



Nano Revolution  
for the Future

# MANA

INTERNATIONAL CENTER  
FOR MATERIALS  
NANOARCHITECTONICS



# MANA's Vision

Toward a better global future:  
Pioneering a new paradigm in materials development  
on the basis of "nanoarchitectonics"

## MANA's Mission

- ▶ Develop groundbreaking new materials on the basis of "nanoarchitectonics"
- ▶ Create a "melting pot" where top-level researchers gather from around the world
- ▶ Foster young scientists who battle to achieve innovative research
- ▶ Construct a worldwide network of nanotechnology research centers

### Cover Art : A Colorful Meeting

Self-assembled fibers of a  $\pi$ -donor- $\pi$ -acceptor compound formed spontaneously at the exterior of a liquid droplet and grew towards its interior. This photomicrograph was obtained using cross-polarized optical microscopy.

International Center for Materials Nanoarchitectonics (WPI-MANA)

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A Message from the Director  
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The new  
**MANA's mission**

Nano Revolution  
for the Future  
**Takayoshi Sasaki**



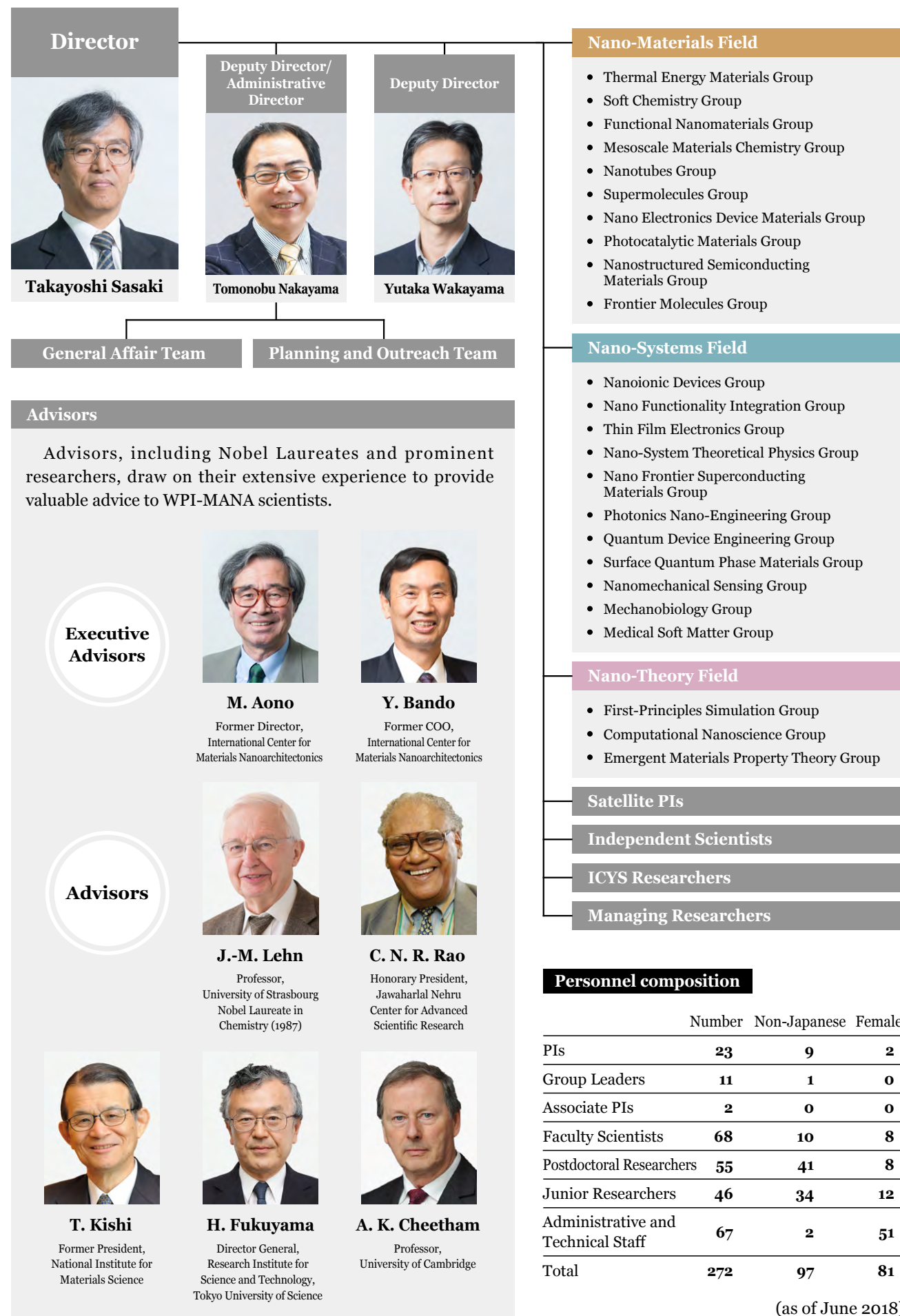
The International Center for Materials Nanoarchitectonics (WPI-MANA) has been established at NIMS in 2007 in the framework of the World Premier International Research Center Initiative (WPI), which is sponsored by Japan's Ministry of Education, Culture, Sports, Science and Technology (MEXT). Thanks to the great effort and support of many people over 10 years, we are proud that WPI-MANA has grown into a representative international research center in the fields of nanotechnology and material science, both in name and reality. It is needless to say that for the sustainable development of human society, innovative technologies that are based on discovery and creation of appropriate materials play a crucial role to solve various problems. In recent years, nanotechnology has made astonishing progress and became a modern pillar of materials discovery and development. WPI-MANA is pursuing innovation on the basis of our concept of "nanoarchitectonics," where

