:** We will provide young researchers an environment where they can carry out their research independently. For that purpose, we will appoint world-leading principal investigators to be their mentors, to encourage young researchers to become independent. Further, we will provide young researchers with sufficient assistants such as technical staff so that they can proceed with their research independently, by receiving help to use common equipment and to get assistant services for work.

- **High salary standard:** We will provide higher salaries than in NIMS to motivate young researchers.

- **Utilization of world-leading equipment in NIMS:** We will establish a system where researchers can use the world's most advanced leading large-scale equipment such as High Magnetic Field, Nano Foundry, Spring-8 dedicated beam line, High Voltage Electron Microscopy, which are available at NIMS.

(6) Indicators for evaluating a center's global standing

i) Criteria and methods to be used for evaluating the center's global standing in the subject field

To evaluate the center's global standing in the materials science area, we can use indicators such as number of papers accepted by renowned journals, ratio of researchers that are considered worthy of being named the world's top level researchers, the number of foreign researchers employed, the total external grants obtained, the number of cooperative research projects with private sector corporations, the number of patents applied and granted, the conditions of patents exploited, the number of invited talks at major international conferences, and the number of academic society awards received. The ranking of the number of citations of papers in the field of materials science presented by ISI can be a strong indicator to evaluate research institutions, although its effectiveness is debatable in the academic community.

ii) Results of current assessment made using said criteria and methods

- According to the ISI's ranking of research organizations based on the total number of citations in the field of materials science over the past 10 years, NIMS, which is the host institution of the center, was ranked the 12th in the world as of May 2007, while it was ranked 31st in 2003 when NIMS first appeared in the ranking. This is a clear indicator of how NIMS has improved its standing in the last four years. When comparing paper citations over the five years before becoming an independent administrative institution (1996-2000) and the five years after becoming an independent administrative institution (2002-2006), NIMS ranked 6th, up from the 31st in the world. This means that the recent organizational reforms after becoming an independent administrative institution six years ago drastically increased its research achievements. NIMS publishes about 1,300 papers a year, only one third of which is in materials science and the rest of which is in the fields of physics, chemistry or biotechnology. Nevertheless, NIMS gained a high standing in the materials science discipline.

- The principal investigators from NIMS gained external grants of 1,358 MJPY in FY2006 alone. In terms of the amount of the external funds gained, the center is equivalent to the world's top level.

- The number of the external grants gained by NIMS, which will be the host institution of the center, is growing every year. Particularly, the growth of the grants from private sector corporations is noticeable with a total amount of more than 500 MJPY in FY2006.

- In the last several years, the number of foreign researchers employed by NIMS has increased dramatically. Around 200 foreigners join NIMS as post-docs or graduate students every year. This indicates that NIMS is an open and attractive international institute for foreign researchers.

iii) Goals to be achieved through the project (at time of interim and final evaluations)

At the point of Mid-term evaluation (5 years later):

- NIMS, the host institution of the center, will rank within top-5 in the materials science field according to the world's institute ranking of ISI based on the number of citations in the past five years.

- The center will have secured 100 young researchers and 50 graduate students from all over the world.

- About 10% of the permanent employees will be foreigners in NIMS.

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At Ex-post evaluation（10 years later）:

- The center will be a high status research center for materials science, which many researchers all over the world aspire to join.
- NIMS will rank within the top-3 in the ISI ranking based on citations in the last five years. Since the citation ranking is advantageous for large institutions, it is impossible to exceed in numbers giant institutes such as Chinese Academy of Sciences or Max-Plank Institute, Germany because of the size difference. Therefore, NIMS set its goal to be in the world's No.3 (which corresponds to No.1 among single institutions).
- NIMS will be the No.1 institute in the materials science discipline in the institute citation ranking in Japan.
- The numbers of total external grants obtained, cooperative research projects, and of collaborative research grants by private businesses will be 1.5 times greater than at present.
- For the ten-year period, the center has secured about 200 young researchers and 100 graduate students from all over the world.
- This center will function as a research center for growing "Emerging Leaders" in materials science. Researchers in this center will promote their careers and about 50 of them will get permanent positions in NIMS, and another 50 at overseas and domestic universities or research institutes after staying for some time in this center as graduate students or post docs.
- About 20% of the permanent employees will be foreign researchers in NIMS.

(7) Securing research funding

i) Past record

The table below shows the actual amount of external funds in recent years obtained by the candidates for principal investigators who are affiliated to NIMS. The funds listed are research funds for which respective researchers are enrolled as principal investigators, and external funds obtained as public competitive funding offered by the national government, etc. and those which were obtained in joint research whose funds are offered by private corporations.

Table: Actual external funds obtained by candidates for principal investigators
(Unit：Million yen)

Name	FY2002	FY2003	FY2004	FY2005	FY2006
Masakazu Aono	58	169	179	412	276
Yoshio Bando	41	493	801	812	792
Eiji Muromachi	0	0	8	7	10
Kenji Kitamura	116	103	119	4	8
Takayoshi Sasaki	47	77	36	9	53
Kazuhiro Hono	90	107	93	51	116
Katsuhiko Ariga	0	0	0	4	12
Yoshio Sakka	69	28	31	25	18
Xiao Hu	2	2	1	0	2
Naoki Ohashi	2	1	15	26	2
Dmitri Golberg	0	0	9	4	0
Jinhua Ye	50	68	60	12	22

As shown in the above table, we have been steadily obtaining an average of about 1.4 billion yen of external funds in recent years. In addition, the funds distributed as operational subsidies of the host institutions are shown in the table in the next page. In recent years, the total amount of operational subsidies allocated and the external funds obtained is remaining at the level from 0.8 to 1.4 billion yen.

The averaged effort (b/a ratio in Appendix II) of the prospective principal investigators is about 80 %. Therefore, the expected amount of the fund that the prospective principal researcher get for the activity of this center is 1.7-2.2 billion yen every year. This value is nearly equivalent to the amount of requested funding shown in the form of "3. Appropriation Plans".

