World Premier International Research Center Initiative (WPI)
Executive Summary (for Final Evaluation)

Host Institution	National Institute for Materials Science (NIMS)	Host Institution Head	Kazuhito Hashimoto
Research Center	International Center for Materials Nanoarchitectonics (MANA)	Center Director	Masakazu Aono

About filling out this form:
This summary is to be based on the Center's Progress Report and Progress Plan, with reference to the following items, prepare the summary within a space of **up to 6 pages.**

A. Progress Report of the WPI Center

I. Summary

In the eight and a half years since it was established, MANA has grown to become one of the world's top research centers in the relevant fields and produced remarkable results in fields ranging from fundamental research to practical applications.

MANA's excellence can be found represented in several key indicators. Among these, A) 118 of MANA's papers are now among the top 1% most cited papers in the world; B) MANA has achieved an extremely high score of 2.42 for Elsevier's Field Weighted Citation Impact (FWCI), a new index created to "fairly compare the quality of papers published by research institutions that work in different fields" (both A and B refer to statistics for papers published between 2008 and 2015); and C) MANA's papers are printed in journals with an extremely high average Impact Factor (IF) of 6.16 (2015). MANA's scores for these indicators are superior to those of many world-class research institutions.

MANA has a unique characteristic compared to other materials science laboratories in the world. Its operations are based on a new concept: a new nanotechnology paradigm called "nanoarchitectonics." This unique concept is the key to MANA's achievement of its striking research results.

In eight and a half years, MANA has accomplished much outstanding research. Some representative examples include a) nanosheet technology and its applications, b) atomic switches and related devices, c) various unimolecular devices, d) highly efficient photocatalysts, e) highly sensitive / parallel molecular sensors (MSS odor sensors, etc.), f) diagnosis and treatment using nanoarchitectonics, g) transmission electron microscopes that can observe electrical, mechanical, and optical properties under high-resolution structural observation, and h) multiple-probe scanning probe microscopes that can measure electrical conductivity at the nanoscopic scale.

Over 50% of the researchers at MANA are non-Japanese, making it the most internationalized research center in Japan. MANA has succeeded in creating an almost perfect environment in that it expeditiously provides administrative and technical support to all MANA researchers, including non-Japanese researchers. MANA can give back to NIMS the obtained knowhow and experience of management an international research center. For example, English-language support for non-Japanese researchers within NIMS as a whole has been greatly improved.

In addition to the WPI program's four pillars, MANA has one extra pillar of its own: the cultivation of young researchers. MANA's systems of independent researchers (approx. 20% of permanent researchers), who pursue their own research topics without belonging to any specific group, and ICYS researchers (approx. 20% of post-doctoral scholars) have attained remarkable achievements.

Since FY 2012, MANA has been defined as one of NIMS's three research arms, and it is becoming a permanent presence within the NIMS research organization. NIMS also provides salaries for approximately 90 permanent staff and otherwise provides comprehensive support for MANA in many ways, something that will continue on into the future.

II. Items

1. Overall Image of our Center

<Vision and background>

When MANA was launched eight and a half years ago, nanotechnology (and the nanoscience on which it is based) was in a state of rapid development and becoming an essential pillar of materials science. It was in this context that we designed MANA with the intention of cultivating a world-class research center that would effectively employ nanotechnology to make powerful advances in the research and development of new materials. We were strongly aware of the common mistake of considering nanotechnology to be a continuation of conventional microtechnology, and moreover that nanotechnology's true power cannot be effectively harnessed unless nanotechnology is properly recognized as being qualitatively different from microtechnology. Thus, we established MANA's guiding vision as "Pioneering a new paradigm of nanotechnology to create a research hub for the best new materials development in the world." In order to concisely express this new technology paradigm, we coined the concept of nanoarchitectonics. This concept is described in more detail in the "Progress Report," but it serves to distinguish MANA's research from other nanotechnology research institutions. We at MANA are pleased to see that the nanoarchitectonics concept has begun to gain approval throughout the world.

<MANA today>

MANA was founded on research in four fields—Nano-Materials, Nano-System, Nano-Power, and Nano-Life—but in FY 2016 it established a new field, Nano-Theory. At present, MANA houses 25 principal investigators, 2 associate principal investigators, 75 permanent researchers, 72 post-doctoral researchers, and 36 students who conduct research in 5 fields. These researchers are supported by 29 administrative and technical staff. The present state of MANA can be summarized by the following five points:

★ Achieved world-class research activities
★ True international center with over half of researchers being of foreign nationality
★ Active fusion research that combines nanotechnology and other fields
★ Steadily fulfilling its responsibility to reform its host institution, NIMS
★ Training excellent young researchers who work throughout the world

<Future outlook>

Building on eight and a half years of experience and confidence, MANA pursues interdisciplinary, fusion research centered around the fusion of "theoretical research and experimental research," and the fusion of "nanotechnology (nanoarchitectonics) and life science." Our final objective is to develop through innovative technologies new materials that will shake up the world. There is tremendous potential for this goal to be realized.

2. Research Activities

<Remarkable research accomplishments>

As explained above, MANA's research is conducted in five fields (Nano-Materials, Nano-System, Nano-Power, Nano-Life, and Nano-Theory.) Below are the main accomplishments of each field of research.

A) Inventing nanosheet-based new materials: MANA developed and implemented creative nanosheet methods used to create a variety of new materials with novel and useful properties. The next step is to use these methods to create metamaterials and new superconductors.

B) Development of atomic switches and related devices/systems: The atomic switch operated by a completely different principle than traditional semiconductor devices. MANA invented the atomic switch and moved it toward practical application, where it brought innovation to things like AI and IoT. It was also discovered that atomic switches display functionality similar to synapses in the brain, and hence the next step is to create neutral network circuits made out of atomic switches.

C) Best high-efficiency artificial photosynthesis in the world: As an example of this, MANA has succeeded in achieving the artificial photosynthesis of methane. The next step is to use a variety of nanoarchitectonic systems to dramatically improve the efficiency of artificial photosynthesis.

D) High-sensitivity / parallel molecular sensors (membrane-type surface stress sensor (MSS)): MANA developed a molecular sensor that is a hundred times more sensitive than traditional molecular sensors, capable of distinguishing between healthy individuals and cancer patients by analyzing their exhaled breath. MANA is currently researching such applications.

E) Development of a revolutionary method of nanoscale measurement: MANA developed a transmission electron microscopy (TEM) that can measure electrical, mechanical, and optical properties in high resolution. MANA also developed multiple-probe (2/3/4 probes) scanning tunneling microscope (STM), atomic force microscope (AFM), and Kelvin probe force microscope that can measure electrical conductivity at the nanoscopic scale.

<MANA's three Grand Challenge research topics>

MANA has posted three Grand Challenge research topics:

★ Artificial brains based on nanoarchitectonics
★ Room-temperature superconductivity
★ Practical artificial photosynthesis

These are long-term research targets, but interesting results are already being achieved. Themes 1 and 3 were touched upon lightly in sections B and C on the previous page. Theme 2 has seen achievement in attempts to create superconductivity by introducing electrons and holes into insulators and semiconductors using field effects. In these attempts, researchers succeeded in metalizing diamond. Separately, it has been theorized that when heavy atoms such as gold are formed into a two-dimensional buckled honeycomb lattice and an electric field is applied perpendicularly, current will flow along its edge with zero resistance, even at high temperatures up to 600 K. Experiments are underway in an attempt to verify this theory.

<Applications of research achievements>

Most of MANA’s fundamental research has led to research into applications conducted in cooperation with a variety of companies including NEC Corporation, Honda Motor Company, Murata Manufacturing Co., and Tokyo Chemical Industry Co. Additionally, MANA researchers applied for a total of 774 patents (541 domestic; 233 international) in the period between October 2007 and December 2015. Meanwhile, MANA registered 581 patents (441 domestic; 140 international) in this same period.

3. Interdisciplinary Research Activities

<Strategic initiatives>

MANA has established the following special funds in order to promote interdisciplinary research that fuses MANA's five fields (Nano-Materials, Nano-System, Nano-Power, Nano-Life, and Nano-Theory).

A) Fusion Research Program
B) Theory-Experiment Fusion Research Program
C) Nano-Life Fusion Research Program
D) Grand Challenge Program
E) Theory-Experiment Pairing (TEP) Program

Research topics were determined through a public submission campaign conducted among young MANA researchers. The final topics were selected by a selection committee.

<Representative achievements>

The following are representative achievements of MANA’s interdisciplinary, fusion research.

- Broad-ranging nanosheet technology research; from fundamental research through application
  (Combination of Soft Chemistry, Materials Physics, and Electronic Device Technology)
- Broad-ranging atomic switch research; from fundamental research through application
  (Combination of Electrochemistry, Electronic Device Technology, and Neuroscience)
- Development and practical implementation of highly sensitive / parallel molecular sensors
  (Combination of Science on Animal Olfactory Organs, Nanoarchitectonics, and Medical Diagnosis)
- Development of efficient artificial photosynthetic systems
  (Combination of Photocatalytic Chemistry, Plant Photosynthesis, and Nanoarchitectonics)
- Nanoarchitectonic treatments for cancer and Alzheimer's disease
  (Combination of Medical Science and Nanoarchitectonics)
- Development of new superconductor devices
  (Fusion of theoretical and experimental research)

4. International Research Environment

<International Brain Circulation>

MANA has established satellite labs at research institutions to which external PIs belong. MANA Satellites are currently established overseas at 5 institutions including the University of California Los Angeles (UCLA), the Georgia Institute of Technology, the French National Centre for Scientific Research (CNRS) / Center for Materials Elaboration and Structural Studies (CEMES), the University of Montreal, and University College London (UCL). These satellites both play a role in MANA’s research in various fields and are also training grounds for MANA’s younger researchers. Furthermore, MANA is visited by large numbers of prominent researchers, young faculty students, and other researchers located both inside and outside of Japan. These numbers are increasing every year.

ICYS researchers are on a tenure track to becoming permanent NIMS research staff, and they are hired during twice annual international application phases. Applications have been received from 1,310 individuals over a period of nine years. 90 were hired and 45 of them were assigned to ICYS-MANA.

Of MANA post-doctoral scholars, 12 have been hired on as permanent NIMS research staff, while 198 have advanced to become researchers at universities and research institutions in Japan and around the world. Further, 27 individuals have been sent to private companies.

One of MANA's missions is to build a network of the world's nanotech research centers, of which MANA is the central hub. MANA has signed MOUs with 56 research institutions from 19 countries with which it engages in research and talent exchange.

<Support system for non-Japanese researchers>

All staff in MANA's Administrative Office speak English and provide comprehensive Japanese-style service to all researchers, regardless of age and nationality. However, we did not simply bring a foreign research environment into Japan; instead, we have built an "international research support system in Japan," where non-Japanese personnel can blend right in.

<Administrative support staff and appropriate support systems>

MANA has succeeded in creating an almost perfect environment in that it expeditiously provides administrative and technical support to all MANA researchers, including non-Japanese researchers. Some representative examples of this environmental support are the bilingualization of documents and communication, livelihood support, technical support, Japanese language classes, and Japanese cultural training.

<Other>

As one method of attracting and cultivating young researchers, MANA's systems of independent researchers (who do not belong to any specific group and pursue research independently) and ICYS researchers have produced great results.

In the interest of cultivating Japanese researchers of an international and interdisciplinary character, MANA encourages young Japanese researchers to take up long work residencies at major research institutions overseas. MANA has also established the YAMATO-MANA Program, the objective of which is to invite excellent young Japanese researchers to MANA and cultivate talent who will lead Japan's future.

5. Organizational Reforms

<Decision-making organization>

The center's Director-General has succeeded in gathering excellent researchers from around the world and building a research culture in which these researchers can work freely and easily while working hard and improving together. The Director-General has displayed strong leadership in his management of the center, including his work setting research policy, streamlining systems and organizations, implementing effective new policies, and distributing research resources. He has created an established global presence for the nanoarchitectonics concept by holding numerous research conferences, publishing special nanoarchitectonics editions of famous journals, distributing online newsletters, and other PR activities. Indeed, there is even happy news that the word "nanoarchitectonics" will be in the next revision to the famous and authoritative Japanese dictionary, *Kojien*.

<Administrative support staff and appropriate support systems>

MANA has succeeded in creating an almost perfect environment in its capacity to expeditiously provide administrative and technical services to all MANA researchers, including non-Japanese researchers.

<WPI program organizational reforms and their ripple effects>

Organizational reforms at MANA

(1) Strongly promoted interdisciplinary research by launching new research programs.
(2) Intensified internationalization at MANA through measures such as promoting bilingual administration and offering research and living support for non-Japanese researchers.
(3) Secured and cultivated young researchers by implementing ICYS, the 3D System, and others.

Ripple effects on the host organization as a whole, etc.

(1) The structure has been put in place to easily spread MANA's organizational reforms to the entirety of NIMS. In the NIMS Mid- to Long-Term Plan (7-year plan), MANA is defined as one of seven core research centers.
(2) Overall English ability at NIMS has been dramatically improved by the implementation of programs to improve the English ability of administrative staff, the translation of important documents and internal announcements into both English and Japanese ("bilingualization"), and other initiatives.

(3) Many excellent young researchers who came of age at MANA have been hired on at NIMS as permanent research staff.
(4) MANA's experience and achievements have spread to NIMS's other research centers: e.g., building design.
(5) Center management offices aspiring to be similar to MANA's Administrative Office have been set up at other NIMS research centers.

<Support from the host institution>

NIMS offers comprehensive support for MANA, providing staff, research funding, and research space to the program, as well as delegating management authority to the Director-General. Since MANA's founding, over 1.4 billion JPY annually has been allocated from NIMS's operational expense grants to pay for research projects and other project expenses necessary to the center's activities.

<Role in the host institution's mid/long term plans, etc.>

In its 3rd five-year plan that began in April 2011, MANA's work in the development of innovative new materials through nanoarchitectonics was recognized as a priority R&D area for NIMS, and MANA was defined as one of NIMS's three research arms: namely, the Nanoscale Materials Division. Further, in NIMS's 4th Mid- to Long-Term Plan (7-year plan), the "International Center for Materials Nanoarchitectonics (MANA)" is explicitly defined as one of NIMS's main research centers. NIMS is also methodically increasing the number of permanent researchers and administrative staff on board at MANA. Thus from April 2011 to March 2016, MANA added 18 permanent staff to its roster, meaning that as of the end of March 2016, MANA had a total of 89 permanent staff.

B. Progress Plan

1. Mid- to Long-term Research Objectives and Strategies Based on the Center's Research Results to Date

<Overview>

After analyzing MANA's research accomplishments over the past eight and a half years, the efficacy of two areas was brought into sharp relief: the fusion of "theoretical research and experimental research," and the fusion of "nanotechnology (nanoarchitectonics) and life science." Therefore, these two fusional areas will be the focus of intensive research in the future.

Additionally, analysis of progress on MANA's three Grand Challenge research themes shows that promising preliminary results are in the process of emerging, and hence this research will also be continued.

<Fusion of theoretical and experimental research>

As stated previously, MANA established in FY 2016 a fifth new field in addition to its four traditional fields of research: Nano-Theory. The Nano-Theory field will constitute a large group of 30 theoretical researchers. This means that approximately one in five MANA researchers will be a theoretical researcher.

Despite the fact that many interesting nanoscopic phenomena are accompanied by excited states, dynamic processes, and many-body effects, contemporary methods of first-principles calculation are not good at handling these elements. To overcome this obstacle, MANA will introduce bold yet appropriate methods of approximation to inspire new developments in theoretical research, which will serve to promote the fusion of theoretical and experimental research. Not only will the field of Nano-Theory serve to fuse theory and experimentation, it will also play a role in promoting interdisciplinary fusion research among MANA's four other fields of research, all of which have experimental research at their core.

<MANA's unique Nano-Life research>

MANA established the Nano-Life field with the aim of opening up a new field that combines MANA's world-best nanotechnology with the life science. One important characteristic of MANA is its environment, in which the best nanotechnology researchers and life science researchers work side-by-side to gain a thorough understanding of each other's fields. This distinctive characteristic of MANA's has recently begun producing remarkable results. In the extension period, MANA will take advantage of these circumstances to completely remodel the Nano-Life field. MANA aims to create new, never-before-seen things and systems by studying the functions of cells, sensory organs, and the brain, incorporating the knowledge gained through this into the best nanoarchitectonics technology. Conversely, MANA will also strongly promote the active utilization of the best nanoarchitectonics technology in Nano-Life research.

<MANA's Grand Challenge>

MANA has laid out three Grand Challenge research targets thus far, and it will continue this work in the future. The outlook for future accomplishments in this areas is quite positive.

Now, MANA is adding a fourth Grand Challenge research target that pertains to the fusion of nanotechnology (nanoarchitectonics) and life science:

★ Super bio-sensing

By combining multiple-probe scanning probe microscopy, ultrasensitive / massively parallel molecular sensors, luminescent nano-particle, nanotubes, and other nanoarchitectonics technology with elements of life science pertaining to cells and biomolecules, we hope to open up a new world of super bio-sensing that is unique to MANA.

2. Management System of the Research Organization

<Research organization management>

In April 2016, one year before the end of the 10-year project period of MANA, the next Mid-Term Plan (7-year plan) starts at NIMS and MANA implements structural reforms based on the following key points: Creating and filling the position of a new deputy director, replacing PIs, establishing the Nano-Theory field, strengthening the Nano-Life field, investing in Grand Challenge research, promoting innovative and challenging research, promoting joint research with universities and private companies, etc.

< Initiatives and planning for organizational reform >

Reforming NIMS: The administrative experience and unique administrative and technical support systems cultivated at MANA will be exported to NIMS.

Internationalization of NIMS and other Japanese research institutions and universities: NIMS will work to export MANA's research environment to other research institutions and universities outside of NIMS.

Expanding the international network: MANA has grown into a well-known world-class research center that attracts researchers from around the globe. MANA will expand its international network beyond just America, Europe, and other developed countries to include countries that are still developing in terms of R&D, encompassing many countries from all regions of the world. In this way, MANA will fulfill its role as a hub for global nanotechnology R&D and the cultivation of young researchers.

3. Center’s Position within the Host Institution, and Measures Taken by Host Institution to Provide Resources to the Center

<Role of the center in the mid/long term outlook of the host institution>

NIMS’s next Mid- to Long-Term Plan will be a 7-year plan, and it will begin in April 2016, one year earlier than the conclusion of the initial WPI project implementation period (10 years). Even after the end of the WPI program, MANA will continue to be NIMS’s main nanotechnology research center, take in most of NIMS’s theoretical researchers, and become an even more solidified international nanotechnology research hub. Specifically, beginning in April 2016 seven research centers will exist within NIMS, and one of those will be MANA. With the theoretical researchers transferring to MANA, the augmented superconductor, and four new hires reinforcing MANA’s roster, MANA will grow into a major research center with permanent staff numbering 104—approximately 1/4 of all permanent research staff at NIMS.

<Host institution’s action plan for maintaining and developing activities befitting of a world-class research center>

NIMS promises provide MANA with the following research resources, and to continue those basic activities on into the future.

i) Although NIMS declared that it would assign approximately 90 permanent NIMS staff to MANA as permanent employees (including principal investigators, associate principal investigators, group leaders, MANA researchers, independent researchers, and administrative staff), from April 2016 this will be greatly increased to a total of 104 staff.

ii) NIMS will contribute 1.6 billion JPY a year out of its management expenses grant to pay for MANA’s research project costs, administrative costs, etc.

After the WPI program concludes, in addition to i) and ii) above, the following policies will be implemented:

iii) Post-doctoral scholars and other fixed-term staff hired using WPI grant funds will be replaced with others hired using external funding.

iv) Programs characteristic of MANA—such as young researcher training programs (ICYS, etc.), symposiums, and outreach activities—will be transferred to and implemented at NIMS.

v) NIMS will implement organizational reforms, scrutinizing and strengthening its own systems with reference to the administrative and technical support that are of especially high quality at MANA.

vi) NIMS is planning to create new open innovation mechanisms that utilize promising research accomplishments at MANA and moves them toward practical applications research. Also a new scheme of internationalization is under designing which enable MANA to develop sustainable international networking with a help of MANA satellites.

World Premier International Research Center Initiative (WPI)
Progress Report of the WPI Center (for Final Evaluation)

Host Institution	National Institute for Materials Science (NIMS)	Host Institution Head	Kazuhito Hashimoto
Research Center	International Center for Materials Nanoarchitectonics (MANA)	Center Director	Masakazu Aono

* Write your report within 30 pages. (The attached forms are in addition to this page count.) Keep the length of your report within the specified number of pages.

Common Instructions:

* Please prepare this report based on the current (31 March 2016) situation of your WPI center.

* Use yen (¥) when writing monetary amounts in the report. If an exchange rate is used to calculate the yen amount, give the rate.

1. Overall Image of Your Center (write within 2 pages including this page)

Describe the Center's current identity and overall image. For centers that have had a change in their directors, describe that transition and the effects of the change.

・ On the sheets in [Appendix 1-1~7], list the Principle Investigators, and enter the number of center personnel, a chart of the center's management system, a campus map showing the center's locations on the campus, project funding, project expenditures, and WPI grant expenditures.

1-1. Introduction

In the eight and a half years since it was established (until the date on which this report was created), MANA has grown to become one of the world's top research centers in the relevant fields and produced remarkable results (refer to Chapter 2 for details). MANA's excellence can be seen in several key indicators. Among these, A) 118 of MANA's papers are now among the top 1% most cited papers in the world (2008-2015); B) MANA has achieved an extremely high score of 2.42 for Elsevier's Field Weighted Citation Impact (FWCI), a new index created to "fairly compare the quality of papers published by research institutions that work in different fields" (2008-2015 average); and C) MANA's papers are printed in journals with an extremely high average Impact Factor (IF) of 5.24 (most recent average for 2011-2015). MANA's scores for these indicators are superior to those of many world-class research institutions.

MANA's development to this point is entirely due to the support by the WPI program, and for that we would like to take this opportunity to express our deep gratitude.

1-2. MANA background

MANA was established eight and a half years ago through its host institution NIMS, Japan's leading research institution in the field of materials science. At that time, nanotechnology (and the nanoscience on which it is based) was in a state of rapid development globally and becoming an essential part of materials science. It was in this context that we designed MANA with the intention of creating a world-class research center that would effectively employ nanotechnology to make powerful advances in the research and development of new materials. In designing MANA, we were strongly aware of the common mistake of considering nanotechnology to be a continuation of conventional microtechnology, and moreover that nanotechnology's true power cannot be effectively harnessed unless nanotechnology is properly recognized as being qualitatively different from microtechnology. The concept of "nanoarchitectonics" was proposed as a straightforward expression of these truths. Nanoarchitectonics is a new technological paradigm built on the following four primary pillars:

1) Create *reliable* nanomaterials or nanosystems by organizing nanoscale structures (nano-parts) even with some unavoidable *unreliability*. "Unreliability-tolerant reliability"
2) Note that the *main players* are not individual nanoparts but *their interactions*, which cause a new functionality to emerge. "From nano-functionality to nanosystem-functionality"
3) Recognize unexpected *emergent functionalities* that can result from assembling or organizing *a huge number of nanoparts*. "More is different"

4) Create *a new theoretical field* where conventional first principles computations are combined with novel *bold approximations*. "Truth can be described with plain words"

The concept of nanoarchitectonics is a distinguishing part of MANA's research and makes MANA unparalleled among the world's nanotechnology research institutions. We at MANA are pleased to see that the nanoarchitectonics concept has begun to gain approval throughout the world.

1-3. MANA: Vision, missions, and organization

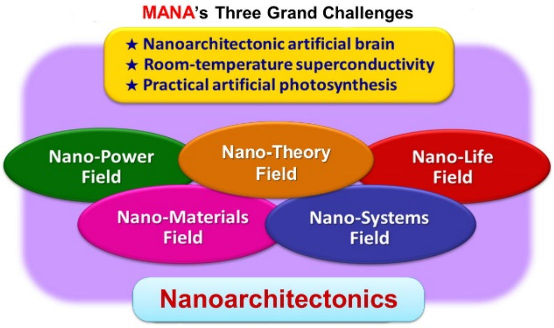
MANA's guiding vision is as follows:

Toward a better global future:
We pioneer a new paradigm in materials development
on the basis of nanoarchitectonics concept.

The following four missions are in place to achieve this vision:

1. World leader in new materials development, based on nanoarchitectonics
2. Fusion of interdisciplinary research fields to open up new research fields
3. Fostering next-generation young research leaders
4. Creation of an international research collaboration network

In order to pursue nanoarchitectonics-based dynamic research from the fundamentals through to applications, as well as to pursue a fusion of different fields through nanoarchitectonics, MANA's research is organized into five fields: Nano-Materials, Nano-System, Nano-Power, Nano-Life, and Nano-Theory (the diagram below also displays MANA's three challenging cross-disciplinary research themes).



1-4. MANA today

Founded on the concept of nanoarchitectonics, today MANA has grown into a world-class research center that produces much ground-breaking research and attracts global attention.

The present state of MANA can be summarized by the following five points:

★ World-class research activities
★ International character due to 51% of researchers being of foreign nationality
★ Active fusion research that combines nanotechnology and other fields
★ Steadily fulfilling its responsibility to reform its host institution, NIMS
★ Training excellent young researchers who work throughout the world

2. Research Activities (within 15 pages)

2-1. Research Results to Date

Describe issues of a global level that the Center has challenged, and give the results. Select 20 representative results achieved during the period from 2007 through March 2016. Number them [1] to [20] and provide a description of each. Place an asterisk (*) in front of those results that could only have been achieved by a WPI center.

In Appendix 2-1, list the papers underscoring each research achievement (up to 40 papers) and provide a description of each of their significance.

<Outline>

MANA was established for the purpose of establishing a new nanotechnology paradigm based on the concept of nanoarchitectonics, and to bring about innovation in new materials development through this paradigm. These objectives are steadily being accomplished. In reality, a number of concepts based on nanoarchitectonics have emerged from MANA's research, including soft chemical nanoarchitectonics, interface nanoarchitectonics, neuromorphic nanoarchitectonics, topological nanoarchitectonics, and in-vivo nanoarchitectonics. Research based on these topics is steadily progressing.

Below is a summary of 20 research achievements selected from MANA's work (page 3-13). These accomplishments fall into three broad categories as shown in the table below: Creation of New Research Fields, Fusion of Interdisciplinary Research Fields, and Other Remarkable Research Results. Each category is divided into three subcategories.

Remarkable Research Results from MANA

Creation of New Research Fields	*Research Results*
★ Nanosheet-based New Horizon for Novel Materials Creation	[1], [2]
★ Atomic Switch and Related Prospective Devices and Systems	[3], [4]
★ Molecular-scale Site-designated Chemical Nanoarchitectonics	[5], [6]
Fusion of Interdisciplinary Research Fields	
★ Nanoarchitectonics-inspired Nano-Life Science	[7], [8]
★ Nano-Life Science-inspired Nanoarchitectonics	[9], [10]
★ Theory-Experiment 'Cross-linkage' for Exploring Novel Nanoscale Materials and Systems	[11], [12]
Other Remarkable Research Results	
★ Innovative Nanoscale Devices and Systems	[13], [14], [15]
★ Innovative Nanoscale Characterization Methodologies	[16], [17]
★ Nanoarchitectonics Related to Sustainable Energy and Environment	[18], [19], [20]

"Creation of New Research Fields" refers to MANA-conceived original research that is in the process of spreading throughout the world. This includes the creation of various new materials through nanosheet technology, research on atomic switches and resulting devices, and research on nanoarchitectonic chemistry that approaches the realization of mono-molecular devices.

"Fusion of Interdisciplinary Research Fields" refers to Nano-Life research that draws on MANA' s advanced nanoarchitectonics, nanoarchitectonics research that draws on Nano-Life research (i.e., the reverse), and research that closely intertwines and fuses theory and experiment.

"Other Remarkable Research Results" contains various other remarkable achievements that do not fall under either of the categories above.

< Twenty major research achievements >

(Refer to papers 1 - 40 in Appendix 2)

Creation of New Research Fields

★ Nanosheet-based New Horizon for Novel Materials Creation

[1] Production of functional nanosheets through exfoliation of layered crystals via massive swelling

Representative researcher: T. Sasaki

We have developed a variety of oxide and hydroxide nanosheets via inducing enormous swelling of layered crystals in liquid phase. The highly swollen crystals can be gently disintegrated into high-quality unilamellar nanosheets in high yield, which is difficult to attain by other delamination procedures. This process has been applied to various layered crystals synthesized in a designed composition and structure to produce a range of nanosheets exhibiting unique and useful properties. The nanosheets thus obtained have been effectively utilized as building blocks for "2D Nanosheet Nanoarchitectonics" to tailor functional nanostructured materials and nanodevices.

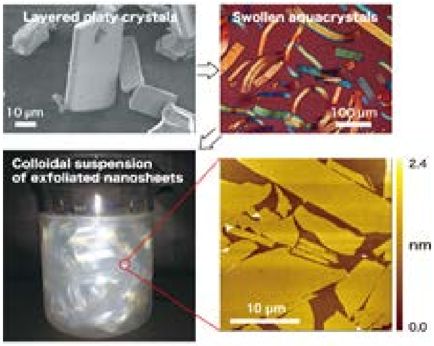


Fig. 1. Platy microcrystals of a layered titanate (top left), their swollen "aqua-crystals" (top right) and exfoliated

We found the amazing phenomena that platy microcrystals of layered metal oxides underwent accordion-like swelling in various amine solutions (see Fig. 1). The interlayer galleries evenly expanded up to 100 times beyond original spacing via penetration of a very large volume the aqueous solution. The resulting

unique “aquacrystals” could be totally delaminated into large-sized nanosheets.
See Papers 1 [*Nature Commun.* **4** (2013) 1632] and 2 [*J. Am. Chem. Soc.* **136** (2014) 5491] in Appendix 2.

[2] Super-high-*k* oxide nanosheets: New 2D materials and devices beyond graphene

Representative researchers: M. Osada & T. Sasaki

We have discovered high-k oxide nanosheets, an important material platform for ultra-scale electronics and post-graphene technology. Newly developed nanosheets (Ti_2NbO_7, $(Ca,Sr)_2Nb_3O_{10}$) exhibited the highest permittivity (ε_r = 210~320) ever realized in all known dielectrics in the ultrathin region (< 10 nm). Our results offer a route to new 2D devices beyond graphene.

2D materials are now considered to be excellent candidates for future electronic applications. High-*k* oxide nanosheets are of major technological importance for establishing the thinnest and highest-*k* nanodielectrics (Fig. 2) that cannot be achieved in graphene and other materials. Notably, all-nanosheet capacitors exceeded textbook limits, opening a route to new capacitors and energy storage devices. A layer-by-layer engineering using high-*k* oxide nanosheets enabled us to design new 2D devices such as nanosheet FETs, artificial ferroelectrics, multiferroics, etc. Graphene is only the tip of the iceberg, and we are now opening up a new era of “post-graphene technology”.

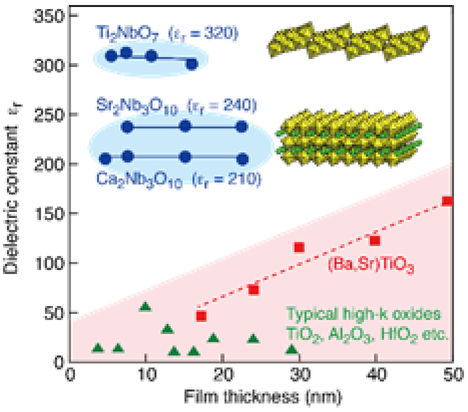


Fig. 2. Dielectric properties of high-*k* oxide nanosheets and various oxide dielectrics.

See Papers 3 [*Adv. Mater.* **24** (2012) 210] and 4 [*ACS Nano* **8** (2014) 2658] in Appendix 2.

★ Atomic Switch and Related Prospective Devices and Systems

[3] Atomic switch: Novel on/off switching characteristics and unique synaptic-like behaviors

Representative researchers: K. Terabe, T. Tsuruoka, M. Aono

We have developed the novel switching device, which is better than conventional semiconductor devices such as DRAM and Flash memory, in terms of simple structure, lower energy consumption, etc. It is almost a commercial reality for the field-programmable gate arrays (FPGAs) in collaboration with NEC Corp. The unique operating mechanisms of the atomic switch, i.e., movement of atoms/ions associated with their redox reaction processes in solids under potential applications, have enabled the further development of various novel devices, such as ‘volatile/nonvolatile three-terminal atom transistor’, ‘on-demand function-selectable atomic switch’, and ‘synapse-like atomic switch junction’.

The synapse-like atomic switch junctions emulate two modes of plasticity of biological synapses in the human brain, i.e., short-term plasticity (STP) and long-term potentiation (LTP), utilizing the structural stability of electron-conducting paths. Depending on the input strength and repetition frequency, the junctions exhibit the transition between the STP and LTP modes. This function can be realized using cation (metal ion) or anion (oxygen vacancy) migrations in various electrolyte systems, as shown in Fig. 3. The results encourage us to develop conceptually new artificial neuromorphic computing systems that do not require any pre-programming.

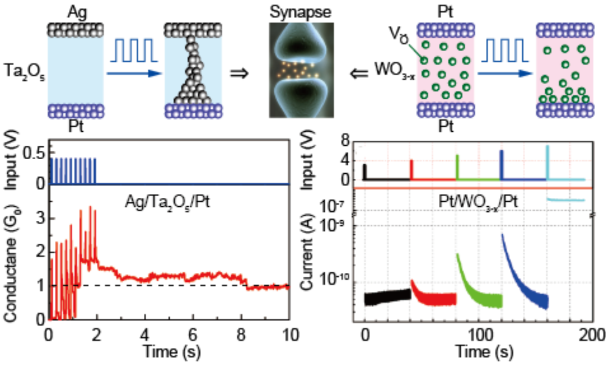


Fig. 3. Atomic switch junctions work as inorganic synapses in systems of $Ag/Ta_2O_5/Pt$ with metal ion migration (left) and $Pt/WO_{3-x}/Pt$ with oxygen vacancy migration (right).

See Papers 5 [*Nature Mater.* **10** (2011) 591] and 6 [*ACS Nano* **6** (2012) 9515] in Appendix 2.

[4] Networks of atomic switches for neuromorphic computation

Representative researchers: J. Gimzewski, A. Stieg, M. Aono

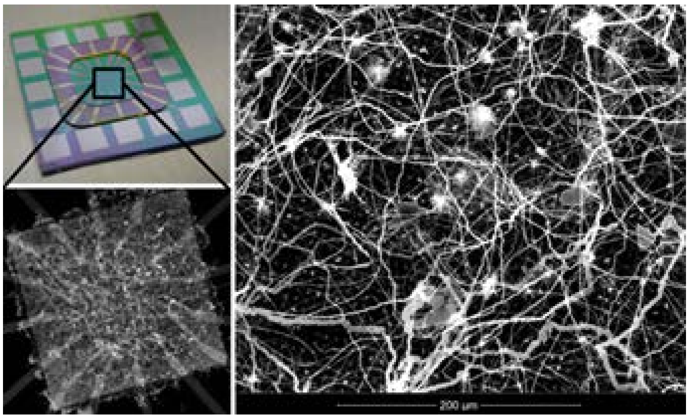


Fig. 4. The ASN device (upper left) is comprised of atomic switch junctions located at the crossing points of self-organized nanowire network. A look inside the ASN (lower left) reveals a highly interconnected neuromorphic architecture (right).

We have developed unique neuromorphic devices, known as atomic switch networks (ASN), comprised of highly interconnected (~10^9/cm^2) atomic switch interfaces which retain the synaptic properties of their component elements and generate a class of emergent behaviors known to underlie biological cognition. The utility of ASN devices in reservoir computing, a biologically inspired framework known to demonstrate unparalleled efficiency in real-time performance of complex tasks, has been demonstrated through performance of various benchmark machine- learning tasks including the parity-n test, NARMA-10 test and the T-maze. ASN devices hold great promise as a scalable hardware platform for signal processing and computation capable of overcoming modern operational limits in the RC paradigm.

The mammalian brain exceeds modern computers in performing complex tasks such as associative memory, pattern recognition, or prediction as a result of the radically divergent physical structures and operating mechanisms. Drawing inspiration from the cortical neuropil, millions of atomic switches have been incorporated into a densely interconnected network of conductive nanowires, as shown in Fig. 4, through the nanoarchitectonics concept of self- organization. By combining concepts of computational neuroscience and machine learning with those of self-organization in complex nanoscale materials, these results lay a foundation for the creation of next-generation cognitive technologies.

See Papers 7 [*PloS ONE* **7** (2012) e42772], 8 [*Adv. Mater.* **24** (2012) 286] and 9 [*Nanotechnology* **24** (2013) 384004] in Appendix 2.

★ Molecular-scale Site-designated Chemical Nanoarchitectonics

[5] Electrical wiring of single molecules via conductive molecular chains

Representative researchers: Y. Okawa, C. Joachim, M. Aono

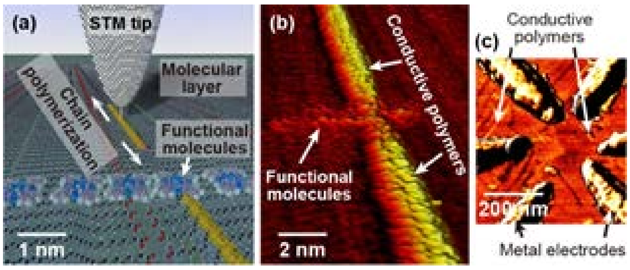


Fig. 5. Schematic illustration (a) and STM image (b) of chemical soldering. Chain polymerization is initiated with the STM tip. Two conductive polymer chains are connected to a single functional molecule (phthalocyanine). (c) Atomic force microscopy image of conductive polymer chains fabricated between metal electrodes on a hexagonal boron nitride substrate.

Though single-molecule electronics has been widely investigated for a long time, the fabrication of practical single-molecule circuits remains challenging because of the lack of viable methods for wiring each molecule. To solve this problem, we have developed a novel method for single molecular wiring. Using a nanoscale-controlled chain polymerization on a molecular layer, we have succeeded in connecting single conductive polymer chains to single functional molecules via covalent bonds. We are investigating the electrical transport properties of the fabricated single molecule devices. These studies will be an important step in advancing the development of single-molecule electronic circuitry.

Figure 5 (a) illustrates the wiring procedure, which we call “chemical soldering”. Stimulation with a tip of scanning tunneling microscope (STM) on a molecular layer of diacetylene compound can initiate chain polymerization of diacetylene molecules, and the reactive front edge of the chain forms a covalent bond with the adsorbed

functional molecule. We have demonstrated that two polydiacetylene chains are connected to a single phthalocyanine molecule (Fig. 5 (b)). We are investigating the electrical transport properties of the fabricated single molecule devices on insulating substrates (Fig. 5 (c)).
See Papers 10 [*J. Am. Chem. Soc.* **133** (2011) 8227] and 11 [*Nanoscale* **4** (2012) 3013] in Appendix 2.

[6] Controlling bound and unbound states of molecules (C_{60}) reversibly at designated sites

Representative researchers: T. Nakayama, M. Nakaya, M. Aono

Toward a realization of ultrahigh-density data storage using single-molecule manipulation with a scanning tunneling microscope (STM), a long-standing problem was how to achieve reversible and repeatable control of a molecular bit to represent 0 and 1. We solved this problem by controlling bound and unbound states of C_{60} molecules at room temperature and demonstrated bit operations at a bit density of 190 Tbits/in^2.

In a thin film of fullerene C_{60} molecules, single-molecule-level chemical reaction between C_{60} molecules was controlled using an STM tip. We found that negative and positive ionization of a designated C_{60} molecule perfectly trigger polymerization and deploymerization reactions of a designated C_{60} molecule with an adjacent molecule in the film, respectively. With this method, an ultra-dense data storage was demonstrated (see Fig. 6).
See Papers 12 [*Adv. Mater.* **22** (2010) 1622] and 13 [*ACS Nano* **5** (2011) 7830] in Appendix 2.

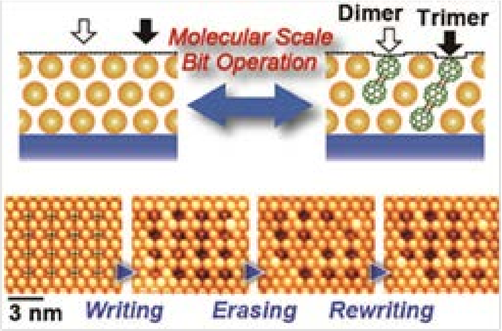


Fig. 6. (Upper) Schematic illustration of local and reversible control of bound and unbound states of C_{60} molecules. (Lower) A series of STM images showing single-molecule-level bit operation.

Fusion of Interdisciplinary Research Fields

★ Nanoarchitectonics-inspired Nano-Life Science

[7] Nanoarchitectonic smart nanofibers for cancer and kidney disease therapy

Representative researcher: M. Ebara

We have developed a smart anticancer nanofiber capable of simultaneously performing thermotherapy and chemotherapy for treating malignant tumors. By tailoring the nanoarchitectures of polymer networks in the fiber, we demonstrated simultaneous heat generation and drug release in response to alternating magnetic field (AMF). Only a 5-10 min application of AMF can successfully induce cancer apoptosis both in vitro and in vivo studies.

The nanofiber is composed of a chemically-crosslinkable temperature-responsive polymer with an anti-cancer drug and magnetic nano-particles, which serve as a trigger of drug release and a source of heat, respectively (Fig. 7(a)). Both *in vitro* and *in vivo* studies show that the majority of tumor cells died in only a 5-10 min application of AMF by double effects of heat and drug (Fig. 7(b)). We believe that the development of a manipulative material is considered to lead not only to improving the survival rate of cancer patients but also to providing minimally invasive treatment methods in combination with endoscopic surgery.
See Papers 14 [*Angew. Chem. Int. Ed.* **51** (2012) 10537] and 15 [*Adv. Func. Mater.* **23** (2013) 5753] in Appendix 2.

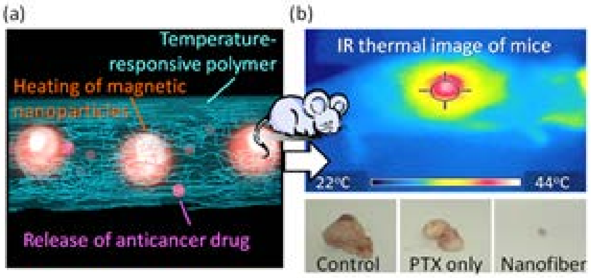


Fig. 7. (a) Schematic illustration of smart nanofiber. (b) *In vivo* studies show that AMF application induces heat generation in mice (top) and the size of tumors were successfully reduced by implantation of the smart nanofiber via double effects of heat and drug (bottom).

[8] Nano- and micro-structured biomaterials for cell function controlling and tissue engineering

Representative researchers: G. Chen, N. Kawazoe

Nano- and micro-structured biomaterials play an important role in tissue engineering to control stem cell functions and to guide the regeneration of new tissues and organs. We have developed a series of functional biomaterials that mimicked the nano-structured microenvironments surrounding cells in vivo. The biomaterials showed specific controlling on the differentiation of stem cells and promotive effects on tissue regeneration.

One type of the biomaterials is surface functionalized nanomaterials. Gold nanoparticles having various geometries were synthesized and functionalized with different functional groups. Surface functionalized gold nanoparticles showed different effects on the osteogenic differentiation of human bone marrow-derived mesenchymal stem cells depending on their surface properties. Another type of biomaterials is porous scaffolds with micropatterned pore structures and biological molecules. The scaffolds were prepared by a unique ice template method and their micropatterned structures could be easily controlled by designing the templates. The scaffolds promoted formation of highly aligned and multi-layered muscle bundle tissues. The scaffolds have been used for regeneration of cartilage, skin, bone and muscle tissues. The functional biomaterials have been shown useful for stem cell research and tissue engineering.

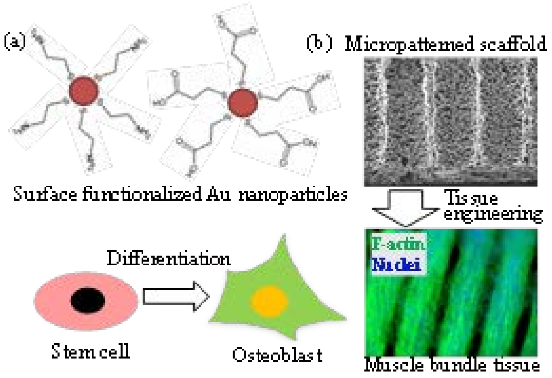


Fig. 8. Surface functionalized gold nanoparticles and their effects on osteogenic differentiation of mesenchymal stem cells (a) and micropatterned collagen porous scaffold and its application for regeneration of skeletal muscle tissue (b).

See Papers 16 [*Adv. Mater.* **24** (2012) 4311] and 17 [*Biomaterials* **54** (2015) 226] in Appendix 2.

★ Nano-Life Science-inspired Nanoarchitectonics

[9] Ultrasensitive and ultraparallel molecular sensing for mobile olfaction and other various Applications

Representative researcher: G. Yoshikawa

We have developed a novel molecular sensor, which researchers had been trying to realize for 20 years all over the world. We named the new sensor "Membrane-type Surface stress Sensor (MSS)", which is based on the comprehensive optimization of materials science, mechanics, crystallography, and electronics, investigated together with Dr. Heinrich Rohrer (Nobel Prize Winner in Physics 1986). In contrast to the %-order improvements in sensitivity by conventional approaches, the MSS achieved more than 100 times higher sensitivity in addition to superior performance in all practical aspects. The MSS is expected to contribute to various fields; medicine, security, and environmental research.

We fabricated MSS chips in collaboration with EPFL, Switzerland, and demonstrated the possibility for non-invasive breath analysis in collaboration with University of Basel, Switzerland (Fig. 9 (a)).