new materials and functions are created by rationally integrating and joining nanoscale parts. "Nanoarchitectonics" has now grown into a concept that is accepted around the world.

As the 10 year WPI funding has ended, WPI-MANA is strongly required to grow and develop further, and to continue world leading research activities as an international hub institute for nanotechnology research. We are well aware of it and will continue to deepen and pursue our "nanoarchitectonics." In connection with it, we are striving for new horizons such as heterojunction of dissimilar materials, close cooperation between theory and experiment, and challenge of large scale and complex systems. All of these are considered to be key research for our "nanoarchitectonics" to demonstrate its real value. We look forward to your continued support for further development of WPI-MANA.

*Takayoshi Sasaki*





## World Premier International Research Center Initiative

Aiming to be highly visible research centers

In recent years, a competitive search for the most talented minds has been advancing rapidly around the world. This trend in human resources is known as "brain circulation."

Japan, too, needs to create a place at the forefront where researchers from around the world can gather as part of this global movement of human resources. In 2007, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) established the World Premier International Research Center Initiative (WPI) Program to promote Japan's presence as a powerhouse of science and technology.

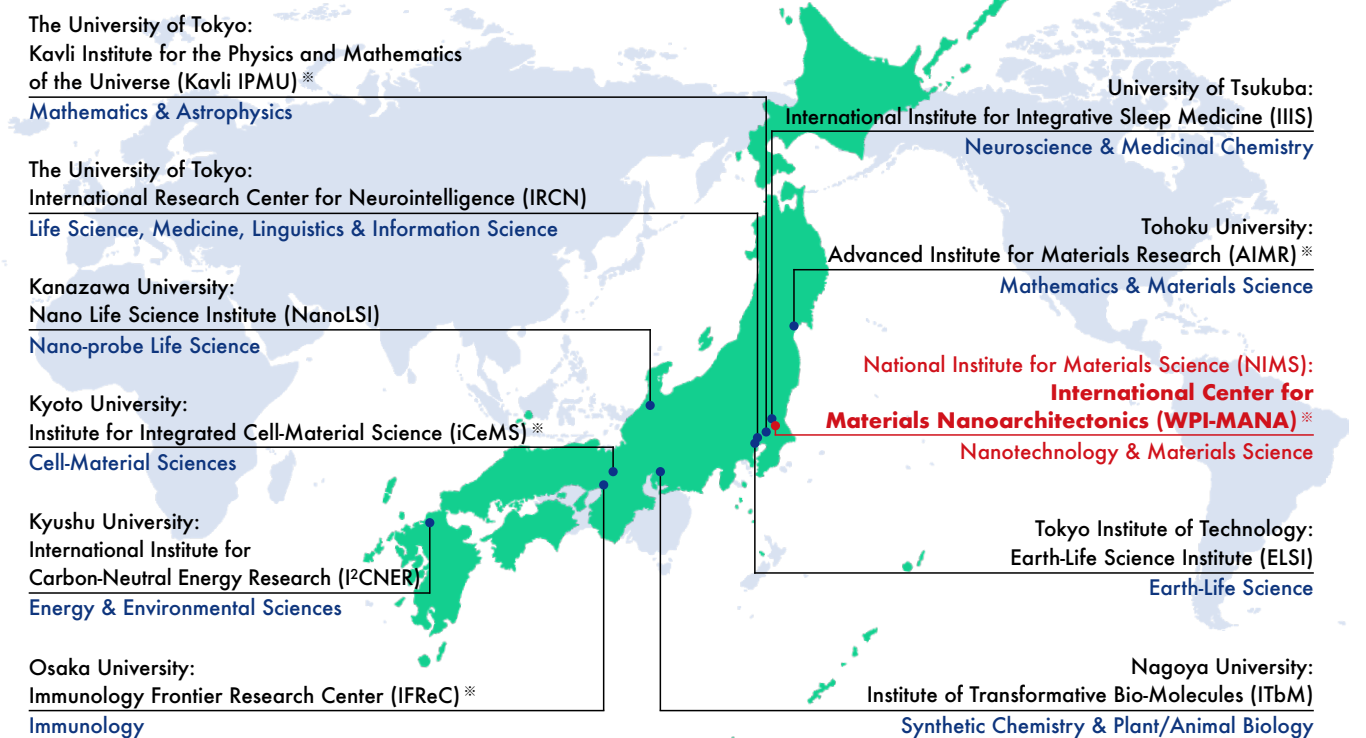
To date, eleven research centers have been selected as WPI centers by meeting these four requirements: the world's highest level of research standards, creation of interdisciplinary research fields, implementation of an international research environment, and openness to reform in the research organization. In 2017, five of eleven WPI centers were certified to have achieved world premier status, and identified as WPI Academy centers after the 10-year subsidy.

WPI centers serve as models of research institutes in Japan, and are expected to bring innovations in science and technology.



World Premier International  
Research Center Initiative

WPI research centers, the highest peaks  
where the world's top researchers gather.



(※ WPI Academy member)



# Our Research Concept

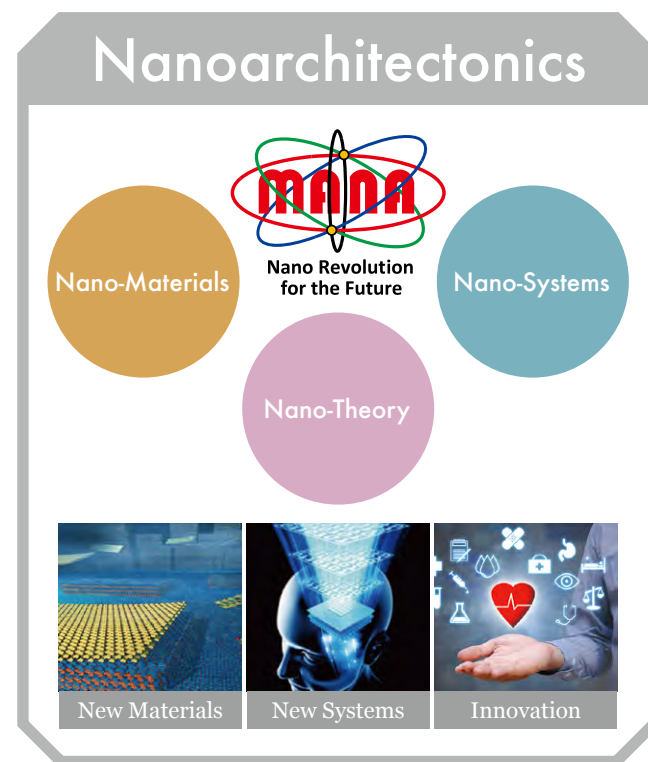
## What is Nanoarchitectonics?