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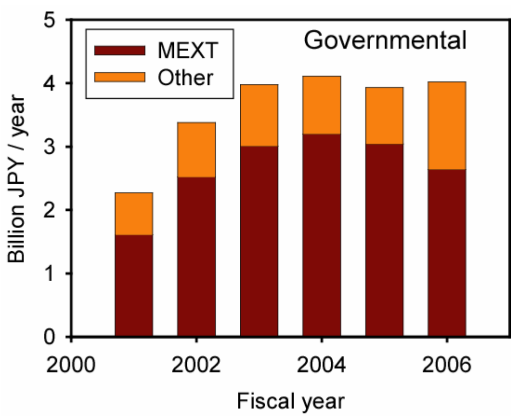
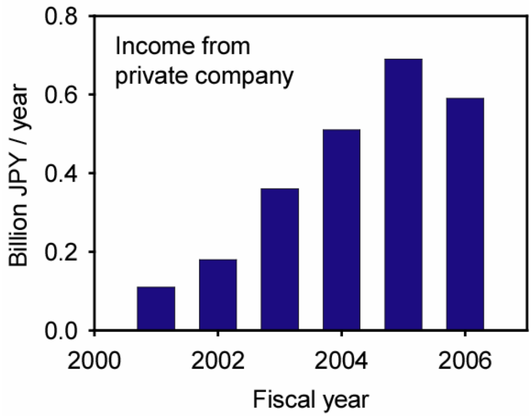
Table: Budget of operational subsidies of candidates for principal investigators (Unit：Million yen)

Name	FY2002	FY2003	FY2004	FY2005	FY2006
Masakazu Aono	108	133	129	127	40
Yoshio Bando	114	195	171	134	81
Eiji Muromachi	85	75	106	46	48
Kenji Kitamura	255	280	190	312	63
Takayoshi Sasaki	126	127	84	88	64
Kazuhiro Hono	67	54	48	213	95
Katsuhiko Ariga	0	23	20	211	25
Yoshio Sakka	18	17	25	23	47
Xiao Hu	7	14	21	20	19
Naoki Ohashi	10	5	20	20	82
Dmitri Golberg	0	0	0	0	22
Jinhua Ye	9	16	9	9	50

As a reference, the funds of host organizations as a whole obtained from government and private sector corporations, etc. are as follows.





ii) Prospects after establishment of the center

In FY 2007, the Nanotechnology Network Project by the Ministry of Education, Culture, Sports, Science and Technology starts, so that we can receive funds for maintenance and operation of advanced shared equipment. The shared equipment operated by the fund may be used for this center project, and therefore, the material amount of external funds obtained will be higher than now estimated.

Furthermore, the number of talented young researchers has increased recently with drastic increase of research achievements. The funds they obtain will continue to grow in the future.

As stated in the Commitment from the Host Institution attached separately, we assume the funds needed by those core principal investigators can be sufficiently secured as before, by continuing to allocate research funds to principal investigators from the operational subsidies.

Others

After project funding ends, NIMS will support the center financially so that the center can maintain its activities at least for 10 more years.

It is quite sure that the main body of NIMS will actively adopt center's successful management systems. The concept of the center is really unique and its experience will be very helpful not only for the main body of NIMS but for other institutions in Japan when they attempt to build their own research centers.

We would like to stress our valuable experiences obtained from the ICYS project. The center will succeed and develop the managerial operation in ICYS and this is our great advantage to realize the world premier research center in addition to our novel materials research technology of nanoarchitectonics.

Center Director's Vision

International Center for Materials Nanoarchitectonics (MANA)

Prospective Center Director:
Masakazu Aono
Fellow
Coordinating Director, Key Nanotechnologies Field
Managing Director, NanoSystem Functionality Center
National Institute for Materials Science (NIMS)

As the prospective director requested to setup a research center supported by the World Premier International Research Center (WPI) Initiative of MEXT, I will describe my enthusiasm toward the establishment of this research center and research vision which is the basis of this enthusiasm.

1 Introduction

1.1 Materials are the mother of science and technology

This title expresses what I have always felt during my 35 years of research. I would like to explain how I acquired this feeling by describing two of my research projects: the first project in which I was engaged in as a researcher and my current ongoing project.

Approximately 35 years ago, electron emission materials with excellent properties were required for the development of electron microscopes and electron-beam lithography machines. At that time, people knew of the existence of a promising candidate material, lanthanum hexaboride (LaB_6), which has an extremely low work function (2.3 eV), although the cause of such an extremely low work function was unclear. I was successful in elucidating the cause (explained later); this success was only possible because I was working at the National Institute for Research in Inorganic

Materials (NIRIM), the predecessor of the National Institute for Materials Science (NIMS). At NIRIM, it was possible to grow single crystals of LaB_6, the melting point of which is extremely high (2700°C), by the floating zone method 30 years ago. I analyzed the surface structure (atomic arrangement) of a grown single crystal of LaB_6 utilizing two new measurement instruments constructed by myself, namely, the angle-resolved X-ray and UV photoelectron spectrometer and the impact-collision ion scattering spectrometer. The results revealed that the (001) surface of LaB_6 is covered by La ions, leading to an extremely low work function. On the basis of this discovery, we developed an electron emission device with a tip made of the (001) surface of a LaB_6 single crystal with Denka Corporation. This device is now indispensable in various devices using electron beams, including electron microscopes and electron-beam lithography machines. Through this series of research, which was my first as a researcher, I developed the strong impression that a new technology is born from a new material or materials.