While the MSS provides a practical sensing element as shown in Fig. 9 (b), a consumer sensor system requires further optimization and nanoarchitectonic integration of lots of components ranging from various hardware to software including big-data analysis with cloud computing. To integrate the cutting-edge technologies, we launched an industry-government-academia joint research framework: the MSS Alliance. Through this framework,

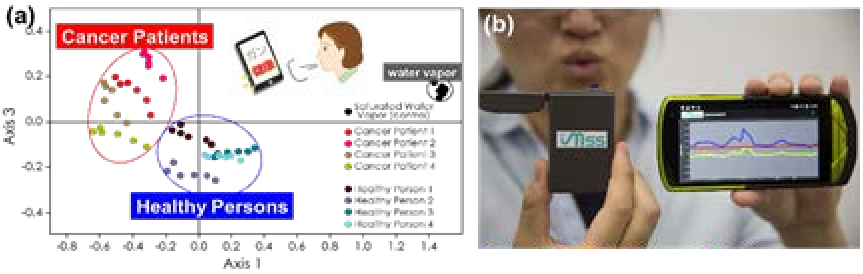


Fig. 9. (a) Experimental results of breath analysis using an array of MSS which could distinguish the breath of cancer patients from that of healthy people in a double blind trial. (b) A prototype of a mobile sensing device based on the MSS technology.

we aim to establish basic technologies for practical mobile olfaction toward safe, healthy, and peaceful life.
See Papers 18 [*Nano Lett.* **11** (2011) 1044] and 19 [*Langmuir* **26** (2013) 7551] in Appendix 2.

[10] Progress in high-efficiency artificial photosynthesis

Representative researcher: J. Ye

We have been conducting a series of pioneering works for challenging a high-efficiency artificial photosynthesis, which offers a potential solution for global warming and energy shortage issues. A new material Ag_3PO_4 with the world's highest quantum efficiency in photocatalytic water oxidation has been developed. Sophisticated control of surface/ interface structure has enabled efficient light harvesting, charge separation, and gas diffusion/conversion, making a big step towards realization of a high-efficiency artificial photosynthesis.

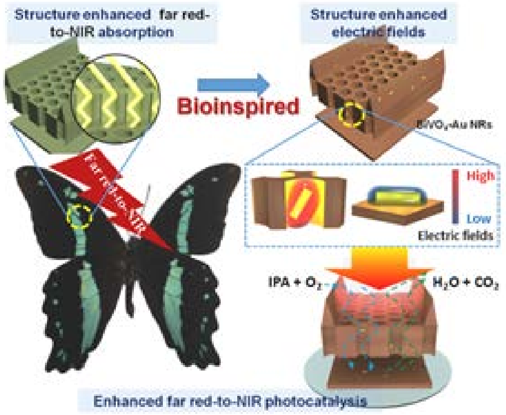


Fig. 10. Schematic illustration of the concept of structure-enhanced bio-inspired far red-to-NIR highly responsive photocatalytic system.

Here we demonstrate a new strategy inspired by nature's far red-to-NIR responsive architectures. The system is constructed by controlled assembly of light-harvesting plasmonic nanoantennas (Au nanorods) onto a typical $BiVO_4$ photocatalytic unit with butterfly wings' 3D micro/nanoarchitectures (Fig. 10). It's found that the unique structure can significantly enhance solar light harvesting including far red-to-NIR, and increase electric-field amplitude of localized surface plasmon, which promotes the rate of electron-hole pair formation, thus substantially reinforcing photocatalysis.
See Papers 20 [*Sci. Rep.* **6** (2016) 20001] and 21 [*Nature Mater.* **9** (2010) 559] in Appendix 2.

★ Theory-Experiment *Cross-linkage* for Exploring Novel Nanoscale Materials Systems

[11] Topological matter nanoarchitectonics for novel quantum devices

Representative researchers: X. Hu, T. Uchihashi

Because the uncertainty of quantum system becomes prominent, the functions of nano devices are hard to realize through design in a way similar to those in the macroscopic worlds. In order to develop a new design principle for advanced nanoquantum devices, we are exploiting the topology of various systems, which links bulk to surface and nano to macro as a quantum holography principle. A brand-new approach coined "topological nanoarchitectonics" is emerging.

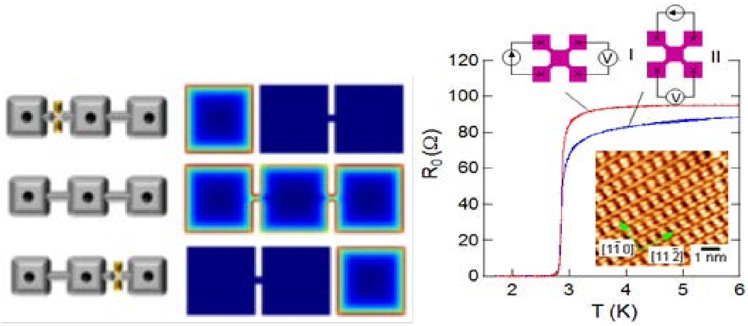


Fig. 11. (Left) Basic blocks for manipulating MFs. Connections among TSs are pinched off by voltages at the junctions, which results in hopping of MFs. (Right) Temperature dependence of zero bias resistance of the Si(111)-($\sqrt{7}\times\sqrt{3}$)-In reconstruction. Inset shows the STM image of sample surface.

At the interface between topological and trivial gapped states, a stable surface state should appear. In a topological superconductor (TS), zero-energy Majorana fermions (MFs) appear at vortex cores and the sample edge, which are equivalent to their antiparticles, whereas in a topological insulator (TI) the edge state can carry zero-resistance current.

We have designed nanoquantum devices for generating and manipulating MFs, exploiting the property that MFs appear only when 2D TSs enclose an odd-number of vortices (Fig. 11). We demonstrate that charge-neutral MFs can be moved by switching on and off point-like gate voltages. We show that the non-Abelian quantum statistics are generated by exchanging positions of MFs, useful for decoherence-free qubits and quantum computation.

In order to realize the TS state experimentally, we are working on an atomically thin superconductor on semiconductor surface with the Rashba effect and self-assembling of magnetic molecules. We demonstrate the surface superconductivity by direct transport measurements (Fig. 11) for the first time in the world. The desirable influence of the self-assembled magnetic molecules on the superconducting properties has also been clarified, and the presence of Josephson vortices was revealed by an intimate collaboration between theory and experiment.

We have also revealed a checkerboard-type pattern in the spin-resolved density of states of MF at the vortex core as a function of energy and distance from the center of vortex. This feature can be detected by the spin-polarized STM/STS technique and serves as the evidence of MF.
See Papers 22 [*Phys. Rev. Lett.* **107** (2011) 207001], 23 [*Phys. Rev. Lett.* **113** (2014) 247004] and 24 [*Phys. Rev. Lett.* **115** (2015) 177001] in Appendix 2.

[12] Large-scale First-principles calculations and experiments for the design of nanoscale devices

Representative researchers: T. Miyazaki, D. R. Bowler, N. Fukata

To enable first-principles electronic structure calculations using density functional theory (DFT) to be performed on systems which correspond to practical nanoscale devices and materials, we have developed a world-leading linear-scaling DFT code: CONQUEST. While it is very difficult to treat systems containing more than a few thousand atoms using standard DFT implementations, with CONQUEST we can treat systems with more than a million atoms. Using the CONQUEST, we have conducted a collaborative theory-experiment research on Si/Ge core-shell nanowires.

CONQUEST can perform robust and accurate electronic structure calculations, including structure relaxations or molecular dynamics on very large systems, which cannot be treated by standard DFT techniques. The code is exceptionally efficient on massively parallel computers like the K computer. We have performed DFT calculations on three-dimensional Ge nano-islands grown on Si(001) substrates, to study the growth mechanism at the atomic scale, treating all the atoms (see Fig. 12 (top)). We have also calculated the atomic and electronic structures of Si/Ge core-shell nanowires (Fig. 12 (bottom)). Based on the calculated results, we synthesized Ge/Si core-shell nanowires and found conclusive evidence of the hole gas accumulation in the core-shell nanowires.
See Papers 25 [*J. Chem. Theory Comput.* **10** (2014) 5419] and 26 [*ACS Nano* **9** (2015) 12182].

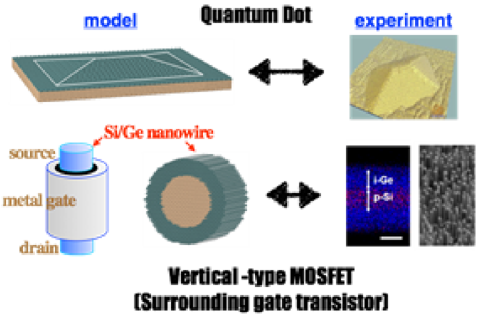


Fig. 12. (Top) Optimized structure of Ge nano-island on Si(001) substrate calculated using CONQUEST, and experimental structure. (Bottom) Atomic models of Si/Ge core-shell nanowire, along with TEM and SEM measurements and schematic of how nanowires can be used in transistors.

Other Remarkable Research Results

★ Innovative Nanoscale Devices and Systems

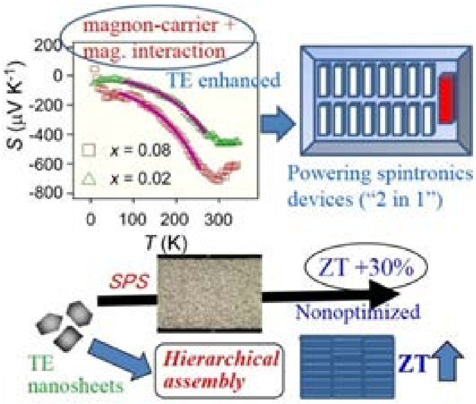


Fig. 13. Thermoelectric enhancement through (Top) magnetic semiconductors and (Bottom) nanosheets.

[13] Novel concepts for developing thermoelectric materials and systems for first wide scale Applications

Representative researcher: T. Mori

The conventional tradeoffs in thermoelectric properties have been long-time barriers to achieving high performance. We have demonstrated new concepts to overcome these. Proposing magnetic semiconductors to achieve high power factors, fabricating thermoelectric nanosheets with phonon selective scattering, achieving excellent p, n control through atomic occupancy variance, we approach breakthrough to the first wide-scale applications.

We have discovered that magnetic semiconductors like carrier-doped chalcopyrite can have enhanced thermoelectric properties (Fig. 13 top). We are further developing this concept with a view to develop

compatible or even “2 in 1” solid-state power sources for stand-alone or wearable spintronics devices of the future. Nanosheets of thermoelectric materials were also synthesized achieving phonon selective scattering and enhanced properties (Fig. 13 bottom). Hierarchical assembly of nanosheets are expected to lead to large enhancements and nanoscale modules and devices.
See Papers 27 [*J. Mat. Chem. A* **2** (2014) 985] and 28 [*Angew. Chem. Int. Ed.* **54** (2015) 12909] in Appendix 2.

[14] Silicon-doped metal oxide thin film transistor for next generation power-saving flat display

Representative researcher: K. Tsukagoshi

We realized a promising material for oxide thin film transistor (TFT) to produce a next generation power-saving flat display. Our Si-doped metal oxide TFT (SiM-OxTFT) behaves as a very stable and high-performance TFT with highly suppressed off-state current [Fig. 14].

As for pixel swithing TFT in the flat panel display, amorphous silicon or poly-silicon film has been customerily used. But because of serious large off-state current in the current TFTs, a new TFT is strongly desired to realize a low-power consumption system. Furthermore, higher mobility of TFT than the amorphous silicon is needed to present high resolution contents. Amorphous metal oxide thin-film transistor (a-OxTFT) is a possible candidate as the post silicon TFTs. Although the InGaZnO film is one of the candidates of the a-OxTFT, however, the InGaZnO is very unstable film in actual production. The electric property of the film is a very sensitive to oxygen absorption or desorption at the bonding sites adjacent to Zn atoms.

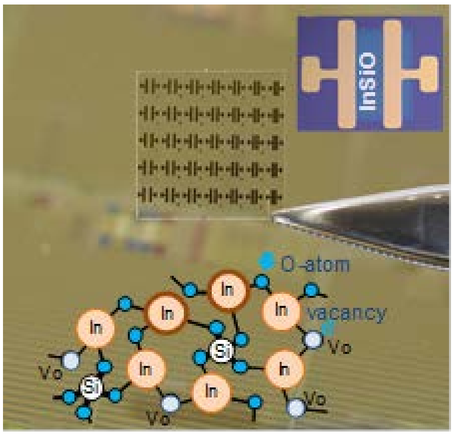


Fig.14 Photo images of the InSiO-OxTFTs on glass substrate. Schematic of vacancy (V_O) suppression by incorporating SiO_2.

We discovered that the electric stability of the TFT is determined by the bond-dissociation energy of the dopant element in InOx film. By incorporating the dopant with higher bond-dissociation energy, such as Silicon atom, the film supresses thermal active vacancy in the film. The basic property of our original InSiO-OxTFT has exceeded that of current commercial production TFTs.
See Papers 29 [*Appl. Phys. Lett.* **103** (2013) 172105] and 30 [*Appl. Phys. Lett. 106 (2015) 192103*] in Appendix 2.

[15] Multi-functional electron tunneling devices with molecular quantum dots

Representative researchers: Y. Wakayama, R. Hayakawa

Precise control of electron tunneling is critical for power-saving electronic devices. Our purpose is to develop electron tunneling devices by taking advantages of organic molecules as quantum dots. A variety of molecular functions are integrated into a Si-based architecture, aiming to bridge a gap between fundamental quantum effect and practical device engineering.

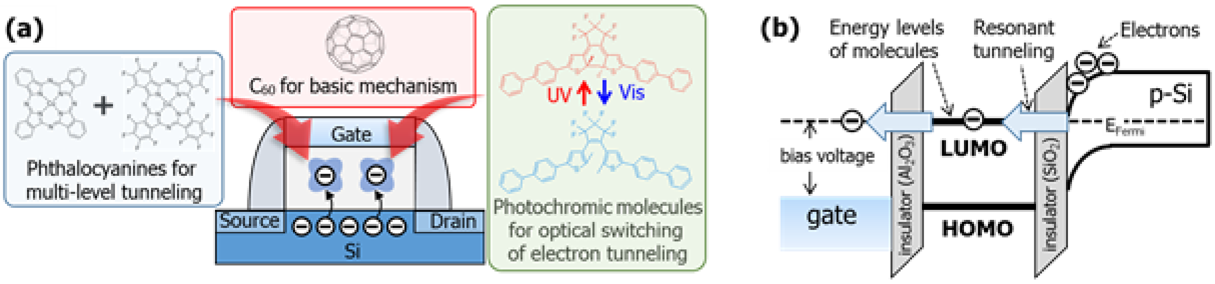


Fig. 15. (a) Device and molecular structures. (b) Energy-level diagram, showing resonant tunneling.

Fullerene (C_{60}) molecules were embedded in a double-tunneling junction consisting of Au/Al_2O_3/C_{60}/SiO_2 multi-layers on Si substrates (Fig. 15(a)). Staircases in current-voltage curves were observed, which can be attributed to resonant tunneling through the empty and occupied energy levels of the molecule as drawn in Fig. 15(b). These results indicate that the tunneling properties can be tuned precisely by designing molecular structure. We applied this mechanism to

various functionalities: multi-level tunneling by using multiple phthalocyanines and optical switching by using photochromic molecules. Importantly, our device configuration is compatible with the conventional MOS-FET and, therefore, these results demonstrate the potential of practical use of molecules for the tunneling devices.
See Paper 31 [*Adv. Func. Mater.* **21** (2011) 2933] in Appendix 2.

★ Innovative Nanoscale Characterization Methodologies

[16] Multiple-probe scanning probe microscopes (STM, AFM, KFM): Development and application

Representative researchers: T. Nakayama, M. Aono

Novel properties which will come from materials nanoarchitectonics must be characterized with innovative instruments and methodologies. Therefore, we developed multiple-probe scanning probe microscopes (MP-SPMs) and realized unique and indispensable nanoscale electrical measurements.

MP-SPMs have individually-driven 2 to 4 probes for identifying a nanostructure of interest and also for performing multiprobe electrical measurements of it. For example, the length of electron mean-free-path of a SWCNT on SiO_2 was measured to be about 500 nm at room temperature (see Fig. 16). MP-STM was converted into multiple-probe atomic force microscope (MP-AFM) using newly developed tuning fork sensor, and non- contact potential mapping via Kelvin force microscopy (KFM) was implemented in MP-AFM. These allow our MP-SPM system to handle nanostructures on insulating substrates.
See Paper 32 [*Adv. Mater.* **24** (2012) 1675] in Appendix 2.

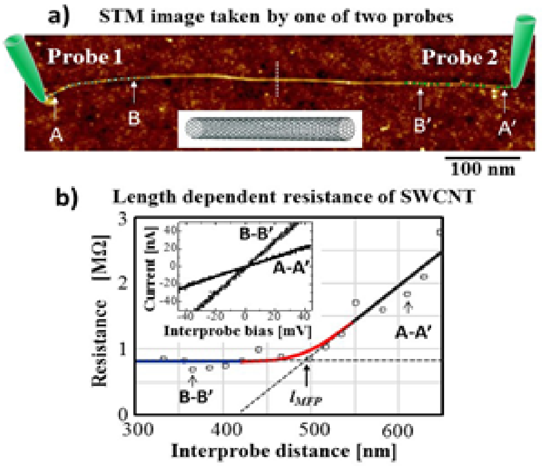


Fig. 16. (a) STM image of a SWCNT placed on a SiO_2/Si substrate. Two probes of the STM in contact with the SWCNT are schematically shown. (b) Length dependent resistance of a SWCNT. I-V curves measured between two probes are shown in the inset.

[17] Novel electrical, mechanical, thermal, optoelectronic and luminescence properties of nanomaterials studied by *in situ* TEM

Representative researchers: D. Golberg, Y. Bando

We have developed revolutionary methods of in situ transmission electron microscopy (TEM) which allow us to measure true properties of nanomaterials, while in-tandem getting the deepest insights into their atomic structures. Designed TEM techniques combining the capabilities of a high-resolution TEM instrument and either an atomic force sensor, or a scanning tunneling microscopy probe, or a laser beam, have become the powerful tools for our study of more than fifty chemical nanosystems shaped in diverse morphologies, e.g. tubes, wires, sheets and particles. The key point of our experiments is that all measurements have been conducted on an individual nanostructure level under the highest spatial, temporal and energy resolution peculiar to TEM, and thus can directly be linked to morphological, structural and chemical peculiarities of a given nanomaterial.

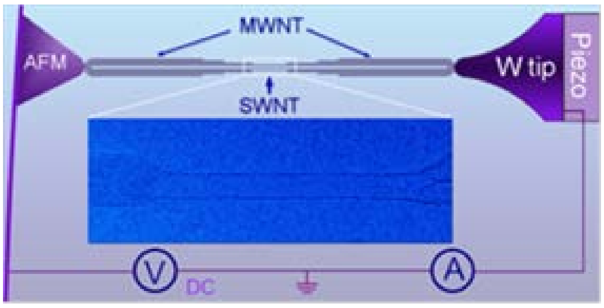


Fig. 17. Schematics of a single-walled C (SWNT) unravelling from the multi-walled C (MWNT) nanotube using Joule heating followed by its direct tensile strength measurement under stretching in a high-resolution TEM.

For example, we succeeded for the first time in the world to measure the tensile strength on individual single-walled and multi-walled C and BN nanotubes (NTs), Fig. 17. The tubes were placed within a force-sensor microdevice inside a high-resolution TEM and their mechanics were then investigated in real-time by correlating the measured strength and Young's moduli, and types, and

sites of NT structural defects under atomic resolution. The huge strength values of ~100 and ~33 GPa were determined for the defect-free C and BN NTs, respectively.
See Papers 33 [*Adv. Mater.* **22** (2010) 4071] and 34 [*Adv. Mater.* **22** (2010) 4895] in Appendix 2.

★ Nanoarchitectonics Related to Sustainable Energy and Environment

[18] Metallic nanoporous materials for next-generation high-performance electrocatalysts

Representative researcher: Y. Yamauchi

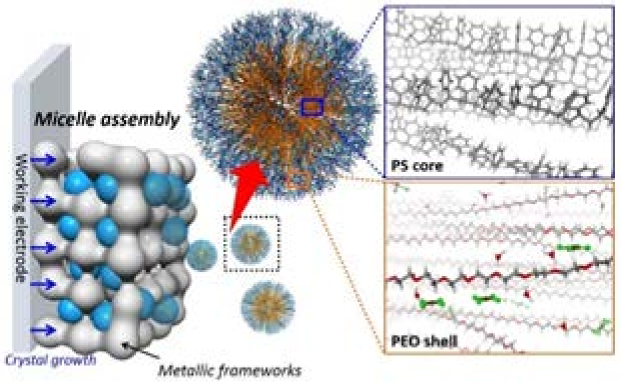


Fig. 18. Electrochemical approach for preparation of nanoporous metals.

Platinum (Pt) and gold (Au) have long been regarded as useful catalysts in fuel cells. However, the high cost of these metals, together with the limited reserves in nature, has been shown to be the major bottleneck for commercial applications. We have developed novel nanoporous metals with highly electrocatalytic activity.

In view of the strong social demand for the reduced use of rare metals, there have been heightened calls for the development of a technology for securing high functionality with low use of Pt and Au by producing porous structures with larger surface areas (Fig. 18). Our group has focused on fine controls of compositions and morphologies which are important factors for design of porous metals. We have developed a route to nanoporous metal films by a simple electrodeposition method in an aqueous surfactant solution. The atomic crystallinity is coherently extending in the pore walls, providing a large number of atomic steps and defect sites, which are very active sites in methanol oxidation reaction and oxygen reduction reaction. As a result, the electrochemical performance is dramatically enhanced, compared to commercially available catalysts.
See Papers 35 [*Nature Commun.* **6** (2015) 6608] and 36 [*Angew. Chem. Int. Ed.* **54** (2015) 11073] in Appendix 2.

[19] Subnanometer-scale molecular manipulation by submeter-scale macroscopic motion: a paradigm shift to functional conformer science

Representative researcher: K. Ariga

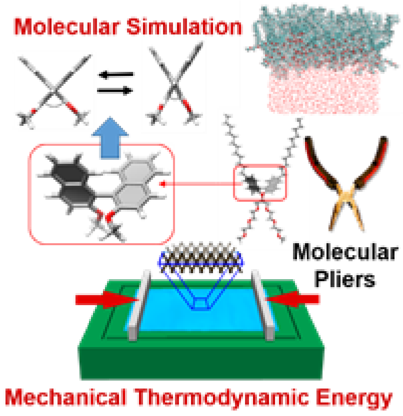


Fig. 19. Mechanochemical control of molecular structures.

We have developed a novel methodology to rationally manipulate functional molecules including molecular machines embedded at movable interface by macroscopic mechanical motions. In attempts with molecular pliers as model machines at the air-water interface, closing and opening motions of the pliers were estimated and simulated by density functional theory and molecular dynamics calculation, which were further compared with macroscopic mechanical energies of the interface by thermodynamic calculation. The obtained results indicated highly efficient conversion of the mechanical energy in tens of centimeter-scale motion into subnanometer-scale modulations of the molecular pliers (Fig. 19).

This finding can be generalized as molecular manipulation to rationally create intermediate molecular conformers that can be adapted to target functions. For example, mechanical manipulations of the synthesized molecular receptor at the air-water interface can realize switchable chiral discriminations of amino acids upon pressure modulation. Another receptor at the interface was mechanically optimized to be capable of discriminating thymine and uracil that cannot be distibguished by naturally occurring DNA and RNA. Molecular functions exceeding biomolecules can be created through conformational modulation of functional molecules, which is regarded as a paradigm shift of synthetic approaches for functional molecules to functional conformer science.

See Papers 37 [*Angew. Chem. Int. Ed.* **54** (2015) 8988] and 38 [*Chem. Mater.* **26** (2014) 519] in Appendix 2.

[20] Highly-efficient plasmonic systems for molecular sensing and energy conversion
Representative researcher: T. Nagao

Plasmonics and metamaterial are the new emerging paradigms for materials science which enable us to control the light in nano-space. We can tailor remarkable functionality such as extraordinary signal enhancement of molecules, enhanced photocatalytic reaction, and smart solar power harvesting. We focus ourselves on manipulating infrared (IR) light waves for the applications in molecular sensing and environmental monitoring. We also develop various light harvesting plasmonic materials and nanostructures for solar thermal energy conversion and solar photoelectric transfer.

Figure 20 (A) shows an example for the selective monitoring of the presence of mercury ions (Hg^{2+}) dissolved in environmental water by plasmon-enhanced infrared (IR) vibrational spectroscopy. From natural water from Lake Kasumigaura (Ibaraki Prefecture, Japan), direct detection of Hg^{2+} with a concentration as low as 37 ppt was demonstrated, indicating the high potential of this simple method. We also develop photonic and plasmonic nanostructure array with high solar absorption power for realizing highly efficient solar photothermal converter as well as solar photoelectric charge separator for energy applications (Fig. 20 (B)).

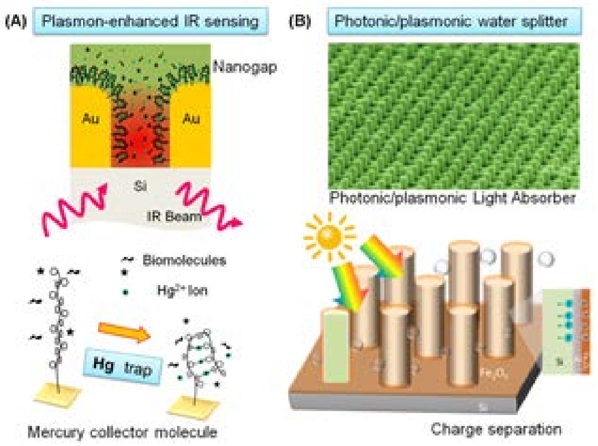


Fig. 20. (A) Schematic illustration of mercury sensing by infrared (IR) plasmon. (B) An example of photonic/plasmonic lattice for efficient solar-light harvesting and charge separation aiming at water splitting.

See Papers 39 [*Sci. Rep.* **3** (2013) 1175] and 40 [ACS *Nano* **9** (2015) 6031] in Appendix 2.

2-2. Research Environment Including Facilities and Equipment

Describe the degree to which the Center has prepared a research environment appropriate for a world premier international research center, including facilities, equipment and support systems, and describe the functionality of that environment.

World-class Research Equipment

The research equipment used by MANA researchers is without question some of the best in the world. With its unique and excellent microfabrication facility ("MANA Foundry"), MANA researchers can efficiently achieve the necessary microfabrication within the research center itself. Thirteen support staff are present. Further, MANA is equipped with equipment like a special electron microscope that can observe electrical, mechanical, thermal, and optical properties under high-resolution structural observation; as well as a multiple-probe scanning probe microscope that can measure electrical conductivity at the nanoscopic scale. MANA also has a photoelectron spectrometer, a Raman spectrometer, a femtosecond laser spectrometer, and many other pieces of high-performance equipment.

Meanwhile, the center's host institution, NIMS, has equipped itself with research equipment of outstanding quality during its history of more than 40 years, and MANA researchers are allowed to freely use this equipment. Among these facilities are various types of world-class ultra-high-resolution electron microscopes, a dedicated beamline at a synchrotron radiation facility (SPring-8), one of the world's most advanced ultra-high magnetic field generators (10 T), an ultra-high-resolution nuclear magnetic resonance (NMR) spectrometer, and an ultra-high pressurizer device (10-100 GPa).

Comfortable Research Space

In October 2008, the entire Nano-Materials and Biomaterials Research Building was allocated to MANA as the MANA Building, the primary space for MANA activities at which all major researchers and equipment were centralized. In March 2012, the WPI-MANA Building was completed and the MANA research environment became even better. The new building was designed with a mind to increasing contact between researchers in diverse fields, and it has had a major positive impact on the facilitation of research at MANA by completely changing the research and work style of MANA’s researchers.

Full Administrative and Technical Support

All staff in the Administrative Office speaks English, and they are equipped with the knowledge and experience necessary to handle a variety of situations. All researchers are provided technical and administrative support without favoritism or discrimination based on nationality or age. The WPI Administrative Office has largely succeeded in fulfilling its mission of “providing an environment for researchers in which they can concentrate solely on their research by eliminating all non-research work.” The types of services provided are described in Section 4.3.

The Administrative Office’s staff includes 6 resident technical support staff who work on tasks including administration and maintenance for over 50 common facilities; laboratory outfitting; reagent management; safety measures; purchasing procedures, moving in, and installation of new equipment; and support for non-Japanese researchers in making applications for external funding.

2-3. Competitive and Other Funding

Describe the results of the Center’s researchers to date in securing competitive and other research funding.

- In Appendix 2-2, describe the transition in acquiring research project funding, and note any external funding that warrants special mention.

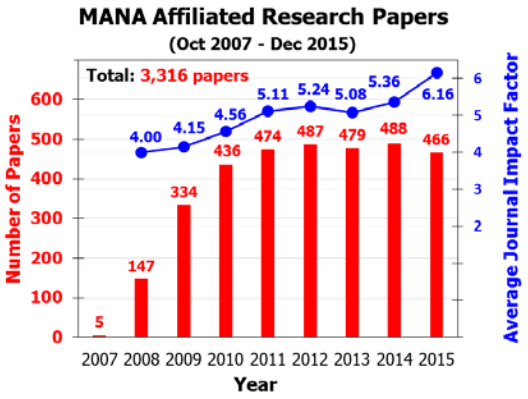
The total research project funding secured by MANA researchers over the past roughly eight and half years has been ¥10.753 billion. This total comprises ¥1.82 billion in competitive funding, ¥3.088 billion in commissioned research (including private funding), and ¥5.863 billion in grants for operating expenses.

Competitive funding MANA has secured in the past includes, for example, numerous Grants-in-Aid for Scientific Research, one NEXT Program grant, nine CREST grants, and thirteen PRESTO grants.

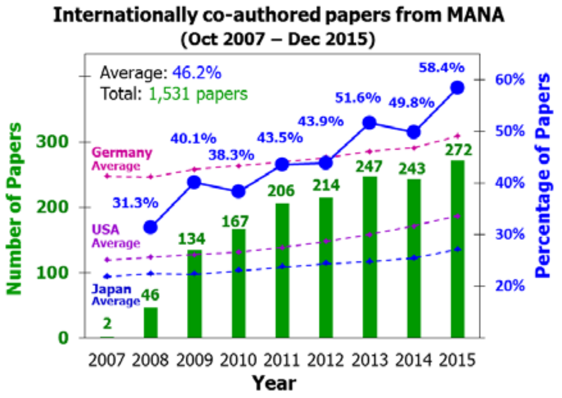
2-4. State of Joint Research

Describe the results of joint research conducted with other research organizations both in and outside Japan.

MANA researchers actively engage in joint research with other researchers both in Japan and around the world. This is supported by the fact that, of the 3,316 papers released by MANA in the past nine years, 46.2% have featured international co-authorship. The number of MANA papers featuring international co-authorship is increasing every year, and such papers accounted for a majority of MANA papers released since 2013. This is high rate of international co-authorship that equals that of Germany, which boasts the highest rate of international co-authorship in the world. This accomplishment demonstrates that MANA is successfully building an organization in which researchers of different countries can come to cooperate on research.



MANA affiliated researcher papers published between October 2007 and December 2015 and average journal impact factor.



Internationally co-authorez papers of MANA published wetween October 2007 and December 2015. Source of national average: SciVal database, Elsevier B.V., downloaded in May 2016.

Additionally, ever since its founding, MANA has welcomed as PIs or APIs researchers from external organizations that are the best in the world in the fields of research that are most important to MANA. The labs of such researchers are called MANA Satellite Labs, and these labs engage in tightly-knit joint research projects through MANA (see Section 4-1-3). At the time of its founding in 2007, MANA had satellites at UCLA and the Georgia Institute of Technology in the United States, Cambridge University in the United Kingdom, CNRS (Toulouse) in France, and the University of Tsukuba (two labs) and the Tokyo University of Science in Japan (i.e. 5 overseas and 3 domestic labs in total). Later, the Satellite Labs were reassessed, and in 2012 the Satellite Labs at Cambridge University, Tokyo University of Science, and the University of Tsukuba (one lab) were shut down. New Satellite Labs were established at the University of Montreal in Canada and the University College London (UCL) in the United Kingdom. At present, MANA is pursuing joint research with six Satellite Labs. Since MANA's founding, Satellite Labs have produced 348 papers in total. For more information on the four overseas Satellite Labs, refer to Section 4-1-1.

When it is determined necessary to coordinate with a research group at an overseas institution on a specific research topic, an MOU is signed between MANA and the institution. Since MANA's founding through to the present, it has signed MOUs with 56 research institutions from 19 countries for the purpose of pursuing cooperation on research. By region, 22 of these institutions are in Europe, 19 in Asia, 8 in North America, 2 in South America, 4 in Australia, and 1 in the Middle East. For more details, refer to Appendix 4-5.

2-5. Appraisal by Society and Scientific Organizations

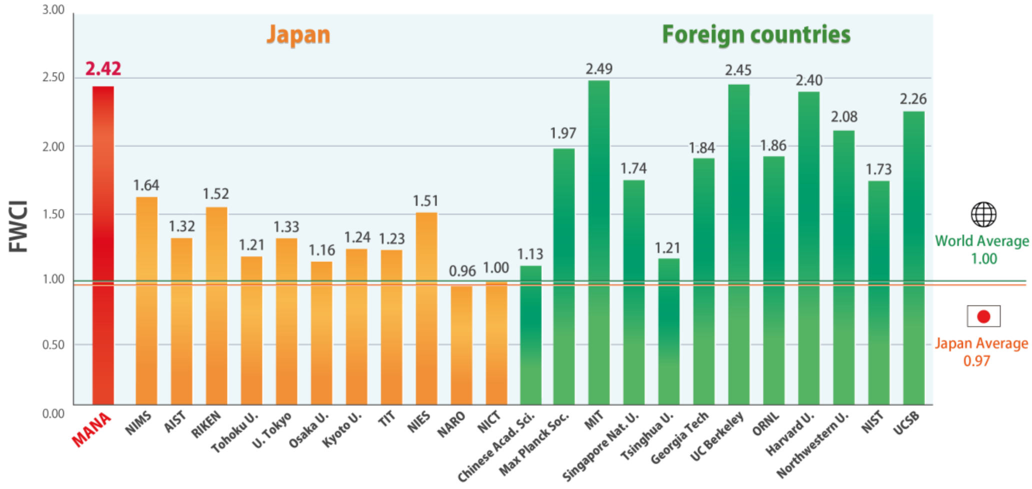
Describe how society and/or scientific organizations in and outside Japan have recognized the Center's research achievements.

・ In Appendix 2-3, list the awards received and invitational lectures given by the Center's researchers.

The quantity and quality of papers released by an institution is a straightforward indicator of the state of fundamental research activities at a research institution. In the nine years since its founding, MANA members have released 3,316 papers. Of these, 118 of MANA's papers are extremely high-profile and among the top 1% most cited papers in the world (i.e. "top 1% papers").

The high quality of MANA's research is also apparent from the fact that MANA's researchers publish many papers in high-impact journals. In 2015, MANA members released 466 papers, and the average Impact Factor of the journals in which these papers were published was extremely high (6.16). In fact, the average annual Impact Factor has been higher than 5.0 every year for the last five years, and these scores are remarkable within the materials science field.

Meanwhile, the company Elsevier B.V. has created a new index called the Field Weighted Citation Impact (FWCI) that adjusts the paper citation count by field of research to enable comparisons of the quality of papers released by research institutions in different fields. MANA's FWCI of 2.42 is extremely high. It is clearly the highest in Japan and reached a level of performance comparable to top-ranked universities in Europe and America.



Field Weighted Citation Impact (FWCI) of MANA and other institutions in the world. Source: SciVal database, Elsevier B.V., downloaded in May 2016. FWCIs were calculated for papers published during 8 years from 2008 to 2015.

In addition, five MANA researchers—Dr. K.Ariga (Materials Science), Dr. Y.Bando (Materials Science), Dr. D.Golberg (Materials Science), Dr. Z.L.Wang (Materials Science, Chemistry) and Dr. O.Yaghi (Chemistry)—were selected for inclusion in Thomson Reuters's list of “Highly Cited Researchers for 2014.” These five researchers received this same recognition in 2015, as well, indicating their high level of recognition throughout the world as top researchers.

Additionally, as demonstrated in Appendix 2-3, MANA researchers have earned many awards and are invited to give many lectures and keynote speeches. MANA researchers are also often invited to write review articles for top-tier international journals (e.g. *Advanced Materials*, *Chemical Reviews*, etc.).

2-6. Feeding Research Outcomes Back into Society

2-6-1. Applications of research results

Describe the applications created from research results, their effect in spawning innovation, intellectual properties (IPs) obtained, and joint research activities conducted with corporations, etc.

One of the main missions of NIMS, MANA’s host institution, is the research and development of practical materials. Hence, MANA engages not only in fundamental research, the pursuit of which is one of the WPI program’s basic principles, but also actively engages in applied research. Below are several examples:

a) One of MANA’s most important research achievements has been the development of atomic switches, which have had a great many practical applications. First, atomic switches are an order of magnitude smaller and consume less power than traditional CMOS transistor switches. For this reason, MANA worked with NEC Co. to implement atomic switches in the switching circuits of field programmable gate arrays (FPGA), the next generation of integrated circuits. This partnership succeeded in improving the performance of FPGAs.
b) Because atomic switches have the ability to be used as a power switch that switches on and off currents larger than traditional transistor switches can handle, the HONDA-NIMS Joint Research Center of Excellence for Advanced Functionality Materials was established within NIMS at the request of Honda Co. Joint research has been initiated there.
c) Another notable MANA research accomplishment is the development of nanosheet technology. Major work on applications of this technology has begun in collaboration with Murata Manufacturing Co. to develop high-performance miniaturized capacitors that utilize nanosheets’ extremely high permittivity.
d) In one application relevant to recent news, MANA developed a new reagent that makes visible the presence of radioactive cesium released by the Fukushima Daiichi Nuclear Power Plant disaster. This reagent has begun to be sold commercially by Tokyo Chemical Industry Co.
e) In another topical application, NIMS succeeded in greatly improving the performance and stability of In_2O_3-based materials (known as IGZO), which are widely used in products like smartphone display screens. Research has begun with a certain company (name still undisclosed) on implementing this technology.
f) The development of highly sensitive / parallel molecular sensors (MSS) has taken a major step toward practical applications in the form of odor sensors. An “MSS alliance” has formed among multiple companies and other parties throughout Japan.

MANA researchers applied for a total of 774 patents (541 domestic; 233 international) in the period between October 2007 and December 2015. Meanwhile, MANA registered 581 patents (441 domestic; 140 international) in this same period.

2-6-2. Achievements of Center’s outreach activities

If the Center has conducted its own unique outreach activities, describe those worthy of special mention.

- In Appendix 2-4, list and describe media coverage, press releases, and reporting.

In order to increase recognition of MANA and further propagate the nanoarchitectonics concept, there have been special MANA-focused issues of several famous journals, including *Advanced Materials* (2012) and *Langmuir* (2013). The former was a collection of research by MANA researchers, and 5 of the 14 papers published became “top 1% papers.” The latter announced an open forum titled “Nanoarchitectonics and the Interface” and accepted a wide range of papers from both MANA and non-MANA researchers. Of the 48 papers collected from around the world, 33 were from non-MANA researchers.

Since FY 2011, the online English newsletter “Mana Research Highlights” has been communicating remarkable MANA research achievements throughout the world. These newsletters are distributed to 2,000 to 3,000 media and science journalists, as well as 2,000 individuals on MANA’s mailing list. Especially outstanding research achievements are communicated through the journal *Science*’s third-party e-mail service to approximately 4,000 researchers located around the globe. For reasons including that papers highlighted by this service become the most downloaded, this is a powerful method of publicizing MANA’s achievements to the world’s scientific community. To date, 24 research accomplishments have been communicated in this way.

Since its founding, MANA has also published the newsletter *Convergence* three times annually in Japanese and English, for a total of 22 issues to the present date. Every issue features updates on the center’s activities as well as interviews with famous, Nobel-class researchers. This newsletter, which is intended for researchers throughout the world, is currently distributed to 1,650 domestic addresses and 1,800 international addresses.

The nanoarchitectonics concept has begun to spread as a result of work like this: for example, the E-MRS Fall Meeting held in September 2014 featured a “nanoarchitectonics” session. MANA has also actively pursued outreach oriented toward the general public. To nurture interest in science among young students, MANA has held events such as the MANA Science Cafe, joint symposiums, summer camps, and “science school” events for elementary and junior high school students featuring Nobel Prize winners (Prof. H. Rohrer, Prof. H. Kroto, etc.). MANA also creates online videos that explain its research achievements in an easy-to-understand way. MANA has also released general introductory books on its research, such as *Nanoarchitectonics: A Revolution in Materials Science* (2014) and *The Nanotech Handbook for Future Scientists* (2015). Moreover, due to the success of this outreach work, “nanoarchitectonics” will be now listed in the famous and authoritative *Kojien* Japanese dictionary, and is becoming increasingly widely known.

3. Interdisciplinary Research Activities (within 3 pages)

3-1. State of Strategic (or “Top-down”) Undertakings toward Creating New Interdisciplinary Domains

MANA has established the following special funds in order to promote interdisciplinary research that fuses MANA's four fields (Nano-Materials, Nano-System, Nano-Power and Nano-Life).

A) Fusion Research Program: This fund was opened to applications from young researchers under the belief that joint research by young researchers from disparate fields is especially important to planting the seeds of new research. 6 projects were selected and ¥10 million in funding provided over 2 years.

B) Theory-Experiment Fusion Research Program: Applications were accepted over a period of two years in an effort to involve more theoretical researchers in MANA to guide and support MANA’s experimental research. A total of 10 projects were selected and ¥20 million in funding provided over three years.

C) Nano-Life Fusion Research Program: Established to promote joint fusion research between Nano-Life researchers and researchers who specialize in other nanotechnology fields, this program provided ¥20 million in funding to 2 projects over 3 years.

D) Grand Challenge Program: This program solicited interdisciplinary research proposals that were innovative and “outside the box,” in addition to being not necessarily limited to materials research. 7 projects were selected and ¥6 million in funding provided over 2 years.

For reference, MANA’s three Grand Challenge research targets are:

★ Nanoarchitectonic brain-like networks
★ Room-temperature superconductivity
★ Practical artificial photosynthesis

None of these research targets can be achieved without fusion research combining disparate fields, and the intention behind posting these research targets within MANA is to promote such fusion research. The benefits of this are starting to take shape. Regardless of field, viewing and hearing these grand research targets every day serves to inspire researchers, and many deeply interesting ideas have begun to emerge at the camp retreat-style Grand Challenge Meeting and other venues.

3-2. State of “Bottom-up” Undertakings from the Center’s researchers toward Creating New Interdisciplinary Domains

MANA Seminars are a type of established venue where MANA researchers and non-MANA researchers can present and discuss on the latest research topics. Although lecturers were initially selected in a top-down manner, recently MANA researchers have begun voluntarily planning the lecturers themselves. The seminars are now true “melting pots” in which MANA researchers from a variety of fields attend and engage in lively discussion. Thus these seminars play a crucial role in promoting the fusion of disparate fields. MANA Seminars have been held 526 times in the eight and a half years since MANA was established.

MANA also hosts the camp retreat-style Grand Challenge Meeting once or twice per year. The purpose of these meetings is to create an opportunity for brainstorming among MANA researchers from different fields about visions of the future of research. Beginning with this, at the suggestion of some young researchers, Grand Challenge Meetings were also held that were only for such young researchers.

In this way, MANA researchers come to understand the importance of fusing disparate fields of research through contact with things like the programs described in Section 3-1 that promote interdisciplinary, fusion research. A culture has taken shape within MANA that promotes the voluntary pursuit of such fusion research. Some of the achievements of this research are described in Section 3-3 below.

3-3. Results of Research in Fused Research Fields

Describe the Center’s record and results by interdisciplinary research activities.

In Appendix 3, list the main papers published (up to 20 papers) on the Center’s interdisciplinary research and provide a description of each of their significance.

Described below is the current state of three Grand Challenges begun with the objective of promoting fusion research that combines disparate fields.

Nanoarchitectonic brain-like networks: As explained in Section 2-1 “Research achievements,” items [3] and [4], highly intriguing research is progressing on nanoarchitectonic brain-like networks. To provide a simplified summary, it is possible using atomic switches to create artificial synapses with characteristics similar to the synapses crucial to the functioning of human brains. If several hundred million such atomic switches are combined to form a random network, the resulting system displays some extremely interesting properties. If electrodes are placed at either end of such a network and a certain amount of DC voltage applied between them, the measured electrical conductivity between the electrodes oscillates at random. This runs counter to the standard assumption that conductivity would simply increase over time. In other words, although this is an inorganic system, it behaves almost as though it were alive. The mechanism for this is still unknown, and joint research has begun on this topic in collaboration with an information theory researcher. This work seems likely to open up a major new field of research, and it is an extremely important fusion of nanoarchitectonics and neuroscience.

Room-temperature superconductivity: It is thought that this may be difficult to achieve with three-dimensional bulk crystals, and hence there is research underway to achieve room-temperature superconductivity using systems controlled at the nanoscopic level. It is unfortunately not possible to disclose the details of this research in full in this space, but essentially researchers are attempting to change several target insulators into superconductors by physically (i.e. not chemically) introducing electrons and holes. The preliminary results of this research are described in Opt. 4 and 5 in Appendix 2. Separately, there have also been interesting theoretical achievements: Namely, researchers succeeded in creating a theoretical design for a new topological insulator in which the edge state carries zero-resistance current optimally under room temperature (See Opt.-3 in Appendix 2). In order to realize this theoretical design, researchers with a high level of experience in crystal physics and atomic layer deposition have begun to participate in the project. This is a bridge-like combination of fields that goes beyond simple cooperation between theoretical and experimental researchers.

Practical artificial photosynthesis: As explained in Section 2-1 “Research achievements,” item [10], MANA is also promoting interdisciplinary, fusion research on photocatalysts (materials science) and plant photosynthesis. This is bold and provocative research that is yielding a number of interesting results.

Below are some other areas of collaborative research.

☐Broad-ranging nanosheet technology research; from fundamental research through application
<Combination of Soft Chemistry, Materials Physics, and Electronic Device Technology>
(Section 2-1 “Research achievements,” items [1] and [2])
MANA utilized its unique nanosheet technology to invent useful new materials. Using this technology and the procedures of soft chemistry, it is possible to systematically develop new materials that would not exist otherwise. This achievement was possible due to the combination of nanosheet technology, materials physics, and electronic device technology.