### The New Paradigm of Nanotechnology

Nanotechnology plays an extremely important role in the development of new materials. Yet, nanotechnology tends to be misunderstood as a simple extension of the conventional microtechnology that has demonstrated great effectiveness in micro-fabrication of semiconductor devices—in other words, as a refinement of microtechnology. In fact, however, nanotechnology and microtechnology are qualitatively different. At WPI-MANA, we call the new paradigm of nanotechnology, which correctly recognizes this qualitative difference, "Nanoarchitectonics."

#### Grand Challenges

- ▶ Nano Perceptive System
- ▶ Nanoarchitectonic artificial brain
- ▶ Room-temperature superconductivity
- ▶ Practical artificial photosynthesis



#### Four key points of Nanoarchitectonics

##### "Unreliability-tolerant reliability"

In the world of microtechnology, structures can be constructed according to a design drawing or "blueprint." This is generally not possible in the world of nanotechnology because the world of nanotechnology is far smaller than that of microtechnology. In nanotechnology, thermal and statistical fluctuations become apparent, and at the same time, nanotechnology confronts the limits of the principles of control methods. Therefore, the viewpoint of realizing reliable functions with structures that contain ambiguity is important.

##### "More is different"

In complex systems that consist of an enormous number of nanoparticles, unexpected new functions often emerge in the system as a whole. Therefore, utilizing and not overlooking, the phenomenon that "quantity changes quality" is another key point.

##### "From nano-functionality to nanosystem-functionality"

Nanoscale structures (nanoparts) frequently display interesting new properties, but there are limits to their functionalities, either as individual units or as simple aggregates. Thus, creating completely new functionalities by effectively utilizing interactions among nanoparts of the same type or different types is important.

##### "Truth can be described with plain words"

Finally, it is also necessary to pioneer a new theoretical field, which is capable of handling the three above-mentioned points. In this, it is necessary to construct a theoretical system that not only treats atoms, molecules, electrons, photons, spin, etc. on a first-principles basis, but also consciously introduces "appropriate bold approximation."

Research Field: 01

## Nano-Materials

Takao Mori  
Field Coordinator

Creating new materials and eliciting novel functions  
by sophisticated control of compositions  
and structures at the nano level

Making full use of WPI-MANA's advanced chemical synthesis technologies, beginning with soft chemistry, supermolecular chemistry and template synthesis, we are researching the creation of new materials such as nanotubes, nanowires, and nanosheets. Based on a wide range of material systems, spanning both organic and inorganic materials, we aim to discover novel physical properties and phenomena arising from size and shape in the nanometer range. WPI-MANA also develops and owns cutting-edge characterization facilities, including an integrated system of the transmission electron microscope with the scanning probe microscope, and is actively using these instruments for *in-situ* analysis of individual nanomaterials. In addition, we are promoting chemical nano- and mesoarchitectonics, in which these nano materials are precisely arranged, integrated and hybridized in the nano-to-meso range. By constructing artificial nanostructured materials in a designed manner, our aim is to create new materials that will exhibit advanced, innovative functions, and contribute to progress in a wide range of technological fields, including electronics, energy and the environment.