I would like to introduce another recent example from my ongoing research. I invented (discovered) an “atomic switch” several years ago. It was indeed a serendipitous discovery. Since I organized/managed the Aono Atomcraft Project of the Exploratory Research for Advanced Technology (ERATO) program sponsored by JST in 1989, it has been one of my interests to fabricate nanoelectronic circuits using atomic chains. I therefore tried to create a conductive path by supplying silver atoms one by one along a given line on a sample surface with the use of the scanning tunneling microscope (STM). For this purpose, we prepared a STM tip made of silver sulfide (Ag_2S) that is a typical solid electrolyte so that silver atoms in it are moving freely, and the tip was scanned on a sample surface, an appropriate voltage being applied. As expected, silver atoms were supplied to the sample surface from the tip and a conductive path was formed along the scan line, but we came across a more important phenomenon. Under a certain applied voltage, silver atoms precipitated at the apex of the silver sulfide tip and created a bridge between the tip and the sample. Furthermore, when the applied voltage was reversed, the silver atoms redissolved into the silver sulfide tip, and the bridge disappeared. We had realized a new nanoscale switch. We decided to call this switch an “atomic switch”. In subsequent research, we found that this switch has many excellent properties exceeding our predictions. NEC Corporation, with which we are conducting joint research, has begun studies on manufacturing next-generation programmable logic operation devices that incorporate atomic switches. Incidentally, the development of recently available new memory devices such as resistive RAM and redox RAM, was triggered by the development of our atomic switch. Through the research concerning this atomic switch, I renewed my conviction that a new technology is created through the development of a new material or materials.

I have consumed much space in describing my own research experiences, but as exemplified by Edison’s light bulb being realized 100 years ago by the use of bamboo from Kyoto, by the information technology of the past 50 years being founded on silicon, by the recent blue diode being realized using gallium nitride, and by fertilizer and agricultural chemicals playing a decisive role in the marked increase in food production, it is a universal fact that new materials bring about new technologies. Although this fact is not well recognized, it can be the proof that new materials for technology are as important as air to us.

1.2 21st century as century of technology and new materials development

The 20th century is said to be the century of science. Indeed, there have been three major developments in the last century: the discovery of the theory of relativity, the establishment of quantum mechanics, and the discovery of DNA. These developments are closely related to our life today in terms of atomic energy, communications technology, and gene therapy. Remarkable scientific developments are expected to continue even in the 21st century (in particular, much progress is expected in the field of brain science); however, I believe that the prediction that the 21st century will be the century of technology will be realized. Technological developments tend to be considered less important than scientific developments. However, the situation of technology in the 21st century will be substantially different from that in the 20th century; technologies in the 21st century will be highly advanced so that it will change not only our life but also our philosophy. As a good example, if mankind can send men to Mars, our philosophy will be affected and change, and such a change will be brought about by technology rather than science.

Technology that brings about numerous benefits and welfare to mankind is also causing serious problems, as represented by global environmental pollution. Also, the rapid and global expansion of industry supported by technology is creating a new crisis of the depletion of natural resources and energy. Thus, the 21st century is a century in which we humans will actually be brought face to face with the limitations of the earth for the first time; the future of mankind depends on whether we can find a path of sustainable growth under the severe restrictions related to energy, environment and resources. These serious problems resulting from the progress in technology must be resolved, not by abandoning technologies but by further advancing the technologies currently available. Japan, which has a national policy of being a world leader in science and technology is obligated to address this issue.

However, the demand for new materials in realizing such advanced new technologies is at a very high level. The reason behind the use of silicon in solar cells is that it is a nice semiconductor; however, such a single function will not be sufficient in the future. Materials with multiple properties, such as those similar to silicon (or those with superior functionality compared with silicon) but require less energy for their production, will be needed. Currently, it is considered a matter of course to cool superconductors used for superconducting magnetic levitation trains to a ultra-low temperature. However, room temperature superconductors will be required in the future.

In the development of nanoelectronics for realizing a ubiquitous information technology society by reforming communication technologies, the development of devices operating on the basis of a completely different principle from that of today's silicon-based CMOS devices is necessary; the development of materials required for these devices will be fairly sophisticated and diversified. The development of new materials that respond to the high level of demand cannot be realized if we maintain the conventional materials development paradigms adopted thus far. It is necessary to adopt a new materials development paradigm.

2 Goal of Research Center

2.1 New paradigm for materials development and nanoarchitectonics

How can we set a paradigm for new materials development? The marked development of nanotechnology and nanoscience during the past 20-odd years has provided us with half of the answer. Regardless of the type of product, such as macroscopic structural materials or microscopic electronic device materials, or the types of inorganic materials, organic materials, and biomaterials, interesting and diversified functions that had previously been unavailable have been added to materials through the control of their structures at the nanoscale. This has been proven by many examples. Such nanoscale structural control will be an unshakable pillar in materials development in the new paradigm.

The marked development of nanotechnology has given great confidence to researchers engaged in materials development, and has built up their hopes of realizing dreamy developments in the extension of current nanotechnology. However, doubt as to whether nanotechnology has made the expected progresses has recently been cast. This reflects the recent recognition of materials researchers that some breakthrough is necessary for nanotechnology to break out of the shell of nanoscience to become a truly practical technology. That is, some essential element is missing.

Nanoscience and nanotechnology have been developed as a science or technology in local nanoscale space locally. Demonstrations that have surprised material scientists have been presented one after another; however, these concerned only a small number of atoms or molecules in limited spaces at the nanoscale. For example, demonstrations of materials creation and fabrication, such as arranging atoms or molecules in a desired manner by manipulating them individually, rearranging atoms and molecules locally under an equilibrium condition into a different arrangement, and fabricating conducting polymer chains at an arbitrary location by inducing chain polymerization reactions via the stimulation of a single molecule, for example, were performed for a limited number of atoms and molecules located in a limited space. Also, demonstrations of the extraordinary high conductivity of carbon nanotubes, the operating characteristics of various single-electron transistors (SET), and the functions of single-molecule transistors, for example, have also been realized for a single molecule or structure. However, for practical applications, the scaling up or improvement of the creation and fabrication methods and the organic integration and mutual linking of individual functional molecules and structures are required. This is essential to create novel functionality of practical use as a whole. As an analogy, although individual cells in biological bodies have excellent functions, a more important fact is that these cells are organized and exhibit a function as a whole.