☐Broad-ranging atomic switch research; from fundamental research through application
<Combination of Electrochemistry, Electronic Device Technology, and Neuroscience>
(Section 2-1 “Research achievements,” items [3] and [4])
The atomic switch was first invented through a synthesis of electrochemistry and electronic device technology. Through the cooperation of the NEC Corporation, MANA’s unique “Beyond CMOS” device has already advanced to the technological level necessary for practical implementation. Further, the fusion of the above technology with neuroscience has led to the beginning of research toward the development of a basic unit for materials-based brain-like computers.

☐Development and practical implementation of ultrasensitive / massively parallel molecular sensors
<Combination of Science on Animal Olfactory Organs, Nanoarchitectonics, and Medical Diagnosis>
(Section 2-1 “Research achievements,” item [9])
MANA drew on lessons from the science on animal olfactory organs to develop ultrasensitive / massively parallel molecular sensors that are superior to animal olfactory organs. This unique technology was applied within medical diagnosis to achieve a method of cancer detection through human breath analysis.

☐Development of efficient artificial photosynthetic systems
<Combination of Photocatalytic Chemistry, Plant Photosynthesis, and Nanoarchitectonics>
(Section 2-1 “Research achievements,” item [10])
MANA is pursuing research to realize highly efficient artificial photosynthetic systems by synthesizing cutting-edge photocatalytic chemistry research and plasmonic light antenna technology, as well as by utilizing the structure of plant leaves that perform highly efficient photosynthesis.

☐ Nanoarchitectonic treatments for cancer and Alzheimer's disease
<Combination of Medical Science and Nanoarchitectonics>
(Section 2-1 “Research achievements,” items [7] and [8])
MANA has successfully created attractive treatment techniques by applying MANA’s superior nanoarchitectonics technology to medicine. For example, MANA developed a treatment for Alzheimer’s disease that utilizes nanoarchitectonic particles to efficiently transport medicine to the brain. MANA also developed a smart nanofiber mesh that, when applied directly to a cancer-affected location, releases anticancer drugs when prompted by an external stimulus (magnetic field).

☐Development of decoherence-free quantum bits, room-temperature superconductor devices
<Fusion of theory and experimentation>
(Section 2-1 “Research achievements,” item [11])
The new world of solid-state physics is opening up due to theoretical research into topological insulators. MANA is developing new nano-electronics devices via a method by which MANA’s theoretical researchers, who have made tremendous contributions to this field, are collaboratively linked up with MANA’s excellent experimental researchers.

4. International Research Environment (within 4 pages)

4-1. International Circulation of Best Brains

4-1-1. Center’s record of attracting and retaining top-world researchers from abroad

Describe the participation of top-world researchers as PIs and the residing of joint researchers at the Center.

- In Appendix 4-1, give the number of overseas researchers among all the Center’s researchers, and the yearly transition in their numbers.

MANA has established satellite labs (hereinafter “MANA Satellites”) at research institutions to which external PIs belong. MANA Satellites have been established at four institutions: the University of California Los Angeles (UCLA), the Georgia Institute of Technology, the French National Centre for Scientific Research (CNRS) / Center for Materials Elaboration and Structural Studies (CEMES), and the University of Montreal. These satellites both play a role in MANA’s research in various fields and are also training grounds for young scientists of MANA.

Dr. James Gimzewski of UCLA is a renowned nanotechnology researcher who received a Feynman Prize in 1997. At MANA, Dr. Gimzewski is conducting Nano-System research on neural networks that is aiming at a creation of artificial brain. He has visited MANA 31 times over 9 years and resided at MANA for a total of 362 days, and in this time he has engaged in joint research projects on new neurocomputer circuits that utilize the learning capabilities of atomic switches. He has so far published 63 papers through MANA.

Dr. Gimzewski’s research is frequently covered by NHK television programs, namely the January 2010 program “Proposal for the Future” and the February 2012 program “Nano Revolution: How Atoms Will Change Our Lives.” Dr. Gimzewski also works hard on training and education for young researchers, graduate students, and young administrative staff by receiving post-doctoral scholars dispatched by MANA to UCLA, contributing greatly to the management of Nanotechnology Students’ Summer School, and accepting MANA office staff as interns, among other efforts.

Dr. Zhong Lin Wang of the Georgia Institute of Technology is a highly active researcher whose papers, as of May 2016, have been cited over 90,000 times and have an H-index of 142. At MANA, he works in the Nano-Materials field and conducts research on photonic structures inspired by biological systems and nanogenerators that harvest mechanical energy. Dr. Wang is also he mentor of group leader Dr. Fukuta, who has visited the Georgia Institute of Technology 15 times for a total of 29 weeks to engage in joint research on nano-devices. The results of this research have been printed in the journal *ACS Nano.* There is also an exchange of personnel that takes place, as for example Dr. Wang’s post-doctoral scholars later become Dr. Fukuta’s post-doctoral scholars. Dr. Wang’s work at MANA Satellites have also prompted Japanese companies to inquire about possible collaborations.

Dr. Christian Joachim of CNRS/CEMES is a renowned computational scientist who won two Feynman Prizes in 1997 and 2005. At MANA, he works in the Nano-System field and researches the design, manufacture, and atomic manipulation of nanocircuits, in addition to working on the theory of surface electron interconnection. He actively engages in joint research with MANA researchers and has released 48 papers through MANA (this includes many papers printed in *Nature Nanotechnology* and other top-tier journals). At CEMES, Dr. Joachim hosted a workshop focused on uniting computational scientists with experimental scientists in October 2009, and a Japan-France workshop on Nano-Materials in November 2010.

Dr. Francoise Winnik of the University of Montreal is a world-renowned researcher in the fields of polymer chemistry, interface and colloid science, and nanoscience. She serves as the Executive Editor of *Langmuir*, the journal of the American Chemical Society. At MANA, Dr. Winnik works in the Nano-Life field and engages in a wide range of research, primarily focusing on the synthesis of new biocompatible polymers but also including various other interdisciplinary fusion research that utilizes nanotubes and nanoparticle materials developed by MANA researchers in other fields. Dr. Winnik operates labs at both MANA and the University of Montreal, but she is focused entirely on her MANA research with zero teaching obligations at the University of Montreal. In the past 5 years, she has spent 765 days at MANA and published 30 MANA papers.

Many other famous researchers, young faculty, students, and other researchers have visited MANA from both Japan and abroad, and the number of such visitors grows every year. This is proof of the fact that MANA is one of Japan’s leading international research hubs at which large numbers of researchers gather from around the world.

4-1-2. Employment of young researchers at the Center and their job placement after leaving the Center

Describe the Center's employment of young researchers, including postdoctoral researchers, and the positions they acquire after leaving the Center.

・ In Appendix 4-2~4, enter the following:
  - The state of international recruitment for postdoctoral researchers, applications received, and selections made
  - The percentage of postdoctoral researchers from abroad
  - The positions that postdoctoral researchers acquire after leaving the Center

Young researchers, mainly fixed-term researchers consisting of doctoral students and post-doctoral scholars, account for more than half of all researchers. In addition to typical post-docs, there is also a higher position in place for "ICYS-MANA researchers." These ICYS-MANA researchers are post-doctoral scholars who are independent of any specific group and pursue their own individual research topics.

ICYS is an organization that serves as a tenure-track system leading to permanent researcher positions at NIMS. ICYS is comprised of several subordinate organizations, one of which is ICYS-MANA. Researchers at ICYS are selected twice annually through an international application process. ICYS as a whole has received applications from 1,310 individuals over the past nine years (1,174 of which were non-Japanese individuals [i.e. 89% of the total]). Of these, 90 were hired, and a half of these (45) were assigned to ICYS-MANA.

Applications for standard doctoral and post-doctoral positions are accepted from around the world via the organization's website and similar. Post-doctoral hires are selected through both a documentary and interview phase overseen by a group of three or more examiners. Doctoral students are selected after a strict and impartial documentary and interview screening process conducted by faculty members of NIMS-affiliated graduate schools (refer to Chapter 6 for details).

Destinations of the 255 MANA postdoc alumni between October 2007 and March 2016.

MANA's policy is not merely to gather young researchers from throughout the world and cultivate them into excellent researchers. Rather, MANA seeks to endow these researchers with a thorough understanding of Japan such that they can advance their careers in countries throughout the world. Till the end of FY2015, 255 MANA's young researchers have "graduated" MANA. 12 of them were selected for permanent research positions at NIMS and 99 became faculty members (professor, associate professor and so on) of universities both inside and outside Japan. Also, 99 have advanced in their careers to become researchers at universities and research institutions, and 27 have moved to private companies. 35% of those who made research at MANA found employment within Japan, and the remaining 65% found positions in the world, primarily in Asia. In this way, there is a growing network of nanotechnology researchers for which MANA is the hub.

4-1-3. Overseas satellites and other cooperative organizations

In Appendix 4-5, describe the state of the Center's agreements concluded with overseas satellites and other cooperative organizations.

Building a network of the world's nanotech centers with MANA as the hub is one of MANA's organizational missions. MANA has to date signed MOUs with 60 research institutions in 19 countries with which it conducts research and personnel exchange.

In order to strengthen MANA research conducted by PIs at MANA satellites, NIMS/MANA has established a system through which it provides funding for joint research. Under this system, NIMS contracts with satellite institutions for joint research and allocates the necessary funds to the satellites from NIMS's management expenses grant. This enables effective coordination between MANA and its satellites, and enables satellites to make large contributions to MANA in return.

4-2. Center's Record of Holding International Symposia, Workshops, Research Meetings, Training Meetings and Others

・ In Appendix 4-6, describe the main international research meetings held by the Center.

Until 2012, MANA's International Symposium focused on annual reporting of MANA's research achievements, but in 2013 it became an international meeting for large groups of the best researchers in the world. It now aspires to be a more externally-oriented, higher-quality event. For each of the MANA International Symposiums in 2013-2016, over 20 top-tier researchers (including Nobel prize laureates) were invited to present their world-leading research and to discuss about research achievements pertaining from MANA. As a result, each symposium brought over 400 participants and the International Symposium was praised as a fruitful, high-level event. In order to promote interchange between young personnel and the world-leading researchers at the MANA International Symposium, a new award was created called the Best Poster Award. All invited speakers were asked to attend the poster session and to grade the posters after engaging in direct discussion with the presenters. This indeed increased the motivation of young scientists and graduate students in MANA.

Meanwhile, there are many government agencies, universities, research institutions, and other organizations that issue requests for MANA to host research conferences. As a result, country-level bilateral workshops have been hosted with Canada, Australia, Switzerland, Spain, and Taiwan, while symposiums have also been conducted with several Japanese and non-Japanese universities (Osaka University, Waseda University, Northwestern University, Université de Montréal, Bristol University, University of Rennes, National Taiwan University, The University of Tokyo, Tokyo University of Science, etc.). In addition, the Asian Symposium of Physical Chemistry and Chemical Physics (PCCP) and The RSC-MANA International Symposium, both jointly hosted by MANA and the Royal Society of Chemistry publishing many renowned academic journals, were organized and held in MANA. Hosting such events are useful ways of publicizing center activities and discovering new partners for joint research work.

4-3. System for Supporting the Research Activities of Overseas Researchers

Describe the Center's preparations to provide an environment conducive for overseas research to concentrate on their work, including for example living support in various languages or living support for their families.

All staff in MANA's Administrative Office speak English and provide comprehensive Japanese-style service to all researchers, regardless of age and nationality. According to one non-Japanese researcher, "Although I have worked at several institutions in America and Europe, MANA provides the best research environment."

・ **<u>Removal of language barriers</u>**: Almost all major guidebooks, documents, intranet services, and other information sources have been translated into both English and Japanese ("bilingualization"). The use of English is thoroughly enforced for all meetings, email contact, etc. In order to assist non-Japanese researchers in obtaining external competitive funding, the center distributes information in English on external funding sources and provides assistance with the application process. Efforts like this to remove language barriers are spreading throughout the entire NIMS organization.

・ Orientation: At regular intervals, MANA staff provide English language orientation and lab tours for new NIMS researchers. Staff work to ensure that researchers can get started with their work at NIMS as quickly as possible by providing necessary information on work regulations, benefits, supplies procurement, intellectual property, paper publication, research ethics, external funding application, and safety and hygiene, in addition to offering tours of the major research facilities.

・ **Livelihood support**: MANA's host organization, NIMS, contracts with the Japan International Science and Technology Exchange Center (JISTEC) to provide livelihood support for non-Japanese researchers. JISTEC handles a wide range of activities, including procedures like residence registration, school enrollment and transfer, opening bank accounts, and moving house. JISTEC also provides a various information relevant to daily living, accompanies individuals to hospitals, and provides support in the event of an accident, in addition to other services.

・ **Help to understand Japan**: MANA offers non-Japanese researchers support including Japanese language classes and Japanese cultural training. In 9 years, a total of 678 individuals have participated in Japanese language classes, and a total of 1,154 individuals have participated in Japanese cultural training classes, offered at a pace of roughly once a month. MANA also offers a comic book, well-received by non-Japanese researchers beginning work at MANA, entitled "The Challenging Daily Life," which offers solutions for problems encountered by non-Japanese researchers conducting research at a Japanese institution. Also many directors, managers and research leaders at overseas research institutions have praised this comic book as a "helpful way of eliminating potential barriers faced when young researchers first come to Japan."

・ **Technical support**: The Administrative Office's technical support team members are knowledgeable, proficient in English, and providing great support for all the MANA researchers, especially for non-Japanese researchers. Additionally, the technical support team uses its specialized knowledge to gather and translate information on external funding into English. Especially for non-Japanese researchers, the team provides support of writing applications and reports in Japanese if Japanese documents are really required.

4-4. Others

Describe the Center's policy for sending Japanese researchers overseas to gain international experience, and give examples of how the Center is working to create career paths for its researchers within a global environment of researcher mobility.

In terms of acquiring and training young researchers, both independent researchers who do not belong to any specific group and the ICYS researcher system have made notable achievements. In particular, the 3D System (Triple Double: double-mentor, double-discipline, double affiliation system) serves to promote diligent study by young researchers overseas by allowing such researchers to pursue interdisciplinary, fusion research under first-tier mentors. This system has a record of encouraging great growth in young researchers and imbuing them with global sensibilities.

For example, Dr. Samuel Sanchez of the Max Planck Institute is one researcher who flourished through the 3D System. When Dr. Sanchez was an ICYS-MANA researcher at MANA, he utilized the 3D System to begin joint research with a German laboratory, eventually advancing in his career to become a group leader at one of Germany's most prominent research institutions.

MANA promotes long-term residencies to perform research at major research institutions overseas as an effective way of cultivating young Japanese researchers into talent of an international and interdisciplinary character. Thus far, MANA has dispatched three young Japanese researchers to work and study for 1- or 2-year periods at the University of Cambridge (UK), RWTH Aachen University, and MINATEC (France).

Of the 197 researchers at the center, 99 are doctoral students or post-doctoral scholars. Of these, 84 (85%) are non-Japanese researchers from 19 countries. In this way, MANA has achieved a melting-pot environment in which young researchers from around the world can meet and work hard together to improve their abilities. At the direction of the Program Committee, in FY 2013 MANA established the YAMATO-MANA Program (Young, Aspiring Motherland Academics To MANA) to invite excellent young Japanese researchers to MANA and cultivate talent who will lead Japan's future. Through this program, MANA hired 8 researchers. (Note: "Yamato" is also an old name for Japan.)

MANA plays an important role in NIMS's effort to build an international research center, and MANA's efforts to create an environment where non-Japanese researchers can succeed was featured as a "best practice" case study in the 2014 White Paper on Science and Technology.

5. Organizational Reforms (within 3 pages)

5-1. Decision –Making System in the Center

Describe the strong leadership that the director is giving the Center's operation and its effect, and the division of roles and authority between the Center and its host institution.

The center's Director-General has succeeded in gathering excellent researchers from around the world and building a research culture in which these researchers can work freely and easily while working hard and improving together. The many brilliant achievements of the center described in Chapter 2 are a testament to the Director-General's success. Underlying this success is the strong leadership that the Director-General has displayed in his management of the center, including his work setting research policy, streamlining systems and organizations, implementing effective new policies, and distributing research resources. Clear examples of his successful policies include the independent researcher system and the 3D (Triple Double) System, which have had a major positive impact on the training of young researchers; as well as the implementation of the funded joint research system that dramatically revitalized the work of satellite research centers.

The Director-General has also succeeded in giving the concept of nanoarchitectonics an established global presence. This is due to the untiring effort to broadly communicate relevant research achievements by holding numerous research conferences, publishing special nanoarchitectonics editions of famous journals, distributing online newsletters, and other PR activities. Indeed, there is even happy news that the word "nanoarchitectonics" will be in the next revision to the famous and authoritative Japanese dictionary, *Kojien*.

The Director-General responded expeditiously to the Program Committee's directives and improved the quality of the center's activities. For example, MANA has established the Grand Challenge research project, which engages in work on challenging topics; the Theoretical-Experimental Fusion Research Program; the Nano-Life Fusion Research Program; the YAMATO-MANA Program that trains young Japanese researchers; and other programs that have all yielded outstanding results.

MANA's host institution, NIMS, has granted broad authority to the Director-General regarding internal management of the center and pays maximum respect to his ideas. Meanwhile, NIMS provides massive support to center management by allocating research resources including 90 permanent staff and as large an operating budget as possible. It is also certain that there will be no change in this policy in the future.

5-2. Arrangement of Administrative Support Staff and Effectiveness of Support System

Describe the assignment of the Center's administrative support staff who have English language and other specialized skills, effort made in establishing the support system, and the system's effectiveness.

Since its founding, NIMS has accumulated knowledge and experience concerning the management of an international research center through programs like the International Center for Young Scientists (ICYS). MANA has inherited that knowledge and continues to polish it further through the current program. As a result, MANA has succeeded in creating an almost perfect environment in its capacity to expeditiously provide administrative and technical services to all MANA researchers, including non-Japanese researchers.

The MANA Administrative Office is comprised of four teams—Planning, General Affairs, Technical Support, and Outreach—but it is essentially the General Affairs team that handles researchers' clerical affairs. There is a system in place to lead this entire team, marshalled by experienced NIMS personnel with thorough knowledge of administrative and general affairs while also being accustomed to working with non-Japanese researchers. No secretary is permanently attached to a single research group; instead, the system is distinguished by its smooth adaptability by reassigning staff as appropriate with due consideration for work aptitude and workload balance. Additionally, MANA's Outreach team works not only on delivering MANA's research accomplishments throughout the world, but also on science education for high schools, junior high schools and even elementary schools. This outstanding work is highly evaluated in NIMS, resulting in a group of Dr. Ebara (MANA Scientist), NIMS administration officers, and the MANA Outreach team being awarded a President's Award in April 2016. The MANA Outreach Team, therefore, receives many invitations and requests, as well, such as, from the city of Tsukuba, asking for participation in science campaigns, and, from a student group of University of Tsukuba, cooperation in the university festival. In this way, this team has contributed tremendously to improving the impression of MANA's research and the center itself among ordinary people.

5-3. System Reforms Advanced by WPI Program and Their Ripple Effects

Concisely itemize the system reforms made to the Center's research operation and administrative organization, and describe their background and results. Describe the ripple effects that these reforms have on the host institution. (Describe the ripple effects on other institutions.)

Organizational reforms at MANA

(1) Strongly promoted interdisciplinary research by implementing Grand Challenge research, Theory-Experiment Fusion Research, and other new research systems.
(2) Intensified internationalization at MANA through measures such as promoting bilingual administration and offering research and living support for non-Japanese researchers.
(3) Promoted the training and promotion systems for young personnel by designing and implementing the ICYS-MANA system, the 3D System, and others.

Ripple effects on the host organization as a whole, etc.

(1) By making MANA a permanent research arm of NIMS and guaranteeing the ongoing development of MANA operations, the system has been put in place to easily spread MANA's organizational reforms to the entirety of NIMS. Moreover, energy and morale of research in NIMS was given a boost by the fact that one of NIMS's research arms has become a WPI center.
(2) Overall English ability at NIMS has been dramatically improved by the spreading to NIMS of MANA's policy of using English as an official language, i.e., the implementation of programs to improve the English ability of NIMS administrative staff, the translation of important documents and internal announcements released by NIMS into both English and Japanese ("bilingualization"), and so on.
(3) Many young researchers who have acquired outstanding accomplishments in MANA's international melting-pot environment have been hired on at NIMS as permanent research staff.
(4) MANA's experience and achievements have been put to maximum use in the conception, planning, and establishment of other research centers, including the Elements Strategy Initiative Center for Magnetic Materials, the Global Research Center for Environment and Energy based on Nano-materials Science, and the Structural Materials Research Center (for example, training and promotion systems similar to ICYS-MANA have been implemented at these centers).
(5) In the 4th Mid-Term Plan (7-year plan) that starts from April 2016, NIMS officially has seven research centers. MANA is one of these centers, and it has been decided that the other six research centers will implement management offices unique to that center in imitation of MANA's success with that policy.
(6) Has offered knowledge of and experience with international research center management to external parties as consultation, advising groups such as AIMR, I2CNER, IIIS, JAXA, JST, the Japan Agency for Marine-Earth Science and Technology, and the Institute for Molecular Science. MANA has also published books on this management knowledge ("This is the International Center for Young Scientists," "The Challenging Daily Life," etc.).

5-4. Support by Host Institution

The following two items concern the support that the host institution provides the Center, including those items of support that it committed to at the time of the initial project proposal submittal or in its revised commitment following the project's interim evaluation. Describe the functional measures that the host institution has taken to sustain and advance the Center's project.

5-4-1. Record of host institution support and its effects

・ In Appendix 5-1, describe the concrete measures being taken by the host institution.

To ensure the smooth operation of MANA, the host institution NIMS guaranteed in the stage of application to the WPI program that it would achieve maximum operational expediency by providing staff, research funding, and research space to MANA, as well as delegating management authority to the Director-General of MANA. It has faithfully fulfilled on these commitments. In addition, since MANA's founding over 1.4 billion JPY annually has been allocated from NIMS's management expenses grants to pay for research projects and other project expenses necessary to the center's activities (e.g., shared research facilities, challenging exploratory research, research funding for MANA satellites, official travel and invitations, symposiums, outreach activities, etc.).

As a result, MANA has been able to implement unique research projects such as Grand Challenge research, Theory-Experiment Fusion Research, and Nano-Life Fusion Research, while a culture has taken shape within the center built around innovative, "outside-the-box" interdisciplinary research. Systems are in place at MANA to support experimental research, with the MANA Foundry and communal laboratories being equipped with the latest research equipment and veteran staffs overseeing equipment maintenance and management in addition to serving as coaches and advisors to experiments. From April 2016, the newly-established Nano-Theory field will take in most of NIMS's theoretical researchers, and although much more of the center's CPU time will be eaten up by MANA, NIMS will provide appropriate support for the increase of the costs.

As explained in Section 4-1-3, joint research agreements have been signed between NIMS and satellite host institutions, and necessary funds are allocated from NIMS's management expenses grant to the satellite centers for joint research. This serves to create effective links between the satellites and MANA itself.

5-4-2. Position of the Center within the host institution's mid-term plan

To Appendix 5-2, attach the cover sheets of the host institution's "Mid-term objectives" and/or "Mid-term plan" and parts of these documents related to the WPI Center.

In its 3rd Mid-Term Plan (five-year plan) that began in April 2011, NIMS was already laying the groundwork to make MANA a permanent research center. MANA's development of innovative new materials through nanoarchitectonics was recognized as a priority R&D area for NIMS, and MANA was defined as one of NIMS's three research arms: namely, the Nanoscale Materials Division. NIMS's 4th Mid-Term Plan (7-year plan) starts from April 2016, and in this plan an "International Nanoarchitectonics Research Center" is explicitly defined as one of NIMS's main research centers.

As it works to make MANA a permanent part of its organization, NIMS is also methodically increasing the number of permanent researchers and administrative staff on board at MANA. From April 2011 to March 2016, MANA added 18 permanent staff to its roster and in the same period 13 permanent staffs moved to the positions outside MANA. And, as of the end of March 2016, MANA has a total of 89 permanent staff which had been 84 at the end of March 2010, meaning that MANA and NIMS have been making effort to circulate researchers and administrative staff to renovate the host institution NIMS. NIMS plans to continue hiring several new researchers every year and expanding the research center further in the future.

5-5. Others

Describe efforts advanced to foster young researchers (e.g., start-up funding, autonomous research environment) and to enlist female researchers.

- In Appendix 5-3, give the transition in the number of female researchers.

<u>Independent researchers</u>

In addition to the WPI program's four major tasks— world-class research, interdisciplinary fusion research, internationalization, and organizational reform—MANA has one extra task of its own: the cultivation of young researchers.

MANA appoints promising young researchers as "independent researchers" and trains them to become future leaders at the center through a system called the 3D (Triple Double) system. Because independent researchers do not belong to any particular research group, they are distinguished by their ability freely conduct research with all sorts of researchers both inside and outside of Japan. These independent researchers are assigned two mentors—one from NIMS and one renowned researcher at an institution overseas ("Double Mentor")—and encouraged to contribute to two research institutions ("Double Affiliation") while straddling two different specializations ("Double Discipline").

MANA provides generous support for independent researchers, who are provided with resources like ¥3 million in annual research funding, one post-doctoral assistant, travel cost reimbursement for trips to meet with mentors, independent research office space, and a shared secretary in order to lessen the burdens of administrative work.

This system is an extremely effective way of training international and interdisciplinary young researchers. In April 2011, three independent researchers were promoted to group leaders in recognition of their achievements. Additional four independent researchers will be promoted to group leader status in April 2016 and one of them, Dr. Yusuke Yamauchi at the age of 35, will be appointed to be a new MANA Principal Investigator at the same time.

<u>Female researchers</u>

In FY 2013, MANA's host institution, NIMS, established a new permanent researcher position open only to women in an effort to expand the number of female researchers on staff. Since FY 2013, NIMS has hired through this system 2 female permanent researchers and 1 of them has been assigned to MANA. In comparison, since FY 2013, a total of 4 female permanent researchers have been assigned to

MANA (by comparison, the number of new male to MANA is 8).

The Director-General regularly orders that efforts be made to hire excellent female researchers. Of the students, post-doctoral scholars, and other young researchers that MANA can currently hire at its discretion, approximately 29% are female.

6. Others

- In addition to the above 1-5 evaluation items, only if there is anything else that deserves mention regarding the center project's progress, please note it.

Performance-based salary system

With the aim of incentivizing researchers to achieve maximum research output within a competitive environment, NIMS implemented individual performance evaluations and performance-linked benefits for its researchers soon after it became an independent administrative institution. NIMS does not use a performance target-based management system because it is not believed that target-based performance evaluations are appropriate for researchers engaged in original, challenging research. To encourage researchers to freely pursue high-quality research, NIMS conducts performance evaluations based on the output of their research and pays large performance bonuses to researchers who have managed great accomplishments, regardless of the researcher's position or age.

Although this was not its intention, NIMS's performance evaluation and benefit system highly evaluates exactly the type of research to which the WPI program aspires (world-class research; interdisciplinary fusion research). Proof of this can be seen in the fact that many MANA researchers have achieved great things and been greatly compensated for it through the MANA system. This system is one reason why MANA researchers are oriented toward highly original research that produces excellent papers and patents.

Post-doctoral scholars with superior performance after joining MANA also receive raises after a special screening process. In general, around 20% of all post-docs receive such raises.

University collaborations

Because NIMS is not a university, NIMS and MANA make special effort to bring in students (and graduate students) in a variety of capacities.

NIMS has signed agreements with the University of Tsukuba, Hokkaido University, Waseda University, and Kyushu University to form the NIMS "Partner Graduate School" program. Graduate students on this program are in residence at NIMS to participate in research, NIMS researchers act as university instructors for the students. Currently, there are 22 MANA researchers serving as instructors through the NIMS Partner Graduate School program. Particularly outstanding graduate students in the program are selected to be NIMS Junior Researchers and receive salaries for their work on NIMS research. There are currently 33 NIMS Junior Researchers at MANA, 31 of whom are non-Japanese.

NIMS also operates an "International Partner Graduate School" program in partnership with famous graduate schools overseas. Under this program, doctoral students come to NIMS for anywhere from several months to a year, during which NIMS researchers guide their PhD research. To date, MANA has accepted 49 students through this program. There is also an internship program in place in which students from Japanese and non-Japanese universities are accepted for up to three months and given the opportunity to participate in nanoarchitectonics research. Thus far, MANA has accepted 405 students into the internship program, 322 of whom were non-Japanese.

Additionally, in April 2016 a young MANA independent scientist, Dr. Yusuke Yamauchi, will be appointed to an official teaching position at a university overseas. This will be achieved through cross-appointment between NIMS and the other university, establishing a direct pipeline between the university and MANA.

Advisors and the evaluation committee

As of the end of March 2016, three external experts have been brought on as advisors. They provide advice on overall center management and offer valuable suggestions regarding individual research projects. They are also involved in outreach activities as lecturers in science classes for elementary and junior high school students. A former MANA advisor, the late Dr. Rohrer, used to attend the MANA International Symposium every year and offer invaluable advice on each of the lectures. He also supervised independent researchers, leading to some groundbreaking results **(Section 2-1 "Research achievements," item [9]; page 7).** In April 2016, three new advisors are scheduled to be brought on to strengthen all research activities conducted at MANA.

The MANA Evaluation Committee is comprised of six external experts headed by Prof. Cheetham of the

University of Cambridge. From 2016 January, one of the committee members, Prof. Kazuhito Hashimoto of the University of Tokyo, has resigned from this committee and now 5 members are active. The committee has met four times—in 2008, 2010, 2012, and 2014—to evaluate the center's management and research activities. This committee provides advice and suggestions from a perspective that differs from that of the WPI program committee, producing action plans for MANA to follow.

MANA Alumni Association

The MANA/ICYS Alumni Association was established for researchers who are alumni of MANA and ICYS (International Center for Young Scientists). The purpose of the association is to create a network of MANA/ICYS alumni throughout the world, promoting interchange among alumni themselves and between alumni and current MANA researchers. A MANA/ICYS Reunion Workshop was held on March 3-4, 2014, and approximately 20 alumni were invited to attend.

At this workshop, researchers reported on their research and then discussed the kind of interchange that could take place by making use of this alumni network. Several excellent ideas emerged that are planned to be integrated into future MANA work, including the idea to print a special magazine edited by MANA researchers and alumni, and an idea to implement a "homecoming program" in which alumni can reside at MANA to conduct joint research.

7. Center's Response to Results of FY2015 Follow-up (including Site Visit Results)

* Describe the Center's Response to Results of FY2015 Follow-up. Note: If you have already provided this information, please indicate where in the report.

1) Interdisciplinary fusion research: Further work is needed to promote interdisciplinary research activities that bridge Nano-Materials and Nano-System with Nano-Life, Nano-Power, and the new field of Nano-Theory (established in FY 2016). One problem is the question of how to proceed with research in the Nano-Life field.

Promoting interdisciplinary fusion research is one of the main concerns of MANA. In fact, as has already been described in Chapter 3 (Interdisciplinary Research Activities), we have implemented various relevant programs, e.g., A) Fusion Research Program, B) Theory-Experiment Fusion Research Program, C) Nano-Life Fusion Research Program, and D) Grand Challenge Program. As a result, interdisciplinary fusion research has arisen in MANA beyond the usual interdisciplinary collaborations. Therefore, at present, the barriers between the five research fields (Nano-Materials, Nano-System, Nano-Power, Nano-Life and Nano-Theory) have become fuzzy to a considerable extent.

As for the Nano-Life field specifically referred to in the present comment of concern, we believe that a unique research field has been opened up in MANA. The research in that new field includes: a) a novel highly-sensitive artificial nose (a smell sensor) using an array of nanomechanical membrane stress sensors (MSS), which can distinguish between cancer patients and healthy persons only by examining exhaled breath; b) neuromorphic network circuits composed of a huge number of synapse-like atomic switches, which exhibit oscillatory behavior even against DC voltage application; c) cell-based mechanobiology in which atomic force microscopy and spectroscopy are effectively applied; d) time-dependent drug delivery to kill local cancer cells using novel nanofiber mesh technology, etc.

2) Cultivating young researchers: In order to maintain current numbers of graduate students and post-doctoral scholars from universities and research institutions both inside Japan and abroad, more interchange is necessary with these kinds of organizations. It is also important to increase researcher exchange activities with influential research institutions overseas, including satellite institutions.

Regarding graduate students, MANA has been using the NIMS domestic Partner Graduate School Program and International Partner Graduate School Program in order to secure 30-40 graduate students. By maintaining the operation of these programs, MANA will be able to secure the same number of graduate students.

As for post-doctoral scholars, about 70 persons are currently working in MANA. As MANA has already obtained an excellent reputation worldwide, many post-doctoral scholars domestically and abroad are interested in joining MANA. In addition, MANA has signed MOUs with over 50 research institutions domestically and abroad, and those institutions would like to send post-doctoral scholars to

MANA. The current number of post-doctoral scholars of about 70 is simply limited by the research budget of MANA. About half of them are hired directly using the WPI subsidy with the remainder supported by external competitive funds. This means that if the WPI subsidy ceases completely, the number of post-doctoral scholars will be decreased by half (to about 35). Of course, we will do our very best to increase the amount of external competitive funding obtained in order to hire as many post-doctoral scholars as possible.

Apart from graduate students and post-doctoral scholars, MANA will continue active exchange of researchers with influential institutions in the world, including MANA's satellite institutions.

3) MANA at NIMS: The Program Committee recommends that MANA remain as an independent organization after WPI aid ends. In this way, MANA's unique culture can continue to influence the direction of its mother organization in positive ways. It is important to create a specific plan by which NIMS will maintain MANA's international approach, deferral of power to young researchers, and the reputation that MANA has built.

For NIMS, the 4th mid-term plan (seven-year plan) started in FY 2016, and MANA has been defined as one of the research divisions of NIMS. The name WPI-MANA will continue to be used as before. This means that MANA has been positioned in NIMS permanently. The know-how developed by MANA thus far, including the international administrative systems, young researcher training systems and global networking of relevant research centers, is also starting to be incorporated into the other research centers of NIMS.

4) Quality of science: In order for MANA to maintain the level of its research as a world research hub, MANA researchers should pursue fundamental research that is of high quality in an international context.

In materials science and technology which MANA covers, it is hard to distinguish between fundamental and applied research. Nevertheless, in the past eight and a half years of the MANA, we have emphasized the importance of fundamental research based on MANA's nanoarchitectonics concept. This policy was successful in the sense that several interesting applications have almost spontaneously arisen from fundamental research. Based on this experience, we will keep emphasizing the importance of fundamental research on the basis of the nanoarchitectonics concept.

World Premier International Research Center Initiative (WPI)

Appendix 1-1. FY 2015 List of Principal Investigators

NOTE:
・Underline names of investigators who belong to an overseas research institution.
・In case of researchers not listed in the latest report, attach Appendix1-1a, "Biographical Sketch of a New Principal Investigator".

<Results at the end of FY2015>

Principal Investigators Total:

Name (Age)	Affiliation (Position title, department, organization)	Academic degree, specialty	Working hours (Total working hours: 100%)				Starting date of project participation	Status of project participation (Describe in concrete terms)	Contributions by PIs from overseas research institutions
			Work on center project		Others				
			Research activities	Other activities	Research activities	Other activities			
Director-General AONO, Masakazu* (71)	Director-General, International Center for Materials Nanoarchitectonics (MANA)	Ph.D. University of Tokyo, 1972 NanoSciene and nanotechnology	60%	15%	15%	10%	10/1/2007	a) usually stays at the center	
BANDO, Yoshio* (68)	Chief Operating Officer, International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Osaka University, 1975 Nanomaterials and transmission electron microscope	70%	30%	0%	0%	10/1/2007	a) usually stays at the center	
SASAKI, Takayoshi* (60)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. (Science) University of Tokyo, 1986 Nanosheet and soft chemistry	100%	0%	0%	0%	10/1/2007	a) usually stays at the center	

ARIGA, Katsuhiko* (53)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Tokyo Inst. Tech., 1990 Supramolecular chemistry and surface science	100%	0%	0%	0%	10/1/2007	a) usually stays at the center	
CHIKYOW, Toyohiro (57)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Waseda University, 1989 Semiconductor and electric materials	70%	10%	10%	10%	4/1/2011	a) usually stays at the center	
GOLBERG, Dmitri* (55)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Moscow Institute for Ferrous Metallurgy, 1990 Nanotubes and nanowires	100%	0%	0%	0%	10/1/2007	a) usually stays at the center	
WANG, Zhong Lin* (54)	Professor, School of Materials Science and Engineering, Georgia Institute of Technology	Ph.D. Arizona State University, 1987 Nano chemistry and nanodevices	15%	5%	60%	20%	10/1/2007	b) stays at the center twice a year, usually at GIT satellite	To conduct research themes of MANA

GIMZEWSKI, James K.* (64)	Dinstinguished Professor, Chemistry & Biochem. Dept., UCLA Director, Nano/Pico Characterization Lab, UCLA California NanoSystems Inst.	Ph.D. (Physical Chemistry) Univ. of Strathclyde, 1977 Nanoscience and nanobio	23%	3%	67%	7%	10/1/2007	b) stays at the center several times a year, usually at UCLA satellite	To conduct research themes of MANA
HU, Xiao (54)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. (Physics) University of Tokyo, 1990 Condensed matter physics	100%	0%	0%	0%	10/1/2007	a) usually stays at the center	
JOACHIM Christian* (58)	Centre National de la Recherche Scientifique (CNRS) Lab: CEMES (UPR8011) Toulouse (France)	Ph.D. in Applied Mathematic Ph.D. in Quantum physics, computer science and nanoscience	18%	3%	72%	7%	10/1/2007	b) stays at the center several times a year, usually at CNRS satellite	To conduct research themes of MANA
TSUKAGOSHI, Kazuhito (48)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Osaka University,1995 Nano electronics	90%	0%	10%	0%	1/1/2009	a) usually stays at the center	
YE, Jinhua* (53)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. University of Tokyo, 1990 Photocatalyst, eco-materials	30%	0%	50%	20%	10/1/2007	a) usually stays at the center	

TAKADA, Kazunori* (54)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Osaka University, 1986 Solid-state chemistry	30%	0%	70%	0%	1/1/2010	a) usually stays at the center	
UOSAKI, Kohei* (69)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Flinders Univ., 1977 Surface physical chemistry	80%	20%	0%	0%	7/1/2008	a) usually stays at the center	
YAGHI, Omar* (51)	The James and Neeltje Tretter Professor of Chemistry, UC Berkley	Ph.D. University of Illinois, 1990 Nanostructure of organic materials	30%	0%	60%	10%	3/10/2008	b) usually stays at UCB c) holds a videoconference from UCB once a week.	To conduct research themes of MANA and to supervise a research group of MANA
CHEN, Guoping (50)	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Kyoto University, 1997 Biomaterials and tissue engineering	100%	0%	0%	0%	4/1/2011	a) usually stays at the center	
NAGASAKI, Yukio* (56)	Professor, Department of Materials Science and Master's Master's School of Medical Sciences, University of Tsukuba	Ph.D. Tokyo University of Science, 1986 Biomaterials and polymer chemistry	20%	0%	70%	10%	10/1/2007	b) usually stays at the University of Tsukuba satellite	

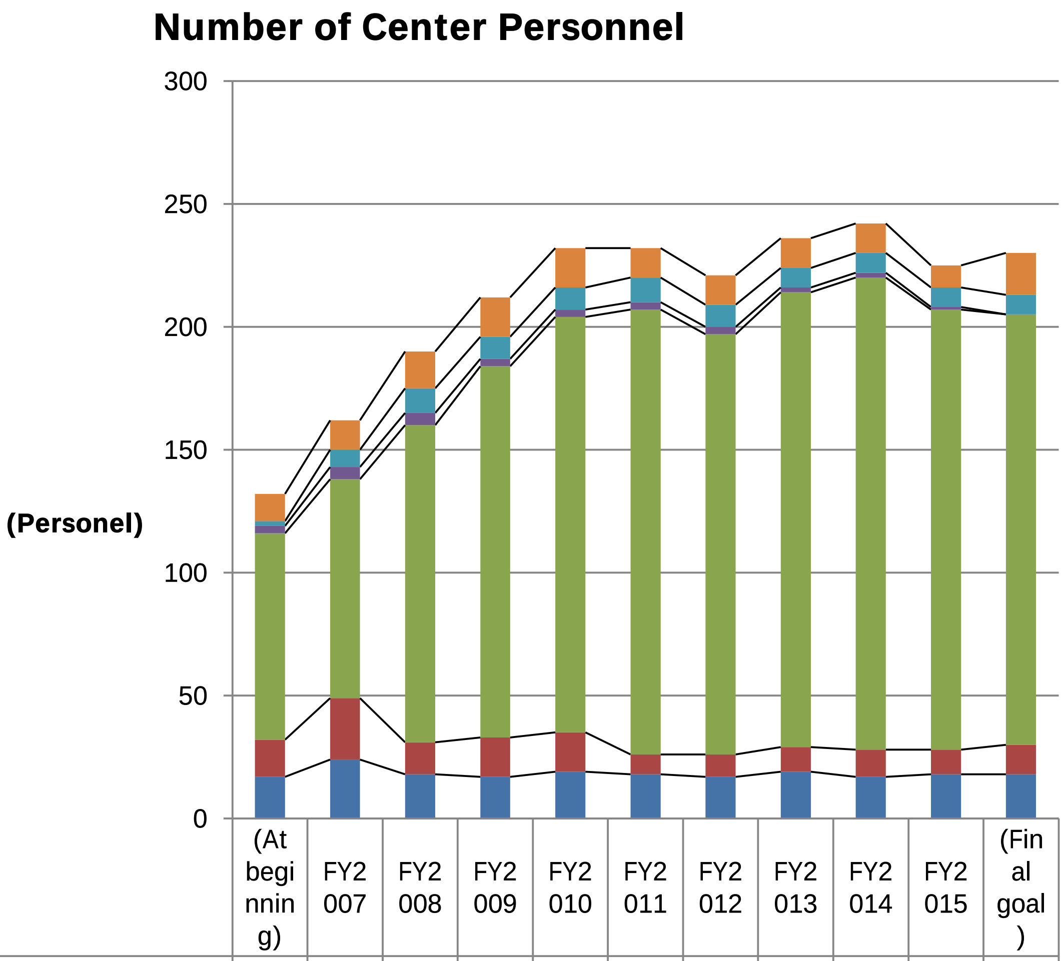
Françoise M. Winnik* (64)	Faculty of Pharmacy and Department of Chemistry, University of Montreal, Canada	Ph.D. (Chemistry) Univ. of Toronto, 1979 Polymer chemistry and photochemistry	40%	10%	40%	10%	4/1/2011	b) stays at the center for five months a year	To conduct research themes of MANA

Researchers unable to participate in project in FY 2015

Name	Affiliation (Position title, department, organization)	Starting date of project participation	Reasons	Measures taken
HASEGAWA, Tsuyoshi (53)	International Center for Materials Nanoarchitectonics (MANA)	10/1/2007	Moving out to Waseda University	Compensation in FY2016 plan
NAKAYAMA, Tomonobu (54)	International Center for Materials Nanoarchitectonics (MANA)	10/1/2008	Promoted to administrative director	Compensation in FY2016 plan
TAKAYANAGI, Hideaki* (64)	Professor, Tokyo University of Science, Research Institute for Science and Technology	10/1/2007	Expiration of term of office	Compensation in FY2016 plan
AOYAGI, Takao* (56)	International Center for Materials Nanoarchitectonics (MANA)	9/1/2010	Moving out to Nihon University	Compensation in FY2016 plan

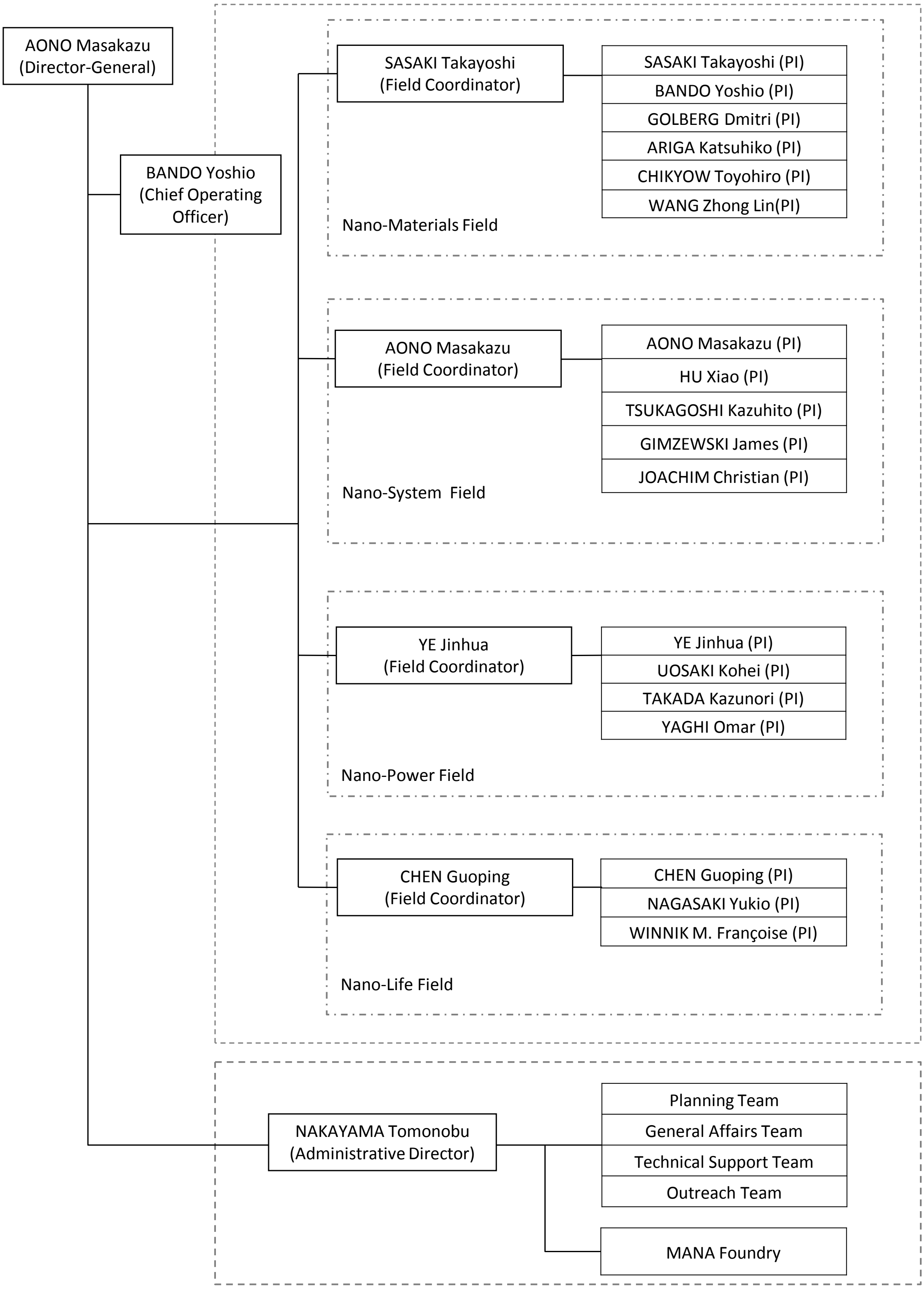
World Premier International Research Center Initiative (WPI)
Appendix 1-2. Annual Transition in the Number of Center Personnel

*Make a graph of the annual transition in the number of center personnel since the start of project.



	(At beginning)	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	(Final goal)
🟧 PI：Researchers from within host institution	11	12	15	16	16	12	12	12	12	9	17
🟦 PI：Foreign researchers invited from abroad	2	7	10	9	9	10	9	8	8	8	8
🟪 PI：Researchers invited from other Japanese institutions	3	5	5	3	3	3	3	2	2	1	0
🟩 Other researchers	84	89	129	151	169	181	171	185	192	179	175
🟥 Research support staffs	15	25	13	16	16	8	9	10	11	10	12
🟦 Administrative staffs	17	24	18	17	19	18	17	19	17	18	18

World Premier International Research Center Initiative (WPI)
Appendix 1-3. Diagram of Management System



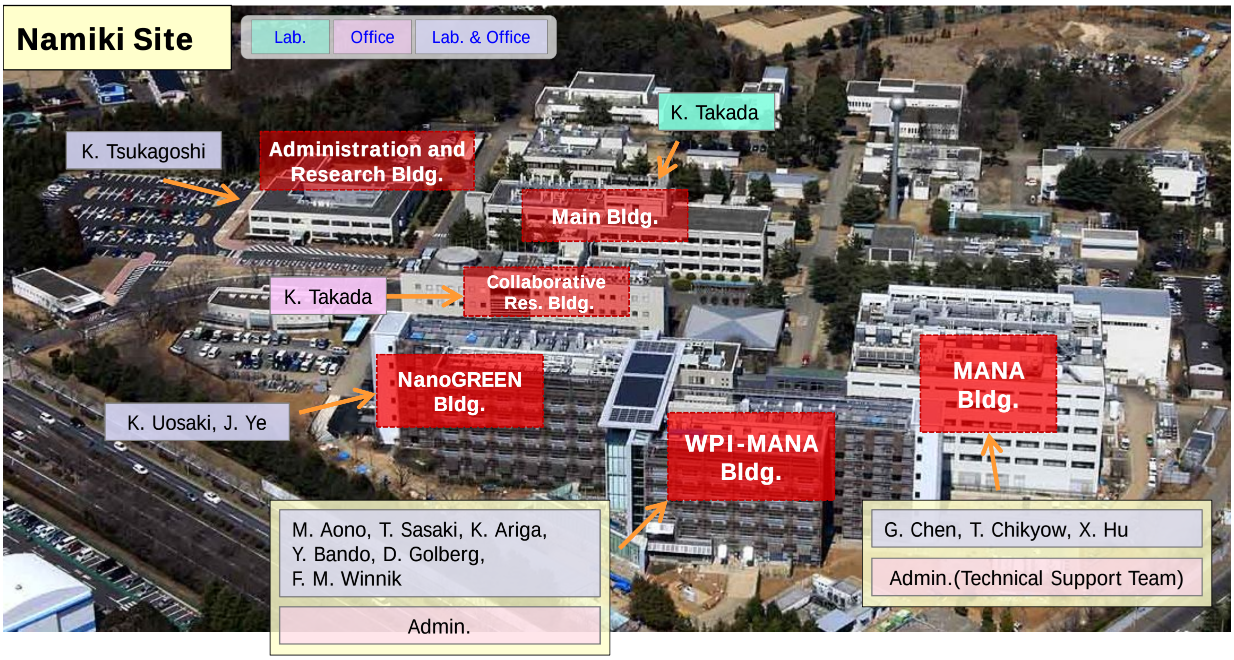
World Premier International Research Center Initiative (WPI)
Appendix 1-4. Campus Map

World Premier International Research Center (WPI) Initiative

D.-G.	M. Aono	Office	Lab.
COO	Y. Bando	Office	Lab.
P.I.	K. Ariga	Office	Lab.
	T. Sasaki	Office	Lab.
	D. Golberg	Office	Lab.
	X. Hu	Office	Lab.
	K. Tsukagoshi	Office	Lab.
	K. Takada	Office	Lab.
	G. Chen	Office	Lab.
	T. Chikyow	Office	Lab.
	J, Ye	Office	Lab.

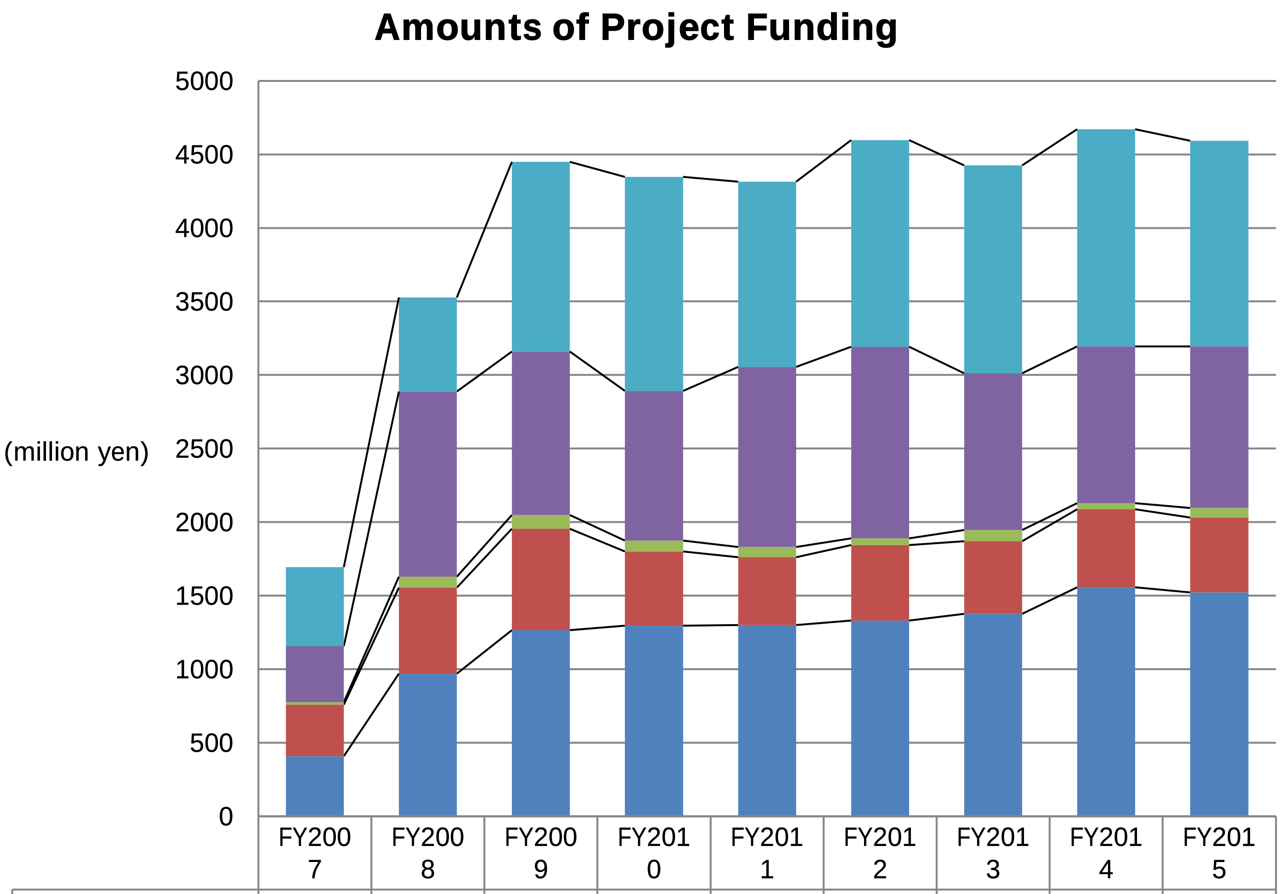
Administrative Office

WPI Center for Materials Nanoarchitectonics
National Institute for Materials Science



World Premier International Research Center Initiative (WPI)
Appendix 1-5. Annual Transition in the Amounts of Project Funding

*Make a graph of the transition in the number of overall project funding.



	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015
🟦 Research projects	537	639	1290	1455	1259	1406	1414	1476	1397
🟪 Equipment	380	1258	1112	1018	1226	1302	1066	1066	1098
🟩 Travel	18	75	92	72	70	47	77	40	66
🟥 Project activities	350	584	689	506	460	513	494	531	510
🟦 Personnel	408	970	1266	1295	1300	1330	1375	1557	1521

Appendix 1-6. FY2015 Project Expenditures (the exchange rate used: 1USD=110JPY)

i) Overall Project Funding

Cost Items	Details	Costs (10,000 dollars)
Personnel	Center director and Administrative director	30.68
	Principal investigators (no. of persons):11	128.22
	Other researchers (no. of persons):192	1,083.07
	Research support staffs (no. of persons):9	56.3
	Administrative staffs (no. of persons):20	84.09
	Total	1382.36
Project activities	Gratuities and honoraria paid to invited principal investigators	14.35
	Cost of dispatching scientists (no. of persons):8	13.95
	Research startup cost (no. of persons):3	34.05
	Cost of satellite organizations (no. of satellite organizations):	57.36
	Cost of international symposiums (no. of symposiums):3	9.01
	Rental fees for facilities	0
	Cost of consumables	30.23
	Cost of utilities	239.15
	Other costs	65.52
	Total	463.62
Travel	Domestic travel costs	0.3
	Overseas travel costs	7.97
	Travel and accommodations cost for invited scientists (no. of domestic scientists):57 (no. of overseas scientists):79	49.16
	Travel cost for scientists on secondment (no. of domestic scientists):2 (no. of overseas scientists):8	2.24
	Total	59.67
Equipment	Depreciation of buildings	371.46
	Depreciation of equipment	627.14
	Total	998.6
Other research projects	Projects supported by other government subsidies, etc.	660.84
	Commissioned research projects, etc.	341.55
	Grants-in-Aid for Scientific Research, etc.	267.39
	Total	1269.78
Total		4174.03

Ten thousand dollars

WPI grant		1,168.80
Costs of establishing and maintaining facilities		0
Establishing new facilities (Number of facilities: , m²)	Costs paid:	0
Repairing facilities (Number of facilities: , m²)	Costs paid:	0
Others		
Cost of equipment procured		392.25
Name of equipment: EDX upgrade for SEM Number of units: 1	Costs	11.78
Name of equipment: UPS for TEM Number of units: 1	Costs	2.87
Name of equipment: Dryer for TEM grids Number of units: 1	Costs	2.65
Name of equipment: Muffle Furnace Number of units: 1	Costs	1.98
Name of equipment: Muffle Furnace Number of units: 1	Costs	51.05
Others		321.92

---

ii) Costs of Satellites and Partner Institutions

Cost Items	Details	Costs (10,000 dollars)
Personnel	Principal investigators (no. of persons):1	
	Other researchers (no. of persons):12	
	Research support staffs (no. of persons):7	
	Administrative staffs (no. of persons):2	
	Total	44.35
Project activities		7.18
Travel		1.18
Equipment		0.29
Other research projects		4.36
Total		57.36

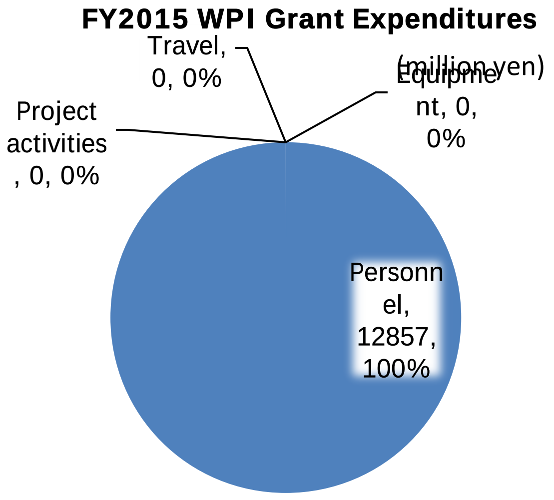
World Premier International Research Center Initiative (WPI)

Appendix 1-7. FY2015 WPI Grant Expenditures (the exchange rate used: 1USD= 110JPY)

i) Overall Expenditures

* Describe a circle graph for cost items.

Cost Items	Details	Costs (10,000 dollars)
Personnel	Center director and Administrative director	30.68
	Principal investigators (no. of person): 14	128.21
	Other researchers (no. of person): 190	925.62
	Research support staffs (no. of person): 10	26.32
	Administrative staffs (no. of person): 25	57.97
	Total	1168.80
Project activities	Gratuities and honoraria paid to invited principal investigators (no. of person)	0
	Cost of dispatching scientists (no. of person)	0
	Research startup cost (no. of person)	0
	Cost of satellite organizations (no. of satellite organization)	0
	Cost of international symposiums (no. of symposiums	0
	Rental fees for facilities	0
	Cost of consumables	0
	Cost of utilities	0
	Other costs	0
	Total	0
Travel	Domestic travel costs	0
	Overseas travel costs	0
	Travel and accommodations cost for invited scientists (no. of domestic scientists) (no. of overseas scientists)	0
	Travel cost for scientists on secondment (no. of domestic scientists) (no. of overseas scientists)	0
	Total	0
Equipment	Cost of equipment procured	0
	Total	0
Total		1168.8



ii) Costs of Satellites and Partner Institutions

Cost Items	Details	Costs (10,000 dollars)
Personnel	Principal investigators (no. of person)	
	Other researchers (no. of person)	
	Research support staffs (no. of person)	
	Administrative staffs (no. of person)	
	Total	0
Project activities		0
Travel		0
Equipment		0
Total		0

World Premier International Research Center Initiative (WPI)
Appendix 2-1. List of Papers Underscoring Each Research Achievement

* List papers underscoring each research achievement listed in the item 2-1 “Research results to date” (up to 40 papers) and provide a description of the significance of each (within 10 lines).
* For each, write the author name(s); year of publication; journal name, volume, page(s), and article title. Any listing order may be used as long as format is the same. If a paper has many authors, underline those affiliated with the Center.
* If a paper has many authors (say, more than 10), all of their names do not need to be listed.
* Place an asterisk (*) in front of those results that could only have been achieved by a WPI center.

Research result [1]

*1. F. Geng, R. Ma, A. Nakamura, K. Akatsuka, Y. Ebina, Y. Yamauchi, N. Miyamoto, Y. Tateyama, and T. Sasaki, “Unusually stable ~100-fold reversible and instantaneous swelling of inorganic layered materials”, *Nature Commun.* **4**, 1632 (2013).

A massive monolithic swelling of layered materials has been achieved in aqueous solution of 2-dimethylaminoethanol (DMAE), which was up to 100-fold with the gallery spacing increased from 0.9 nm to 90 nm. With quantitative analysis, it was determined that the largely expanded space was primarily occupied with H_2O along with minor trace of the DMAE. The swollen phase was unusually stable with no obvious observation of peeling or translational shifts during the swelling process, maintaining a nearly perfect three-dimensional lattice structure of >3000 layers. First-principle simulations of the molecules in the gallery yielded a long-range directional structuring of the H_2O molecules that may help to stabilize the highly swollen structure. The crystals could also instantaneously shrink back to their original sizes.

*2. F. Geng, R. Ma, Y. Ebina, Y. Yamauchi, N. Miyamoto and T. Sasaki, “Gigantic swelling of inorganic layered materials: A bridge to molecularly thin two-dimensional nanosheets”, *J. Am. Chem. Soc.* **136**, 5491 (2014).

The macroscopic swelling could be realized in a wide variety of amines, ranging from primary amine, tertiary amine, to quaternary ammonium hydroxide, with little dependence on ion identity. The ammonium ion intercalation was mostly determined by the acid-base equilibrium and the accompany H_2O inflow was governed by osmotic pressure balance between the gallery and the solution environment, both of which are substantially molarity dependent. Therefore, in most cases, the ammonium ion intercalation saturated at a value of 37% relative to the exchange capacity, and the maximum swelling degree was ~100-fold with gallery expansion of ~90 nm. Although the swelling process was unselective, the nature of the intercalated ion was critical to the stability of the resulting swollen structure; that is, ions of higher polarity and smaller size helped stabilize the highly expanded structure, while ions of low polarity and larger size readily led to exfoliation.

Research result [2]

*3. M. Osada, T. Sasaki, “Two-dimensional dielectric nanosheets: Novel nanoelectronics from nanocrystal building blocks”, *Adv. Mater.* **24**, 210 (2012).

Two-dimensional (2D) nanosheets, which possess atomic or molecular thickness and infinite planar lengths, are attractive for the use in next-generation nanoelectronics. Despite significant advances in graphene-like 2D materials, it remains a challenge to explore high-□dielectric counterparts of graphene, which are essential for many devices such as memories, capacitors, and gate devices. In this paper, we review the progress made in 2D dielectric oxide nanosheets, highlighting emerging functionalities in electronic applications. Ti- and perovskite-based nanosheets exhibit the highest permittivity (ε_r = 210~320) ever realized in all known dielectrics in the ultrathin region (< 10 nm). A layer-by-layer engineering using these oxide nanosheets promises unique possibilities in the design of thin-film device architectures, such as capacitors, transistors, artificial ferroelectrics and spin-electronics. Graphene is only the tip of the iceberg, and we are now starting to discover new possibilities afforded by 2D oxides.

*4. C.X. Wang, M. Osada, Y. Ebina, B.W. Li, K. Akatsuka, K. Fukuda, W. Sugimoto, R.Z. Ma, T. Sasaki, "All-Nanosheet Ultrathin Capacitors Assembled Layer-by-Layer via Solution-Based Processes", *ACS Nano* **8**, 2658 (2014).

All-nanosheet ultrathin capacitors of $Ru_{0.95}O_2^{0.2-}/Ca_2Nb_3O_{10}^{-}/R_{0.95}O_2^{0.2-}$ were successfully assembled through facile room-temperature solution-based processes. As a bottom electrode, conductive $R_{0.95}O_2^{0.2-}$ nanosheets were first assembled on a quartz glass substrate through a sequential adsorption process with polycations. On top of the $R_{0.95}O_2^{0.2-}$ nanosheet film, $Ca_2Nb_3O_{10}^{-}$ nanosheets were deposited by the Langmuir Blodgett technique to serve as a dielectric layer. Deposition parameters were optimized for each process to construct a densely packed multilayer structure. The multilayer buildup process was monitored by various characterizations such as atomic force microscopy (AFM), ultraviolet visible absorption spectra, and X-ray nanosheet films with the designed multilayer structures. This work demonstrates the great potential of functional oxide nanosheets as components for nanoelectronics, thus contributing to the development of next-generation high-performance electronic devices.

Research result [3]

*5. T. Ohno, T. Hasegawa, T. Tsuruoka, K. Terabe, J. K. Gimzewski, M. Aono, “Short-term plasticity and long-term potentiation mimicked in single inorganic synapses”, *Nature Mater.* **10**, 591 (2011).

Memory is believed to occur in the human brain as a result of two types of synaptic plasticity: short-term plasticity (STP) and long-term potentiation. In neuromorphic engineering, emulation of known neural behavior has proven to be difficult to implement in software because of the highly complex interconnected nature of thought processes. In this study, we have succeeded in emulating the synaptic behavior using a single Ag_2S-based atomic switch. The synaptic functions of both STP and LTP characteristics through the use of input pulse repetition time were demonstrated. The results have attracted much attention because it achieves dynamic memorization in a single device without the need of external preprogramming, indicating a potential for the further creation of artificial neural systems that emulate characteristics of human memory.

*6. R. Yang , K. Terabe , G. Liu , T. Tsuruoka , T. Hasegawa, J. K. Gimzewski , M. Aono, “On-demand nanodevice with electrical and neuromorphic multifunction realized by local ion migration”, *ACS Nano* **6**, 9515 (2012).

In this paper, electrical and neuromorphic multifunctions were demonstrated using a WO_{3-x}-based gapless-type atomic switch, in which migration of oxygen ions are controlled. The device showed a wide range of time scales of memorization, resistance switching, and rectification varying from volatile to permanent in a single device. The device, showing on-demand electrical and neuromorphic multifunction, has a unique paradigm shifting potential for the fabrication of configurable circuits, analog memories, digital neural fused networks, and more in one device architecture.

Research result [4]

*7. A.V. Avizienis, H.O. Sillin, C. Martin-Olmos, H.-H. Shieh, M. Aono, J. K. Gimzewski, “Neuromorphic atomic switch networks”, *Plos One* **7**, e42772 (2012).

Conventional fabrication techniques are unable to efficiently generate electronic devices with the highly complex interconnectivity found in biological neuronal networks. In this paper, we demonstrated the physical realization of a self-assembled neuromorphic device comprised of over a billion interconnected atomic switch elements that exhibit synapse-like operational characteristics embedded in a complex network of silver nanowires. Observations of these atomic switch networks (ASN) were in agreement with recent theoretical predictions, while emergent behaviors akin to brain function are observed, namely spatially distributed memory, recurrent dynamics and the activation of feedforward subnetworks. These devices display the functional characteristics required for implementing unconventional, biologically and neurally inspired computational methodologies in a synthetic experimental system.

*8. A. Z. Stieg, A. V. Avizienis, H.O. Sillin, C. Martin-Olmos, M. Aono, J. K. Gimzewski, “Emergent criticality in complex Turing B-type atomic switch networks”, *Adv. Mater.* **24**, 286 (2012).

The operation of atomic switches as individual synapse-like devices has demonstrated the ability to process information with both short-term and long-term memorization in a single two terminal junction. In this paper, atomic switches were self-assembled within a highly interconnected network of silver nanowires similar in structure to Turing’s “B-Type unorganized machine”. These atomic switch networks (ASN) exhibited emergent criticality similar in nature to previously reported electrical activity of neuronal assemblies. Rapid fluctuations in electrical conductance display power law scaling of temporal correlation lengths that were attributed to dynamic reorganization of the interconnected electroionic network. These collective properties indicate a potential utility for real-time, multi-input processing of distributed sensory data through reservoir computing. We proposed these highly coupled, nonlinear electronic networks as an implementable hardware-based platform toward the creation of physically intelligent machines.

*9. H. O. Sillin, H.-H. Shieh, R. Aguilera, A. V. Avizienis, M. Aono, A. Z. Stieg, J. K. Gimzewski, “A theoretical and experimental study of neuromorphic atomic switch networks for reservoir computing”, *Nanotechnology* **24**, 384004 (2013).

Atomic switch networks (ASN) have been shown to generate network level dynamics that resemble those observed in biological neural networks. In this paper, we developed and validated a numerical model based on the synapse-like properties of individual atomic switches and the random nature of the network wiring. The reported results highlighted the possibility to functionalize the network plasticity, differences between an atomic switch in isolation and its behaviors in a network, as well as the effects of changing network connectivity on the observed nonlinear dynamics. To demonstrate their utility for computation, we subjected the simulated network to training within the framework of Reservoir Computing (RC) and showed initial evidence of the ASN acting as a reservoir which may be optimized for specific tasks. This work represented initial steps in a unified approach of experimentation and theory to make ASNs a uniquely scalable platform for neuromorphic computing.

Research result [5]

*10. Y. Okawa, S. K. Mandal, C. Hu, Y. Tateyama, S. Goedecker, S. Tsukamoto, T. Hasegawa, J. K. Gimzewski, M. Aono, “Chemical Wiring and Soldering toward All-Molecule Electronic Circuitry”, *J. Am. Chem. Soc.* **133**, 8227 (2011).

This paper presents a novel method for connecting functional molecules with conductive nanowires. Stimulation with a tip of scanning tunneling microscope (STM) on a molecular layer of diacetylene compound can initiate chain polymerization of diacetylene molecules. Since the front edge of chain polymerization necessarily has a reactive chemical species, the created polymer nanowire forms chemical bonding with an encountered molecular element. We name this spontaneous reaction ‘chemical soldering’. First-principles theoretical calculations are used to investigate the structures and electronic properties of the connection. It is demonstrated that two conductive polymer nanowires are connected to a single phthalocyanine molecule. A resonant tunneling diode formed by this method is discussed.

*11 Y. Okawa, M. Akai-Kasaya, Y. Kuwahara, S. K. Mandal, M. Aono, “Controlled chain polymerisation and chemical soldering for single-molecule electronics”, *Nanoscale* **4**, 3013 (2012).

The method of initiating chain polymerization using the tip of a scanning tunneling microscope is very useful for fabricating single conductive polymer chains at designated positions and thereby wiring single-molecules. In this feature article, developments in the controlled chain polymerization of diacetylene compounds and the electronic and structural properties of polydiacetylene chains are summarized. The “chemical soldering” technique, which enables the covalent connection of single polydiacetylene chains to single functional molecules, is also discussed. In addition to the review parts, this feature article also reports original data. For example, the connection of single conductive polydiacetylene chains to isolated single phthalocyanine molecules is demonstrated.

Research result [6]

*12. M. Nakaya, S. Tsukamoto, Y. Kuwahara, M. Aono, T. Nakayama, "Molecular-scale control of unbound and bound C_{60} for topochemical ultradense data storage in an ultrathin C_{60} film", *Adv. Mater.* **22**, 1622 (2010).

We found that the unbound and bound states of C_{60} molecules can be controlled reversibly at the single-molecule level in an ultrathin film of C_{60} using a tip of the scanning tunneling microscope (STM) at room temperature (RT). The reversible switching was almost perfectly controlled by changing the polarity of an electric field that was locally applied to any designated position on the film by the STM tip. From experimental and theoretical studies, we concluded that the excellent controllability is achieved owing to negative and positive ionizations of C_{60} molecules which cause electron donation into and electron removal from a bonding state between the molecules, respectively: Negative and positive ionization efficiently lower activation energies necessary for the formation of a bound state of C_{60} molecules and for the dissociation of the bound state, respectively. Also, this chemical reaction method enabled topochemical data storage with a bit size of a single C_{60} molecule (about 1 nm) and with a data density of 190 Tbit/in^2.

*13. M. Nakaya, M. Aono, T. Nakayama, "Molecular-scale size tuning of covalently bound assembly of C_{60} molecules", *ACS Nano* **5**, 7830 (2011).

Reference [6]-1 showed that, when a negative sample bias voltage is applied to a tunneling junction between the C_{60} film and the tip of a scanning tunneling microscope (STM), a C_{60} molecule beneath the tip covalently bonds to an adjacent molecule in the underneath layer. We further found that such a chemical reaction is not necessarily limited to the top and second layers of the C_{60} film and that the resulting C_{60} oligomer can be tuned to form a dimer, trimer, tetramer, or pentamer; the number of interconnected C_{60} molecules increases one by one upon increasing the magnitude of the local electric field under the STM tip. The created oligomers are linear chains of C_{60} molecules starting from the top layer and aligned toward the interface layer in the multilayer C_{60} films. The electrostatic negative ionization of C_{60} molecules and its spatial distribution in the multilayer C_{60} film are critical factors in achieving size-tuning in oligomerization.

Research result [7]

*14. Y.J. Kim, M. Ebara, T. Aoyagi, "A smart nanofiber web that captures and release cells", *Angew. Chem. Int. Ed.* **51**, 10537 (2012).

This paper describes a novel approach for encapsulating and releasing cells using a smart nanofiber web without using any cross-linking/degradation processes. The smart web was fabricated by an electrospinning method with a newly synthesized photo-cross-linkable temperature-responsive polymer. We demonstrated the ability to capture, encapsulate, and release cells by dynamically transforming the fibrous structure of the nanofibers into hydrogel-like structures by wrapping, swelling, and deswelling processes in response to alternations of external temperature. This novel nanofiber enables the facile encapsulation and on-demand release of cells in response to external signals.

*15. Y.J. Kim, M. Ebara, T. Aoyagi, "A smart hyperthermia nanofiber with switchable drug release for inducing cancer apoptosis", *Adv. Func. Mater.* **23**, 5753 (2013).

A smart hyperthermia nanofiber is described with simultaneous heat generation and drug release in response to 'on-off ' switching of alternating magnetic field (AMF) for induction of skin cancer apoptosis. The nanofiber is composed of a chemically-crosslinkable temperature-responsive polymer with an anticancer drug (doxorubicin; DOX) and magnetic nanoparticles (MNPs), which serve as a trigger of drug release and a source of heat, respectively. The 70% of human melanoma cells died in only 5 min application of AMF in the presence of the MNPs and DOX incorporated nanofibers by double effects of heat and drug. Taken together these advantages on both the nano- and macroscopic scale of nanofibers demonstrate that the dynamically and reversibly tunable structures have the potential to be utilized as a manipulative hyperthermia material as well as a switchable drug release platform by simple switching an AMF 'on' and 'off '.

Research result [8]

*16. H.H. Oh, Y.G. Ko, H. Lu, N. Kawazoe, G. Chen, “Preparation of Porous Collagen Scaffolds with Micropatterned Structures”, *Adv. Mater.* **24**, 4311 (2012).

We developed a novel method to fabricate spatially micropatterned pores and to micropattern bioactive substances in porous collagen scaffolds using a dispensing technology. Ice micropatterns of pure water or an aqueous mixture of collagen and bioactive substance solutions were used as templates to make the micropatterned structures. The micropatterned structures can be controlled by the template micropatterns that can be easily tethered by designing a code. The micropatterned porous scaffolds will be useful for guiding cell localization and guided tissue regeneration. The method is simple and reproducible and could be applied to other materials for a wide range of applications.

*17. J.J. Li, N. Kawazoe, G.P. Chen, “Gold nanoparticles with different charge and moiety induce differential cell response on mesenchymal stem cell osteogenesis”, *Biomater.* **54**, 226 (2015).

Stem cells exist in an *in vivo* microenvironment that provides biological and physiochemical cues to direct cell fate decisions. How the stem cells sense and respond to these cues is still not clearly understood. Gold nanoparticles (AuNPs) have been widely used for manipulation of cell behavior due to their ease of synthesis and versatility in surface functionalization. In this study, AuNPs with amine (AuNP–NH_2), carboxyl (AuNP–COOH) and hydroxyl (AuNP–OH) functional groups possessing different surface charge were synthesized. Human bone marrow-derived mesenchymal stem cells (hMSCs) were treated with the surface functionalized AuNPs and assessed for cell viability and osteogenic differentiation ability. The surface functionalized AuNPs were well tolerated by hMSCs and showed no acute toxicity. Positively charged AuNPs showed higher cellular uptake. These results provide some insight on the influence of surface functionalized AuNPs on hMSCs behavior and the use of these materials for strategic tissue engineering.

Research result [9]

*18. G. Yoshikawa, T. Akiyama, S. Gautsch, P. Vettiger, H. Rohrer, "Nanomechanical membrane-type surface stress sensor", *Nano Lett.* **11**, 1044 (2011).

In this paper, we presented a membrane-type surface stress sensor (MSS), which is based on the piezoresistive read-out integrated in the sensor chip. The MSS originates from a conventional cantilever structure, while we found that the membrane-based structure can achieve much better performance. Evaluation of a prototype MSS used in the present experiments demonstrates a high sensitivity which is comparable with that of optical methods and a factor of more than 20 higher than that obtained with a standard piezoresistive cantilever. The finite element analyses indicate that changing dimensions of the membrane and beams can substantially increase the sensitivity further. Given the various conveniences and advantages of the integrated piezoresistive read-out, this platform is expected to open a new era of surface stress-based sensing.

*19. G. Yoshikawa, F. Loizeau, C. J. Lee, T. Akiyama, K. Shiba, S. Gautsch, T. Nakayama, P. Vettiger, N. F. de Rooij, M. Aono, "Double-side-coated nanomechanical membrane-type surface stress sensor (MSS) for one-chip- one-channel setup", *Langmuir* **29**, 7551 (2013).

One of the major issues of nanomechanical sensors is the difficulty of coating receptor layers on their surfaces to which target molecules adsorb or react. To have measurable deflection, a single-side coating is commonly applied to cantilever-type geometry, and it requires specific methods or protocols, such as inkjet spotting or gold–thiol chemistry. In this paper, we demonstrated the feasibility of the double-side coating on a membrane-type surface stress sensor (MSS) and verify its working principle by both finite element analysis (FEA) and experiments. In addition, simple hand-operated dip coating is demonstrated as a proof of concept, achieving practical receptor layers without any complex instrumentation. The compatibility with double-side coating enables MSS to be applied to most standard assays in medical and biological fields.

Research result [10]

*20. R.Y. Yan, M. Chen, H. Zhou, T. Liu, X.W. Tang, K. Zhang, H.X. Zhu, J.H. Ye, D. Zhang, T.X. Fan, *Bio-inspired Plasmonic Nanoarchitectured Hybrid System Towards Enhanced Far Red-to-Near Infrared Solar Photocatalysis*, *Sci. Rep.* **6**, 20001 (2016).

Solar conversion to fuels or to electricity in semiconductors using far red-to-near infrared (NIR) light, which accounts for about 40% of solar energy, is highly significant. One main challenge is the development of novel strategies for activity promotion and new basic mechanisms for NIR response. Mother Nature has evolved to smartly capture far red-to-NIR light via their intelligent systems due to unique micro/nanoarchitectures, thus motivating us for biomimetic design. Here we report the first demonstration of a new strategy, based on adopting nature's far red-to-NIR responsive architectures for an efficient bio-inspired photocatalytic system. The system is constructed by controlled assembly of light-harvesting plasmonic nanoantennas onto a typical photocatalytic unit with butterfly wings' 3D micro/nanoarchitectures. This proof-of-concept study provides a new methodology for NIR photocatalysis and would potentially guide future conceptually new NIR responsive system designs.

*21. Z. Yi, J. Ye, N. Kikugawa, T. Kako, S. Ouyang, H. Stuart-Williams, H. Yang, J. Cao, W. Luo, Z. Li, Y. Liu, R. L. Withers, “An orthophosphate semiconductor with photooxidation properties under visible-light irradiation”, *Nature Mater.* **9**, 559 (2010).

The search for active semiconductor photocatalysts that directly split water under visible-light irradiation remains one of the most challenging tasks for solar-energy utilization. Over the past 30 years, the search for such materials has focused mainly on metal-ion substitution as in $In_{1-x}Ni_xTaO_4$ and (V-; Fe- or Mn-)TiO_2, non-metal-ion substitution as in $TiO_{2-x}N_x$ and $Sm_2Ti_2O_5S_2$ or solid-solution fabrication as in $(Ga_{1-x}Zn_x)(N_{1-x}O_x)$ and $ZnS–CuInS_2–AgInS_2$. Here we report a new photocatalyst Ag_3PO_4, which was developed by incorporating p block element into a simple AgO oxide with narrow band gap. The new photocatalyst showed extremely high quantum yield (~90% at 420 nm) towards water oxidation, which is one of the key process for artificial photosynthesis, under visible light irradiation. The obtained quantum yield marked the world’s highest record, approaching that in natural photosynthesis. The new photocatalyst also showed amazing activity in decomposition of organic contaminants in aqueous solution. This study not only supplies a new strategy for developing highly efficient visible-light-driven photocatalysts, but also shows a great step towards the realization of an artificial photosynthetic system.

Research result [11]

*22. T. Uchihashi, P. Mishra, M. Aono, T. Nakayama, "Macroscopic superconducting current through a silicon surface reconstruction with indium adatoms: Si(111)-($\sqrt{7}\times\sqrt{3}$)-In", *Phys. Rev. Lett.* **107**, 207001 (2011). [Highlighted as an Editor's Suggestion and a Viewpoint in Physics].

Macroscopic and robust supercurrents are observed by direct electron transport measurements on a silicon surface reconstruction with In adatoms [Si(111)-($\sqrt{7}\times\sqrt{3}$)-In]. The superconducting transition manifests itself as an emergence of the zero resistance state below 2.8 K. I-V characteristics exhibit sharp and hysteretic switching between superconducting and normal states with well-defined critical and retrapping currents. The two-dimensional (2D) critical current density $J_{2D,c}$ is estimated to be as high as 1.8 A/m at 1.8 K. The temperature dependence of $J_{2D,c}$ indicates that the surface atomic steps play the role of strongly coupled Josephson junctions.

*23. S. Yoshizawa, H. Kim, T. Kawakami, Y. Nagai, T. Nakayama, X. Hu, Y. Hasegawa, T. Uchihashi, “Imaging Josephson Vortices on the Surface Superconductor Si(111)-($\sqrt{7}$ x $\sqrt{3}$)-In using a Scanning Tunneling Microscope”, *Phys. Rev. Lett* **113**, 247004 (2014).

We have studied the superconducting Si(111)−($\sqrt{7}\times\sqrt{3}$)−In surface using a ^{3}He-based low-temperature scanning tunneling microscope. Zero-bias conductance images taken over a large surface area reveal that vortices are trapped at atomic steps after magnetic fields are applied. The crossover behavior from Pearl to Josephson vortices is clearly identified from their elongated shapes along the steps and significant recovery of superconductivity within the cores. Our numerical calculations combined with experiments clarify that these characteristic features are determined by the relative strength of the interterrace Josephson coupling at the atomic step.

*24. T. Kawakami, X. Hu, "Evolution of Density of States and a Spin-Resolved Checkerboard-Type Pattern Associated with the Majorana Bound State", *Phys. Rev. Lett* **115**, 177001 (2015).

In terms of the Bogoliubov–de Gennes approach, we investigate the Majorana bound state (MBS) in a vortex of proximity-induced superconductivity on the surface of a topological insulator. Mapping out the local density of states (LDOS) of quasiparticle excitations as a function of energy and distance from the vortex center, it is found that the spectral distribution evolves from a V shape to a Y shape with the emergence of a MBS upon variation of the chemical potential, consistent with the STM/STS measurement in a very recent experiment [Xu et al., *Phys. Rev. Lett.* 114, 017001 (2015)] on a Bi_2Te_3 thin layer on the top of $NbSe_2$. Moreover, we demonstrate that there is a checkerboard-type pattern in the relative LDOS between the spin-up and -down channels, where the quantum mechanical wave function of the MBS manifests itself clearly as a single quantum state. Therefore, a spin-resolved STM/STS technique is expected to be able to provide phase-sensitive evidence for a MBS in the vortex core of a topological superconductor.

Research result [12]

*25. M. Arita, D.R. Bowler, T. Miyazaki, "Stable and Efficient Linear Scaling First-Principles Molecular Dynamics for 10000+Atoms", *J. Chem. Theory and Comput.* **10**, 5419 (2014).

The recent progress of linear-scaling or O(N) methods in density functional theory (DFT) is remarkable. Given this, we might expect that first-principles molecular dynamics (FPMD) simulations based on DFT could treat more realistic and complex systems using the O(N) technique. However, very few examples of O(N) FPMD simulations exist to date, and information on the accuracy and reliability of the simulations is very limited. In this paper, we show that efficient and robust O(N) FPMD simulations are now possible by the combination of the extended Lagrangian Born–Oppenheimer molecular dynamics method, which was recently proposed by Niklasson (*Phys. Rev. Lett.* 2008, 100, 123004), and the density matrix method as an O(N) technique. Using our linear-scaling DFT code Conquest, we investigate the reliable calculation conditions for accurate O(N) FPMD and demonstrate that we are now able to do practical, reliable self-consistent FPMD simulations of a very large system containing 32768 atoms.

*26. N. Fukata, M. Yu, W. Jevasuwan, T. Takei, Y. Bando, W. Wu, Z.L. Wang, "Clear Experimental Demonstration of Hole Gas Accumulation in Ge/Si Core–Shell Nanowires", *ACS Nano* **9**, 12182 (2015).

Selective doping and band-offset in germanium (Ge)/silicon (Si) core–shell nanowire (NW) structures can realize a type of high electron mobility transistor structure in one-dimensional NWs by separating the carrier transport region from the impurity-doped region. Precise analysis, using Raman spectroscopy of the Ge optical phonon peak, can distinguish three effects: the phonon confinement effect, the stress effect due to the heterostructures, and the Fano effect. The Fano effect is the most important to demonstrate hole gas accumulation in Ge/Si core–shell NWs. Using these techniques, we obtained conclusive evidence of the hole gas accumulation in Ge/Si core–shell NWs. The control of hole gas concentration can be realized by changing the B-doping concentration in the Si shell.

Research result [13]

*27. C. Nethravathi, C.R. Rajamathi, M. Rajamathi, R. Maki, T. Mori, D. Golberg, Y. Bando, "Synthesis and thermoelectric behaviour of copper telluride nanosheets", *J. Mat. Chem. A* **2**, 985 (2014).

Developing reliable synthetic methods for the fabrication of nanostructures of prospective materials is vital for emerging technologies like thermoelectrics that are in need of a breakthrough. In thermoelectrics nanostructuring can potentially enhance phonon scattering while preserving electrical conductivity due to the different length scales of phonons and electrical carriers. A solvothermal reaction between a colloidal dispersion of dodecylsulfate intercalated copper hydroxide layers in ethylene glycol and an alkaline solution of

TeO_2 was found to successfully yield single crystalline 2D nanosheets of copper telluride, $Cu_{1.75}Te$. Ethylene glycol reduces TeO_2 to Te^{2-} and Cu^{2+} to Cu^+ leading to the formation of $Cu_{1.75}Te$. The solvated copper hydroxide layers act as templates to facilitate the formation of nanosheets. The nanosheets are a few nanometers in thickness and their lateral dimensions are in the order of micrometers. Thermoelectric measurements suggest that the nanosheet fabrication helps in dramatically decreasing the lattice thermal conductivity thereby increasing ZT.

*28. R. Ang, A.U. Khan, N. Tsujii, K. Takai, R. Nakamura, T. Mori, “Thermoelectricity Generation and Electron-Magnon Scattering in a Natural Chalcopyrite Mineral from a Deep-Sea Hydrothermal Vent”, *Angew. Chem. Int. Ed.* **54**, 12909 (2015).

Current high-performance thermoelectric materials require elaborate doping and synthesis procedures, particularly in regard to the artificial structure, and the underlying thermoelectric mechanisms are still poorly understood. Here, we report that a natural chalcopyrite mineral, $Cu_{1+x}Fe_{1-x}S_2$, obtained from a deep-sea hydrothermal vent can directly generate thermoelectricity. The resistivity displayed an excellent semiconducting character, and a large thermoelectric power and high power factor were found in the low x region. Notably, electron–magnon scattering and a large effective mass was detected in this region, thus suggesting that the strong coupling of doped carriers and antiferromagnetic spins resulted in the natural enhancement of thermoelectric properties during mineralization reactions. The present findings demonstrate the feasibility of thermoelectric energy generation and electron/hole carrier modulation with natural materials that are abundant in the Earth’s crust.

Research result [14]

*29. S. Aikawa, T. Nabatame, K. Tsukagoshi, “Doping control in In-X-O metal oxide semiconductors for thin-film transistor applications”, *Appl. Phys. Lett.* **103** (2013) 172105.

Amorphous metal oxide thin-film transistors (TFTs) are fabricated using InO_x-based semiconductors doped with TiO_2, WO_3, or SiO_2. Even at low-dopant densities, the electrical properties of the film strongly depend on the dopant used. We found that this dependence could be reasonably explained by differences in the bond-dissociation energy of the dopants. By incorporating a dopant with a higher bond-dissociation energy, the film became less sensitive to the partial pressure of oxygen used during sputtering and remained electrically stable upon thermal annealing. Thus, choosing a dopant with an appropriate bond-dissociation energy is important when fabricating stable metal-oxide TFTs for flat-panel displays.

*30. S. Aikawa, N. Mitoma, T. Kizu, T. Nabatame, T. Tsukagoshi, “Suppression of excess oxygen for environmentally stable amorphous In-Si-O thin-film transistors”, *Appl. Phys. Lett.* **106**, 192103 (2015).

We discuss the environmental instability of amorphous indium oxide (InOx)-based thin-film transistors (TFTs) in terms of the excess oxygen in the semiconductor films. A comparison between amorphous InOx doped with low and high concentrations of oxygen binder (SiO_2) showed that out-diffusion of oxygen molecules causes drastic changes in the film conductivity and TFT turn-on voltages. Incorporation of sufficient SiO_2 could suppress fluctuations in excess oxygen because of the high oxygen bond-dissociation energy and low Gibbs free energy. Consequently, the TFT operation became rather stable. The results would be useful for the design of reliable oxide TFTs with stable electrical properties.

Research result [15]

*31. R. Hayakawa, N. Hiroshiba, T. Chikyow, Y. Wakayama, "Single-Electron Tunneling through Molecular Quantum Dots in a Metal-Insulator-Semiconductor Structure", *Adv. Func. Mater.* **21**, 2933 (2011).

A sigle-electron tunneling (SET) in a metal-insulator-semiconductor (MIS) structure is demonstrated, in which C_{60} and copper phthalocyanine (CuPc) molecules are embedded as quantum dots in the insulator layer. The SET is found to originate from resonant tunneling via the energy levels of the embedded molecules, (e.g., the highest occupied molecular orbital (HOMO) and the lowest unoccupied molecular orbital (LUMO)). These findings show that the threshold voltages for SET are tunable according to the energy levels of the molecules.

Furthermore, SET is observable even near room temperature. The results suggest, together with the fact that these properties are demonstrated in a practical device configuration, that the integration of molecular dots into the Si-MIS structure has considerable potential for achieving novel SET devices. Moreover, the attempt allows large-scale integration of individual molecular functionalities.

Research result [16]

*32. T. Nakayama, O. Kubo, Y. Shingaya, S. Higuchi, T. Hasegawa, C.-S. Jiang, T. Okuda, Y. Kuwahara, K. Takami, M. Aono, "Development and application of multiple-probe scanning probe micro- scopes", *Adv. Mater.* **24**, 1675 (2012).