In short, a new technology system, in which we can arrange individual nanostructures that have useful functions into a desired arrangement, is required. We call this technological system “nanoarchitectonics*”, and explore it at this research center.

Nanoarchitectonics can be classified into two major areas: “NanoMaterials Creation” and “NanoSystems Organization” (refer to Fig. 1). As a simple example of NanoMaterial Creation, the creation of a new material that cannot exist in nature has already been accomplished by compositing a material with single nanosheets obtained by chemical exfoliation from a different layered material. It will be possible to create new interesting materials with new functions by advancing a similar method. A simple example of NanoSystems Organization is the construction of a nanoelectronics circuit. Interesting electronics devices made of carbon nanotubes and functional molecules have been experimentally fabricated as single devices; however, they cannot be put to practical use unless these devices are integrated and mutually linked into one system.

At this research center, we will realize nanoarchitectonics through the development of new various technologies in four areas: 1) Atom/Molecule Novel Manipulation, 2) Chemical NanoManipulation, 3) Field-induced Material Control, and 4) “Artificial” Self-organization (“artificial” means “controlled” or “guided”). Their contents are shown in Fig. 2 using examples (all of these examples are selected from the world’s first research of their kind performed at NIMS).

In Atom/Molecule Novel Manipulation, the basic approach is the control of the arrangement and bonding state of individual atoms and molecules using the proximity

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*** Note**

The word “nanoarchitectonics” in this context was used for the first time in the world at the First International Symposium on Nanoarchitectonics Using Suprainteractions (NASI-1) for which I served as chairman. The second symposium, NASI-2, was held in Los Angeles and chaired by Prof. Jim Gimzewski of UCLA (one of the principal investigators of this research center), and the third symposium NASI-3 is scheduled to be held in Cambridge and will be chaired by Prof. Mark Welland of Cambridge University (also one of the chief researchers of this research center). “Suprainteraction” in the symposium name is also a coined term by us meaning long-range interaction. This is also another important concept in this research project.

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probe (tip) of a scanning tunneling microscope (STM) or an atomic force microscope (AFM). This method is unique in the sense that individual atoms and molecules can be manipulated, and cannot be replaced with any other method; however, it is disadvantageous because much time is required to manipulate a large number of atoms and molecules. Our approach is to aggressively overcome this disadvantage and advantage of the excellent property of this method rather than abandoning it. The disadvantage can be overcome by superparallel driving of multiple probes by computer

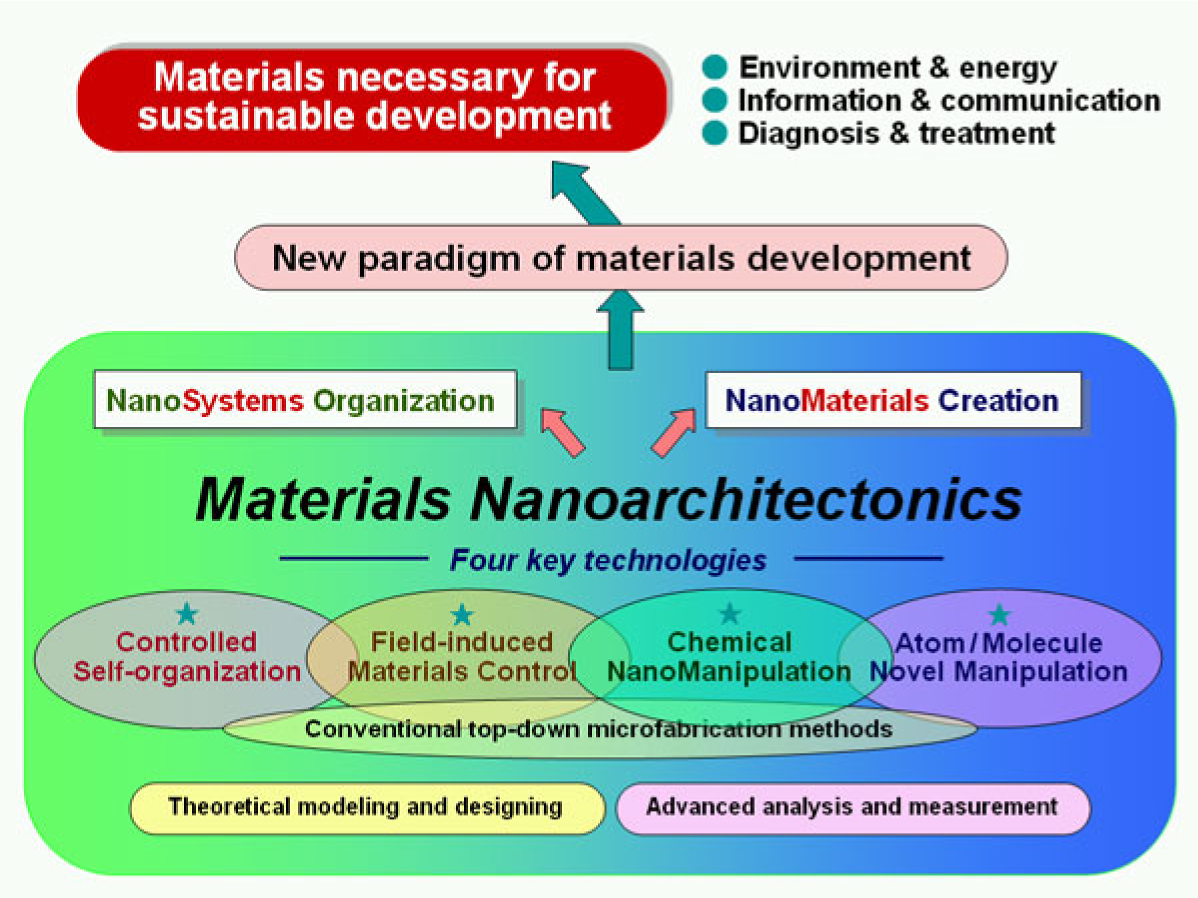

Fig. 1 New paradigm in materials development through material “nanoarchitectonics