We reviewed multiple-probe scanning probe microscopes (MP-SPMs), in which two, three or four scanning tunneling microscope (STM) or atomic force microscope (AFM) probes are operated independently. Each probe in an MP-SPM is used not only for observing high-resolution STM or AFM images but also for forming an electrical contact enabling nanoscale local electrical conductivity measurement. We developed the world's first double-probe STM (DP-STM) and directly observed ballistic transport of electrons through one-dimensional metal nanowires and carbon nanotubes. Quadruple-probe STM (QP-STM) has also been developed and clarified the conductivity of two-dimensionally polymerized C_{60} films without the ambiguity of contact resistance between the probe and sample. Moreover, a quadruple-probe AFM (QP-AFM) with four tuning-fork-type self-detection force sensor has been developed to measure the conductivity of a nanostructure on an insulating substrate.

Research result [17]

*33. M.S. Wang, D. Golberg, Y. Bando, "Tensile tests on individual single-walled carbon nanotubes: Linking nanotube strength with its defects", *Adv. Mater.* **22**, 4071 (2010).

In this work, we present the first reported set of tensile strength measurements on twelve individual carbon singlewalled nanotubes (SWNTs). We applied a technique that is able to produce an individual SWNT by a consecutive stepwise in situ electrical breakdown of multiwalled C nanotube (MWNT) shells inside a high resolution transmission electron microscope (HRTEM) equipped with a conducting atomic force microscope (AFM) unit. The tensile properties of thus produced tubes were then investigated by correlating the tensile strength and types, and sites of structural defects under direct tube lattice imaging (spatial HRTEM resolution was ~1.7 Å). The SWNTs of various structures/morphologies exhibited different fracture strength ranging from 25 GPa to ~100 GPa, the latter approaching the theoretical limit. The tubes with relatively higher strength possessed visibly perfect shell structures. By contrast, significant strength reduction in low-strength samples was attributed to clearly identifiable shell structural defects, e.g. atomic steps containing spatially separated 5/7 C-ring pairs.

*34. X.L. Wei, M.S. Wang, Y. Bando, D. Golberg, "Tensile tests on individual multi-walled boron nitride nanotubes", *Adv. Mater.* **22**, 4895 (2010).

Herein we reported the first detailed measurements regarding the mechanical responses of individual multi-walled boron nitride nanotubes (BNNTs) under tensile loading or pulling-out of nested multi-walled BNNTs inside a high-resolution transmission electron microscope (HRTEM) equipped with an integrated atomic force microscope (AFM) system within the side-entry transmission electron microscope (TEM) holder. By measuring the applied forces and tube lengths until tubes broke, we obtained real stress-strain curves from which the ultimate tensile strengths and strains, and the Young's modulus of tubes were directly calculated. The tensile strength reached 33 GPa, and the Young's modulus might be up to 1.3 TPa. Also, under parallel HRTEM observations we unambiguously determined the breaking sites, broken shell number and tube diameters, and also the atomic structures of tubes. This enabled us to explore the effects of experimental conditions (such as mechanical system misalignment and the tube atomic structures) on the first time measured mechanical quantities.

Research result [18]

*35. C. Li, O. Dag, T.D. Dao, T. Nagao, Y. Sakamoto, T. Kimura, O. Terasaki, Y. Yamauchi, “Electrochemical synthesis of mesoporous gold films toward mesospace-stimulated optical properties”, *Nature Commun.* **6**, 6608 (2015).

Mesoporous gold (Au) films with tunable pores are expected to provide fascinating optical properties stimulated by the mesospaces, but they have not been realized yet because of the difficulty of controlling the Au crystal growth. Here, we report a reliable soft-templating method to fabricate mesoporous Au films using stable micelles of diblock copolymers, with electrochemical deposition advantageous for precise control of Au crystal growth. Strong field enhancement takes place around the center of the uniform mesopores as well as on the walls between the pores, leading to the enhanced light scattering as well as surface-enhanced Raman scattering (SERS), which is understandable, for example, from Babinet principles applied for the reverse system of nanoparticle ensemblest.

*36. Y.Q. Li, B.P. Bastakoti, V. Malgras, C.L. Li, J. Tang, J.H. Kim, Y. Yamauchi, “Polymeric Micelle Assembly for the Smart Synthesis of Mesoporous Platinum Nanospheres with Tunable Pore Sizes”, *Angew. Chem. Int. Ed.* **54**, 11073 (2015).

A facile method for the fabrication of well-dispersed mesoporous Pt nanospheres involves the use of a polymeric micelle assembly. A core–shell–corona type triblock copolymer [poly(styrene-*b*-2-vinylpyridine-*b*-ethylene oxide), PS-*b*-P2VP-*b*-PEO] is employed as the pore-directing agent. Negatively charged $PtCl_4^{2-}$ ions preferably interact with the protonated $P2VP^+$ blocks while the free PEO chains prevent the aggregation of the Pt nanospheres. The size of the mesopores can be finely tuned by varying the length of the PS chain. Furthermore, it is demonstrated that the metallic mesoporous nanospheres thus obtained are promising candidates for applications in electrochemistry.

Research result [19]

*37. D. Ishikawa, T. Mori, Y. Yonamine, W. Nakanishi, D.L. Cheung, J.P. Hill, K. Ariga, “Mechanochemical Tuning of the Binaphthyl Conformation at the Air-Water Interface”, *Angew. Chem. Int. Ed.* **54**, 8988 (2015).

Gradual and reversible tuning of the torsion angle of an amphiphilic chiral binaphthyl, from −90° to −80°, was achieved by application of a mechanical force to its molecular monolayer at the air–water interface. This 2D interface was an ideal location for mechanochemistry for molecular tuning and its experimental and theoretical analysis, since this lowered dimension enables high orientation of molecules and large variation in the area. A small mechanical energy ($<1\ \mathrm{kcal\,mol^{-1}}$) was applied to the monolayer, causing a large variation ($>50\,\%$) in the area of the monolayer and modification of binaphthyl conformation. Single-molecule simulations revealed that mechanical energy was converted proportionally to torsional energy. Molecular dynamics simulations of the monolayer indicated that the global average torsion angle of a monolayer was gradually shifted.

*38. K. Ariga, T. Mori, S. Ishihara, K. Kawakami, J.P. Hill, “Bridging the Difference to the Billionth-of-a-Meter Length Scale: How to Operate Nanoscopic Machines and Nanomaterials by Using Macroscopic Actions”, *Chem. Mater.* **26**, 519 (2014).

Useful materials are generally required at the macroscale in bulk quantities, while nanotechnology handles nanosized objects. Fine functions based on nanoscopic systems operated by applying macroscopic stimuli could become a key process to access nanotechnological functions in our everyday lives. To bridge the gulf in dimension between the macroscale and molecular or nanoscale, we must develop a new methodological paradigm. In this short review, both leading examples and novel challenges of nanosystem controls are described including (i) operation of single molecular machines, biochemical machines, and supramolecular machines; (ii) functional control of nanostructured materials by applying stimuli such as light and heat; (iii) mechanical control of nanomaterials and molecular machines. In the latter subject, the importance of dimensional coupling at an interfacial environment is emphasized.

Research result [20]

*39. C.V. Hoang, M. Oyama, O. Saito, M. Aono, T. Nagao, "Monitoring the Presence of Ionic Mercury in Environmental Water by Plasmon-Enhanced Infrared Spectroscopy", *Sci. Rep.* **3**, 1175 (2013).

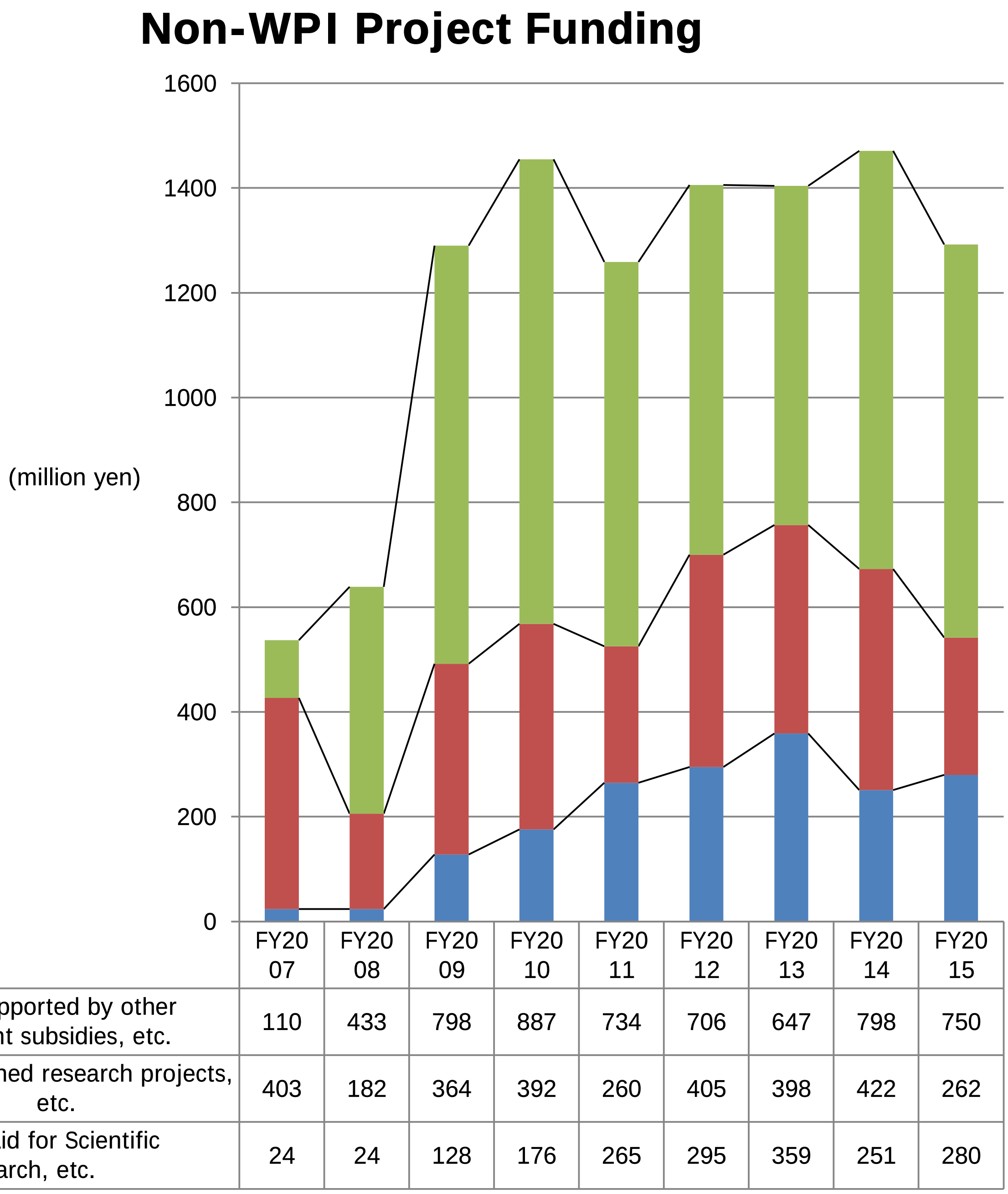
We demonstrate the ppt-level single-step selective monitoring of the presence of mercury ions (Hg^{2+}) dissolved in environmental water by plasmon-enhanced vibrational spectroscopy. We combined a nanogap-optimized mid-infrared plasmonic structure with mercury-binding DNA aptamers to monitor in-situ the spectral evolution of the vibrational signal of the DNA induced by the mercury binding. Here, we adopted single-stranded thiolated 15-base DNA oligonucleotides that are immobilized on the Au surface and show strong specificity to Hg^{2+}. The mercury-associated distinct signal is located apart from the biomolecule-associated broad signals and is selectively characterized. For example, with natural water from Lake Kasumigaura (Ibaraki Prefecture, Japan), direct detection of Hg^{2+} with a concentration as low as 37 ppt (37×10^{-10} %) was readily demonstrated, indicating the high potential of this simple method for environmental and chemical sensing of metallic species in aqueous solution.

*40. K. Chen, B.B. Rajeeva, Z.L. Wu, M. Rukavina, T.D. Dao, S. Ishii, M. Aono, T. Nagao, Y.B. Zheng, "Moire Nanosphere Lithography", *ACS Nano* **9**, 6031 (2015).

We have developed moiré nanosphere lithography (M-NSL), which incorporates in-plane rotation between neighboring monolayers, to extend the patterning capability of conventional nanosphere lithography (NSL). NSL, which uses self-assembled layers of monodisperse micro/nanospheres as masks, is a low-cost, scalable nanofabrication technique and has been widely employed to fabricate various nanoparticle arrays. Combination with dry etching and/or angled deposition has greatly enriched the family of nanoparticles NSL can yield. In this work, we introduce a variant of this technique, which uses sequential stacking of polystyrene nanosphere monolayers to form a bilayer crystal instead of conventional spontaneous self-assembly. Sequential stacking leads to the formation of moiré patterns other than the usually observed thermodynamically stable configurations. Subsequent O_2 plasma etching results in a variety of complex nanostructures. Using the etched moiré patterns as masks, we have fabricated complementary gold nanostructures and studied their optical properties. We believe this facile technique provides a strategy to fabricate complex nanostructures or metasurfaces.

World Premier International Research Center Initiative (WPI)
Appendix 2-2. Annual Transition in Non-WPI Project Funding (Grants)

*Make a graph of the annual transition in non-WPI project funding (grants). Describe external funding warranting special mention.



	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015
🟩 Projects supported by other government subsidies, etc.	110	433	798	887	734	706	647	798	750
🟥 Commissioned research projects, etc.	403	182	364	392	260	405	398	422	262
🟦 Grants-in-Aid for Scientific Research, etc.	24	24	128	176	265	295	359	251	280

[External funding warranting special mention]

<u>JST Strategic Basic Research Programs (CREST)</u>

- T. Sasaki: Next-generation electronics using inorganic nanosheets (2008) [Budget: 167,863,800 yen]
- K. Ariga: Dynamic interfacial nanotechnology (2009) [Budget: 88,465,000 yen]
- T. Hasegawa: Three-terminal nonvolatile device 'atom transistor' (2009) [Budget: 117,390,000 yen]
- T. Nagao: Control of interfacial electromagnetic field and utilization of thermal energy in the heterolayer of ceramics (2013) [Budget: 201,500,000 yen]

- T. Mori: Development of novel magnetic semiconductor thermoelectric materials and power generation devices (2015) [Budget: 150,000,000 yen]

JST Strategic Basic Research Programs (PRESTO)

- N. Fukata: Vertical three-dimensional semiconductor devices (2007) [Budget: 49,270,000 yen]
- Y. Tateyama: Reaction design for redox reactions on solid/solution interfaces (2007) [Budget: 44,265,000 yen]
- Y. Yamauchi: Next-generation magnetic record media (2008) [Budget: 106,600,000 yen]
- L. Sang: Multi-band engineering of III-Nitride for high efficiency photoelectricity energy conversion devices (2012) [Budget: 53,300,000 yen]
- N. Shirahata: Well-designed nanostructures of monolayers/semiconductors for environmentally-friendly optoelectronic applications (2013) [Budget: 52,000,000 yen]
- T. Nagata: Development of fluoride based universal high-k dielectric thin film materials (2014) [Budget: 41,730,000 yen]

MEXT/JSPS Grant-in-Aid for Scientific Research (A)

- K. Tsukagoshi: High-performance atomic film device (2009) [Budget: 47,060,000 yen]
- T. Nakayama: New functional scanning probes (2010) [Budget: 48,490,000 yen]
- A. Belik: Functional transition metal oxides (2010) [Budget: 47,970,000 yen]
- Y. Okawa: Measurement of functions of single molecular device wired by conductive macromolecular chain (2012) [Budget: 37,700,000 yen]
- T. Uchihashi: Development and control of superconductivity in super structure of semiconductor surface (2013) [Budget: 34,200,000 yen]
- N. Fukata: Control of carrier transport in core-shell heterojunction nanowires by site selective doping (2014) [Budget: 33,100,000 yen]
- T. Sasaki: Heteroassembly of 2D nanosheets to develop novel functionalities (2015) [Budget: 32,500,000 yen]

MEXT/JSPS Grant-in-Aid for Young Scientists (S)

- T. Nagao: Metallic nano-materials and infrared plasmons (2008) [Budget: 88,900,000 yen]

MEXT/JSPS Grant-in-Aid for Young Scientists (A)

- M. Ebara: Development of early detection method by on-site infection disease biomarker in low infrastructure regions (2013) [Budget: 18,500,000 yen]
- S. Moriyama: Observation of electron orbit and electromagnetic response of controlling element for a single relativistic particle (2013) [Budget: 19,600,000 yen]

Funding Program for Next-Generation World-Leading Researchers (NEXT Program)

- N. Fukata: Next-generation high efficiency solar cells using functionalized silicon nanostructures (2010) [Budget: 113,100,000 yen]

Adaptable and Seamless Technology transfer Program through target-driven R&D(A-STEP)

- T. Chikyow: Fabrication of ZnO green LED with super low electric power consumption on Si base (2011) [Budget: 20,800,000 yen]
- A. Yamamoto: Application of biodegradable metallic materials for bone fixing devices (2011) [Budget: 39,657,000 yen]
- T. Chikyow: Development of ferroelectric capacitor for next-generation power semiconductor enabling ultrahigh efficient energy conversion (2013) [Budget: 20,410,000 yen]

JST Revitalization Promotion Program

- G. Chen: Development of fabrication apparatus system for medical porous materials (2012) [Budget: 6,500,000 yen]

World Premier International Research Center Initiative (WPI)
Appendix 2-3. Major Awards, Invited Lectures, Plenary Addresses (etc.)(within 2 pages)

1. Major Awards

*List main internationally-acclaimed awards received/unofficially announced in order from the most recent.
* For each, write the recipient's name, name of award, and year issued.
In case of multiple recipients, underline those affiliated with the center.

1) Katsuhiko ARIGA, Yoshio BANDO, Dmitri GOLBERG.G, Omar YAGHI and Zhong Lin WANG, Highly Cited Researchers (by Thomson Reuters), 2015
2) Dmitri GOLBERG, Seto Award (by the Microscopy Society of Japan), 2015
3) Katsuhiko ARIGA, Yoshio BANDO, Dmitri GOLBERG.G, Omar YAGHI and Zhong Lin WANG, Highly Cited Researchers (by Thomson Reuters), 2014
4) Guping CHEN, Fellow of the Royal Society of Chemistry (by the Royal Society), 2014
5) Hitoshi KAWAKITA, The Japan Institute of Metals and Material Meritorious Award (by the Japan Institute of Metals), 2014
6) Takako KONOIKE, Young Scientist's Encouragement Award (by the Physical Society of Japan), 2014
7) Yukio NAGASAKI, Award of the Japanese Society for Biomaterials (by the Japanese Society for Biomaterials), 2014
8) Zhong Lin WANG, James C. McGroddy Prize in New Materials (by the American Physical Society), 2014
9) Masakazu AONO, Nanoscience Prize (at ACSIN-12 conference), 2013
10) Katsuhiko ARIGA, Fellow of the Royal Society of Chemistry (by the Royal Society of Chemistry), 2013
11) Alexei BELIK, Young Scientist's Prize (by the Japanese Ministry of Education, Culture, Sports, Science and Technology, MEXT), 2013
12) Takayoshi SASAKI, Science and Technology Prize (by the Japanese Ministry of Education, Culture, Sports, Science and Technology, MEXT), 2013
13) Kazuhito TSUKAGOSHI, JSPS Prize (by the Japan Society for the Promotion of Science), 2013
14) Françoise M. WINNIK, SPSJ International Award (by the Society of Polymer Science, Japan, SPSJ), 2013
15) Yusuke YAMAUCHI, PCCP Prize (by the Chemical Society of Japan), 2013
16) Yusuke YAMAUCHI, Young Scientist's Prize (by the Japanese Ministry of Education, Culture, Sports, Science and Technology, MEXT), 2013
17) Genki YOSHIKAWA, Tsukuba Encouragement Prize for Young Researchers (by the Science and Technology Promotion Foundation of Ibaraki), 2013
18) Yoshio BANDO, Dmitri GOLBERG, Thomson Reuters Research Front Award (by Thomson Reuters), 2012
19) Takayoshi SASAKI, CSJ Academic Prize (by the Chemical Society of Japan), 2012
20) Satoshi TOMINAKA, Funai Research Incentive Award (by the FUNAI Foundation for Information Technology), 2012
21) Yusuke YAMAUCHI, Tsukuba Encouragement Prize for Young Researchers (by the Science and Technology Promotion Foundation of Ibaraki), 2012
22) Tadaaki NAGAO, Fellow of the Institute of Physics (by the Institute of Physics, UK), 2011
23) Tadaaki NAGAO, Naito Taisyun Memorial Award (by the Naito Taisyun Science and Technology Foundation), 2011
24) Jun NAKANISHI, Young Scientist's Prize (by the Japanese Ministry of Education, Culture, Sports, Science and Technology, MEXT), 2011
25) Katsunori WAKABAYASHI, PSJ Young Scientist Award (by the Physical Society of Japan), 2011
26) Zhong Lin WANG, MRS Medal (from Materials Research Society), 2011
27) Mark E. WELLAND, Knighthood in the Queen's Birthday Honors list (by Queen's Birthday Honors, UK), 2011
28) Françoise M. WINNIK, CIC Macromolecular Science and Engineering Award (by the Chemical Institute of Canada), 2011
29) Masakazu AONO, Feynman Prize in Nanotechnology (by the Foresight Institute, Palo Alto, USA), 2010
30) Katsuhiko ARIGA, Nice Step Researcher (by the Japan Science and Technology Agency), 2010
31) Tetsushi TAGUCHI, Award of the Adhesion Society of Japan (by the Adhesion Society of Japan),

2010

32) Kohei UOSAKI, CSJ Award (by the Chemical Society of Japan), 2010
33) Katsunori WAKABAYASHI, Young Scientists's Award (by the Japanese Ministry of Education, Culture, Sports, Science and Technology, MEXT), 2010
34) Daisuke FUJITA, Ichimura Award (by the New Technology Development Foundation, Japan), 2009
35) James K. GIMZEWSKI, Fellow of the Royal Society, FRS (by the Royal Society, London, UK), 2009
36) James K. GIMZEWSKI, Institute of Electronic Technology, AWARD to honor 10 Millionth Record Inspection, London, UK, 2009
37) Kazuhiro HONO, Honda Frontier Award (by the Honda Memorial Foundation), 2009
38) Naoki OHASHI, Richard M. Fulrath Award (by the American Ceramics Society), 2009
39) Kohei UOSAKI, Fellow of the Electrochemical Society (by the Electrochemical Society), 2009
40) Yoshio BANDO, Fellow of the American Ceramic Society (by the American Ceramic Society), 2008
41) Kenji KITAMURA, Inoue Harushige Award (by Japan Science and Technology Agency), 2008
42) Takayoshi SASAKI, Minoru OSADA, Tsukuba Prize (by the Science and Technology Promotion Foundation of Ibaraki), 2008
43) Kohei UOSAKI, Fellow of the International Society of Electrochemistry (by the International Society of Electrochemistry), 2008

2. Invited Lectures, Plenary Addresses (etc.) at International Conferences and International Research Meetings

* List up to 20 main presentations in order from most recent.
*For each, write the lecturer/presenter's name, presentation title, conference name and date(s)

1) Takayoshi SASAKI, Preparation of molecularly thin 2D titania nanosheets and their organization into functional materials, MRS Spring Meeting & Exhibit, April 6- 10, 2015
2) Yutaka WAKAYAMA, Molecules meet Si bridging single-molecular function with practical device, Trends in Nanotechnology International Conference, Sept 8- 11, 2015
3) Dmitri GOLBERG, Recent advances in boron nitride and dichalcogenide nanotubes and nanosheets, MRS Spring Meeting and Exhibit, Aug.24- 30, 2014
4) Jonathan HILL, Porphyrins Assembled at Surfaces: Hydrogen-bonding and binary systems, 225th Electrochemical Society Meeting, May 11- 16, 2014
5) Minoru OSADA, Molecular Thin film technology based on 2D oxide nanosheets, 13th International Ceramic Congress, June 8- 12, 2014
6) Masakazu AONO, Controlling single atoms and molecules at solid surfaces and interfaces, 12th International Conference on Atomically Controlled Surfaces, Interfaces and Nanostructures, Nov 5 -8, 2013
7) Zhong Lin WANG, Nanogenerators as new energy technology and piezotronics for Functional Systems, European Congress and Exhibition on Advanced Materials and Processes, Sep 9– 12, 2013
8) Françoise M. WINNIK, Functions of self -assembled soft materials designed through materials nanoarchitectonics, 175th Anniversary Symposium of the Finnish Society of Sciences and Letters, Sep 1- 2, 2013
9) James K. GIMZEWSKI, Atomic switch networks: dynamical systems for universal computation, Discussion Workshop: New Horizons in Electrochemistry- at the Boundary to Physics and Materials Science, Aug 26- 28, 2013
10) Naoki FUKATA, Doping and characterization of impurity atoms in Si and Ge nanowires, E-MRS, May 27- 31, 2013
11) Katsuhiko ARIGA, Two-dimensional nanoarchitectonics: clay, graphene and nanofrake in assembly, 245th American Chemical Society National Meeting & Exposition, Apr 7- 11, 2013
12) Tomonobu NAKAYAMA, Multiple-probe scanning probe microscopes for nanosystems research, The 6th International Conferece on Advanced Materails and Nano, Feb 11- 15, 2013
13) Tadaaki NAGAO, Plasmons in atomic-scale/nanoscale objects and their applications, The 7th International Conference on Photonics and Applications, Nov 26- 29, 2012
14) Katsunori WAKABAYASHI, Electronic transport and magnetic properties of graphene nanoribbons, The International Union of Materials Research Societies – International Conference on Electronic Materials 2012, Sep 23- 28, 2012
15) Kohei UOSAKI, Formation and structural determination of 'confined molecular catalysts' on and within molecular layers formed on Si(111) surface with direct Si-C bond for photoelectrochemical

hydrogen generation and CO2 reduction, American Chemistry Society National Meeting &Exposition, Aug 19- 23, 2012

16) Xiao HU, Majorana fermion in topological superconductor, 11th International Conference on Condensed Matter Theory, Aug 12- 15, 2012
17) Dmitri GOLBERG, In situ TEM measurements of nanotube and nanosheet properties, Microscopy and Microanalysis 2012, Jul 29- Aug 2, 2012
18) Takao MORI, Nanostructured borides and perspectives of high temperature thermoelectric materials, Materials Research Society Spring Meeting 2012, Apr 9- 13, 2012
19) Yoshio BANDO, Novel synthesis and property of BN nanotubes and nanosheets, Pacifichem 2010, Dec 15- 20, 2010
20) Takayoshi SASAKI, Layer-by-layer assembly of transition metal oxide nanosheets into ultrathin functional films, 12th International Ceramics Congress, Jun 6- 11, 2010

World Premier International Research Center Initiative (WPI)

Appendix 2-4. List of Achievements of Center's Outreach Activities

* Using the table below, show the achievements of the Center's outreach activities from FY2007 through FY2015 (number of activities, times held).

Activities	FY2007 (number of activities, times held)	FY2008 (number of activities, times held)	FY2009 (number of activities, times held)
PR brochure, pamphlet	0	1	3
Lectures, seminars for general public	0	0	0
Teaching, experiments, training for elementary and secondary school students	0	0	0
Science cafe	0	0	0
Open houses	0	1	1
Participating, exhibiting in events	0	0	0
Press releases	5	4	4

Activities	FY2010 (number of activities, times held)	FY2011 (number of activities, times held)	FY2012 (number of activities, times held)
PR brochure, pamphlet	3	4	5
Lectures, seminars for general public	0	7	7
Teaching, experiments, training for elementary and secondary school students	2	12	12
Science cafe	1	0	1
Open houses	1	2	2
Participating, exhibiting in events	2	3	2
Press releases	27	11	21

Activities	FY2013 (number of activities, times held)	FY2014 (number of activities, times held)	FY2015 (number of activities, times held)
PR brochure, pamphlet	5	5	3
Lectures, seminars for general public	5	7	1
Teaching, experiments, training for elementary and secondary school students	15	30	33
Science cafe	0	0	0
Open houses	2	2	2
Participating, exhibiting in events	3	5	5
Press releases	18	13	21

List of Media Coverage of Projects carried out between FY 2007 – 2015

(within 2 pages)

* Select main items of press releases, media coverage, and reports for FY 2007-2015 (especially by overseas media)

1) Japan

No.	Date	Type media (e.g., newspaper, magazine, television)	Description
1	Jul 11, 2008 Jul 15, 2008 Jul 17, 2008 Jul 22, 2008 Jul 25, 2008 Nov 22, 2008	The Chemical Daily; Joyo Shimbun, The Chemical Times; Nikkei; Nikkan Kogyo Shimbun; Science News; Asahi Shimbun	Dr. Jinhua Ye succeeded in development of novel photocatalyst with high activity in visible light.
2	Jul 16, 2008	Ibaraki Shimbun, Joyo Shimbun, Mainichi Shimbun, Nikkan Kogyo Shimbun, Nihon Keizai Shimbun (Nikkei), Nikkei Sangyo Shimbun, Sankei Shimbun	Dr. Takayoshi Sasaki and Dr. Minoru Osada won the 2008 Tsukuba Prize for “Synthesis of inorganic nanosheets and their organization into functional materials.”
3	Dec, 2008	NHK TV	MANA was introduced as a WPI center in “Good Morning Japan.”
4	Sep 29, 2009	Nikkei	Dr. Yoshio Bando was interviewed on internationalization at MANA and ICYS.
5	Jan, 2010 Feb, 2010	NHK BS-1 TV; NHK BS-hi TV	In the TV program “The proposal for the future –Nanotech revolution changes the world,” Prof. James K. Gimzewski was interviewed on the future of nanotech and his collaborative work in science and art.
6	Jan, 2011	NHK TV	Dr. Jinhua Ye and Dr. Yusuke Yamauchi were featured in the NHK Special program “Can Japan Survive?”
7	Jun 27, 2011 Jul 8, 2011	Ibaraki Shimbun, Mainichi Shimbun, Nikkan Kogyou Shimbun, Nikkei, Nikkei Sangyo Shimbun; Science News	In joint research with UCLA, US, Dr. Tsuyoshi Hasegawa developed a new "synapse device" that autonomously reproduces two distinctive features of the neural activity of the brain, "memory of necessary information" and "forgetting of unnecessary information," in a single device.
8	Dec 20, 2011 Dec 26, 2011 Jan 16, 2012 Jan 27, 2012	Chemical Daily, Nikkan Kogyo Shimbun; Nikkei, Nikkei Sangyo Shimbun; Asahi Shimbun; Science News	Dr. Yusuke Yamauchi succeeded in the formation of a very large number of mesoporous material in a Prussian blue crystal structure.
9	Jan 1, 2012	NHK BS Premium	Research at MANA was featured in the first broadcast, "Atom changes life," in the television series "Nano Revolution."
10	Dec 21, 2012 Dec 22, 2012	Asahi Shimbun; Yomiuri Shimbun	Dr. Katsuhiko Ariga succeeded in precise sub-millimeter visualization of the position of cesium.
11	Feb 11, 2013 Mar 5, 2013 Mar 22, 2013 Jun 7, 2013	Asahi Shimbun; Nikkan Kogyo Shimbun; Science News; Newton	Dr. Katsuhiko Ariga succeeded in development of a gel material that releases drugs in response to human applied force.

12	Jun 15, 2013 Jun 17, 2013 Jun 19, 2013 Jun 27, 2013 Jun 28, 2013 Jul 16, 2013	Mainichi Shimbun, Nikkei, Tokyo Shimbun, Yomiuri Shimbun; Chemical Daily, Nikkan Kogyo Shimbun, Nikkei Sangyo Shimbun; TV Asahi; Asahi Shimbun; Science News; NHK General TV	Dr. Mitsuhiro Ebara developed a nanofiber mesh that makes it possible to realize thermotherapy and chemotherapy of cancer simultaneously.
13	Feb 20, 2014 Feb 22, 2014	Chemical Daily, Ibaraki Shimbun, Nikkan Kogyo Shimbun, Nikkei, Sankei Shimbun; Yomiuri Shimbun	Dr. Mitsuhiro Ebara developed a portable blood purification system using a wristwatch-type cartridge as an alternative to dialysis.
14	Apr 8, 2014 Apr 18, 2014 Apr 21, 2014	Nikkan Sangyo Shimbun; Nikkei; Sankei Shimbun	The “Smart Polymer Rangers” appeared at the NIMS Open House and presented an easy-to-understand explanation of smart polymer biomaterials to general citizens.
15	May 12, 2014 May 13, 2014 May 20, 2014 May 30, 2014	Nikkan Kogyo Shimbun, Nikkei Sangyo Shimbun; The Chemical Daily; Nikkan Sangyo Shimbun; The Science News	Dr. Takeo Minari developed a technology for forming organic thin-film transistors by printing at room temperature without heating.
16	Jun 17, 2014 Jun 18, 2014 Jun 20, 2014 Jul 11, 2014	The Chemical Daily, Ibaraki Shimbun, NHK TV, Nikkei, Yomiuri Shimbun; Mainichi Shimbun, Nikkan Kogyo Shimbun, Tokyo Shimbun; Joyo Shimbun, Sankei Shimbun; Science News	Dr. Hirokazu Komatsu and Dr. Katsuhiko Ariga, for the first time in the world, successfully visualized the cesium distribution in cells of plants that absorbed cesium.
17	Mar 24, 2015 Apr 1, 2015 Apr 9, 2015 Apr 13, 2015	Nikkan Kogyo Shimbun; Japan Metal Daily, Nikkan Sangyo Shimbun; Nikkan Kogyo Shimbun	Dr. Yusuke Yamauchi, in cooperation with other research organizations in Japan and overseas, successfully developed a nanoporous gold material with a regular, uniform pore arrangement using polymers as a template.
18	Sep 30, 2015 Oct 1, 2015 Oct 7, 2015 Oct 29, 2015 Jan 1, 2016 Jan 9, 2016 Jan 15, 2016	The Chemical Daily, Nikkan Kogyo Shimbun; The Chemical Daily; Nikkei Sangyo Shimbun; Mainichi Shimbun; The Chemical Daily; Yomiuri Shimbun; Yomiuri Shimbun	Six organizations including NIMS, Kyocera, Osaka University, NEC, Sumitomo Seika and NanoWorld jointly launched the MSS Alliance, with the purpose of establishing a de facto standard for odor analysis and sensor systems employing an ultra-small sensor element called the Membrane-type Surface stress Sensor (MSS).
19	Mar 13, 2016	TBS TV	Dr. Mitsuhiro Ebara was featured on TV, TBS’s "A Door Opened to Dreams (Yume no Tobira)", introducing his research activities on “Smart Polymer” and more.

2) Overseas

No.	Date	Type media (e.g., newspaper, magazine, television)	Description
1	Sep. 28, 2012	Science Vol. 337	Introduction of examples of operation of overseas laboratories bringing together outstanding researchers from countries around the world in the column “Satellite Labs Extend Science.” (Omar Yaghi)
2	Mar. 16, 2013	Canadian Broadcasting Corporation	Broadcast of the NHK international joint production program, "Nano Revolution." (James Gimzewski)

World Premier International Research Center Initiative (WPI)
Appendix 3. List of Papers of Representative of Interdisciplinary Research Activities

* List **up to 20 papers** that underscoring each interdisciplinary research activity and give brief accounts (within 10 lines).
* For each, write the author name(s); year of publication; journal name, volume, page(s), and article title. Any listing order may be used as long as format is the same. If a paper has many authors, underline those affiliated with the Center.
* If a paper has many authors (say, more than 10), all of their names do not need to be listed.

1. F. Geng, R. Ma, A. Nakamura, K. Akatsuka, Y. Ebina, Y. Yamauchi, N. Miyamoto, Y. Tateyama, and T. Sasaki, "Unusually stable ~100-fold reversible and instantaneous swelling of inorganic layered materials", *Nature Commun.* **4**, 1632 (2013).

A massive monolithic swelling of layered materials has been achieved in aqueous solution of 2-dimethylaminoethanol (DMAE), which was up to 100-fold with the gallery spacing increased from 0.9 nm to 90 nm. With quantitative analysis, it was determined that the largely expanded space was primarily occupied with H_2O along with minor trace of the DMAE. The swollen phase was unusually stable with no obvious observation of peeling or translational shifts during the swelling process, maintaining a nearly perfect three-dimensional lattice structure of >3000 layers. First-principle simulations of the molecules in the gallery yielded a long-range directional structuring of the H_2O molecules that may help to stabilize the highly swollen structure. The crystals could also instantaneously shrink back to their original sizes.

2. J.J. Li, N. Kawazoe, G.P. Chen, "Gold nanoparticles with different charge and moiety induce differential cell response on mesenchymal stem cell osteogenesis", *Biomater.* **54**, 226 (2015).

Stem cells exist in an *in vivo* microenvironment that provides biological and physiochemical cues to direct cell fate decisions. How the stem cells sense and respond to these cues is still not clearly understood. Gold nanoparticles (AuNPs) have been widely used for manipulation of cell behavior due to their ease of synthesis and versatility in surface functionalization. In this study, AuNPs with amine (AuNP–NH_2), carboxyl (AuNP–COOH) and hydroxyl (AuNP–OH) functional groups possessing different surface charge were synthesized. Human bone marrow-derived mesenchymal stem cells (hMSCs) were treated with the surface functionalized AuNPs and assessed for cell viability and osteogenic differentiation ability. The surface functionalized AuNPs were well tolerated by hMSCs and showed no acute toxicity. Positively charged AuNPs showed higher cellular uptake. These results provide some insight on the influence of surface functionalized AuNPs on hMSCs behavior and the use of these materials for strategic tissue engineering.

3. R.Y. Yan, M. Chen, H. Zhou, T. Liu, X.W. Tang, K. Zhang, H.X. Zhu, J.H. Ye, D. Zhang, T.X. Fan, *Bio-inspired Plasmonic Nanoarchitectured Hybrid System Towards Enhanced Far Red-to-Near Infrared Solar Photocatalysis*, *Sci. Rep.* **6**, 20001 (2016).

Solar conversion to fuels or to electricity in semiconductors using far red-to-near infrared (NIR) light, which accounts for about 40% of solar energy, is highly significant. One main challenge is the development of novel strategies for activity promotion and new basic mechanisms for NIR response. Mother Nature has evolved to smartly capture far red-to-NIR light via their intelligent systems due to unique micro/nanoarchitectures, thus motivating us for biomimetic design. Here we report the first demonstration of a new strategy, based on adopting nature's far red-to-NIR responsive architectures for an efficient bio-inspired photocatalytic system. The system is constructed by controlled assembly of light-harvesting plasmonic nanoantennas onto a typical photocatalytic unit with butterfly wings' 3D micro/nanoarchitectures. This proof-of-concept study provides a new methodology for NIR photocatalysis and would potentially guide future conceptually new NIR responsive system designs.

4. M. Osada, G. Takanashi, B. W. Li, K. Akatsuka, Y. Ebina, K. Ono, H. Funakubo, K. Takada, T. Sasaki, "Controlled polarizability of one-nanometer-thick oxide nanosheets for tailored, high-κ nano-dielectrics", *Adv. Funct. Mater.* **22**, 3482 (2011).

The ever-increasing requirements on smaller, higher-performance electronic devices result in efforts to incorporate new materials into microelectronics, in order to overcome the physical limits of current materials. In this context, the latest Semiconductor Roadmap predicts the implementation of high-κ ultrathin films (< 10 nm) in future applications. In this paper, we reported a rational approach to produce high performance nanodielectrics using 1-nm-thick oxide nanosheets. In titano-niobate nanosheets ($TiNbO_5$, Ti_2NbO_7, Ti_5NbO_{14}), the octahedral distortion inherent to site engineering by Nb incorporation resulted in a giant molecular polarizability, and their multilayer nanofilms exhibited high dielectric constant (160–320), the largest value being seen so far in high-*κ* nanofilms with the thickness down to 10 nm. Furthermore, these nanosheets offered simultaneous improvements in temperature dependence, lower loss and leakage current. Our work provides a new recipe for designing nanodielectrics desirable for practical high-*κ* devices.

5. M. Osada, T. Sasaki, “Two-dimensional dielectric nanosheets: Novel nanoelectronics from nano-crystal building blocks”, *Adv. Mater.* **24**, 210 (2012).

Two-dimensional (2D) nanosheets, which possess atomic or molecular thickness and infinite planar lengths, are attractive for the use in next-generation nanoelectronics. Despite significant advances in graphene-like 2D materials, it remains a challenge to explore high-κ dielectric counterparts of graphene, which are essential for many devices such as memories, capacitors, and gate devices. In this paper, we review the progress made in 2D dielectric oxide nanosheets, highlighting emerging functionalities in electronic applications. Ti- and perovskite-based nanosheets exhibit the highest permittivity ($\boldsymbol{\varepsilon_r}$ = 210~320) ever realized in all known dielectrics in the ultrathin region (< 10 nm). A layer-by-layer engineering using these oxide nanosheets promises unique possibilities in the design of thin-film device architectures, such as capacitors, transistors, artificial ferroelectrics and spin-electronics. Graphene is only the tip of the iceberg, and we are now starting to discover new possibilities afforded by 2D oxides.

6. T. Ohno, T. Hasegawa, T. Tsuruoka, K. Terabe, J. K. Gimzewski, M. Aono, “Short-term plasticity and long-term potentiation mimicked in single inorganic synapses”, *Nature Mater.* **10**, 591 (2011).

Memory is believed to occur in the human brain as a result of two types of synaptic plasticity: short-term plasticity (STP) and long-term potentiation. In neuromorphic engineering, emulation of known neural behavior has proven to be difficult to implement in software because of the highly complex interconnected nature of thought processes. In this study, we have succeeded in emulating the synaptic behavior using a single Ag_2S-based atomic switch. The synaptic functions of both STP and LTP characteristics through the use of input pulse repetition time were demonstrated. The results have attracted much attention because it achieves dynamic memorization in a single device without the need of external preprogramming, indicating a potential for the further creation of artificial neural systems that emulate characteristics of human memory.

7. R. Yang , K. Terabe , G. Liu , T. Tsuruoka , T. Hasegawa, J. K. Gimzewski , M. Aono, “On-deman nanodevice with electrical and neuromorphic multifunction realized by local ion migration”, *ACS Nano* **6**, 9515 (2012).

In this paper, electrical and neuromorphic multifunctions were demonstrated using a WO_{3-x}-based gapless-type atomic switch, in which migration of oxygen ions are controlled. The device showed a wide range of time scales of memorization, resistance switching, and rectification varying from volatile to permanent in a single device. The device, showing on-demand electrical and neuromorphic multifunction, has a unique paradigm shifting potential for the fabrication of configurable circuits, analog memories, digital neural fused networks, and more in one device architecture.

8. S. Yoshizawa, H. Kim, T. Kawakami, Y. Nagai, T. Nakayama, X. Hu, Y. Hasegawa, T. Uchihashi, “Imaging Josephson Vortices on the Surface Superconductor Si(111)-(√7 x √3)-In using a Scanning Tunneling Microscope”, *Phys. Rev. Lett* **113**, 247004 (2014).

We have studied the superconducting Si(111)−($\sqrt{7}\times\sqrt{3}$)−In surface using a ^{3}He-based low-temperature scanning tunneling microscope. Zero-bias conductance images taken over a large surface area reveal that vortices are trapped at atomic steps after magnetic fields are applied. The crossover behavior from Pearl to Josephson vortices is clearly identified from their elongated shapes along the steps and significant recovery of superconductivity within the cores. Our numerical calculations combined with experiments clarify that these characteristic features are determined by the relative strength of the interterrace Josephson coupling at the atomic step.

9. A.Z. Stieg, A. V. Avizienis, H.O. Sillin, C. Martin-Olmos, M. Aono, J. K. Gimzewski, “Emergent criticality in complex Turing B-type atomic switch networks”, *Adv. Mater.* **24**, 286 (2012).

The operation of atomic switches as individual synapse-like devices has demonstrated the ability to process information with both short-term and long-term memorization in a single two terminal junction. In this paper, atomic switches were self-assembled within a highly interconnected network of silver nanowires similar in structure to Turing’s “B-Type unorganized machine”. These atomic switch networks (ASN) exhibited emergent criticality similar in nature to previously reported electrical activity of neuronal assemblies. Rapid fluctuations in electrical conductance display power law scaling of temporal correlation lengths that were attributed to dynamic reorganization of the interconnected electroionic network. These collective properties indicate a potential utility for real-time, multi-input processing of distributed sensory data through reservoir computing. We proposed these highly coupled, nonlinear electronic networks as an implementable hardware-based platform toward the creation of physically intelligent machines.

10. T. Kawakami, X. Hu, “Evolution of Density of States and a Spin-Resolved Checkerboard-Type Pattern Associated with the Majorana Bound State”, *Phys. Rev. Lett* **115**, 177001 (2015).

In terms of the Bogoliubov–de Gennes approach, we investigate the Majorana bound state (MBS) in a vortex of proximity-induced superconductivity on the surface of a topological insulator. Mapping out the local density of states (LDOS) of quasiparticle excitations as a function of energy and distance from the vortex center, it is found that the spectral distribution evolves from a V shape to a Y shape with the emergence of a MBS upon variation of the chemical potential, consistent with the STM/STS measurement in a very recent experiment [Xu et al., *Phys. Rev. Lett.* 114, 017001 (2015)] on a Bi_2Te_3 thin layer on the top of $NbSe_2$. Moreover, we demonstrate that there is a checkerboard-type pattern in the relative LDOS between the spin-up and -down channels, where the quantum mechanical wave function of the MBS manifests itself clearly as a single quantum state. Therefore, a spin-resolved STM/STS technique is expected to be able to provide phase-sensitive evidence for a MBS in the vortex core of a topological superconductor.

11. Y.J. Kim, M. Ebara, T. Aoyagi, “A smart hyperthermia nanofiber with switchable drug release for inducing cancer apoptosis”, *Adv. Func. Mater.* **23**, 5753 (2013).

A smart hyperthermia nanofiber is described with simultaneous heat generation and drug release in response to ‘on-off ’ switching of alternating magnetic field (AMF) for induction of skin cancer apoptosis. The nanofiber is composed of a chemically-crosslinkable temperature-responsive polymer with an anticancer drug (doxorubicin; DOX) and magnetic nanoparticles (MNPs), which serve as a trigger of drug release and a source of heat, respectively. The 70% of human melanoma cells died in only 5 min application of AMF in the presence of the MNPs and DOX incorporated nanofibers by double effects of heat and drug. Taken together these advantages on both the nano- and macroscopic scale of nanofibers demonstrate that the dynamically and reversibly tunable structures have the potential to be utilized as a manipulative hyperthermia material as well as a switchable drug release platform by simple switching an AMF ‘on’ and ‘off ’.

12. M. Arita, D.R. Bowler, T. Miyazaki, “Stable and Efficient Linear Scaling First-Principles Molecular Dynamics for 10000+Atoms”, *J. Chem. Theory and Comput.* **10**, 5419 (2014).

The recent progress of linear-scaling or O(*N*) methods in density functional theory (DFT) is remarkable. Given this, we might expect that first-principles molecular dynamics (FPMD) simulations based on DFT could treat more realistic and complex systems using the O(*N*) technique. However, very few examples of O(*N*) FPMD simulations exist to date, and information on the accuracy and reliability of the simulations is very limited. In this paper, we show that efficient and robust O(*N*) FPMD simulations are now possible by the combination of the extended Lagrangian Born–Oppenheimer molecular dynamics method, which was recently proposed by Niklasson (*Phys. Rev. Lett.* 2008, 100, 123004), and the density matrix method as an O(*N*) technique. Using our linear-scaling DFT code Conquest, we investigate the reliable calculation conditions for accurate O(*N*) FPMD and demonstrate that we are now able to do practical, reliable self-consistent FPMD simulations of a very large system containing 32768 atoms.

13. G. Yoshikawa, T. Akiyama, S. Gautsch, P. Vettiger, H. Rohrer, "Nanomechanical membrane-type surface stress sensor", *Nano Letters* **11**, 1044 (2011).

In this paper, we presented a membrane-type surface stress sensor (MSS), which is based on the piezoresistive read-out integrated in the sensor chip. The MSS originates from a conventional cantilever structure, while we found that the membrane-based structure can achieve much better performance. Evaluation of a prototype MSS used in the present experiments demonstrates a high sensitivity which is comparable with that of optical methods and a factor of more than 20 higher than that obtained with a standard piezoresistive cantilever. The finite element analyses indicate that changing dimensions of the membrane and beams can substantially increase the sensitivity further. Given the various conveniences and advantages of the integrated piezoresistive read-out, this platform is expected to open a new era of surface stress-based sensing..

14. G. Yoshikawa, F. Loizeau, C. J. Lee, T. Akiyama, K. Shiba, S. Gautsch, T. Nakayama, P. Vettiger, N. F. de Rooij, M. Aono, "Double-side-coated nanomechanical membrane-type surface stress sensor (MSS) for one-chip- one-channel setup", *Langmuir* **29**, 7551 (2013).

One of the major issues of nanomechanical sensors is the difficulty of coating receptor layers on their surfaces to which target molecules adsorb or react. To have measurable deflection, a single-side coating is commonly applied to cantilever-type geometry, and it requires specific methods or protocols, such as inkjet spotting or gold−thiol chemistry. In this paper, we demonstrated the feasibility of the double-side coating on a membrane-type surface stress sensor (MSS) and verify its working principle by both finite element analysis (FEA) and experiments. In addition, simple hand-operated dip coating is demonstrated as a proof of concept, achieving practical receptor layers without any complex instrumentation. The compatibility with double-side coating enables MSS to be applied to most standard assays in medical and biological fields.

15. H. Zhou, J. Guo, P. Li, Tongxiang Fan, Di Zhang, J. Ye, ”Leaf-architectured 3D hierarchical artificial photosynthetic system of perovskite titanates towards CO_2 photoreduction into hydrocarbon fuels”, *Sci. Rep.* **3**, 1667 (2013).

As a nano-life science-inspired nanoarchitectonics, here we report an unique strategy for constructing a promising 3D artificial photosynthetic system (APS) for efficient CO_2 photoreduction into hydrocarbon fuels. Natural leaf is a synergy of complex architectures and functional components to produce an amazing bio-machinery for photosynthesis. Mimicking the structural and functional elements in the natural photosynthesis should be promising to achieve an efficient artificial photosynthetic system. In this work, by using leaves of cherry tree as the template, we have successfully fabricated perovskite titanates (e.g., $SrTiO_3$, $CaTiO_3$) with a modified sol-gel method. After acid treatment and calcination at 600°C, organics could be removed completely, leaving crystalline perovskite titanates. The obtained material preserves the morphological features of leaf at multi-scaled levels. It was found that leaf-architectured $SrTiO_3$ exhibits about a 3.5~4 fold improvement in activities than the referenced $SrTiO_3$ synthesized without templates. A further mechanism study revealed that the enhanced conversion efficiency of CO_2 into hydrocarbon fuels can be attributed to the synergistic effect of efficient mass flow/light harvesting network relying on the morphological replacement of a concept prototype-leaf's 3D architecture..

16. Z. Yi, J. Ye, N. Kikugawa, T. Kako, S. Ouyang, H. Stuart-Williams, H. Yang, J. Cao, W. Luo, Z. Li, Y. Liu, R. L. Withers, "An orthophosphate semiconductor with photooxidation properties under visible-light irradiation", *Nature Mater.* **9**, 559 (2010).

The search for active semiconductor photocatalysts that directly split water under visible-light irradiation remains one of the most challenging tasks for solar-energy utilization. Over the past 30 years, the search for such materials has focused mainly on metal-ion substitution as in $In_{1-x}Ni_xTaO_4$ and (V-, Fe- or Mn-)TiO_2, non-metal-ion substitution as in $TiO_{2-x}N_x$ and $Sm_2Ti_2O_5S_2$ or solid-solution fabrication as in $(Ga_{1-x}Zn_x)(N_{1-x}O_x)$ and $ZnS–CuInS_2–AgInS_2$. Here we report a new photocatalyst Ag_3PO_4, which was developed by incorporating p block element into a simple AgO oxide with narrow band gap. The new photocatalyst showed extremely high quantum yield (~90% at 420 nm) towards water oxidation, which is one of the key process for artificial photosynthesis, under visible light irradiation. The obtained quantum yield marked the world's highest record, approaching that in natural photosynthesis. The new photocatalyst also showed amazing activity in decomposition of organic contaminants in aqueous solution. This study not only supplies a new strategy for developing highly efficient visible-light-driven photocatalysts, but also shows a great step towards the realization of an artificial photosynthetic system.

17. N. Fukata, M. Yu, W. Jevasuwan, T. Takei, Y. Bando, W. Wu, Z.L. Wang, "Clear Experimental Demonstration of Hole Gas Accumulation in Ge/Si Core–Shell Nanowires", *ACS Nano* **9**, 12182 (2015).

Selective doping and band-offset in germanium (Ge)/silicon (Si) core–shell nanowire (NW) structures can realize a type of high electron mobility transistor structure in one-dimensional NWs by separating the carrier transport region from the impurity-doped region. Precise analysis, using Raman spectroscopy of the Ge optical phonon peak, can distinguish three effects: the phonon confinement effect, the stress effect due to the heterostructures, and the Fano effect. The Fano effect is the most important to demonstrate hole gas accumulation in Ge/Si core–shell NWs. Using these techniques, we obtained conclusive evidence of the hole gas accumulation in Ge/Si core–shell NWs. The control of hole gas concentration can be realized by changing the B-doping concentration in the Si shell.

18. T. Uchihashi, P. Mishra, M. Aono, T. Nakayama, "Macroscopic superconducting current through a silicon surface reconstruction with indium adatoms: Si(111)-($\sqrt{7}\times\sqrt{3}$)-In", *Phys. Rev. Lett.* **107**, 207001 (2011). [Highlighted as an Editor's Suggestion and a Viewpoint in Physics].

Macroscopic and robust supercurrents are observed by direct electron transport measurements on a silicon surface reconstruction with In adatoms [Si(111)-($\sqrt{7}\times\sqrt{3}$)-In]. The superconducting transition manifests itself as an emergence of the zero resistance state below 2.8 K. I-V characteristics exhibit sharp and hysteretic switching between superconducting and normal states with well-defined critical and retrapping currents. The two-dimensional (2D) critical current density $J_{2\mathrm{D},c}$ is estimated to be as high as 1.8 A/m at 1.8 K. The temperature dependence of $J_{2\mathrm{D},c}$ indicates that the surface atomic steps play the role of strongly coupled Josephson junctions.

19. Q. Liang, L. Wu, X. Hu, "Electrically tunable topological state in [111] perovskite materials with an antiferromagnetic exchange field", *New J. Phys.* **15**, 063031 (2013).

We propose a scheme of band engineering by means of staggered electric potential, anti-ferromagnetic exchange field and spin–orbital coupling for electrons on a honeycomb lattice. With fine control on the degrees of freedom of spin, sublattice and valley, one can achieve a topological state with simultaneous non-zero charge and spin Chern numbers. In terms of first principles calculations, we demonstrate that the scheme can be realized by material modification to perovskite G-type antiferromagnetic insulators, such as LaCrO3 grown along the [111] direction, where Dirac electrons are contributed from Au+3 ions which replace Cr ions on an atomic sheet of buckled honeycomb lattice.

In a finite sample, this state provides a spin-polarized zero-resistance edge current optimally up to room temperature, robust to both non-magnetic and magnetic defects. The spin polarization is reversible by electric field while the whole system does not show net magnetization, which is extremely ideal for spintronics.

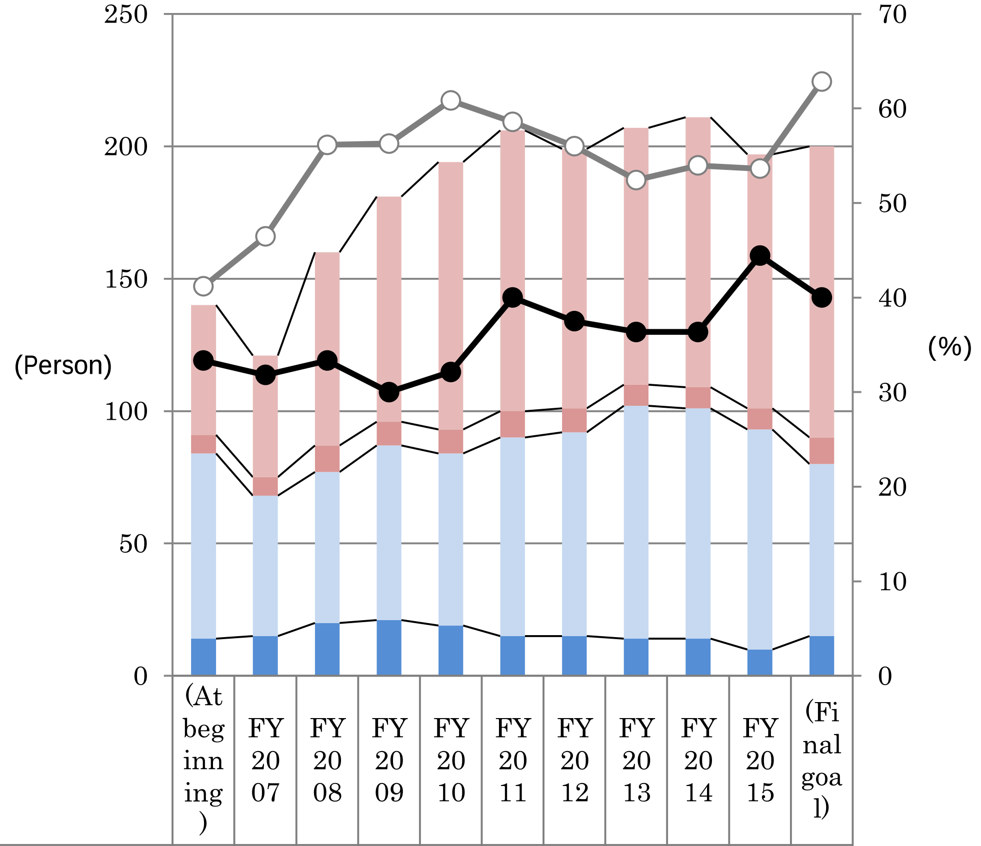
20. T. Tsuchiya, K. Terabe, M. Aono, “All-solid-state electric-double-layer transistor based on oxide ion migration in Gd-doped CeO_2 on $SrTiO_3$ single crystal”, *Appl. Phys. Lett.* **103**, 073110 (2013).

An all-solid-state electric-double-layer transistor (EDLT) with a Gd-doped CeO_2 (GDC) oxide ionconductor/$SrTiO_3$ (STO) insulator structure has been developed. At 473 K, the drain current of the EDLT was well controlled, from less than nA order to μA order, by electrostatic carrier doping at the GDC/STO interface due to oxide ion (O^{2-}) migration in the GDC, in contrast to an inactiveness at room temperature. The EDL capacitance at the interface, measured with an AC impedance spectroscopy, was 14 $\mu F\ cm^{-2}$, higher than that reported for a microporous-SiO_2 EDLT and comparable to that of an ionic-liquid-gated EDLT.

World Premier International Research Center Initiative (WPI)
Appendix 4-1. Number of Overseas Researchers and Annual Transition

*Make a graph of the transition in the number of overseas researchers since the application.

Number of Overseas Researchers



	(At beginning)	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	(Final goal)
■ Researchers from abroad	49	46	73	85	101	106	98	97	102	96	110
■ PIs from abroad	7	7	10	9	9	10	9	8	8	8	10
■ Japanese researchers excluding PIs	70	53	57	66	65	75	77	88	87	83	65
■ Japanese PIs	14	15	20	21	19	15	15	14	14	10	15
● Ratio of PIs from abroad	33.3	31.8	33.3	30.0	32.1	40.0	37.5	36.4	36.4	44.4	40.0
○ Ratio of researchers from abroad	41.2	46.5	56.2	56.3	60.8	58.6	56.0	52.4	54.0	53.6	62.9

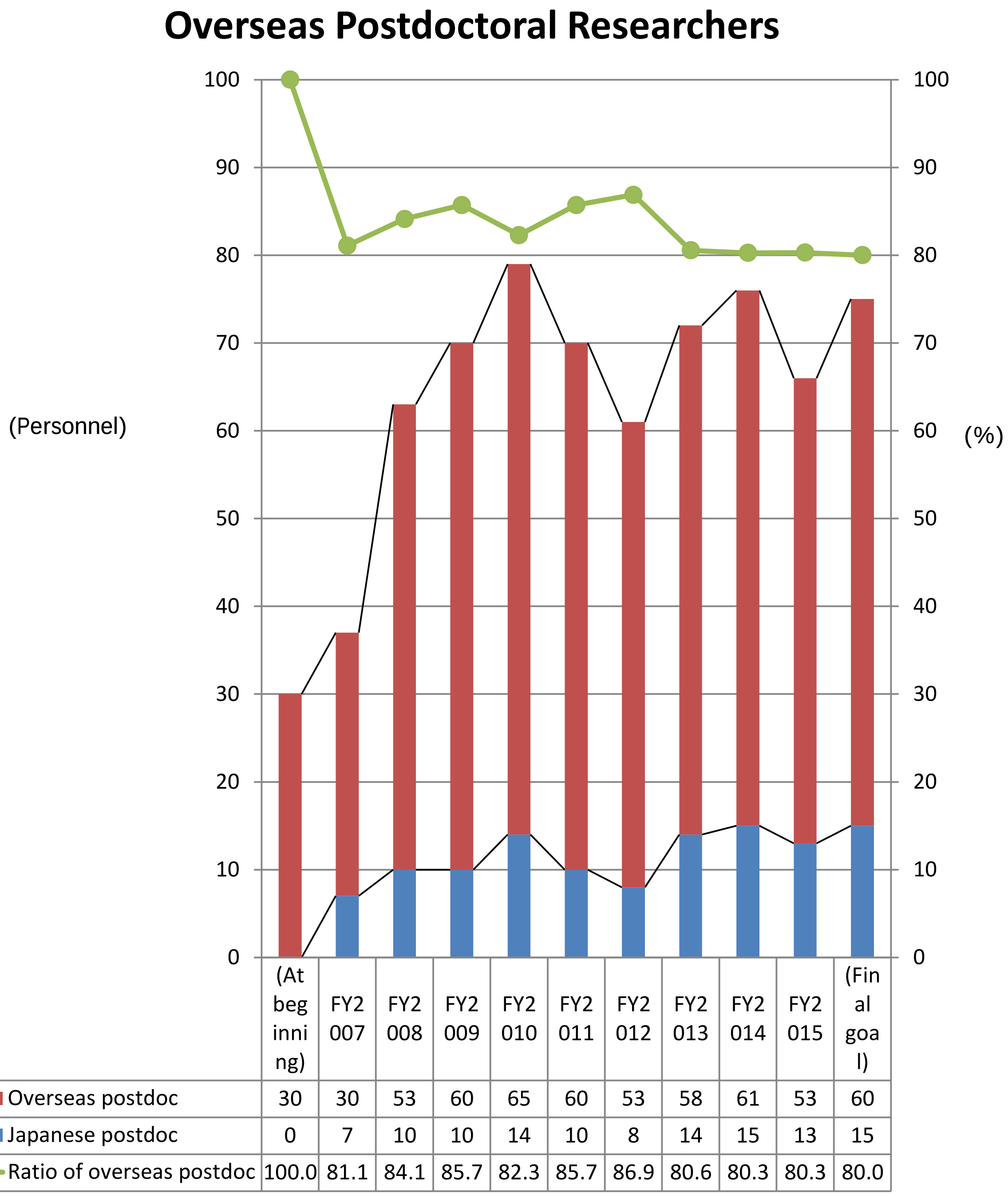
World Premier International Research Center Initiative (WPI)
Appendix 4-2. Postdoctoral Positions through Open International Solicitations

- In the column of number of applications and number of selection, put the number and percentage of overseas researchers in the < > brackets.

FY	number of applications	number of selection
FY2007	167 < 141, 85%>	9 < 6, 67%>
FY2008	119 < 109, 92%>	10 < 7, 70%>
FY2009	84 < 73, 87%>	3 < 1, 34%>
FY2010	128 < 112, 88%>	3 < 3, 100%>
FY2011	94 < 86, 92%>	5 < 4, 80%>
FY2012	169 < 148, 88%>	5 < 4, 80%>
FY2013	181 < 166, 92%>	4 < 3, 75%>
FY2014	183 < 163, 89%>	3 < 2, 67%>
FY2015	185 < 176, 95%>	3 < 2, 67%>

World Premier International Research Center Initiative (WPI) Appendix 4-3. Number of Overseas Postdoctoral Researchers and Annual Transition

*Make a graph of the transition in the number of overseas postdoctoral researchers since the application.



	(At beginning)	FY2007	FY2008	FY2009	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	(Final goal)
🟥 Overseas postdoc	30	30	53	60	65	60	53	58	61	53	60
🟦 Japanese postdoc	0	7	10	10	14	10	8	14	15	13	15
● Ratio of overseas postdoc	100.0	81.1	84.1	85.7	82.3	85.7	86.9	80.6	80.3	80.3	80.0

World Premier International Research Center Initiative (WPI)

Appendix 4-4. Status of Postdoc Employment at Institutions of Postdoctoral Researchers

*List each researcher in 1 line. If the list exceeds this form, please add extra pages.

Japanese Postdocs

Period of project participation	Previous Affiliation, Position title (Country)	Next Affiliation, Position title (Country)
2007/10/1-2011/3/31	Kumamoto University, JSPS Research Fellow (DC2&PD) (Japan)	Kyushu University, Assistant Professor(Japan)
2007/10/1-2010/3/31	AIST, Postdoc (Japan)	Tokyo Zokei University, Part time lecturer (Japan)
2008/4/1-2010/3/31	University of Tsukuba, Ph.D. (Japan)	Tokyo Institute of Technology, Assistant Professor (Japan)
2008/4/1-2010/3/31	Osaka University, Postdoc (Japan)	AIST, Researcher (Japan)
2008/4/1-2010/8/31	Rice University, Graduate Research Assistant (USA)	NIMS, Senior Researcher (Japan)
2008/4/1-2011/3/31	Faculty of Electrical, Electronic Information, Science and Technology, Meijo University, JSPS(D2) (Japan)	NIMS, Senior Researcher (Japan)
2008/4/1-2011/3/31	NIMS, JST-I CORP Researcher (Japan)	Mitsuboshi Diamond Industrial Co., Ltd., Researcher (Japan)
2008/4/1-2011/3/31	University of Tsukuba, Ph.D. (Japan)	RIKEN, JSPS Researcher (Japan)
2008/4/1-2012/6/30	Tohoku University, Postdoc (Japan)	WPI-AIMR, Tohoku University, Associate Professor (Japan)
2008/5/7-2011/4/30	Kanagawa University, Postdoc (Japan)	Light Industry Institute of Chemical Power Sources, Suzhou University, Postdoc (China)
2008/7/1-2010/3/31	Tokyo Denki University, Assistant Professor (Japan)	University of Bologna, Research Fellow (Italy)
2008/10/1-2010/3/31	Tokyo University of Agriculture and Technology, Ph.D. (Japan)	Ultizyme International Ltd., Researcher (Japan)
2008/12/1-2011/9/30	University of Tokyo, Co-operative Research Fellow (Japan)	TDK Corporation, Researcher (Japan)
2009/3/1-2010/4/30	Lund University, Ph.D. (Sweden)	University of California, Irvine, Postdoc (USA)
2009/4/1-2011/3/31	London Centre for Nanotechnology and University College London, Ph.D. (UK)	Tohoku University, Researcher (Japan)
2009/4/1-2011/7/1	Tokyo Institute of Technology, Ph.D. (Japan)	Yamagata University, Associate Professor (Japan)
2009/4/1-2011/7/30	Department of Physics, University of Basel, Visiting Scientist (Switzerland)	MANA/NIMS, Independent Scientist (Japan)
2009/4/1-2013/3/31	University of Tsukuba, Assistant Professor (Japan)	NIMS, Postdoc. (Japan)

2009/4/1 -2014/3/31	Waseda University, JSPS (Japan)	NIMS, Senior Researcher (Japan)
2009/6/1 -2015/3/31	Hiroshima University, Assistant Professor (Japan)	Kansei Gakuin University, Professor (Japan)
2009/11/1-2010/6/30	Japan Woman’s University, Postdoc (Japan)	The University of Electro-Communications, Assistant Professor (Japan)
2009/11/6-2010/11/6	University of Tokyo, Ph.D. (Japan)	NIMS, JSPS Fellow (Japan)
2010/4/1-2012/3/31	University of Tsukuba, Ph.D. (Japan)	Tokyo University of Science, Assistant Professor (Japan)
2010/4/1-2012/3/31	Kagoshima University, Ph.D. (Japan)	University of Alberta, Postdoc (Canada)
2010/4/1-2012/6/30	Osaka Prefecture University, Ph.D. (Japan)	MANA/NIMS, Independent Scientist (Japan)
2010/4/1-2012/8/31	Kyoto University, Ph.D. (Japan)	NIMS, Senior Researcher (Japan)
2010/4/1-2013/3/31	Department of Chemistry, Osaka University, Postdoc (Japan)	Maeda and Partners, Patent Office, Engineer (Japan)
2010/4/1-2011/3/31	London Centre for Nanotechnology and University College London, Ph.D. (UK)	Tohoku University, Research Associate (Japan)
2010/8/1-2013/3/31	Kyushu University, JSPS(PD) (Japan)	Waseda University, Assistant Professor (Japan)
2010/9/1-2011/11/18	University of Oklahoma, Postdoc (USA)	Private company, N/A (USA)
2010/10/1-2011/3/31	University of Tsukuba, Ph.D. (Japan)	NIMS, Engineer (Japan)
2011/4/1-2012/4/30	University of Tsukuba, Ph.D. (Japan)	Lawrence Berkeley National Laboratory, Visiting research scholar (USA)
2011/4/1 -2013/6/30	Kyushu University, Postdoc (Japan)	NIMS, Senior Researcher (Japan)
2012/3/5-2013/2/28	LPS, University Paris Sud, Postdoc (France)	MANA/NIMS, Postdoc (Japan)
2012/4/1 -2014/7/31	Waseda University, Ph.D. (Japan)	MANA/NIMS, ICYS-Researcher (Japan)
2012/4/1-2012/11/30	The University of Tokyo, JSPS (DC1) (Japan)	Yamanashi University, Assistant Professor (Japan)
2012/4/1 -2015/1/15	NIMS, JSPS Fellow (Japan)	Mitsubishi Electric, Researcher (Japan)
2012/7/1 -2014/3/31	Keio University, Postdoc (Japan)	Sapporo Sacred Heart School, Teacher (Japan)
2012/10/1-2014/9/30	University of Tokyo, Postdoc (Japan)	NIMS, Postdoc (Japan)
2013/4/1 -2014/3/31	University of Tsukuba, Ph.D. (Japan)	Tokyo University of Science, Assistant Professor (Japan)
2013/4/1-2014/12/31	NIMS, Postdoc (Japan)	KENT State University, Postdoc (USA)
2013/4/1 -2015/3/31	University of Tsukuba, Postdoc (Japan)	Tokyo University of Agriculture and Technology, Assistant Professor (Japan)

2013/6/1 -2015/3/31	NIMS, Postdoc (Japan)	Department of Applied Physics, Faculty of Science, Tokyo University of Science, Postdoc (Japan)
2013/6/1-2015/5/31	Institute for Molecular Science, Postdoc (Japan)	NIMS, Postdoc (Japan)
2013/8/1 -2016/3/31	NIMS, Postdoc (Japan)	Department of Functional Nanomaterials and Nanodevices, Nanoscience and Nanotechnology Center,The Institute of Scientific and Industrial Research, Osaka University, Assistant professor (Japan)
2014/4/1 -2015/3/31	Kumamoto University, Research Assistant (Japan)	Private High School, N/A (Japan)
2014/4/1-2015/12/31	Hokkaido University, JSPS Fellow (Japan)	Sagami Chemical Research Center, Postdoc (Japan)
2014/4/1 -2016/3/31	Tohoku University, Ph.D. (Japan)	Tokyo City University, Lecturer (Japan)
2014/5/1-2014/11/30	University of Tokyo, Ph.D. (Japan)	Tokyo local authorities, N/A (Japan)

Overseas Postdocs

Period of project participation	Previous Affiliation, Position title (Country)	Next Affiliation, Position title (Country)	Nationality
2007/10/1-2009/8/31	University of Science and Technology of China, Research assistant (China)	AIST, Research Fellow (Japan)	China
2007/10/1-2009/10/24	Bergische Universität Wuppertal, Humboldt Research Fellow (Germany)	ADOCIA Lyon, Head of Chemistry Team (France)	France
2007/12/1-2009/11/1	University of Bayreuth, Research Fellow (Germany)	Ashapura Minechem, R&D Manager (India)	India
2008/1/1 -2009/5/31	University of Tsukuba, Ph.D. (Japan)	Japan Fine Ceramics Center, Senior Researcher (Japan)	China
2008/2/21-2008/3/31	NIMS, Postdoc (Japan)	NIMS, Postdoc (Japan)	India
2008/4/1 -2008/8/31	Chinese Academy of Science, Postdoc (China)	Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Professor (China)	China
2008/4/1 -2008/12/31	Department of Materials Engineering and the Ilse Kartz Center for Meso and Nanoscale Science and Technology, Ben-Gurion University, Postdoc (Israel)	Centre for Advanced Materials, Indian Association for the Cultivation of Science, Assistant Professor (China)	India
2008/4/1 -2009/7/22	Material Science, Oxford University, MSc by research (UK)	Max Planck Institute for Polymer Research, Postdoc (Germany)	Italy
2008/4/1 -2009/9/30	Imperial College London, Postdoc (UK)	Panasonic Manufacturing UK Ltd., Fuel Cell R&D Engineer (UK)	UK

2008/4/1 -2010/2/16	Tohoku University, SORST, JST Postdoc (Japan)	Uppsala University, Associate Professor (Sweden)	Sweden
2008/4/1 -2010/2/28	University of Tsukuba, Ph.D. (Japan)	MINT, University of Alabama, Postdoc. (USA)	India
2008/4/1 -2010/3/31	Department of Organic and Polymeric Materials, Tokyo Institute of Technology, Ph.D. (Japan)	Committee of Qúzhōu High-Tech Park, Section Chief (China)	China
2008/4/1 -2010/3/31	University of Heidelberg, Postdoc (Germany)	H.C.Stark Co.Ltd., Associate Manager (Japan)	Germany
2008/4/1 -2010/3/31	JST, Researcher(CREST) (Japan)	Tokyo University of Science, Assistant Professor (Japan)	China
2008/4/1 -2010/8/31	Department of Physics, University of Tokyo, Ph.D. (Japan)	Department of Physics and Astronomy, Shanghai Jiao Tong University, Distinguished Research Fellow (China)	China
2008/4/1 -2010/9/30	Analytical Chemistry, Brigham Young University, Ph.D. (USA)	NIMS, Postdoc (Japan)	USA
2008/4/1 -2011/3/31	Indian Institute of Science, Ph.D. (India)	Jawaharlal Nehru Centre for Advanced Scientific Research, Faculty (Ramanujan Fellow) (India)	India
2008/4/1 -2011/7/13	University of Tsukuba, Ph.D. (Japan)	T-4, Theoretical Division, Los Alamos National Laboratory, Postdoc (USA)	China
2008/4/1 -2012/3/31	Chungxin International Semiconductor Development Co., Ltd, Engineer (China)	Tianjin University, Associate Professor (China)	China
2008/6/1 -2011/3/31	Institute of Metal Research, Chinese Academy of Sciences, Ph.D. (China)	Ningbo Institute of Materials Technology &. Engineering, Chinese Academy of Sciences, Associate Professor (China)	China
2008/6/16-2011/3/31	Department of Electronics, Peking University, Postdoc (China)	MIT, Postdoc (USA)	China
2008/7/1 -2011/3/31	Nanotechnology Research Institute, AIST, JSPS Fellow (Japan)	School of Material Science and Engineering, Hebei University of Technology, Professor (China)	China
2008/7/1 -2009/7/1	Department of Physics, Zhejiang University, Professor (China)	Department of Physics, Zhejiang University Hangzhou, Professor (China)	China
2008/7/15-2010/7/14	Nanyang Technological University, Postdoc (Singapore)	Environmental Futures Centre, Griffith University, Research Fellow (Australia)	China
2008/7/15-2010/9/30	University of Karlsruhe, Visiting Scientist (Germany)	Nanjing University of Aeronautics and Astronautics, Professor (China)	China

2008/7/25-2010/10/31	Research Institute of Petroleum Industry, Researcher (Iran)	Physics Department, Yazd University, Assistant Professor (Iran)	Iran
2008/8/1 -2010/7/31	National Institute for Interdisciplinary Science and Technology, Researcher (India)	Department of Neurology, Government Medical College, Researcher (India)	India
2008/8/1 -2011/3/31	Tokyo Institute of Technology, Postdoc (Japan)	Meiji University, Researcher (Japan)	China
2008/8/13-2010/8/12	Institute of Physics, Chinese Academy of Sciences, Assistant Professor (China)	Institute of High Energy Physics, Chinese Academy of Sciences, Assistant Professor (China)	China
2008/8/20-2010/8/19	Defense Metallurgical Research Laboratory, Scientist (India)	Indira Gandhi Centre for Atomic Research, Kalpakkam, Professor (India)	India
2008/8/28-2009/8/27	Institute of Physics, Chinese Academy of Sciences, Postdoc (China)	Wuhan Institute of Physics and Mathematics, Associate Professor (China)	China
2008/8/30-2010/12/15	Wuhan University, Ph.D. (China)	University of California at San Diego, Postdoc (USA)	China
2008/9/1 -2009/8/31	Institute of Physics, Chinese Academy of Sciences, Ph.D. (China)	Institute of Physics, Chinese Academy of Sciences, Associate Professor (China)	China
2008/9/1 -2010/8/31	Shanghai Institute of Ceramics, Chinese Academy of Sciences, Researcher (China)	Division of Information Technology, University of South Australia, Research Associate (Australia)	China
2008/9/1 -2011/3/31	University of Hyderabad, Ph.D. (India)	North Carolina State University, Postdoc (USA)	India
2008/9/1 -2011/3/31	Indian Institute of Chemical Technology, Senior Research Fellow (India)	NIMS, Postdoc (Japan)	India
2008/9/1 -2011/3/31	Chinese Academy of Sciences, Research Associate (China)	NIMS, ICYS-Researcher (Japan)	China
2008/9/1 -2011/8/31	Institute of Solid State Physics, Chinese Academy of Sciences, Assistant Professor (China)	Fudan University, Professor (China)	China
2008/9/11-2010/9/10	Moscow State University, Ph.D. (Russia)	Agrorus-Ryazan, Leading Engineer (Russia)	Russia
2008/10/1-2009/3/31	Nanjing University, Ph.D. (China)	Jiangsu University, Professor (China)	China
2008/10/1-2009/3/31	Tohoku University, Postdoc (Japan)	Southeast University, Professor (China)	China
2008/10/1-2009/6/30	Tokyo Institute of Technology, JSPS Fellow (Japan)	Department of Electrical & Electronic Engineering, Imperial College London, Postdoc (UK)	China

2008/10/1-2009/10/18	Seoul National University of Korea, Postdoc (Korea)	AIST, Researcher (Japan)	China
2008/10/6-2012/10/8	Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Postdoc (China)	SK Lab. of Electroanalytical Chem., Changchun Inst. of Applied Chem., CAS, Professor (China)	China
2008/11/1-2009/3/31	China University of Petroleum, Assistant Professor (China)	Tsinghua University, Professor (China)	China
2008/11/1-2009/8/31	The Chinese University of Hong Kong, Postdoc (China)	State Key Laboratory of Materials Processing and Die & Mould Technology, School of Materials Science and Engineering, Huazhong University of Science and Technology (HUST), Associate Professor (China)	China
2008/11/1-2011/3/31	Yokohama National University, JSPS Fellow (Japan)	International Advanced Research Center for Powder Metallurgy and New Materials, Senior Scientist (Leader) (India)	India
2008/11/10-2011/3/31	Shanghai Institute of Ceramics, Chinese Academy of Sciences, Assistant Researcher (China)	Kochi University, Postdoc (Japan)	China
2008/12/1-2010/3/30	State Key Laboratory of Silicon Materials, Zhejiang University, Ph.D. (China)	MANA/NIMS, MANA Scientist (Japan)	China
2008/12/2-2009/11/13	Sungkyunkwan University, Senior Researcher (Korea)	Samsung Electronics.Co.Ltd., researcher (Korea)	Korea
2009/2/1-2010/7/31	Saha Institute of Nuclear Physics, Postdoc (India)	Department of Physics, Visva-Bharati University, Assistant professor (India)	India
2009/3/1-2010/4/30	Autonomous University of Barcelona, Assistant Professor (Spain)	Max Planck Institute for Intelligent Systems, Research Group Leader (Germany)	Spain
2009/3/3-2011/3/4	Department of Chemistry, University of Aveiro, Postdoc (Portugal)	Jilin University, Associate Professor (China)	China
2009/3/16-2011/10/31	Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences, Ph.D. (China)	Lanzhou University, Professor (China)	China
2009/4/1-2009/9/30	Bhabha Atomic Research Centre, Scientific Officer (India)	Bhabha Atomic Research Centre, Scientific Officer (India)	India
2009/4/1-2011/3/31	National University of Singapore, Postdoc (Singapore)	Institute of Process Engineering, Chinese Academy of Sciences, Researcher (China)	China
2009/4/1-2012/3/31	Monash University, Postdoc (Australia)	Helmholtz-Zentrum Geesthacht, Scientist (Germany)	Australia

2009/4/1 -2010/3/31	The University of Tokyo, JSPS Fellow (Japan)	Korea Institute of Energy Research, Professor (Korea)	Italy
2009/4/1 -2010/3/31	Indian Institute of Technology, Senior Project Associate (India)	Department of Frontier Materials, Nagoya Institute of Technology, Postdoc (Japan)	India
2009/5/1 -2010/3/31	AIST, Researcher (Japan)	South China Normal University, Professor (China)	China
2009/5/1 -2012/3/31	Shizuoka University, COE Researcher (Japan)	School of Chemistry & Chemical Engineering, Shouxihu Campus, Yangzhou University, Assistant Professor (China)	China
2009/5/1 -2012/6/30	Surface Physics Division, Jabalpur University, Ph.D. (India)	NIMS, JSPS Fellow (Japan)	India
2009/6/1 -2011/5/31	Institute of Solid State Physics, Chinese Academy of Sciences, Research Fellow (China)	Kyoto University, Postdoc (Japan)	China
2009/6/6 -2011/5/31	Department of Chemical Science and Technology, University of Rome, Ph.D. (Italy)	University of Rome, Postdoc (Italy)	Italy
2009/7/1 -2010/12/31	University of California, Santa Barbara, Postdoc (USA)	LIM Innovations, Chief Technology Officer (USA)	USA
2009/7/1 -2012/3/31	Raman Research Institute, Jawaharlal Nehru University, Ph.D. (India)	MANA/NIMS, Postdoc (Japan)	India
2009/7/15-2010/7/14	Universitat Autonomade Barcelona, Postdoc (Spain)	Nanyang Technological University, Postdoc (Singapore)	Italy
2009/7/27-2012/10/31	Division of Physics and Applied Physics, Nanyang Technological University, Postdoc (Singapore)	State Key Lab of Luminescence and Applications, Changchun Institute of Optics, Fine Mechanics and Physics, CAS, Professor (China)	China
2009/8/1 -2011/3/31	Indian Institute of Chemical Technology, Senior Research Fellow (India)	UC Berkeley, Postdoc. (USA)	India
2009/8/1 -2014/7/31	Institute of Physics, Chinese Academy of Sciences, Ph.D. (China)	Universite de Strasbourg Laboratoire de Nanochimie, ISIS, Postdoc (France)	China
2009/8/15-2010/8/14	Oxford University, Postdoc (UK)	University of Tsukuba, Assistant Professor (Japan)	UK

2009/9/1 -2012/8/31	Department of Materials Science and Engineering, University of Science and Technology, Ph.D. (China)	Xi'an Technological University, Assistant Professor (China)	China
2009/9/4 -2011/9/3	AIST, Postdoc (Japan)	MANA/NIMS, MANA Scientist (Japan)	China
2009/10/1-2011/3/31	Nanjing University, Ph.D. (China)	NIMS, Postdoc (Japan)	China
2009/10/1-2012/8/31	AIST, Balzan Fellow (Japan)	National Center for Nanoscience and Technology, Associate Professor (China)	China
2009/10/1-2012/9/30	Max-Planck Institute of Colloids and Interfaces, Postdoc (Germany)	School of Chemistry and Chemical Engineering, Southeast University, Professor (China)	China
2009/10/1-2012/9/30	Institute of Laser Engineering, Osaka University, JSPS Fellow (Japan)	Institute of Industrial Science, The University of Tokyo, Researcher (Japan)	Korea
2010/1/1 -2013/1/11	Cornell University, Postdoc (USA)	State Key Lab of Polymer Phys.& Chem., Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, N/A (China)	China
2010/3/1 -2010/3/31	Indian Institute of Technology, Ph.D. (India)	Tohoku University, JSPS Researcher (Japan)	India
2010/3/15-2013/1/9	National Research Council of Argentina, Fellow (Argentine)	UC Berkeley, Postdoc (USA)	Argentine
2010/4/1 -2011/9/30	Osaka University, Assistant Professor (Japan)	CSIR-Indian Institute of Chemical Technology, Scientist (India)	India
2010/4/1 -2012/3/31	University of Tsukuba, Ph.D. (Japan)	University of New South Wales, Research Associate (Australia)	China
2010/4/1 -2012/4/30	Materials Science and Engineering, Stanford University, Postdoc (USA)	Korea Research Institute of Standards and Science, Senior Researcher (Korea)	Korea
2010/4/1 -2012/7/31	Yokohama National University, Ph.D. (Japan)	MANA/NIMS, MANA Scientist (Japan)	Nepal
2010/4/1 -2012/9/30	The Chinese University of Hong Kong, Research Assistant (China)	School of Physics and Engineering, Sun Yat-Sen University, Associate Professor (China)	China
2010/4/1 -2011/3/31	Institute of Physics, Chinese Academy of Sciences, Ph.D. (China)	University of Oxford, Postdoc (UK)	China
2010/4/1 -2011/3/31	Saitama University, Ph.D. (Japan)	University of Nova Gorica, Assistant Professor (Slovenia)	Bulgaria
2010/4/1 -2013/3/31	ERATO-SORST Aida Nanospace Project, JST Researcher (Japan)	Tokyo Metropolitan University, Assistant Professor (Japan)	Jordan

2010/4/1 -2013/3/31	School of Material Science and Engineering, Georgia Institute of Technology, Ph.D. (USA)	Tokyo Institute of Technology, Postdoc (Japan)	China
2010/5/1 -2012/3/31	Warsaw University of Technology, Postdoc (Poland)	Warsaw University of Technology, Research Assistant (Poland)	Poland
2010/5/1 -2012/4/30	Tohoku University, Ph.D. (Japan)	NIMS, Postdoc (Japan)	Korea
2010/5/16-2011/3/31	Huazhong Normal University, Ph.D. (China)	School of Material Science and Engineering, Hebei University of Technology, Professor (China)	China
2010/6/1 -2012/3/31	Physical Chemistry of Biomaterials, University of Pennsylvania, Postdoc (USA)	Indian Institute of Technology Mandi, Assistant Professor (India)	India
2010/7/1 -2011/6/30	Department of Chemistry, Yangzhou University, Teacher (China)	College of Chemistry and Chemical Engineering, Yangzhou University, Associate Professor (China)	China
2010/8/1 -2013/7/31	University of Tsukuba, Ph.D. (Japan)	Ulsan National Institute of Science and Technology, Researcher (Korea)	China
2010/8/1 -2011/7/31	Department of Bioengineering, University of Washington, Senior Fellow (USA)	Washington University, Postdoc (USA)	USA
2010/8/1 -2013/7/31	Shanghai Institute of Ceramics, Chinese Academy of Sciences, Ph.D. (China)	Institute of Metal Research, Chinese Academy of Sciences, Professor (China)	China
2010/8/1 -2014/4/30	University of Tsukuba, Ph.D. (Japan)	Soochow University, Professor (China)	China
2010/8/3 -2012/6/30	University of Rome, Ph.D. (Italy)	Osaka University, Postdoc (Japan)	Italy
2010/8/14-2011/3/31	University of Poitiers & Istanbul Technical University, Joint Ph.D. Scholarship from French Government (Turkey)	Istanbul Technical University, Research Assistant (Turkey)	Turkey
2010/8/20-2012/8/19	Temasek Laboratories, Nanyang Technological University, Research Assistant (Singapore)	Nanyang Technological University, Research Fellow (Singapore)	Indonesia
2010/9/1 -2011/3/31	Tokyo Institute of Technology, Postdoc (Japan)	Nanjing University of Science and Technology, Researcher (China)	China
2010/9/1 -2012/3/31	Department of Physics, Shivaji University, Ph.D. (India)	The University of Queensland, Postdoc (Australia)	India
2010/9/1 -2015/3/31	NIMS, Posydoc (Japan)	MANA/NIMS, Senior Researcher (Japan)	China

2010/9/10-2012/12/8	Heidelberg University, Ph.D. (Germany)	Institute of Materials Science Vietnam Academy of Science and Technology, Researcher (Vietnam)	China
2010/9/27-2012/6/23	Washington State University, Ph.D. (USA)	National Institute of Health and National Institute of Science and Technology, Maryland, Postdoc (USA)	India
2010/10/1-2013/6/21	Beihang University, Ph.D. (China)	NIMS, Postdoc (Japan)	China
2010/10/1-2013/9/30	Institute of Physics and Beijing Laboratory for Condensed Matter Physics, Chinese Academy of Sciences, Ph.D. (China)	Semiconductor Nanotechnology Research Group, Meiji University, Postdoc (Japan)	China
2010/10/1-2013/9/30	Institute of Chemistry, Chinese Academy of Sciences, Ph.D. (China)	MANA/NIMS, ICYS-Researcher (Japan)	China
2010/9/1-2013/8/31	Institute of Chemistry, Chinese Academy of Sciences, Ph.D. (China)	Huazhong University of Science and Technology, Professor (China)	China
2010/10/11-2012/10/10	Loughborough University, Ph.D. (UK)	MANA/NIMS, Postdoc (Japan)	Spain
2010/11/18-2013/11/17	Department of Macromolecular Physics, Faculty of Mathematics and Physics, Charles University, Research Associate (Czech Republic)	NIMS, Postdoc (Japan)	Czech Republic
2010/12/15-2012/4/30	Department of Chemistry, Nagoya University, Postdoc (Japan)	Institute of Process Engineering, CAS, Professor (China)	China
2011/1/1-2011/5/31	ETH-Zurich, Senior Scientist, Group Leader (Switzerland)	MIT, Senior Scientist (USA)	Switzerland
2011/2/1-2011/5/31	ReVolt Technology Ltd., Chief Engineer (Switzerland)	ReVolt Technology Ltd., N/A (Switzerland)	Germany
2011/2/1-2013/1/31	French Atomic Energy Commission, Research Engineer (France)	Department of Physics, Shiv Nadar University, Assistant Professor (India)	India
2011/4/1-2011/9/14	Peking University, Ph.D. (China)	Peking University, Assistant Professor (China)	China
2011/4/1-2013/3/31	Ibaraki University, Postdoc (Japan)	Department of Physics, National Institute of Technology, Assistant Professor (India)	India
2011/4/1-2014/1/31	NIMS, Postdoc (Japan)	NIMS, Postdoc (Japan)	China
2011/4/1-2014/6/18	Institute of Physics, Prague, Research Assistant (Czech Republic)	Optics Department, Institute of Physics, Research Assistant (Czech Republic)	Russia