control and controlling self-organization of atoms and molecules on a resulting template. In Chemical NanoManipulation, nanoscale materials and structures can be constructed by skillfully and differentially using the chemical equilibrium and inequilibrium states in a liquid or solid phase in time and space. Nanomaterials and various nanostructures can be constructed more efficiently than by the atom/molecule novel manipulation method. In Field-induced Material Control, we exploit the state change of materials under the presence of electric field, magnetic field, electromagnetic field (light and X-ray), strain field, electron flux and ion flux. Although this method has previously been employed even until now, we will aggressively develop new untried approaches at this research center. For example, it has been clarified in a recent study that after molecules, which have been adsorbed onto a substrate, are arranged in a desired pattern using a scanning probe, their positions can be fixed by irradiating X-rays that have a wavelength specific to the molecule of concern. Furthermore, the possibility of controlling the crystal orientation of nonmagnetic nanoparticles using a magnetic field has been demonstrated. In “Artificial” Self-organization, we will adopt the conventional self-organization method of mutual interaction that molecules (or atoms) possess, but add “artificial” modifications. There are two types of modifications. One is the control of self-organization using external fields (including the application of a local field and the use of a template), and the other is the modification of structures formed by self-organization with the use of subsequent skillful fabrication methods. As demonstrated by some of the examples described above, it is important to fuse the various technologies of the four areas.

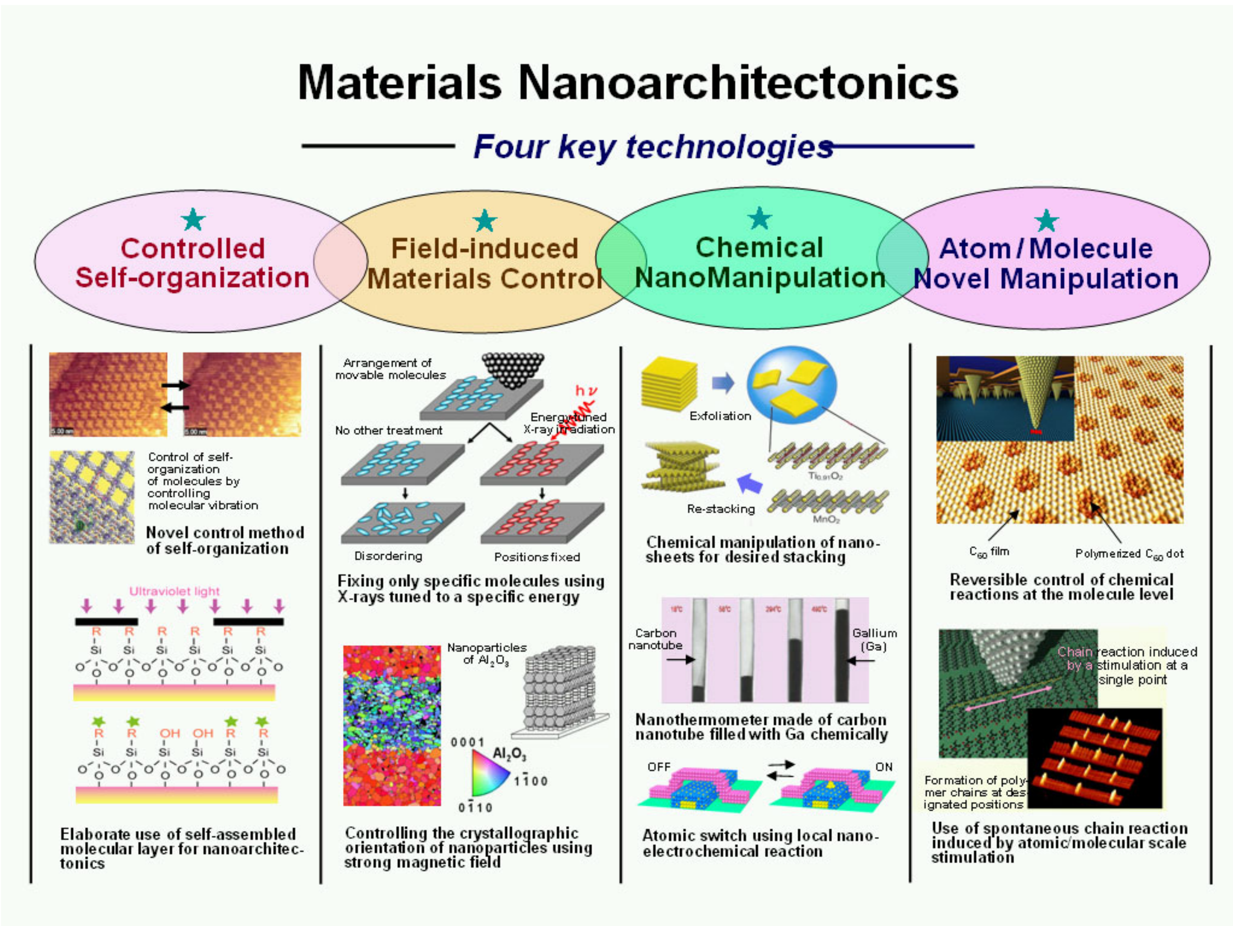

Fig. 2 Illustration of materials “nanoarchitectonics”

We will explore new paradigms for materials research on the basis of nanoarchitectonics, which is based on the above-described technological development, and create innovative materials that will enable the development of the new technologies required for sustainable growth in the 21st century.