2011/4/1 -2011/10/13	University of Science and Technology of China, Ph.D. (China)	Hefei University of Technology, Professor (China)	China
2011/4/5 -2013/3/31	Jawaharlal Nehru Center for Advanced Scientific Research, Ph.D. (India)	MANA/NIMS, ICYS-Researcher (Japan)	India
2011/5/1 -2012/4/30	Korea Institute of Science and Technology, Postdoc (Korea)	University of Bayreuth, N/A (Germany)	India
2011/5/1 -2013/4/30	Shandong University, Ph.D. (China)	NIMS, Postdoc (Japan)	China
2011/5/9 -2013/5/8	Physics Department, University of Shaoxing, Lecture (China)	Physics Department, University of Shaoxing, Associate Professor (China)	China
2011/6/16-2012/6/15	The Warsaw University of Technology, Ph.D. (Poland)	The Warsaw University of Technology, Researcher (Poland)	Poland
2011/7/1 -2012/8/31	University of Hong Kong, Research Assistant (Hong Kong)	Sheffield Institute for Translational Neuroscience University of Sheffield, Postdoc (UK)	Hong Kong
2011/7/1 -2011/11/30	University of Bristol, Royal Society University Research Fellow (UK)	University of Bristol, Assistant Professor (UK)	UK
2011/9/5 -2015/9/4	NIMS, JSPS Fellow (Japan)	Herbert Gleiter Institute of Nanoscience, Nanjing University of Science and Technology, Professor (China)	China
2011/9/20-2013/8/31	Indian Institute of Science, Bangalore, Research Associate (India)	Indian Institute of Science, Bangalore, Research Associate (India)	India
2011/10/1-2013/2/28	East China Normal University, Graduate Researcher (China)	Melbourne School of Engineering, University of Melbourne, Research Fellow (Australia)	China
2011/10/1-2013/7/29	Materials Technology Division, Hong Kong Productivity Council, Associate Consultant (Hong Kong)	Nano and Advanced Materials Institute Limited, Assistant Technical Manager (China)	Hong Kong
2011/10/1-2014/9/1	Hunan University, Ph.D. (China)	Temple University, Assitant Professor (USA)	China
2011/11/1-2013/10/31	Lab. of Prof. Dr. Wim Dehaen, Katholieke Universiteit, Assistant Doctor (Belgium)	University of Southampton, Postdoc (UK)	Belgium
2011/11/1-2013/10/31	Okayama University, Ph.D. (Japan)	NIMS, Postdoc (Japan)	China

2011/11/13-2013/3/31	University of Rome Tor Verga, Ph.D. (Italy)	International Clinical Research Center, Integrated Center of Cellular Therapy and Regenerative Medicine, St. Anne's University Hospital Brno, Junior Researcher (Czech Republic)	Italy
2011/11/29-2013/11/28	Physico-chemistry, University of Bordeaux, Ph.D. (France)	Erdyn Consultants, Consultant (France)	France
2011/12/1-2012/11/30	GLOBALFOUNDRIES Singapore Pte. Ltd., Senior Engineer (Singapore)	Intellectual Property Office of Singapore, Patent attorney (Singapore)	Singapore
2011/12/1-2013/8/31	Grenoble University, Institute of Technology, Grenoble, Ph.D. (France)	Department of Energy and Materials Engineering, Dongguk University, Research Assistant Professor (Korea)	China
2011/12/1-2014/1/31	University of Oregon, Postdoc (USA)	Institute of Bioengineering and Nanotechnology, Research Scientist (Singapore)	India
2011/12/1-2015/2/28	NIMS, Postdoc (Japan)	Qatar Foundation, Senior Scientist (Qatar)	Algerian
2011/12/1-2015/4/30	Saga University, Ph.D. (Japan)	NIMS, JSPS Fellow (Japan)	India
2012/0101-2012/12/31	Shanghai Jiao Tong University, Assistant Researcher (China)	Department of Colloid Chemistry, Max Planck Institute of Colloids and Interfaces, Postdoc (Germany)	China
2012/1/10-2013/3/31	School of Chemical & Biomolecular Engineering, Georgia Institute of Technology, Postdoc (USA)	Department of Chemical System Engineering, The University of Tokyo, Assistant Professor (Japan)	Thai
2012/4/1-2013/12/27	Katholieke Universiteit Leuven, Ph.D. (Belgium)	Procter & Gamble, Administrative Project Assistant (Belgium)	Belgium
2012/4/1-2012/9/14	Department of Chemical Science and Technologies, University of Rome, Ph.D. (Italy)	University of Liverpool, Research Assistant (UK)	China
2012/4/1-2014/6/30	NIMS, Postdoc (Japan)	NIMS, Independent Scientist (Japan)	China
2012/4/1-2014/11/30	NIMS, Junior Researcher (Japan)	NIMS, JSPS (Japan)	Iran
2012/4/1-2015/8/31	National Center for Nanoscience and Technology of China, N/A (China)	National Center for Nanoscience and Technology of China, Assistant Professor (China)	China

2012/5/1 -2013/6/30	Faculty of Materials Science and Engineering, Warsaw University of Technology, Ph.D. (Poland)	Warsaw University of Technology, Research Fellow (Poland)	Poland
2012/5/1 -2014/4/30	NIMS, Postdoc (Japan)	IMRAM, Tohoku University, Postdoc Researcher (Japan)	India
2012/6/20-2014/5/31	Huazhong University of Science and Technology, Assistant Professor (China)	School of Materials Science and Engineering, Hebei University of Technology, Associate Professor (China)	China
2012/8/1 -2014/7/31	Flinders University, Ph.D. (Australia)	University of Nottingham, Postdoc (UK)	Australia
2012/10/1-2013/7/29	Department of Chemical Engineering, National Taiwan University, Postdoc (Taiwan)	National Taiwan University, Postdoc (Taiwan)	Taiwan
2012/10/1-2014/3/31	Korea University, Ph.D. (Korea)	Samsung, N/A (Korea)	Korea
2012/10/1-2014/7/29	University of Hyderabad, Ph.D. (India)	Bharathidasan University, DST-Inspire Faculty member (India)	India
2012/11/1-2013/10/31	Institute of Physics, Chinese Academy of Sciences, Postdoc (China)	Shandon University, Researcher (China)	China
2012/11/1-2013/11/15	University of Tsukuba, Ph.D. (Japan)	National Center for Nanoscience and Technology of China, Associate Professor (China)	China
2012/11/1-2014/10/31	NIMS, Postdoc (Japan)	Beijing Institute of nanoenergy and nanosystem. Chinese academy of science, Postdoc (China)	China
2012/11/1-2014/11/1	Nanjing University, Assistant Professor (China)	Nanjing University, Assistant Professor (China)	China
2012/11/1-2015/4/30	Tokyo Institute of Technology, Ph.D. (Japan)	Private Company, N/A (Japan)	China
2012/11/1-2015/9/10	National University of Singapore, Post Graduate Student Research Assistant (Singapore)	Nanyang Technological University, Postdoc (China)	Singapore
2012/11/1-2014/10/31	Colorado State Univ., Postdoc (USA)	Department of Chemistry, Indian Institute of Technology Kanpur, Institute Postdoc (India)	India
2012/11/5-2013/5/31	Cavendish Laboratory, University of Cambridge, Ph.D. (UK)	Dongguk University, Research Professor (Korea)	China
2012/11/12-2013/10/31	University of Sydney, Ph.D. (Australia)	University of Sydney, Research Associate (Australia)	China

2013/1/7 -2013/8/17	National Taiwan University, Associate Professor (Taiwan)	National Taiwan University, Associate Professor (Taiwan)	Taiwan
2013/1/15-2014/1/20	Institute of Electrophysics, National Chiao Tung University, Postdoc (Taiwan)	Department of Physics, National Chung-Hsing University, Assistant Professor (Taiwan)	China
2013/2/1 -2013/8/31	University of Bristol, EPSRC Advanced Research Fellow (UK)	Department of Chemistry, University of Bath, Senior Researcher (UK)	UK
2013/2/1 -2013/7/31	Dublin City University, Postdoc (Ireland)	National Centre for Sensor Research, National Biophotonics & Imaging Platform Ireland, Technical Officer (Ireland)	India
2013/2/1 -2013/12/27	Fujian Institute of Research on the Structure of Matter, Chinese Academy of Sciences, Postdoc. (China)	The State University of New Jersey,Postdoc. (USA)	China
2013/2/1 -2014/2/28	Budapest University of Technology and Economics, Ph.D. (Hungary)	CNRS, Postdoc (France)	Hungary
2013/4/1 -2013/6/30	Changchun Institute of Applied Chemistry, Chinese Academy of Sciences, Postdoc (China)	NIMS, JSPS (Japan)	China
2013/4/1 -2014/3/31	Waseda University, Ph.D. (Japan)	MANA/NIMS, ICYS-Researcher (Japan)	China
2013/4/1 -2014/3/31	Jadavpur University, Ph.D. (India)	IACS Consulting Company, Postdoc (Italy)	India
2013/4/1 -2014/3/31	University of Montreal, Research Assistant (Canada)	BIOASTRA Technologies Inc., Platform leader (Canada)	Poland
2013/4/1 -2015/3/31	NIMS, Postdoc (Japan)	National Institute of Technology, Nagaland, Assistant Professor (India)	India
2013/4/1 -2015/3/31	University of Tokyo, Postdoc (Japan)	NIMS, N/A (Japan)	China
2013/4/1 -2015/9/30	University of Western Ontario, Postdoc (Canada)	NIMS, Postdoc (Japan)	China
2013/4/1 -2015/8/31	JSPS Fellow (Japan)	Department of Physics, Indian Institute of Science Education and Research (IISER), N/A (India)	India
2013/4/1 -2016/3/31	Chinese Academy Sciences, N/A (China)	Soochow University, Postdoc (China)	China
2013/4/22-2014/8/8	Institute of Physics, Chinese Academy of Science, Associate Professor (China)	Chinese Academy of Science, N/A (China)	China

2013/5/1 -2015/3/31	The Hong Kong Polytechnic University, N/A (Hong Kong)	Kansei Gakuin University, JSPS Post-Doc Fellowship for Overseas Researchers (Japan)	China
2013/5/1 -2015/4/24	NIMS, Postdoc (Japan)	Surface Science Laboratory, Department of Physics, National University of Singapore, Research Fellow (Singapore)	Indonesia
2013/6/1 -2015/8/31	The University of Hong Kong, Postdoc (Hong Kong)	Harbin Institute of Technology, Professor (China)	China
2013/9/1 -2014/8/31	Helmholtz-Zentrum Berlin fur Materialien und Energie GmbH, Researcher, (Germany)	NIMS, Postdoc (Japan)	Germany
2013/9/1 -2014/8/31	Institute of Functional Nano& Soft Materials, Soochow Univ., Lecture (China)	Institute of Functional Nano& Soft Materials, Soochow University, Lecture (China)	China
2013/10/1-2014/9/30	Hokkaido University, Ph.D. (Japan)	HARIMA Chemicals Inc., N/A (Japan)	China
2013/10/1-2015/9/30	NIMS, postdoc (Japan)	NIMS, Postdoc (Japan)	Korea
2013/11/18-2014/12/31	NIMS, Postdoc (Japan)	MANA/NIMS, ICYS-Researcher (Japan)	France
2014/1/1 -2015/7/31	NIMS, postdoc (Japan)	NIMS, Postdoc (Japan)	Czech Republic
2014/3/1 -2015/2/28	University of Cambridge, Ph.D. (UK)	National Sun Yat-sen University, Assistant Professor (Taiwan)	Taiwan
2014/3/10-2016/3/9	State Key Laboratory of Catalysis, DICP, Chinese Academy of Sciences, Ph.D. (Japan)	Beijing Institute of Technology, Associate Professor (China)	China
2014/4/1 -2014/9/30	University of Tokyo, Postdoc (Japan)	Department of Physics, East China Normal University, Shanghai, Associate Professor (China)	China
2014/4/1 -2015/3/31	Nagoya University, Researcher (Japan)	BML, Inc., N/A (Japan)	China
2014/4/1 -2016/2/29	National Institutes of Natural Sciences, Ph.D. Student (Japan)	Huazhong University of Science and Technology, Associate Professor (China)	China
2014/5/1 -2014/12/31	NIMS, Junior Researcher (Japan)	Soochow University, Associate Professor (China)	China
2014/5/1 -2015/1/15	University of Tokyo, Postdoc (Japan)	AIST, Researcher (Japan)	France
2014/6/1 -2015/7/31	Aarhus University, Ph.D. (Denmark)	Cancer and Inflammation Research, Institute for Molecular Medicine, Postdoc (Denmark)	Myanmar
2014/7/1 -2015/7/6	Western Kentucky University, N/A (USA)	King Faisal University, Assistant Professor (Saudi Arabia)	India
2014/8/1 -2015/4/30	Technical University of Munich, Postdoc (Germany)	CSIR-Central ElectroChemical Research Institute, Scientist (India)	India
2014/8/7 -2015/8/6	University of Houston, N/A (USA)	University of Houston, Postdoc (USA)	China
2014/10/1-2015/3/31	Kanazawa University, Ph.D. (Japan)	NIMS, NIMS postdoc (Japan)	China

2015/3/1 -2015/11/30	NIMS, Postdoc (Japan)	Yamagata University, Professor (Japan)	Germany
2015/4/1 -2015/12/31	AIST, Postdoc (Japan)	SUMITOMO SEIKA CHEMICALS CO.,LTD., N/A (Japan)	China
2015/4/1 -2016/3/31	National Institute of Advanced Industrial Science and Technology, N/A (Japan)	MANA/NIMS, ICYS-Researcher (Japan)	Romanian
2015/9/1 -2016/1/30	The Flinders University of South Australia, Postdoc (Australia)	Flinders University School of Medicine, Postdoc (Australia)	Australia

5. List of the cooperative research agreements outside Japan

1.	Counterpart of an Agreement:	Department of Chemistry, Kent State University, USA
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Design of novel nanoporous materials”
	Dates of an Agreement:	Signed on 2008 January 10 Valid until 2013 January 10 (expired)
	Summary of an Agreement:	For joint research activities between MANA and Kent State University, including research collaborations, exchange of personnel and organizing workshops.
2.	Counterpart of an Agreement:	Chemical and Biological Engineering, Rensselaer Polytechnic Institute (RPI), USA
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Design of novel nanoporous materials”
	Dates of an Agreement:	Signed on 2008 February 28 Valid until 2013 February 28 (expired)
	Summary of an Agreement:	For joint research activities between MANA and RPI, including research collaborations, exchange of personnel and organizing workshops.
3.	Counterpart of an Agreement:	California NanoSystems Institute (CNSI), University of California, Los Angeles (UCLA), USA
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Materials Science and Technology”
	Dates of an Agreement:	Signed on 2008 March 24 Valid until 2013 March 24 (expired)
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at CNSI (PI Prof. James K. Gimzewski).
4.	Counterpart of an Agreement:	Center for Nanostructure Characterization (CNC), Georgia Institute of Technology (GIT), USA
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Materials Nanoarchitectonics”
	Dates of an Agreement:	Signed on 2008 May 6 Valid until 2013 May 6 (expired)
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at GIT (PI Prof. Zhong Lin Wang).
5.	Counterpart of an Agreement:	Centre National de la Recherche Scientifique (CNRS), Regional Delegate of the Midi-Pyrénées Delegation, Toulouse, France
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Materials Nanoarchitectonics”
	Dates of an Agreement:	Signed on 2008 May 30 Valid until 2013 May 30 (expired)
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at CNRS (PI Dr. Christian Joachim).
6.	Counterpart of an Agreement:	Nanoscience Centre, University of Cambridge, UK
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Materials Nanoarchitectonics”
	Dates of an Agreement:	Signed on 2008 June 20 Valid until 2013 June 20 (expired)
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at University of Cambridge (PI Prof. Mark E. Welland).
7.	Counterpart of an Agreement:	Indian Institute of Chemical Technology (IICT), India
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on

		“Chemistry of Nanoporous Materials”
	Dates of an Agreement:	Signed on 2008 July 3 Valid until 2013 July 3 (expired)
	Summary of an Agreement:	For joint research activities between MANA and IICT, including research collaborations, exchange of personnel and organizing workshops.
8.	Counterpart of an Agreement:	National Center of Competence for Nanoscale Science (NCCR), Institute of Physics, University of Basel, Switzerland
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Materials Nanoarchitectonics”
	Dates of an Agreement:	Signed on 2008 July 22 Valid until 2013 July 22 (expired)
	Summary of an Agreement:	For joint research activities between MANA and NCCR, including research collaborations, exchange of personnel and organizing workshops.
9.	Counterpart of an Agreement:	Yonsei University, Korea
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Sustainable Chemical Technology and Nano-bio Fusion Technology”
	Dates of an Agreement:	Signed on 2008 September 1 Valid until 2013 September 1 (expired)
	Summary of an Agreement:	For joint research activities between MANA and Yonsei University, including research collaborations, exchange of personnel and organizing workshops.
10.	Counterpart of an Agreement:	Chemical and Biological Engineering, Indian Institute of Science Education and Research (IISER), India
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Design of novel nanomaterials and their application in energy and environment”
	Dates of an Agreement:	Signed on 2008 December 19 Valid until 2013 December 19 (expired)
	Summary of an Agreement:	For joint research activities between MANA and IISER, including research collaborations, exchange of personnel and organizing workshops.
11.	Counterpart of an Agreement:	Supramolecular Chemistry Group, Institute for Inorganic Chemistry, University of Karlsruhe, Germany
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Nanostructured Transition Metal Complexes and Oxides”
	Dates of an Agreement:	Signed on 2009 January 29 Valid until 2014 January 29 (expired)
	Summary of an Agreement:	For joint research activities between MANA and University of Karlsruhe, including research collaborations, exchange of personnel and organizing workshops.
12.	Counterpart of an Agreement:	New Energy and Materials Leboratory (NEML), Department of Chemistry, Fudan University, China
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Utilizing insulative thermo-conductive composite materials to solve safety problems of lithium ion batteries for electric vehicles”
	Dates of an Agreement:	Signed on 2009 March 16 Valid until 2014 March 16 (expired)
	Summary of an Agreement:	For joint research activities between MANA and NEML, including research collaborations, exchange of personnel and organizing workshops.

13.	Counterpart of an Agreement:	National Centre for Catalysis Research, Indian Institute of Technology (IIT), India
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Chemistry of Nanoporous Materials”
	Dates of an Agreement:	Signed on 2009 April 5 Valid until 2014 April 5 (expired)
	Summary of an Agreement:	For joint research activities between MANA and IIT, including research collaborations, exchange of personnel and organizing workshops.
14.	Counterpart of an Agreement:	Inorganic and Materials Chemistry, Institute of Inorganic Chemistry, University of Cologne, Germany
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Research on Fabrication and applications of advanced nanomaterials”
	Dates of an Agreement:	Signed on 2009 May 28 Valid until 2014 May 28 (expired)
	Summary of an Agreement:	For joint research activities between MANA and University of Cologne, including research collaborations, exchange of personnel and organizing workshops.
15.	Counterpart of an Agreement:	Institute of Microengineering (IMT), Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Cantilever and Probe Array Technology (CAPATEC)”
	Dates of an Agreement:	Signed on 2009 July 20 Valid until 2014 July 20 (expired)
	Summary of an Agreement:	For joint research activities between MANA and IMT, including research collaborations, exchange of personnel and organizing workshops.
16.	Counterpart of an Agreement:	Center for Nanoscience & Nanotechnology & Innovative Instrumentation (NAST), University of Rome Tor Vergata, Italy
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Nanostructured Materials for Sustainable Development”
	Dates of an Agreement:	Signed on 2009 July 30 Valid until 2014 July 30 (expired)
	Summary of an Agreement:	For joint research activities between MANA and NAST, including research collaborations, exchange of personnel and organizing workshops.
17.	Counterpart of an Agreement:	Kirchhoff Institute of Physics, University of Heidelberg, Germany
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Atom-scale and mesoscale infrared plasmonic structures at the metal-Si interfaces”
	Dates of an Agreement:	Signed on 2009 August 31 Valid until 2014 August 31 (expired)
	Summary of an Agreement:	For joint research activities between MANA and University of Heidelberg, including research collaborations, exchange of personnel and organizing workshops.
18.	Counterpart of an Agreement:	Department of Chemistry, Loughborough University, UK
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Structures of Stable Aza-substituted Organic Semiconductors”
	Dates of an Agreement:	Signed on 2009 October 28 Valid until 2014 October 28 (expired)
	Summary of an Agreement:	For joint research activities between MANA and

		Loughborough University, including research collaborations, exchange of personnel and organizing workshops.
19.	Counterpart of an Agreement: Name of an Agreement: Dates of an Agreement: Summary of an Agreement:	Lawrence Berkeley National Laboratory (LBNL), University of California, USA Memorandum of Understanding (MOU) for collaboration on "Electronic Configuration Evolution in Micro-Solid Oxide Fuel Cell (μ-SOFC) Electrode and Electrolyte Materials in operating Conditions: a Real-Time Dynamic Study in Soft X-rays Spectroscopy" Signed on 2010 February 9 Valid until 2015 February 9 (expired) For joint research activities between MANA and LBNL, including research collaborations, exchange of personnel and organizing workshops.
20.	Counterpart of an Agreement: Name of an Agreement: Dates of an Agreement: Summary of an Agreement:	Institute of Electronic Microelectronic and Nanotechnology (IEMN), University of Valenciennes – Hainaut Cambrésis, France Memorandum of Understanding (MOU) for collaboration on "Interconnects and Nanocontacts for Nanorod- and Nanowire-based Electronic Devices Applications" Signed on 2010 May 20 Valid until 2015 May 20 (expired) For joint research activities between MANA and IEMN, including research collaborations, exchange of personnel and organizing workshops.
21.	Counterpart of an Agreement: Name of an Agreement: Dates of an Agreement: Summary of an Agreement:	Erlangen Catalysis Resource Center, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany Memorandum of Understanding (MOU) for collaboration on "Design of novel nanoporous materials" Signed on 2010 June 21 Valid until 2015 June 21 (expired) For joint research activities between MANA and University Erlangen-Nürnberg, including research collaborations, exchange of personnel and organizing workshops.
22.	Counterpart of an Agreement: Name of an Agreement: Dates of an Agreement: Summary of an Agreement:	Department of Materials Science, Fudan University, China Memorandum of Understanding (MOU) for collaboration on "Organic-Inorganic Nano Hybrid Materials for Optoelectronic Applications" Signed on 2010 July 23 Valid until 2015 July 23 (expired) For joint research activities between MANA and Fudan University, including research collaborations, exchange of personnel and organizing workshops.
23.	Counterpart of an Agreement: Name of an Agreement: Dates of an Agreement: Summary of an Agreement:	Center for Intelligent Nano Bio Materials (CINBM), Department of Chemistry and Nanoscience (Brain Korea 21), Ewha Womans Univeristy, Korea Memorandum of Understanding (MOU) for collaboration on "Design of novel nanoparticles, nanoporous materials and nanohybrids" Signed on 2010 August 27 Valid until 2015 August 27 (expired) For joint research activities between MANA and CINBM, including research collaborations, exchange of personnel and organizing workshops.

24.	Counterpart of an Agreement:	Karlsruhe Institute of Technology (KIT), Germany
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Metal Oxide Aqueous Interfacial Chemistry"
	Dates of an Agreement:	Signed on 2010 September 16 Valid until 2015 September 16 (expired)
	Summary of an Agreement:	For joint research activities between MANA and KIT, including research collaborations, exchange of personnel and organizing workshops.
25.	Counterpart of an Agreement:	CNRS, Regional Delegation Provence et Corse, and Université de la Méditerrannée, France
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Transient chemistry of metal ions for low temperature ultrafast laser-assisted growth of hetero-nanostructures in aqueous solutions"
	Dates of an Agreement:	Signed on 2010 September 20 Valid until 2015 September 20 (expired)
	Summary of an Agreement:	For joint research activities between MANA and CNRS and Université de la Méditerrannée, including research collaborations, exchange of personnel and organizing workshops.
26.	Counterpart of an Agreement:	Anhui Key Laboratory of Nanomaterials and Nanostructres, Institute of Solid State Physics, Chinese Academy of Sciences, China
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Low dimensional Nanostructures"
	Dates of an Agreement:	Signed on 2010 October 6 Valid until 2015 October 6 (expired)
	Summary of an Agreement:	For joint research activities between MANA and Anhui Key Laboratory, including research collaborations, exchange of personnel and organizing workshops.
27.	Counterpart of an Agreement:	Multidisciplinary Center for Development of Ceramic Materials (MCDCM), Brazil
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Research and development of nanostructured materials for alternative energy and sensor devices"
	Dates of an Agreement:	Signed on 2010 October 26 Valid until 2015 October 26 (expired)
	Summary of an Agreement:	For joint research activities between MANA and MCDCM, including research collaborations, exchange of personnel and organizing workshops.
28.	Counterpart of an Agreement:	Laboratory for Nanotechnology (LNT), Vietnam National University Ho Chi Minh City (VNU-HCM), Vietnam
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Optoelectronic and bioelectronics nanodevices"
	Dates of an Agreement:	Signed on 2011 January 24 Valid until 2016 January 24 (expired)
	Summary of an Agreement:	For joint research activities between MANA and LNT, including research collaborations, exchange of personnel and organizing workshops.
29.	Counterpart of an Agreement:	Petrochemical Research Chair, King Saud University, Kingdom of Saudi Arabia
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Design of novel nanoporous materials and Catalysis"
	Dates of an Agreement:	Signed on 2011 January 25 Valid until 2016 January 25 (expired)

	Summary of an Agreement:	For joint research activities between MANA and King Saud University, including research collaborations, exchange of personnel and organizing workshops.
30.	Counterpart of an Agreement:	CNRS, Regional Delegate for Alpes and Institut Polytechnique de Grenoble (IPG), France
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Biomaterials, ferrelectric materials and photonic crystals”
	Dates of an Agreement:	Signed on 2011 February 1 Valid until 2016 February 1 (expired)
	Summary of an Agreement:	For joint research activities between MANA and IPG, including research collaborations, exchange of personnel and organizing workshops.
31.	Counterpart of an Agreement:	Université de Montreal (UdeM), Canada
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Functional nanoparticles and interfaces for radiation-sensitive spatio-temporal therapeutic and imaging applications”
	Dates of an Agreement:	Signed on 2011 July 4 Valid until 2016 July 4
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at UdeM (PI Prof. Françoise M. Winnik).
32.	Counterpart of an Agreement:	Flinders University of South Australia, Australia
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Research in Nanotechnology”
	Dates of an Agreement:	Signed on 2011 July 19 Valid until 2016 July 19
	Summary of an Agreement:	For joint research activities between MANA and Flinders University, including research collaborations, exchange of personnel and organizing workshops.
33.	Counterpart of an Agreement:	University of Melbourne, Australia
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Innovative nanomaterials which improve quality of life whilst being safe for communities and the environment”
	Dates of an Agreement:	Signed on 2011 September 21 Valid until 2016 September 21
	Summary of an Agreement:	For joint research activities between MANA and University of Melbourne, including research collaborations, exchange of personnel and organizing workshops.
34.	Counterpart of an Agreement:	Biomaterials and Tissue Engineering Research Center, Shanghai Institute of Ceramics (SIC), Chinese Academy of Science, China
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Development of Three-Dimensional Porous Scaffolds for Tissue Engineering”
	Dates of an Agreement:	Signed on 2011 December 1 Valid until 2016 December 1
	Summary of an Agreement:	For joint research activities between MANA and SIC, including research collaborations, exchange of personnel and organizing workshops.
35.	Counterpart of an Agreement:	Department of Materials Science & Engineering, Tsinghua University, China
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “New Functional Nanomaterials for Energy and Environment Applications”
	Dates of an Agreement:	Signed on 2012 January 28

		Valid until 2017 January 28
	Summary of an Agreement:	For joint research activities between MANA and Tsinghua University, including research collaborations, exchange of personnel and organizing workshops.
36.	Counterpart of an Agreement:	International Training Institute for Materials Science (ITIMS), Hanoi University of Science and Technology (HUST), Vietnam
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Application of plasmonic materials for sensors and energy conversion devices"
	Dates of an Agreement:	Signed on 2012 February 7 Valid until 2017 February 7
	Summary of an Agreement:	For joint research activities between MANA and ITIMS, including research collaborations, exchange of personnel and organizing workshops.
37.	Counterpart of an Agreement:	Instituto de Fisica de São Carlos, University of Sao Paolo, Brazil
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Nanotechnology for Organized Materials"
	Dates of an Agreement:	Signed on 2012 April 25 Valid until 2017 April 25
	Summary of an Agreement:	For joint research activities between MANA and University of Sao Paolo, including research collaborations, exchange of personnel and organizing workshops.
38.	Counterpart of an Agreement:	London Centre for Nanotechnology (LCN), University College London (UCL), UK
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Electronic Structure Calculations of Nanowires"
	Dates of an Agreement:	Signed on 2012 October 8 Valid until 2017 October 8
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at UCL (API Dr. David Bowler).
39.	Counterpart of an Agreement:	Department of Polymer Science and Engineering, Kyungpook National University, Korea
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Development of advanced functional biomaterials with controllable compositions and nano/microscopic structures for stem cell differentiation and tissue regeneration"
	Dates of an Agreement:	Signed on 2013 January 18 Replaced on 2014 September 27
	Summary of an Agreement:	For joint research activities between MANA and Kyungpook National University, including research collaborations, exchange of personnel and organizing workshops.
40.	Counterpart of an Agreement:	Centre Interdisciplinaire de Nanoscience de Marseille (CINaM-CNRS) and Physique des Interactions Ioniques et Moléculaires (PIIM-CNRS), France
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on "Low-dimensional nanomaterial architectonics"
	Dates of an Agreement:	Signed on 2013 May 2 Valid until 2018 May 2
	Summary of an Agreement:	For joint research activities between MANA and CINaM-CNRS and PIIM-CNRS, including research collaborations, exchange of personnel and organizing workshops.
41.	Counterpart of an Agreement:	National Center for Nanoscience and Technology (NCNST), China

	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Quest for neuromorphic behavior of materials”
	Dates of an Agreement:	Signed on 2013 June 24 Valid until 2018 June 24
	Summary of an Agreement:	For joint research activities between MANA and NCNST, including research collaborations, exchange of personnel and organizing workshops.
42.	Counterpart of an Agreement:	School of Materials Science and Engineering, Huazhong University of Science and Technology (HUST), China
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Advanced Functional Materials for Energy and Environment Applications”
	Dates of an Agreement:	Signed on 2013 July 29 Valid until 2018 July 29
	Summary of an Agreement:	For joint research activities between MANA and HUST, including research collaborations, exchange of personnel and organizing workshops.
43.	Counterpart of an Agreement:	Center for Nanostructure Characterization (CNC), Georgia Institute of Technology (GIT), USA
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Inorganic Nanomaterials for Energy-Related Applications”
	Dates of an Agreement:	Signed on 2013 November 25 Valid until 2018 November 25
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at GIT (PI Prof. Zhong Lin Wang). Renewal of expired MOU.
44.	Counterpart of an Agreement:	Centre National de la Recherche Scientifique (CNRS), Regional Delegate of the Midi-Pyrénées Delegation, France
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Molecular devices and related materials”
	Dates of an Agreement:	Signed on 2013 December 10 Valid until 2018 December 10
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at CNRS (PI Dr. Christian Joachim). Renewal of expired MOU.
45.	Counterpart of an Agreement:	St. Petersburg State Electrotechnical University (LETI), Russia
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Nanoarchitectonics on Future Electric Devices”
	Dates of an Agreement:	Signed on 2014 February 28 Valid until 2019 February 28
	Summary of an Agreement:	For joint research activities between MANA and LETI, including research collaborations, exchange of personnel and organizing workshops.
46.	Counterpart of an Agreement:	Bristol Centre for Nanoscience and Quantum Information (NSQI), University of Bristol, UK
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Nanomaterials and Nanodevices”
	Dates of an Agreement:	Signed on 2014 March 7 Valid until 2019 March 7
	Summary of an Agreement:	For joint research activities between MANA and NSQI including research collaborations, exchange of personnel and organizing workshops.
47.	Counterpart of an Agreement:	The Regents of the University of California, on behalf of its Los Angeles Campus, USA

	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “MANA Brain: Neuromorphic Atomic Switch Networks”
	Dates of an Agreement:	Signed on 2014 September 8 Valid until 2019 September 8
	Summary of an Agreement:	For scientific and technical cooperation between MANA and the MANA Satellite at CNSI (PI Prof. James K. Gimzewski). Renewal of expired MOU.
48.	Counterpart of an Agreement:	Donostia International Physics Center (DIPC), San Sebastian, Spain
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Nanostructures and complex functional materials”
	Dates of an Agreement:	Signed on 2014 September 9 Valid until 2019 September 9
	Summary of an Agreement:	For joint research activities between MANA and DPIC including research collaborations, exchange of personnel and organizing workshops.
49.	Counterpart of an Agreement:	School of Applied Chemical Engineering (SACE), Graduate School, Kyungpook National University (KNU), Korea
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Development of advanced functional materials with controllable compositions and nano/microscopic structures”
	Dates of an Agreement:	Signed on 2014 September 27 (Replacement of MOU signed on 2013 January 18) Valid until 2019 September 27
	Summary of an Agreement:	For joint research activities between MANA and Kyungpook National University, including research collaborations, exchange of personnel and organizing workshops.
50.	Counterpart of an Agreement:	Department of Applied Physics and the School of Pharmacy, University of Eastern Finland (UEF), Kuopio, Finland
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Mesoporous Materials for Biomedical Applications”
	Dates of an Agreement:	Signed on 2014 December 31 Valid until 2019 December 31
	Summary of an Agreement:	For joint research activities between MANA and UEF including research collaborations, exchange of personnel and organizing workshops.
51.	Counterpart of an Agreement:	Indian Institute of Science (IISc), Bangalore, India
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Development of Carbide-based Nanomaterials and Plasmonic Devices for Solar Energy Conversion”
	Dates of an Agreement:	Signed on 2015 January 13 Valid until 2020 January 13
	Summary of an Agreement:	For joint research activities between MANA and IISc including research collaborations, exchange of personnel and organizing workshops.
52.	Counterpart of an Agreement:	Department of Materials Science & Engineering, University of Toronto, Canada
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Nanomaterials and nanotechnology”
	Dates of an Agreement:	Signed on 2015 January 21 Valid until 2020 January 21
	Summary of an Agreement:	For joint research activities between MANA and University of Toronto including research collaborations, exchange of

		personnel and organizing workshops.
53.	Counterpart of an Agreement:	Institute for Energy Materials (IEM), Chongqing University of Science & Technology (CQUST), China
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Synthesis and Characterization of Functional Nanomaterials”
	Dates of an Agreement:	Signed on 2015 May 15 Valid until 2020 May 15
	Summary of an Agreement:	For joint research activities between MANA and CQUST including research collaborations, exchange of personnel and organizing workshops.
54.	Counterpart of an Agreement:	Paul Drude Institute for Solid State Electronics (PDI), Berlin, Germany
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Electronic state of wide band gap oxide semiconductors”
	Dates of an Agreement:	Signed on 2015 May 29 Valid until 2020 May 29
	Summary of an Agreement:	For joint research activities between MANA and PDI including research collaborations, exchange of personnel and organizing workshops.
55.	Counterpart of an Agreement:	Department of Materials Science and Engineering, Promotion Center for Global Materials Research, National Cheng Kung University (NCKU), Taiwan
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Synthesis/Fabrication of Nano-Hybrids by Soft Processing”
	Dates of an Agreement:	Signed on 2015 May 30 Valid until 2020 May 30
	Summary of an Agreement:	For joint research activities between MANA and NCKU including research collaborations, exchange of personnel and organizing workshops.
56.	Counterpart of an Agreement:	Molecular Engineering & Sciences Institute (MolES), University of Washington (UW), USA
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Smart Nano-Biomaterials”
	Dates of an Agreement:	Signed on 2015 September 15 Valid until 2020 September 15
	Summary of an Agreement:	For joint research activities between MANA and UW including research collaborations, exchange of personnel and organizing workshops.
57.	Counterpart of an Agreement:	University of Science and Technology of Hanoi (USTH), Vietnam
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Functional Nanostructured Materials for the Application in Water and Environmental Studies”
	Dates of an Agreement:	Signed on 2015 September 24 Valid until 2020 September 24
	Summary of an Agreement:	For joint research activities between MANA and USTH including research collaborations, exchange of personnel and organizing workshops.
58.	Counterpart of an Agreement:	University of Wollongong (UOW), Australia
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on the advancement of academic and education collaboration and exchanges
	Dates of an Agreement:	Signed on 2015 September 29

		Valid until 2020 September 29
	Summary of an Agreement:	For joint research activities between MANA and UOW including research collaborations, exchange of personnel and organizing workshops.
59.	Counterpart of an Agreement:	University of Chemistry and Technology (UCT), Prague, Czech Republic
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “nanomaterials synthesis and structure characterizations”
	Dates of an Agreement:	Signed on 2016 January 18 Valid until 2021 January 18
	Summary of an Agreement:	For joint research activities between MANA and UCT including research collaborations, exchange of personnel and organizing workshops.
60.	Counterpart of an Agreement:	Australian Institute for Nanoscale Science and Technology (AINST), University of Sydney, Australia
	Name of an Agreement:	Memorandum of Understanding (MOU) for collaboration on “Nanoscale Systems”
	Dates of an Agreement:	Signed on 2016 February 16 Valid until 2021 February 16
	Summary of an Agreement:	For joint research activities between MANA and AINST including research collaborations, exchange of personnel and organizing workshops.

World Premier International Research Center Initiative (WPI)

Appedex 4-6. Holding International Research Meetings

* For each fiscal year, indicate the number of international research conferences or symposiums held and give up to two examples of the most representative ones using the table below.

Date	Meeting title and Place held	Number of participants
2008 March10,13	MANA International Symposium 2008, Tsukuba	191
2009 Feb.25-27	MANA International Symposium 2009, Tsukuba	310
2010 March 3-5	MANA International Symposium 2010, Tsukuba	351
2011 March 3-5	MANA International Symposium 2011, Tsukuba	410
2012 Feb.29-March 2	MANA International Symposium 2012, Tsukuba	389
2013 Feb. 27-March 1	MANA International Symposium 2013, Tsukuba	414
2014 March 5-7	MANA International Symposium 2014, Tsukuba	425
2015 March11-13	MANA International Symposium 2015, Tsukuba	410
2016 March 9-11	MANA International Symposium 2016, Tsukuba	410
2009 Oct. 23	Symposium on Frontiers in Nanotechnology and Materials, Tsukuba	152
2012 Oct. 10.1	PCCP Asian Symposia 2012, Tsukuba	106
2014 March24-25	International Symposium on Smart Biomaterials, Tsukuba	135
2014 Apr.1-2	International Workshop “Topology in the New Frontiers of Materials Science”, Tsukuba	174
2014 Nov.27-28	International Symposium on the Functionality of Organized Nanostructures 2014, Tokyo	223
2014 July 18	Material Architectonics for Sustainable Action 2014, Tsukuba	109
2014 Dec.4-5	6th Tsukuba International Coating Symposium	115
2015 July 29-30	International Symposium on Nanoarchitectonics for Mechanobiology, Tsukuba	118
2015 Oct.15-16	RSC-MANA Joint International Symposium, Tsukuba	120

World Premier International Research Center Initiative (WPI)

Appedex 5-1. Host Institution’s Commitment

1. Contributions from host institution

(1) Fund, Personnel

* Regarding "Fund" entry, describe with reference to the items in the Progress Report (Jisseki-hokoku-sho) based on Article 12 of the Grant Guidelines (Kofu-yoko).
* Don’t include competitive funding obtained by researchers (used as research project funding)
* Under “Personnel”, enter the number of full-time administrative staff within the parenthesis.

(2007-2012)

<Fund> **(million yen)**

Fiscal Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Personnel - Faculty members (including researchers)	**54**	**157**	**141**	**172**	**1**	**1**
Full-time	**54**	**157**	**141**	**172**	**1**	**1**
Concurrent	**0**	**0**	**0**	**0**	**0**	**0**
Postdocs	**0**	**0**	**0**	**0**	**0**	**0**
RA ect.	**0**	**0**	**0**	**0**	**0**	**0**
Research support staffs	**0**	**0**	**0**	**0**	**0**	**0**
Administrative staffs	**0**	**0**	**0**	**0**	**0**	**0**
Project activities	**237**	**555**	**680**	**497**	**458**	**582**
Travel	**5**	**69**	**87**	**68**	**32**	**36**
Equipment	**31**	**250**	**260**	**154**	**109**	**140**
Research projects	**1187**	**920**	**1054**	**1089**	**736**	**877**
Total	**1514**	**1951**	**2222**	**1980**	**1336**	**1636**

<Personnel> **(person)**

Fiscal Year	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Personnel - Faculty members (including researchers)	**170**	**190**	**214**	**232**	**232**	**221**
Full-time	**51**	**56**	**65**	**63**	**88**	**89**
Concurrent	**7**	**26**	**23**	**24**	**4**	**4**
Postdocs	**37**	**65**	**72**	**79**	**70**	**61**
RA etc.	**26**	**12**	**21**	**31**	**44**	**41**
Research support staffs	**25**	**13**	**16**	**16**	**8**	**9**
Administrative staffs	**24(5)**	**18(4)**	**17(4)**	**19(4)**	**18(3)**	**17(4)**

(2013-2016)

<Fund> **(million yen)**

Fiscal Year	**2013**	**2014**	**2015**	**2016**	**Total**
Personnel - Faculty members (including researchers)	31	223	235	318	1,333
Full-time	31	223	235	318	1,333
Concurrent	0	0	0	0	0
Postdocs	0	0	0	0	0
RA etc.	0	0	0	0	0
Research support staffs	0	0	0	0	0
Administrative staffs	0	0	0	0	0
Project activities	536	498	509	513	5,065
Travel	38	59	66	79	539
Equipment	86	51	25	66	1,172
Research projects	963	645	750	799	9,020
Total	1654	1476	1585	1775	17,129

<Personnel> **(person)**

Fiscal Year	**2013**	**2014**	**2015**	**2016**	**Total**
Personnel - Faculty members (including researchers)	236	242	225	192	2,154
Full-time	94	98	94	87	785
Concurrent	5	4	4	3	104
Postdocs	72	76	66	60	658
RA etc.	36	33	33	19	296
Research support staffs	10	11	10	9	127
Administrative staffs	19(3)	20(3)	18(4)	14(4)	184(38)

(2) Provision of land and/or building(s), lab space, etc.

・WPI-MANA building:	6,354 m^2
・MANA building:	12,934 m^2
・Collaborative building:	298 m^2
・Main building:	606 m^2
・Administration and Research building:	918 m^2

2. System under which the center's director is able to make substantive personnel and budget allocation decisions

- Annual allocation of research project expenses and center activity expenses from NIMS's operations subsidies to MANA
- Provision of approximately 90 tenure positions to MANA

3. Support for the center director in coordinating with other departments at host institution when recruiting researchers, while giving reasonable regard to the educational and research activities of those departments

- Making MANA a permanent research organization and its researchers full-time by defining MANA as a Nanoscale Materials Division of NIMS (till March, 2015) and, from April, 2016, as one of the seven research centers in NIMS.

4. Revamping host institution's internal systems to allow introducing of new management methods

(e.g., English-language environment, merit-based pay, cross appointment, top-down decision making unfettered by conventional modes of operation)

- Stipulating MANA's role in promoting some of NIMS's system reforms (internationalization and development of young researchers) in the 3rd NIMS's Mid-Term Plan (five-year plan) and also in the 4th NIMS's Mid- to Long-Term Plan (seven-year plan).
- Revision of individual performance evaluation system for tenured researchers with the aim of enabling them to tackle challenging research topics
- Implementation of programs to improve the English proficiency of NIMS administrative staff to establish an institute-wide bilingual administration system.
- Establishment of funded joint research system to make PIs in the satellites undertake MANA research.
- Implementation of administration office to all the research centers of NIMS from April, 2016.

5. Utilities and other infrastructure support provided by host institution.

(*In addition to listed in the item 1. Contributions from host institution)

※ All of the support is included in "Research projects" of the item 1: start-up funds for newcomers, operating expenses for MANA Foundry, installing costly shared-use equipment, NIMS supercomputer's CPU time to MANA theoreticians, required utilities, etc.

6. Support for other types of assistance

- Bolstering of MANA workforce by assigning new permanent staff
- Research Abroad Program for sending permanent researchers to overseas institutions
- Livelihood support for foreign researchers
- Establishing various joint graduate school programs with domestic and overseas schools to recruit research assistants
- NIMS Invitation Program and NIMS Internship Program for inviting scientists and students
- 'Seeds' development research grants for all the permanent researchers

World Premier International Research Center Initiative (WPI)

Appedex 5-2. The Host Institution's Mid-term Plan

Plan for Achieving the Mid-Term Goals of the National Institute for Materials Science

(Seven-Year Plan)

(April 1, 2016 - March 31, 2023)

Approved: March 31, 2016

National Institute for Materials Science

(Snip)

1.1.5 Nanomaterials research and development

In this field, NIMS will establish nanoarchitectonics as a technique for fabricating new nanomaterials whose functionalities—which manifest themselves in more refined forms through the control of the sizes and shapes of materials at the nanometer level—and reactions can be highly controlled or modulated. With this, we will fabricate new materials and devices that will lead to innovations in electronics, environmental and energy technology, and biotechnology. More specifically, for a wide range of materials from the organic to the inorganic to metals, we will undertake the advanced sequencing, integration, and aggregation of nanomaterials with precisely controlled compositions, structures, sizes, and shapes, and we will strive to yield novel functions with the artificial nanomaterials and nanosystems designed or constructed with this process. Centered on our nanomaterials scientists, this field will aggregate experts from the fields of physics, chemistry, biomaterials, devices, and theoretical computation, and this cross-disciplinary pollination will lead to the creation of new material technologies that can yield new developments in a variety of technical fields.

Concrete projects include the following:

- Creation of function from chemical nano- and meso-architectonics;
- Development of functions using system nanoarchitectonics.

With these projects, NIMS will achieve the following technical goals by FY2022:

- Develop technologies to control and integrate nanomaterials in the range of 1~100 nanometers;
- Fabricate new high performance energy materials, such as thermoelectric materials that are made from ubiquitous elements and possess a conversion efficiency of at least 10%;
- Develop an ultra-low energy consuming high-speed nuclear film transistor that requires 1/100 of the conventional power and new atomic, molecular, and quantum device and systems technologies;
- Develop a neuromorphic material that emulates brain-like information processing and establish technologies for the systematization thereof;
- Develop a nanoarchitectonic system to deliver simple, low-invasive cancer diagnoses and treatments.