2.2 Outstanding feature of NIMS as host organization

It is important not only to develop but also to combine individual technologies in order to achieve concrete results in the development of new materials through the integrated development of the above-described new technologies in nanoarchitectonics. Therefore, the organization responsible for such a task must be one that is exclusively dedicated to materials research and that has talented personel, experience, and facilities that exceed a certain level. In this sense, NIMS is a highly suitable organization as the host institute of the research center. In fact, NIMS boasts numerous outstanding achievements such as (1) the first successful fabrication of diamond thin films by chemical vapor deposition, (2) the ultrahigh-pressure synthesis of single-crystal diamond, (3) the discovery and structural identification of bismuth oxide high-temperature superconductors, (4) the growth of single-crystal dielectrics of the world's largest size and highest quality, (5) the basic research and practical use of an excellent electron emission material of single-crystal lanthanum hexaboride (mentioned previously), (6) the development of various super-heat-resistant alloys, the development of "super steel", which is unparalleled by any other in the world, and (7) the development and practical use of coiled wire fabrication technology of high-temperature superconducting materials. Here, this tradition is being continued with recent eminent results, such as (8) the discovery of the cobalt oxide superconductor, (9) the development of superhigh-speed plastic ceramic, and (10) the production of the superconducting diamond. In the area of materials development in the nanoscale region, NIMS has a distinguished track record, including (11) experience in the construction of various nanostructures by means of manipulating atoms and molecules since the inauguration of the Aono Atomcraft Project under the ERATO program organized 18 years ago (discussed previously), (12) the discovery and application of atomic switches resulting from atomic and molecular manipulation (discussed previously), (13) the formation of conductive polymer chains at desired locations by chain polymerization, (14) the development of memory with bit density greater than 100 Tb/in^2 by using C_{60} molecules, (15) the development of a nanothermometer using carbon nanotubes, (16) the discovery and use of metal oxide nanosheets with useful functions, and (17) the realization of semiconductor quantum dots, of which even the internal structure is controlled, by droplet epitaxy. Also, in the area of nanoscale measurement technologies, achievements include (18) the development and use of multiprobe STM (nanotesters) with 2, 3, and 4 multitips, (19) the development and use of a new technology for analyzing the nanostructure and electron state, as well as the spin state, of light emitted from an STM by spectroscopy and polarization analysis, and (20) the development and use of STM operated at ultralow temperatures, in strong magnetic field, and in ultrahigh-vacuum. In addition to the above, NIMS operates many large-scale facilities, such as (21) the world's strongest magnetic field generator, (22) the world's highest-frequency nuclear magnetic resonance (NMR) spectrometer using the strong magnetic field generator, (23) an ultrahigh-pressure generator that can be used even for the fabrication of artificial diamond, (24) an exclusive beamline at the synchrotron radiation facility (SPring-8), and (25) a high-current metal ion beam generator.

It is necessary to promote research at the research center by recruiting talented researchers from all over the world by opening our door to the world (open environment; this is one of the major goals of the World Premier International Research Center (WPI) initiative of MEXT). To this end, experience in internationalization, such as the use of English as the official language, is required. NIMS has an ample track record in this area. Through the five-year management experience since the inauguration of the International Center for Young Scientists (ICYS), we have accumulated a great variety of experience related to international matters by using English as the official language (in both research activity and administrative work), by organizing multinational groups of young researchers, and by appointing internationally prominent researcher advisers. Moreover, NIMS holds a student summer school every year in cooperation with Cambridge University and the University of California, with special emphasis on international exchange among young researchers.

NIMS with its excellent environment in both research and management, is no doubt the appropriate organization to handle the formation of a research center for the WPI initiative.

2.3 Fostering young research leaders

Cognizant that the mission of the WPI initiative is the establishment of a world-class research center, I would like to emphasize the importance of fostering young researchers, particularly young research leaders, at this type of research center. It may not be necessary to mention that in many cases, research is advanced by the originality of young researchers. When the current status of science and technology in Japan is viewed from this perspective, the fostering of young researchers (which include students, postdoctoral fellows and young research leaders) is not necessarily systematized. In many universities, students are not taught how to write scientific papers in English. Postdoctoral fellows, in many cases, carry out subcontract-type research for their superiors. Young research leaders, such as research associates in universities and group leaders in research organizations, are busy with menial chores. Another recent phenomenon is that young researchers in Japan have no desire to go out of Japan to acquire international experience. It is timely that the WPI initiative promotes the formation of an environment in which postdoctoral fellows and senior researchers can devote themselves to research and internationalization. If this is the goal of the WPI initiative, I believe that an additional step should be taken including the fostering of young researchers (successors, from a person of my age) as another goal of this project. I think this is extremely important for the development of Japan's science and technology. NIMS has been putting special emphasis on fostering young researchers and on internationalization. The operation of the International Center for Young Scientists (ICYS), the holding of student summer schools in cooperation with Cambridge University and the University of California (I am in charge of the summer school with Cambridge University and will visit the university with approximately 20 students this summer), and the holding of closed mini seminars with Novel laureates (Dr. H. Rohrer and Prof. H. Kroto) are some typical examples of our activities.

From the viewpoint of fostering young researchers, at this research center, we will not only carry out the world's top-level research but also enrich student education by incorporating the Graduate School of Material Science of the University of Tsukuba, which is operated by NIMS, as well as plan to adopt a mentor system in which principal investigators nurture young research leaders. Furthermore, we hope that young researchers will learn cooperation with industry to realize the practical applications of their research accomplishments. To this end, we plan to use our Platform, that is, cooperative research operated by NIMS in association with companies and the Evening Seminars (held every week) that are open to researchers from industry.

3 Conclusion

Finally, Japan, which has a national policy of being a world leader in science and technology, is obligated to address the serious issue that technology, which on the one hand, provides us with benefits and welfare, but on the other hand, also causes global-scale environmental destruction. Japan should lead in exploring a path towards sustainable growth. To this end, the development of various new technologies related to environment, energy, resources, information and communication (in reality, more than half of the energy used by advanced countries is for information and communications), and medical treatment is necessary, and the development of innovative materials required in such technologies is of extreme importance. To respond to such needs, we will establish a new paradigm for materials development on the basis of nanoarchitectonics, develop innovative materials and offer them to the world.