Furthermore, with regard to cultivating emerging technologies, we aim to discover specific physical properties, quantum phenomena, and reactions related to the nano-scale and express higher functions at the nano and meso-scale by way of their nanoarchitectonics. To do this, we will search for new nanomaterials and develop methods for nanomeasurement and theoretical computation as part of multifaceted basic research in cooperation with other disciplines.

As for cooperation with outside parties, even after the subsidized project for the World Premier International Research Center Initiative (WPI-MANA) concludes, we will ensure that MANA maintains the nanotechnology research networks it built and continues to serve as a hub for global intellectual circulation. In addition, we will create next-generation materials technologies and cultivate the young researchers who can promote these technologies globally with original initiatives, including theoretician-experimentalist pairing, interdisciplinary research, and ICYS-MANA. Moreover, the outcomes of research projects will be used to develop nanomaterials with an eye on their practical application and to systematize and integrate nanodevices even further as we seek to strengthen ties with industry.

(Snip)

1.1.5 Nanomaterials

- Development of functions using chemical nano- and meso-architecture

This project aims to create functions from chemical nano- and meso-architectonics. We will promote research into chemical nano- and meso- architectonics through the precise synthesis and higher-order integration of a variety of non-organic and organic nanomaterials to create new materials that exhibit advanced functionalities. To achieve this, we will combine leading-edge synthesis technologies and computational scientific approaches to synthesize new nanomaterials and establish chemical processes that sequence, integrate, and aggregate these materials from the nano- into the meso-range. These technologies will became the platform for the design of artificial nanostructures with the aim of realizing functions and effects based on these new mechanisms. Ultimately we will develop new materials and techniques that can be used for new developments in electronic, environmental, and energy technology fields, which will, in turn, serve as the keys to solving economic and social problems and realizing an ultra-smart society.

In particular, for the creation of nanomaterials, MANA’s specialization in areas such as stripping technologies, core/shell formation techniques, and template synthesis techniques will be applied to synthesize low-dimensional nanomaterials with highly controlled compositions, structures, and sizes, as well as synthesize nanoporous materials, refining the unique material functionalities inherent at the nano-scale level. Then, we will use these materials as building blocks for building design-oriented higher-order nano-structures and nanojunction interfaces to realize new technologies that work in concert between nanoparts and induce and control hybrid effects. These efforts will allow us to develop new electronics materials, energy materials and devices such as high-efficiency thermo-electric materials and nano-wire solar cells which can be used as new power storage materials that provide both high capacities and output performance.

- Development of functions using system nanoarchitectonics

In this project, we will promote research that aims to pioneer the core scientific technologies for creating new value, including technologies for realizing ultra-low power consumption information processing as well as effective, low-cost tailor-made medical technologies. To achieve this, we will develop atomic, molecular, and quantum nanodevices, develop next-generation nanoarchitectonic devices, analyze the functional emergence of nanoarchitectonic systems, and pioneer nanoarchitectonic life systems. Researchers drawn from a broad range of fields such as physics, chemistry, biology, engineering, and medicine will aim to work together in cross-disciplinary efforts to realize their goals.

In particular, for nanodevices, we will advance proposals and demonstrations of atomic, molecular, and quantum nanodevices that stand apart from conventional electronic devices, including single-molecule diodes, nanoionic function switches, nanoplasmonic devices, and room-temperature zero-resistance devices. For nanoarchitectonic next-generation devices, we will develop atomic-layer level thin-membrane transistors and superconducting devices that require 1/100 to 1/1000 the usual power to operate. We will also realize the world’s first, multi-function, high-speed multi-scanning probe microscope and analyze emerging functions of nanoarchitectonics towards the development of essential basic technologies within system nanoarchitectonics. Moreover, we will realize functional predictions of device systems by advancing large-scale first principle calculation techniques that can handle over one million atoms. Furthermore, we will strive to establish nanolife systems conducive to life innovations such as world-class portable breath diagnostic devices and cancer treatments that are minimally-invasive and free of side effects.

Operational Goals of the National Institute for Materials Science
(Seven-year Goals)

March 1, 2016

Ministry of Education, Culture, Sports, Science and Technology

(Snip)

1.1.5 Nanomaterials research and development

Nanoarchitectonics takes the functionalities expressed and the reactions induced by controlling the shape of materials at the nanometer scale and subjects them to even more higher-order control and modulation to yield functions. It is an excellent method for fabricating innovative materials that could not be achieved as an extension of conventional technologies, and it is an important core technology for creating future industries and fomenting social change.

To this end and in accordance with the aforementioned concept, for a wide range of materials from the organic to the inorganic to metals, NIMS will develop the technologies to fabricate new nanomaterials with precisely controlled compositions, structures, sizes, and shapes, and we will subject these to advanced sequencing, integration, and aggregation to yield novel functions with the artificial nanomaterials designed or constructed with this process. Our ultimate aim is to fabricate new materials and devices that will lead to innovations in electronics, environmental and energy technology, and biotechnology. Furthermore, we aim to create the next generation of emerging technologies by searching for new nanomaterials and developing methods for nanomeasurement and theoretical computation.

(Snip)

Appendix: Evaluation Axes for the National Institute for Materials Science

Research Field		Evaluation Axis	Related Evaluation and Monitoring Indicators
Basic research and fundamental R&D for materials science and technology	Functional materials	○ Have outcomes been achieved that contribute to the solution of issues that the Government set forth in the Science and Technology Basic Plan? ○ Have outcomes been achieved that contribute to realizing an ultra-smart society with an eye on creating future industries and transforming society? ○ Have basic technologies been accumulated in an effort to enhance adaptability to unforeseen future issues? ○ Has research and development been appropriately managed to maximize its outcomes?	*Evaluation Indicators* ・Progress in efforts to contribute to resolving the issues the Government needs to address ・Progress in efforts to contribute to the creation of new value with an eye on creating future industries and transforming society ・Outcomes of cross-disciplinary cooperation and cooperation between universities and industry ・Creation and administration of a management framework that allows the President to exercise his or her leadership *Monitoring indicators* ・Outcomes of research on cultivating emerging technologies / project-based research (e.g., number of articles and indicators of article quality (top 10% in number of articles published, average impact factor, etc.)) ・Outcomes of competitive research and industry-university-independent agency alliances (number and size of partner institutions)
	Materials for energy and the environment		
	Magnetism and spintronics		
	Structural materials		
	Nanomaterials		
	Analytical technologies for advanced materials		
	Materials research by information integration		
Encouraging the dissemination and utilization of research outcomes	Promoting public relations and outreach activities	○ Are efforts being actively pursued to explain materials research as well as NIMS' activities and research outcomes to the general public and gain their understanding? ○ Are efforts being made to enhance the understanding and promote the usage of NIMS' research outcomes?	*Evaluation Indicators* ・Results of efforts to enhance the understanding and recognition of NIMS' activities and research outcomes ・Results of efforts to disseminate the research outcomes of NIMS by enhancing the understanding and promoting the usage thereof *Monitoring indicators* ・Number of outreach activities to provide people at all levels of society with a broad understanding ・Number of presentations given at international symposia and academic conferences; number of submissions to and publications in academic journals
	Disseminating research outcomes and other information		

	Encouraging the use of intellectual property	○ Is intellectual property appropriately acquired, managed, and utilized? ○ Are research outcomes applied to a variety of fields?	*Evaluation Indicators* ・Results of efforts to utilize various cooperative schemes for the transfer of technology *Monitoring indicators* ・Number of intellectual property applications submitted / rights acquired and revenue generated from patents licensing fees in light of the patentability, marketability, and cost-effectiveness of said intellectual property
Activities as a core center	Shared usage of facilities and equipment	○Have we fulfilled our role as a core institution that comprehensively engages in basic research and fundamental R&D for materials science and technology? ○ Do we share our research facilities and equipment, have we fulfilled our role as a networking hub for research institutions, and are we contributing to improving the quality of Japan's materials science research? ○ Are we sustaining and developing the intellectual infrastructure to support Japan's materials research by cultivating and improving the quality of researchers and technicians? ○ Are we fulfilling our duty to further enhance the academic vitality of Japan's materials research by developing academic partnerships? ○Are we using research outcomes to create bridges to industry and proactively undertaking efforts to develop ties with industry for the commercialization of said outcomes? ○Are we regularly assessing, analyzing, taking advantage of, and disseminating national strategies and international trends in order to respond to society's demands for materials research? ○Are we cooperating with accident investigations in response to requests from public institutions and engaging in appropriate international standardization practices for the field of materials science?	*Evaluation Indicators* ・Results of efforts to cooperate with research institutes that possess shared equipment and efforts to improve technologies for support ・Results of efforts to cultivate and improve the quality of researchers and technicians ・Results of efforts to use research outcomes to create bridges to industry and efforts aimed at the commercialization of said outcomes ・Results of efforts to respond to accident investigations, undertake international standardization practices, and respond to other societal needs. *Monitoring indicators* ・Instances of research facility and equipment sharing ・Instances of cooperation with academic institutions ・Number of researchers accepted and dispatched (e.g., number of researchers employed under the Cross-Appointment System)
	Cultivating and improving the quality of researchers and technicians		
	Developing academic alliances for materials research		
	Developing alliances with industry for materials research		
	Analysis, strategic planning and information dissemination pertaining t materials research		
	Other activities as a core center		

World Premier International Research Center Initiative (WPI)

Appedex 5-3. Transition in the Number of Female Researchers

* Enter the number and percentage of female researchers in the top of each space from 2010 to 2015 and the total number of all the researchers in the bottom.

(person)

	FY2010	FY2011	FY2012	FY2013	FY2014	FY2015	Final goal
Researchers	38, 19.3%	45, 22.0%	45, 22.6%	43, 20.8%	41, 19.4%	38, 19.3%	50, 25.0%
	197	206	199	207	211	197	200
Principal investigators	1, 3.5%	2, 8.0%	2, 8.3%	2, 9.1%	2, 9.1%	2, 11.1%	3, 12%
	28	25	24	22	22	18	25
Other researchers	37, 21.9%	43, 24.0%	43, 24.6%	41, 22.2%	39, 20.6%	36, 20.1%	47, 27.0%
	169	181	175	185	189	179	175

World Premier International Research Center Initiative (WPI)
Progress Plan (For Final Evaluation)

Host Institution	National Institute for Materials Science (NIMS)	Host Institution Head	Kazuhito Hashimoto
Research Center	International Center for Materials Nanoarchitectonics (MANA)	Center Director	Masakazu Aono

* Write your report **within 6 pages**.

* Use yen (¥) when writing monetary amounts in the report. If an exchange rate is used to calculate the yen amount, give the rate.

1. Mid- to Long-term Research Objectives and Strategies Based on the Center’s Results during Funded Period

Describe new challenges in the Center’s research objectives and plans after the funding period ends. If major adjustments will be made in the Center’s operation, such as newly set research themes/objectives or a change in the director, describe the strategic background to the adjustments.

1-1. Overview

With its vision of "Pioneering a new paradigm of nanotechnology to create a research hub for the best new materials development in the world," MANA has built its new paradigm of a new concept unique to MANA: nanoarchitectonics. Now, eight and a half years later, MANA is proud to say that it has developed into the top research center in the world for new materials development. This is concisely expressed by the following indicators: In the past eight and a half years, MANA has released 3,316 papers, and 118 of these are now among the top 1% most cited papers in the world. The average Impact Factor (IF) of papers released by MANA in 2015 (466 papers total) is quite high at 6.16. Still further, MANA’s Field-Weighted Citation Impact (FWCI) score, a new index created to fairly compare the quality of papers published by different research institutions around the world, is also high at 2.42 (this refers to papers released in the period 2008-2015). MANA’s scores for these indicators are superior to those of many world-class research institutions around the globe.

In terms of research accomplishments, as well, MANA has been a world leader in producing great quantities of creative and original results. These include many proud, world-class accomplishments in fundamental research into materials science, including new artificial materials created through nanosheet technology, atomic switch research from the fundamentals through to practical applications, the invention and application of ultrasensitive/massively-parallel molecular sensors, and the development of surface/local superconductors; as well as research on practical artificial photosynthesis, from fundamentals through applications; and the development of new nano-level measuring techniques.

MANA will generally continue to maintain and continue this direction of research in the future, but it will attempt the following two new developments. After analyzing MANA’s research accomplishments thus far, the efficacy of two areas was brought into sharp relief: the fusion of “theoretical research and experimental research”, and the fusion of “nanotechnology (nanoarchitectonics) and life science”. Therefore, these two fusional areas will be the focus of intensive research in the future (refer to Sections 1-2 and 1-3 for details).

Additionally, analysis of progress on MANA’s three Grand Challenge research themes shows that promising results are in the process of emerging (refer to Section 1-4), and hence this research will also be continued.

The main parts of MANA’s research are divided into five fields: Nano-Materials, Nano-System, Nano-Power, Nano-Life—and now Nano-Theory.

Although MANA’s research has thus far been conducted, in accordance with the WPI program’s basic policy, under the leadership of center director Masakazu Aono, a new director will take over in FY 2017, the younger Takayoshi Sasaki.

1-2. Fusion of theoretical and experimental researches

Many of MANA's most outstanding research accomplishments thus far have emerged from the fusion of theoretical and experimental research. Therefore, in addition to MANA’s four traditional fields of research, MANA created in FY 2016 a fifth new field, Nano-Theory. This is explained in detail in Section 2-1 below, but the Nano-Theory field will constitute a large group of about 30 theoretical researchers.

The new Nano-Theory field will empower MANA to effectively utilize some of the world’s most advanced computers (K-computer, etc.). However, one of MANA's most important objectives is to lead the world to a new paradigm of theoretical research that is free from a prioritization of first-principles calculations over all else. Despite the fact that many interesting nanoscale phenomena are accompanied by excited states, dynamic processes, and many-body effects, contemporary methods of first-principles calculation are not necessarily good at handling these elements. To overcome this obstacle, MANA will introduce bold yet appropriate methods of approximation to inspire new developments in theoretical research. Further, this will serve to promote the fusion of theoretical and experimental research. Moreover, not only will the field of Nano-Theory serve to fuse theory and experimentation, it will also play a role in promoting interdisciplinary fusion research among MANA's four other fields of research, all of which have experimental research at their core.

One example of a research theme at MANA is the use of the K-computer or similar to perform first-principles calculations improved by CONQUEST, an ultra-large-scale computational code that MANA researchers played a key role in developing, to examine and explain electronic states and structures of large systems containing more than a million atoms. This will likely serve as a tremendous encouragement for experimental research at MANA. Despite the fact that certain processes occur frequently in the real world, it is nearly impossible to simulate those same processes on a realistic time scale using current first-principles calculation methods that attempt to explain the processes by the movements of atoms and molecules. Examples of such processes are excited states and processes with a very small probability of occurrence, at the tails of probability distributions (these processes can all cause dramatic structural changes at the atomic and molecular level). In first principles calculations, these phenomena are nothing more than “rare events,” but the real world is strongly governed by them (this is similar to the way in which biological evolution is strongly affected by spontaneous mutation, which is not easy to predict). To overcome this obstacle, researchers at MANA and their external research collaborators have recently formed a group to study rare event sampling methods, and the center strongly supports this effort. Spurred on by the theoretical research of topological insulators, which explores principles without relying on conventional computer science, a new realm of solid state physics has started to open up, and MANA researchers have contributed significantly to this development. By combining this research with MANA's outstanding nanoarchitectonics technology, MANA researchers hope to develop an entirely new world of quantum devices.

1-3. MANA's unique Nano-Life research

MANA established the Nano-Life field with the aim of opening up a new field that combines MANA's world-best nanotechnology with the life science. One important characteristic of MANA is its environment, in which the best nanotechnology researchers and life science researchers work side-by-side to gain a thorough understanding of each other's fields. This distinctive characteristic of MANA's has recently begun producing remarkable results. In the future, MANA will take advantage of these circumstances to create a Nano-Life field that is unique to MANA. MANA aims to create new, never-before-seen things and systems by studying the functions of cells (the foundation of life), sensory organs, and the brain—the most complex biological structure—and incorporating the knowledge gained through this into the best nanoarchitectonics technology. Conversely, MANA will also strongly promote the active utilization of the best nanoarchitectonics technology in Nano-Life research.

Research in this field includes, for example, a study using brain-like network circuits composed of hundreds of millions of MANA-developed synaptic atomic switches, the interesting emergent functions of which have already been detected. These circuits are used to create a materials-based prototype of an artificial brain. MANA also aims to physically apply new calculation algorithms learned from the remarkable functionality of single cells to inorganic materials. MANA has already developed ultrasensitive / massively parallel molecular sensors created based on knowledge of animal olfactory organs to enable the early detection of cancer through analysis of exhaled breath (a joint research project with the University of Basel in Switzerland). MANA also seeks to revolutionize methods for analyzing gases and liquids in a wide range of other fields by developing these sensors further. In addition, MANA is pursuing applied research for medical care, including the development of a smart polymer fiber mesh that, when applied directly to a cancer-affected location, releases anticancer drugs when prompted by an outside stimulus like an electromagnetic field external to the body.

1-4. MANA's Grand Challenge research themes

MANA has had three Grand Challenge research targets thus far:

★ Nanoarchitectonic artificial brain
★ Room-temperature superconductivity
★ Practical artificial photosynthesis

These are long-term research targets, and no achievements are expected from this research in the short term. However, certain interesting results have already emerged, and hence this research will be continued on into the future. The current state of and future plans for this research is detailed below.

★ **Nanoarchitectonic artificial brain:** It has been discovered to great interest that atomic switches, developed by MANA, have characteristics similar to synapses in the brain. When several tens of millions of such atomic switches are combined to form a network, a number of surprising properties can be observed (e.g., electrical conductivity increases and decreases randomly when a DC voltage is applied, etc.). In the extension period, MANA will utilize these interesting properties to develop new methods of computation. Experimental researchers are working closely with theoreticians on this issue where appropriate.

★ **Room-temperature superconductivity**: Researchers are attempting to change insulators and semiconductors into superconductors by physically (e.g. through field effects) introducing electrons and holes. As one example of the research being performed, MANA researchers succeeded in using field effects to introduce a hole into a diamond and metalize it, but they have not yet gotten to the point of superconductivity. Research in this direction will be continued on into the future, but a surprising theory has arisen among researchers at MANA. It has been theorized that when heavy atoms such as gold are formed into a two-dimensional buckled honeycomb lattice and an electric field is applied perpendicularly, current will flow along its edge with zero resistance, even at high temperatures up to 600 K. Experiments are underway in an attempt to verify this theory.

★ **Practical artificial photosynthesis**: MANA researchers have already succeeded in achieving several photosynthetic reactions using new photocatalysts, and next they will focus on developing systems by which to increase the efficiency of these reactions. Research is underway on systems that intensify light by effectively using plasmonic technology, already one of MANA's strong areas. In another interesting attempt, MANA researchers demonstrated high photosynthetic conversion efficiency in a system made to imitate the structure of plant leaves that actually perform such highly efficient conversion. A later study revealed that the high conversion efficiency can be attributed not only to increased surface area, but also to the three-dimensionally interconnected tunnel structure.

Now, MANA is adding a fourth Grand Challenge research target as follows.

★ **Super bio-sensing:** This target is closely related to efforts to open up a new area of study within MANA’s original Nano-Life field described above. To do this, it will be necessary to make full use of MANA’s original nanoarchitectonic sensing methods, which have not been achieved anywhere else. These methods include using multiple-probe scanning probe microscopy (STM, AFM, KFM) to analyze signaling between specifically selected points in a neural network, ultrasensitive / massively parallel molecular sensors that can sense stimuli at more than 1000x the sensitivity of human sensory organs, and bio-imaging with near-infrared light that can pass through the human body—something that has been impossible until now. The ultimate aim of this Grand Challenge goal is to generate innovation in the life sciences by striving to develop these kinds of nanoarchitectonic bio-sensing methods.

1-5. Research in the fields of Nano-Materials, Nano-System, Nano-Power, Nano-Life, and Nano-Theory

The initial four Grand Challenge fields form the core of MANA's research. In these fields, clear distinctions were made between clear opposites: e.g., fundamental vs. applied research, materials vs. systems, and inorganic materials vs. living organisms. However, these groups were intentionally organized in such a way to encourage fusion among the fields. In FY 2016, MANA has established a new fifth field, Nano-Theory, to reinforce previous theoretical research (as was explained above). Below are representative examples of the challenging research that will be undertaken in these five fields.

Nano-Materials field: This field aims to exploit the science and technology for the creation of new nanosheet-based materials that MANA has accumulated to date to realize metamaterials (e.g. a material not found in nature that possesses a negative refractive index) and room-temperature superconducting devices by using nanosheets with massive electric permittivity, etc. MANA will also develop more novel nano-measurement methods to support these kinds of research projects.

Nano-System field: This field aims to use a network of atomic switches to realize the basic unit of a nanoarchitectonic artificial brain; to achieve the world's first truly monomolecular device; to develop a new, decoherence-free quantum bit using topological insulators; to develop a room temperature superconducting device etc. MANA will also promote the development of methods to enable the measurement of local (i.e., nanometer scale) electrical conductivity at any position, something that is essential for conducting these kinds of research.

Nano-Power field: This field aims to realize highly efficient nanoarchitectonic systems in order to achieve practical artificial photosynthesis. To do this, MANA will actively promote plasmonics technology and close cooperation with researchers conducting theoretical calculations using rare event sampling methods.

Nano-Life field: As explained above in “MANA’s unique Nano-Life research,” MANA will promote the close interdisciplinary fusion of life science and nanoarchitectonics research. It is believed that some of this work will lead to technologies that can be used for diagnosis and medical care in real medical situations.

Nano-Theory field: As mentioned above in “Fusion of theoretical and experimental research,” MANA aims to develop new theoretical research techniques driven by rare event sampling instead of the high-level first-principles calculations performed on the world's fastest supercomputer like K-computer. MANA will promote the fusion of theory and experimentation in a wide range of research, including theoretical research into the latest topological insulators.

2. Management System of the Research Organization

2-1. Describe the Center’s Research Organizational Management System that will Execute the Research Strategy and Plan Described above.

- In Appendix 1, list the PIs who will ensure that the Center’s project is sustained and advanced after the funding period ends.
- In Appendix 2, diagram the Center’s organizational management system.

In April 2016, one year before the end of the 10-year project period of MANA, the next Mid-Term Plan (7-year plan) starts at NIMS and MANA implements structural reforms based on the following key points:

i) In April 2017 Dr. Takayoshi Sasaki will be appointed as the new Center Director of MANA. A new Deputy Director will be assigned later. Thus, MANA’s management will be strengthened by the current administrative troika system comprised of the Center Director, the Deputy Director and the Administrative Director (Dr. Tomonobu Nakayama). Dr. Masakazu Aono, a former Center Director, and Dr. Yoshio Bando, a former Chief Operating Officer (COO), will provide advice to MANA on research and management.

ii) PIs will be replaced to breathe new life into the ranks of PIs. Associate PIs will be promoted to PIs, and new PIs will be appointed in connection with the establishment of the new Nano-Theory field and the strengthening of the Nano-Power and Nano-Life fields. Young researchers will be considered for these positions. The performance of all PIs will be evaluated by professionals from outside MANA.

iii) MANA will maintain its satellites, which have contributed significantly to MANA's achievements by raising the quality of research, training young researchers, and internationalizing the center, among other things.

iv) MANA will establish a new Nano-Theory field staffed by roughly 40 theoreticians. 30 researchers from the NIMS Computational Materials Science Unit were moved to the new Theoretical Research Building (next to the WPI-MANA Building) will be combined with MANA’s more than a dozen theoreticians. As a result, nearly one-fifth of MANA's researchers will be theoreticians. MANA will establish a Theory-Experiment Pairing (TEP) Program to enforce the fusion of theoretical and experimental research. In general, every theoretician will be paired with an experimentalist. These pairs will work together on various research topics. It is hoped that this system will dramatically accelerate the formation of links between theory and experiment, and stimulate further progress of nanoarchitectonics research.

v) Nano-mechanical sensors and other top nanoarchitectonics technologies will be combined with Nano-Life research to promote Nano-Life research that is unique to MANA. Researchers in the Nano-Life field will be replaced and new researchers hired.

vi) Aiming to achieve the four goals of the MANA Grand Challenges, MANA will strategically invest research resources (e.g., research funds, post-docs etc.) into these topics. MANA will also invite guest researchers to lead workshops and brainstorming sessions on specific topics (e.g., atomic switches, nanosheets, nano-mechanobiology, etc.).

vii) MANA will continue encouraging efforts to tackle innovative and challenging topics, as well as conduct interdisciplinary research by holding Grand Challenge Meetings and setting up special funding programs. In particular, MANA will engage in efforts to acquire research funding through collaboration with universities.

2-2. Initiatives and Plans that will Impel System Reforms

Describe the Center's action plan that embodies the basic policies of the National University Reform Plan or Independent Administrative Agency Reform Plan, and the Center's plan and strategies that lead to host institution reforms either directly or via ripple effects (also to other institutions, if applicable). Describe also the Center's strategies for fostering and securing the next generation of researchers (e.g., introduction of tenure tracks), and the system for enhancing the Center's organizational management, such as the implementation/verification PDCA system.

a) Reforming NIMS

The administrative experience cultivated at MANA, including the culture of encouraging fusion research, the methods used for recruiting and training outstanding young researchers, and the unique administrative and technical support systems, will be exported to NIMS.

b) Internationalization of NIMS and other Japanese research institutions and universities

It can be said that NIMS's efforts toward internationalization, of which MANA is the central model, have been brought to a mostly successful conclusion during the third five-year plan. In the future, there will be an effort to export MANA's research environment to other research institutions and universities outside of NIMS.

First, MANA will compile the internationalization knowledge and experience that has been accumulated to date, publishing it online and in print. Workshops will be concurrently held on internationalization, an e-mail consultation service has started, and on-demand seminars are planned. It is also believed that understanding is increased by direct exposure to the tangible and intangible assets that have been amassed on the WPI Project. So a training course on internationalization will be established at MANA with participants invited from universities and research institutions around Japan.

c) Expanding the international network

Over the past nine years, MANA has grown into a well-known world-class research center that attracts researchers from around the globe, and the recognition of our name has increased. This is evident from the increasing number of requests to visit MANA received from government agencies from around the world, and from researchers who want to hold joint workshops. Additionally, many young researchers who have worked at MANA are now doing research at institutions throughout the world.

In this way, MANA is well on its way to achieve its mission of becoming the hub of a global network of research centers. But MANA will continue more than ever before to strengthen its cooperative ties with top-tier universities and research institutions in developed nations and further promote research and personnel exchange with them.

Meanwhile, many developing countries in Asia, the Middle East, and Africa have requested educational guidance from MANA. As a government research institution, MANA researchers believe they have a duty to respond to these requests, and hence educators will be invited for the purpose of training researchers and technical support staff in these countries.

Through these activities, MANA will expand its international network beyond just the advanced countries of America and Europe to include many countries and regions of the world.

3. Center's Position within Host Institution and Measures to Provide It Resources

Describe the Center's future plans with regard to the following points after the funding period ends.

3-1. From a Mid- to Long-term Perspective, the Position of the Center within the Organization of the Host Institution

Describe where the Center will be placed within the host institution's overall organizational strategy under the leadership of the institution's president.

- In Appendix 3, diagram the Center's position within the organization of the host institution, and describe that positioning using excerpts from the institution's mid- to long-term plan. If the plan has not been established yet, describe the consideration being given to the Center's positioning.

NIMS's 4th Mid- to Long-Term Plan is a 7-year plan, and it has begun in April 2016, one year earlier than the conclusion of the WPI project implementation period (10 years) for MANA. At the end of March 2016, a plan was decided upon by which necessary adjustments and corrections would be made to MANA's organization, systems, research fields, etc. It was decided that even after the end of the 4th Mid- to Long-Term Plan (7-year plan), MANA continues to be NIMS's main nanotechnology research center, as well as take in most of NIMS's theoretical researchers and continue to preserve the strength of that roster. Specifically, in the seven years beginning in April 2016, seven research centers will exist within NIMS, and one of those will be MANA. The name of the center will remain “International Center for Materials Nanoarchitectonics (MANA),” just as it had been during the WPI project period, and it will be responsible for 2 of the 10 research projects that NIMS will implement over the course of the Mid- to Long-Term Plan. The number of permanent MANA staff members has increased substantially as of April 2016 compared to the 90 such personnel on staff at the end of March. Compared to the previous reduction in staff that coincided with the revision of work in the Nano-Life field, the new additions are substantial due to establishing Nano-Theory field, strengthen superconductor research, and the placement of four new hires. As a result, MANA’s permanent staff count has climbed to 104 people.

3-2. Host Institution’s Action Plan for Sustaining and Advancing the Center as a World Premier International Research Center (e.g., positioning, financial resources)

Regardless of whether the WPI program grant is extended or not, NIMS has already promised to provide MANA with the following resources and continue its basic activities.

i) Approximately 90 core members, including principal investigators, associate principal investigators, group leaders, MANA researchers, independent researchers, and administrative staff will be assigned to MANA as “permanent employees of NIMS assigned to MANA.” There is no change to this plan, but it has been determined that more than 90 staff will join in April 2016, for a total of 104 permanent staff.

ii) R&D expenses required to sustain basic and fundamental research at MANA such as research project expenses, MANA Foundry operation expenses, fees for inviting and dispatching researchers, facility utilities, and other expenses necessary in performing fundamental / foundational research (1.6 billion JPY for FY2016) will be contributed out of NIMS’s management expenses grant.

After the WPI program concludes, in addition to i) and ii) above, it will be important for MANA to secure post-docs, students, and staff in addition to closely examining the various programs that give MANA its unique character and introducing new such initiatives. As such, NIMS intends to take the following measures.

iii) Post-doctoral scholars and other fixed-term staff hired using WPI grant funds will be replaced with others hired using external funding. To do this, it will be necessary strengthen efforts to promote challenging and interdisciplinary fusion research, and work to raise research potential in a way that leads to a massive increase in external funding. As a part of these efforts, we will strengthen its research connections with the University of Tokyo, the Tokyo University of Science, and other Japanese universities and research institutions.

iv) Programs characteristic of MANA—such as young researcher training programs (ICYS-MANA, etc.), symposiums, and outreach activities—will be transferred to and implemented at NIMS.

v) NIMS will implement organizational reforms such as establishing administrative offices in research divisions and establishing local campus technical support stations, scrutinizing and strengthening its own systems with reference to the administrative and technical support that are of especially high quality at MANA.

vi) After the end of the WPI program subsidies, establishing an Open Innovation Center (tentative) in NIMS is under consideration that will work together with external institutions on practical applications research pertaining to promising research accomplishments at MANA. This will serve to develop MANA’s research, including everything from fundamental research through practical applications research. Also, NIMS is planning to propose a new scheme for internationalization which absorbs a large part of international network which has been developed by MANA, greatly helping sustainable operation of MANA.

World Premier International Research Center Initiative (WPI)

Appendix 1. List of Principal Investigators for Progress Plan

- If the number of principal investigators exceeds 10, add columns as appropriate.
- Place an asterisk (*) by the name of the investigators who are considered to be ranked among the world's top researchers.
- Give age as of 1 April 2017
- For investigators who cannot participate in the center project from its beginning, indicate the time that their participation will start in the "Notes" column.

This is a tentative list and all the PIs will be peer-reviewed by outside professionals.

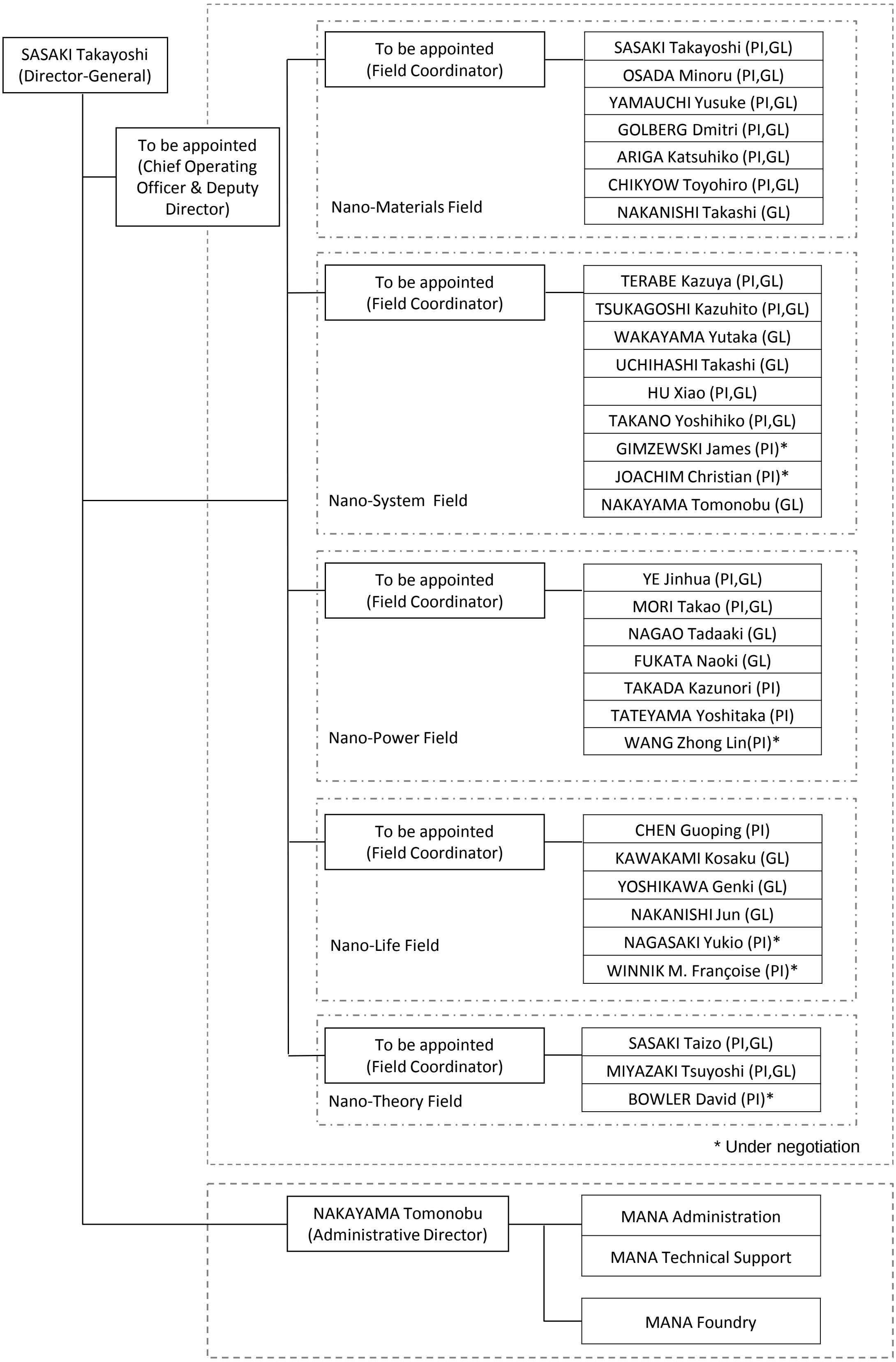
Name	Age	Current affiliation (organization, department)	Academic degree and current specialties	Notes (Enter "new" or "ongoing")
1. SASAKI, Takayoshi*	61	Director-General, International Center for Materials Nanoarchitectonics (MANA)	Ph.D. (Science) University of Tokyo, 1986 Nanosheet and soft chemistry	Ongoing
2. OSADA, Minoru	47	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Tokyo Institute of Technology, 1998 Nanosheet Functionality	Ongoing (FY2016～)
3. YAMAUCHI, Yusuke	36	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Waseda University, 2007 Mesoscale Materials Chemistry	Ongoing (FY2016～)
4. GOLBERG, Dmitri*	56	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Moscow Institute for Ferrous Metallurgy, 1990 Nanotubes and nanowires	Ongoing
5. ARIGA, Katsuhiko*	54	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Tokyo Inst. Tech., 1990 Supramolecular chemistry and surface science	Ongoing
6. CHIKYOW, Toyohiro	58	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Waseda University, 1989 Semiconductor and electric materials	Ongoing
7. TERABE, Kazuya	54	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Nagoya University, 1992 Nanoionics	Ongoing (FY2016～)
8. TSUKAGOSHI, Kazuhito	49	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Osaka University,1995 Nano electronics	Ongoing

9. HU, Xiao	55	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. (Physics) University of Tokyo, 1990 Condensed matter physics	Ongoing
10. TAKANO, Yoshihiko	51	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Yokohama City University, 1995 Superconducting materials	Ongoing (FY2016～)
11. GIMZEWSKI, James K.*	65	Dinstinguished Professor, Chemistry & Biochem. Dept., UCLA Director, Nano/Pico Characterization Lab, UCLA California NanoSystems Inst.	Ph.D. (Physical Chemistry) Univ. of Strathclyde, 1977 Nanoscience and nanobio	Ongoing
12. JOACHIM Christian*	59	Centre National de la Recherche Scientifique (CNRS) Lab: CEMES (UPR8011) Toulouse (France)	Ph.D. in Applied Mathematic Ph.D. in Quantum physics, computer science and nanoscience	Ongoing
13. YE, Jinhua*	54	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. University of Tokyo, 1990 Photocatalyst, eco-materials	Ongoing
14. MORI, Takao	50	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. University of Tokyo, 1996 Thermoelectric materials	Ongoing (FY2016～)
15. TAKADA, Kazunori*	55	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Osaka University, 1986 Solid-state chemistry	Ongoing
16. TATEYAMA, Yoshitaka	46	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. University of Tokyo, 1998 Condensed matter theory	Ongoing (FY2016～)
17. WANG, Zhong Lin*	55	Professor, School of Materials Science and Engineering, Georgia Institute of Technology	Ph.D. Arizona State University, 1987 Nano chemistry and nanodevices	Ongoing
18. CHEN, Guoping	51	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Kyoto University, 1997 Biomaterials and tissue engineering	Ongoing
19. NAGASAKI, Yukio*	57	Professor, Department of Materials Science and Master’s Master's School of Medical Sciences, University of Tsukuba	Ph.D. Tokyo University of Science, 1986 Biomaterials and polymer chemistry	Ongoing

20. WINNIK, Françoise M.*	65	Faculty of Pharmacy and Department of Chemistry, University of Montreal, Canada	Ph.D. (Chemistry) Univ. of Toronto, 1979 Polymer chemistry and photochemistry	Ongoing
21. SASAKI, Taizo	58	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. Tohoku University, 1987 Condensed matter theory	Ongoing (FY2016～)
22. MIYAZAKI, Tsuyoshi	50	International Center for Materials Nanoarchitectonics (MANA)	Ph.D. University of Tokyo, 1995 First-principles calculations	Ongoing (FY2016～)
23. BOWLER, David	46	Condensed Matter and Material Physics, University College London, UK	Ph.D. Oxford University, 1997 Condensed matter theory and calculations	Ongoing (FY2016～)

World Premier International Research Center Initiative (WPI)

Appendix 2. Diagram of Center Management System



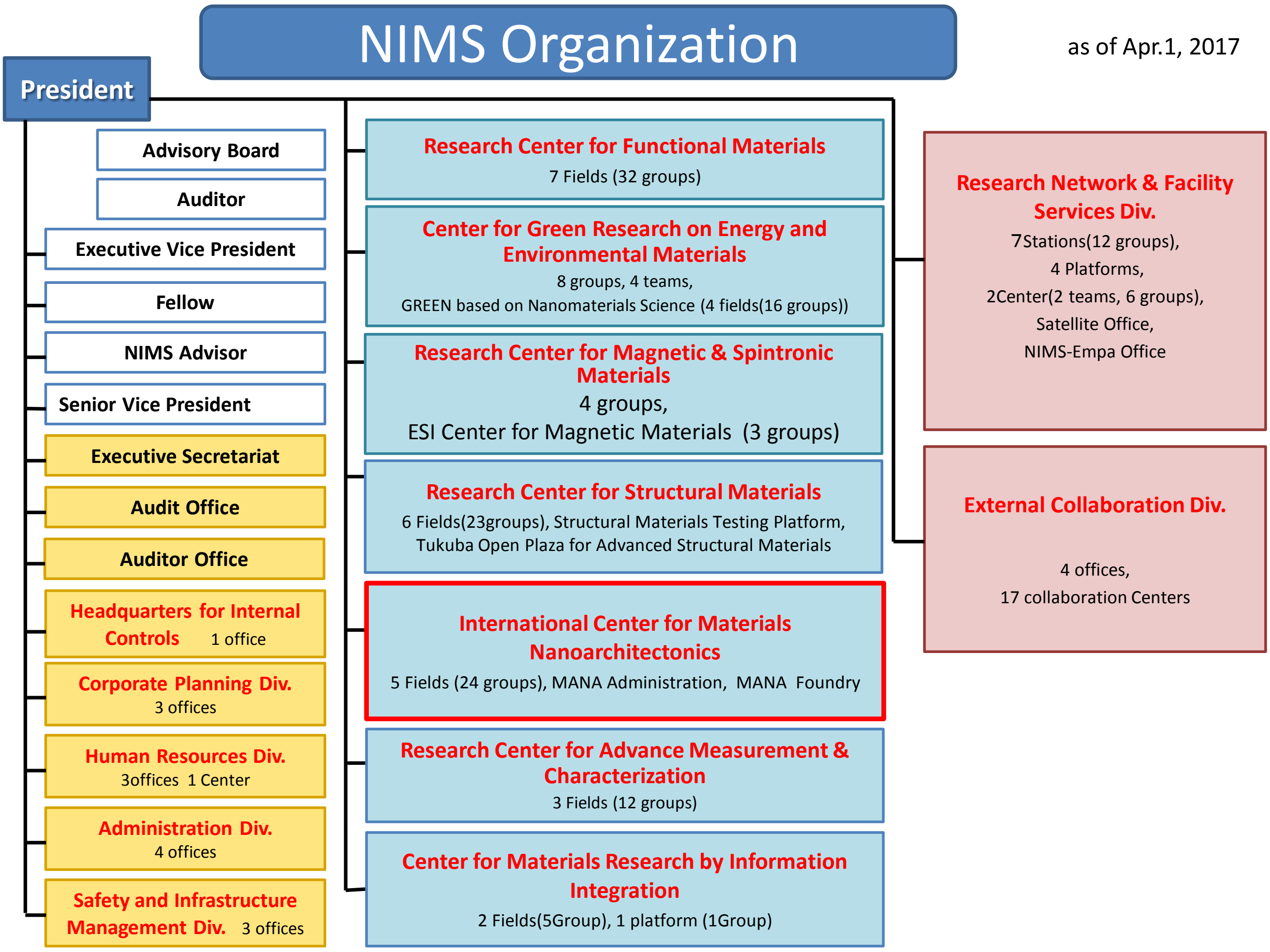
AONO Masakazu (former Center Director) and BANDO Yoshio (former COO) give advices to MANA on research and management.

World Premier International Research Center Initiative (WPI)

Appendix 3. Position of the Center within Host Institution

* Diagram the Center's position within the organization of the host institution, and describe that positioning using excerpts from the institution's mid- to long-term plan. If the plan has not been established yet, describe the consideration being given to the Center's positioning.

From April 1st, 2016, MANA is positioned as one of the seven NIMS's research centers. In the NIMS's Seven-Year Plan (FY2016-FY2022), MANA's development of innovative new materials and systems based on the unique concept of "nanoarchitectonics" is recognized as an important direction of NIMS's strategy. At the same time, MANA is the only center which has a word "international" in the name of center. MANA is definitely a core part of the NIMS and expected to be the leading research center by its world-top level research and internationality.



as of Apr.1, 2017

World Premier International Research Center Initiative (WPI)

Appendix 4. Resource Allocation Plan for Sustaining and Advancing the WPI Center

Annual Plans (FY 2017 – FY 2021)

<Fund > **(million Yen)**

Fiscal Year	**2017**	**2018**	**2019**	**2020**	**2021**
- WPI grant	-(*)	-(*)	-(*)	-(*)	-(*)
- Funding from host institution	**1600**	**1600**	**1600**	**1600**	**1600**
(details)					
Personnel	900	900	900	900	900
Project activities	340	340	340	340	340
Travel	20	20	20	20	20
Equipment	30	30	30	30	30
Other research projects	300	300	300	300	300
Costs of Satellites	10	10	10	10	10
- Funding from external sources	**800**	**800**	**850**	**850**	**900**
Total	**2400**	**2400**	**2450**	**2450**	**2500**

<Personnel> **(person)**

Fiscal Year	**2017**	**2018**	**2019**	**2020**	**2021**
- Personnel resources from host institution	**188**	**188**	**193**	**193**	**198**
- Faculty members (including researchers)	**104**	**104**	**104**	**104**	**104**
Full-time	100	100	100	100	100
Concurrent	4	4	4	4	4
- Postdocs	**35**	**35**	**40**	**40**	**45**
- RA etc.	**35**	**35**	**35**	**35**	**35**
- Research support staffs	**4**	**4**	**4**	**4**	**4**
- Administrative staffs	**10**	**10**	**10**	**10**	**10**

(*) Do not include expected grant.
- When entering amounts, round down numbers to the first decimal.
- When funding is stated in a range between two amounts, explain the reason for the lower and upper amounts and fluctuations between them.

< Measures to be implemented from FY 2017>

– Strategy and action plan for allocating personnel (posts) , space, and others measures required for the Centers' Progress.

NIMS plans to maintain the MANA research workforce of about 110 permanent staffs (scientists, engineers and administration staffs) after the WPI program concludes. To promote diversification of the research workforce, we will try to hire no less than 50% Non-Japanese and no less than 25% female scientists especially when we hire postdocs. Also NIMS plans to maintain or even increase the size of MANA by hiring several permanent researchers every year.

NIMS has allocated the two buildings to MANA: MANA Building (12,934m^2) in October 2008 and WPI-MANA Building (7,629m^2) in April 2012. NIMS renovated an old building (519m^2) adjacent to the two MANA Buildings and reopened it as Theoretical Research Building in April 2014. NIMS allocates this building to MANA in April 2016 when NIMS moves a large part of theoreticians from NIMS's Computational Materials Science Unit to the new Nano-Theory Field of MANA.

MANA continues tremendous efforts to increase the amount of funding from external sources, such as CREST, PRESTO, and Kakenhi grants by promoting strategic research collaborations between MANA and major universities in Japan. Also, MANA will explicitly participate in the NIMS's strategy to realize open-innovation with private companies to increase investment from the companies.