To accomplish the above, we will form this research center by inviting excellent researchers from the world over under NIMS as the host organization. The participation of principal investigators from UCLA, Cambridge University, Georgia Institute of Technology, CNRS in France, Tsukuba University and Tokyo University of Science has been confirmed.

Finally, I am sincerely grateful to Dr. Heinrich Rohrer, who was awarded the Nobel Prize for Physics in 1986 for his contribution to the invention of the scanning tunneling microscope (STM), and whom I highly respect, for offering to write a recommendation for me as the prospective center director.

（Host institution： National Institute for Materials Science
Title of Center Project International Center for Materials Nanoarchitectonics）

Host Institution's Commitment

Date

To MEXT

Name of host institution

National Institute for Materials Science (NIMS)

Name and title of head of host institution

Teruo Kishi, President

Signature

I confirm that the measures listed below will be taken faithfully if "International Center for Materials Nanoarchitectonics" is adopted under the World Premier International Research Center (WPI) Initiative.

＜Provision in host institution's mid-to-long-term plan＞

Looking from NIMS's point of view, the center is designed as an organization undertaking the two following roles, classified roughly: (1) an advanced research organization to conduct basic research for materials, fusing fields of materials science, chemistry and physics; (2) an organization to foster researchers who will create the future of material research in an international and interdisciplinary atmosphere.　The objective related to (1) is the "development of innovative materials to realize a sustainable society", and this is perfectly consistent with the 2nd midterm objectives and midterm plan of NIMS.　Accordingly, the center can be positioned as an organization which will play a principle role to lead the main body of NIMS by carrying out the research in a radically accelerated manner.　On the other hand, to put (2), the fostering of researchers, as the other pillar of the concept is a very important point of the center, from the standpoint of NIMS.　We have decided that, if this proposal is realized, NIMS's new staff researchers with tenure will be chosen, in principle, from young researchers of the center.　Thus, the center is also positioned as a place to foster NIMS's future research staff with tenure. Therefore, the center is definitely incorporated into long-term strategies of the main body of NIMS in both aspects of research initiatives and supply of human resources.

＜Concrete Measures＞

(1)

NIMS will support the center in the following manner.

i) Labor costs of permanent staff (such as researchers with tenure and clerical staff) and non-permanent staff that join the center from NIMS will be allocated from operational subsidies and other funds of NIMS except for those who are fully enrolled in the center.

ii) As for projects with operational subsidies that are handled by researchers who join the center from NIMS as senior researchers, we will allocate an equivalent amount of the research funds to the center to implement the project at the center. Among competitive grants obtained by researchers who joined from NIMS, we will allocate an amount equivalent to the direct costs to the center, if the research plan is consistent with that of the center.

iii) We will secure sufficient space mainly at the Nano/Biomaterial Research Building in the Namiki District.

Other than the above, we will give additional assistance for budgeting and space as the need arises.

(2)

The center director is given authority for the center's general operation by the president of NIMS. In other words, the center director has the authority to employ, renew contracts, make payroll decisions, determine research expenses, and allocate space for researchers who are invited to the center, except for NIMS permanent staff. His authority also includes employment and renewal of contracts of administrative staff members, except for NIMS permanent staff. If the center director makes the request and the NIMS president confirms its necessity, NIMS personnel are allowed to move to the center. If these are required to be secured, we will make the necessary rule in NIMS's internal regulations.

(3)

NIMS personnel are allowed to move to the center if the center director requests it and he/she accepts the request and the NIMS president confirms its necessity. As stated above, the center will play a role to supply young staff researchers with tenure to the main body of NIMS. Conversely, it does not basically produce any problem that necessary human resources are supplied from the main body of NIMS to the center. We believe such mobility of human resource between the center and the main body of NIMS may stimulate both organizations.

(4)

We have already experienced in pioneering operations of English use as the official language, clerical work support system in English, creation of bilingual clerical documents, annual salary system, researcher's performance evaluation, salary assessment, renewal of contracts, etc. at the International Center for Young Scientists (ICYS). There is no problem in adopting such a flexible and distinctive management style which can be seen as an extension of the above operations experienced. We are planning to actively adopt the center's successful management systems to the main body of NIMS.

(5)

For the research activities at the center, we will provide a space, approximately 10,000 m^2 for study, mainly at the Nano/Biomaterial Research Building in the Namiki District. The space will be used to secure the following:

Space for experimentation:

We will provide laboratory space at the Nano Biomaterial Research Building for young researchers such as post-doctoral fellows who will proceed with their research independently (about 4,000 m^2 in total). We will provide approximately 1/2 span (20 m^2) as their experimental space. We will provide necessary and sufficient space to principal investigators invited from external organizations.

Single-occupied office and cafeteria:

We will provide young researchers with a single-occupied office (approx. 12 m^2) where they can devote themselves to research and to live in a comfortable environment. Also, to realize an ideal Melting Pot environment, we will put all the living rooms together in one place, and secure enough space for casual talks, including a cafeteria. At the center, we will utilize single-occupied offices which are currently used by ICYS

.

We will allow researchers at the center to freely use research equipment and facilities such as Nano Foundry that NIMS possesses, and will make an effort to accommodate their needs for the use as a priority. Furthermore, we will secure world's top-level advanced facilities with high commonality, in cooperation with the center in a well-planned manner.

(6)

We assume that the center project is extremely effective in activating the whole of NIMS, so we are willing to make efforts for the smooth implementation to the fullest. NIMS is expecting that the center will play a principle role in leading the main body of NIMS. However, this does not mean that NIMS intends to exploit the center to solve NIMS's specific issues such as the aging researcher population. Such problems should be, of course, solved through NIMS's own efforts. Actually, NIMS is expecting the center to play just two roles, i) leading of the main body of NIMS by carrying out research in a radically accelerated manner and ii) fostering of NIMS's future research leaders with establishment of NIMS's tenure-track system.

List of Principal Investigators

Name	Current affiliation (organization, department) and specialties	Academic degree
① AONO, Masakazu	Director-General, International Center for Materials Nanoarchitectonics Specialty on NanoSciene and Nanotechnology	PhD. Tokyo Univ (1972)
② BANDO, Yoshio	Deputy Director-General, International Center for Materials Nanoarchitectonics International Center for Young Scientists, National Institute for Materials Science (**NIMS**), and Graduate School of Pure and Applied Sciences, **University of Tsukuba** Specialty on Nanomaterials and Transmission electron microscope	Ph.D. Osaka University, 1975
③ MUROMACHI, Eiji	Deputy Director-General, International Center for Materials Nanoarchitectonics National Institute for Materials Science (**NIMS**), Advanced Nano Materials Laboratory, Specialty on Solid-State Chemistry and Softchemistry	Ph.D. Tokyo Institute of Technology, 1983
④ SAKKA, Yoshio	Deputy Director-General, International Center for Materials Nanoarchitectonics Nano Ceramics Center, National Institute for Materials Science (**NIMS**), and Graduate School of Pure and Applied Sciences, **University of Tsukuba** Specialty on nanopowder technology and ceramics	Dr. Eng. Kyushu University, 1983
⑤ KITAMURA, Kenji	Optronic Material Center, National Institute for Materials Science (**NIMS**), and Interdisciplinary Graduate School of Eng. Sci. Kyushu University Specialty on crystal growth, nonlinear optical materials, ferroelectric materials	Ph.D. Tohoku University 1983

⑥	Hono, Kazuhiro	Magnetic Materials Center, National Institute for Materials Science (**NIMS**), and Graduate School of Pure and Applied Sciences, **University of Tsukuba** Specialty on Magnetic nanomaterial, Atom probe	Ph.D. The Pennsylvania State University, 1988
⑦	ARIGA, Katsuhiko	Supermolecules Group, Advanced Nano Materials Laboratory and Organic Nanomaterial Center, National Institute for Materials Science (**NIMS**) Specialty on Supramolecular Chemistry and Surface Science	Dr. (Eng.): Tokyo Institute of Technology, 1990
⑧	OHASHI, Naoki	Optronic Materials Center, National Institute for Materials Science and Faculty of Science and Technology, Tokyo University of Science, major: Optoelectronics of oxide and nitride semiconductors	Ph.D. Tokyo Institute of Technology, Japan (1992)
⑨	HU, Xiao	Computational Materials Science Center, National Institute for Materials Science (**NIMS**), and Graduate School of Pure and Applied Sciences, **University of Tsukuba** Specialty on condensed-matter-physics	Ph.D. (Physics), University of Tokyo, 1990
⑩	FUJITA, Daisuke	Advanced Nano Characterization Center, National Institute for Materials Science, Specialty:Advanced nanomaterials characterization	Ph.D. The University of Tokyo,1991
⑪	YE, Jinhua	Photocatalytic Materials Center, National Institute for Materials Science (**NIMS**) Specialty on Photocatalyst, Eco-Materials	Ph.D. The University of Tokyo, 1990
⑫	HASEGAWA, Tsuyoshi	NanoSystem Functionality Center, National Institute for Mateirals Science (**NIMS**), Nano-devices	Ph.D. (science) The Tokyo Inst. Tech., 1996
⑬	SASAKI, Takayoshi	Nanoscale Materials Center, National Institute for Materials Science (**NIMS**), and Graduate School of Pure and Applied Sciences, **University of Tsukuba** , Specialty on nanosheet and softchemistry	Doctor of Science (The University of Tokyo)
⑭	GOLBERG, Dmitri	Nanoscale Materials Center, National Institute for Materials Science(**NIMS**), and Graduate School of Pure and Applied Sciences, **University of Tsukuba** Specialty on nanotubes and nanowires	Ph.D. Moscow Institute for Ferrous Metallurgy, 1990
⑮	TAKAYANAGI, HIdeaki	Tokyo University of Science, Department of Applied Physics Major: mesoscopic superconductivity and quantum information physics	Ph.D. (science) The University of Tokyo, 1987

⑯	KADOWAKI, Kazuo	Institute of Materials Science, Graduate School of Pure and Applied Sciences, **University of Tsukuba**: Specialty on Superconductivity and Nanoelectronics	Ph.D. Osaka University, 1980
⑰	NAGASAKI, Yukio	Department of Materials Science and Master' s Master's School of Medical Sciences, **University of Tsukuba** Specialty on Biomaterials and Polymer Chemistry	Ph.D. Tokyo University of Science (1986)
⑱	GIMZEWSKI, James K.	Dinstinguished Professor, Chemistry & Biochem. Dept., Univ. of California, Los Angeles Director, Nano/Pico Characterization Lab, UCLA California NanoSystems Inst., Specialty on Nanoscience and Nanobio	Ph.D., Physical Chemistry
⑲	JOACHIM Christian*	Centre National de la Recherche Scientifique (CNRS) Lab: CEMES (UPR8011) Toulouse (France) Specialty on Computer science and Nanoscience	PhD in Applied Mathematic PhD in Quantum Physics
⑳	WELLAND, Mark E.	University of Cambridge Specialty on Nanoscience and nanofabrication	PhD (Physics) University of Bristol 1984
21	WANG, Zhong Lin	School of Materials Science and Engineering, Georgia Institute of Technology, Specialty on Nano Chemistry and Nanodevices	Ph.D. Arizona State University, 1987
22	YAGHI, Omar	Dept of Chemistry and Biochemistry, UCLA, USA Specialty on Nanostructure of organic materials	PhD（University of Illinoise, 1990）
23	Gerber, Christoph	Scientific Communication of the National Center of Competence for Nanoscale Science at the Institute of Physics, University of Basel, Switzerland Specialty Nanoscience and Nanoengineering using AFM	PhD