#### Research Groups

Thermal Energy Materials Group

Soft Chemistry Group

Functional Nanomaterials Group

Mesoscale Materials Chemistry Group

Nanotubes Group

Supermolecules Group

Nano Electronics Device  
Materials Group

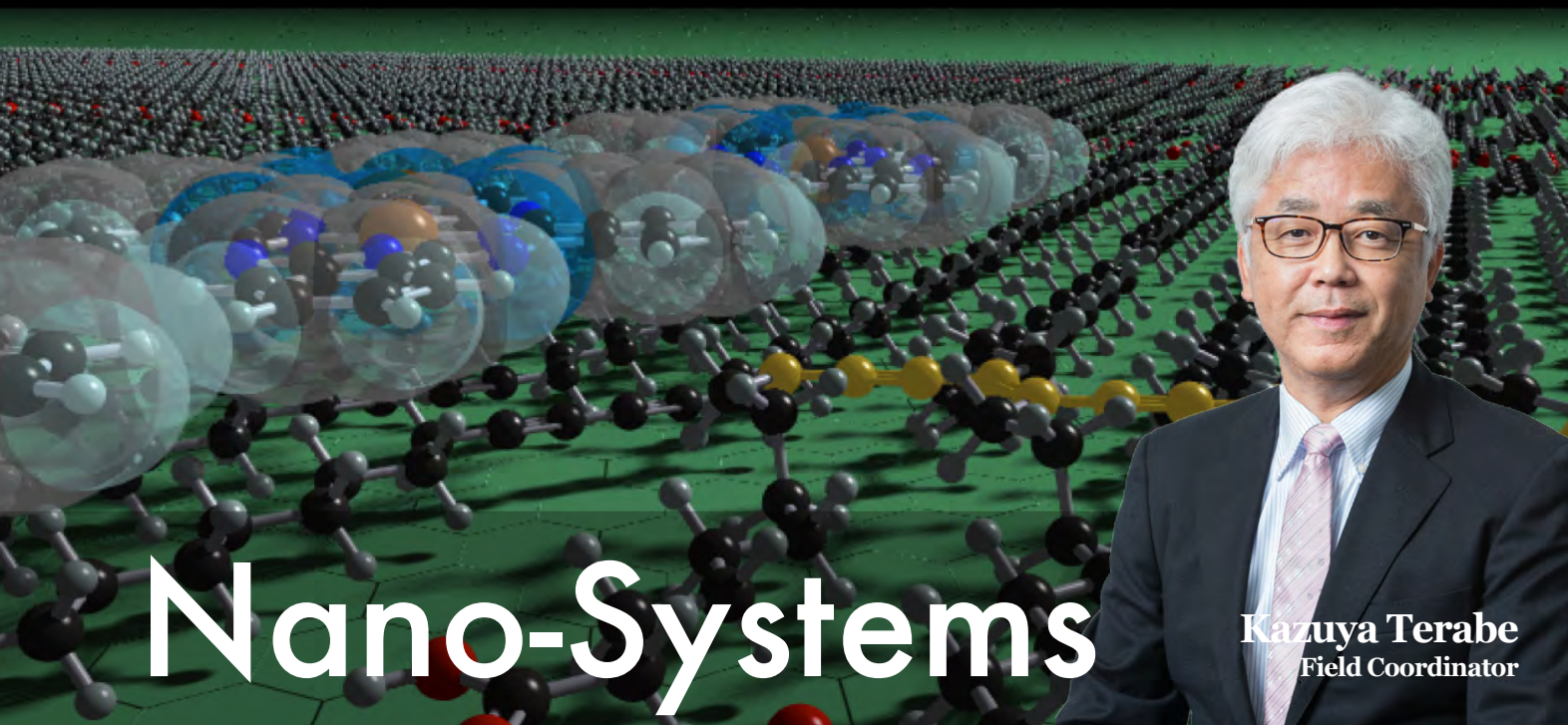
Photocatalytic Materials Group

Nanostructured Semiconducting  
Materials Group

Frontier Molecules Group







# Nano-Systems

**Kazuya Terabe**  
Field Coordinator

New nano-systems are changing the world:  
from artificial intelligence to energy and  
the environment, diagnosis and medicine

This research field is searching for various nano-systems that will express novel functions by the interaction of nanostructures with unique characteristics, and is engaged in research to utilize those new nano-systems systematically. Concretely, based on basic research on nanoscale materials, such as atomic and molecular transport and chemical reaction processes, polarization and excitation of charge and spin and superconducting phenomena, we are conducting research on atomic switches, artificial synapses, molecular devices, new quantum bits, neural network-type circuits, next-generation devices, high sensitivity integrated molecular sensors and other new applied technologies. Since the development of new nanoscale measurement methods is also a high priority, we are developing multi-probe scanning probe microscopes and other cutting-edge instruments. We also attach great importance to interdisciplinary fusion-type research with other research fields.

## Research Groups

Nanoionic Devices Group

Nano Functionality Integration Group

Thin Film Electronics Group

Nano-System Theoretical Physics Group

Nano Frontier Superconducting  
Materials Group

Photonics Nano-Engineering Group

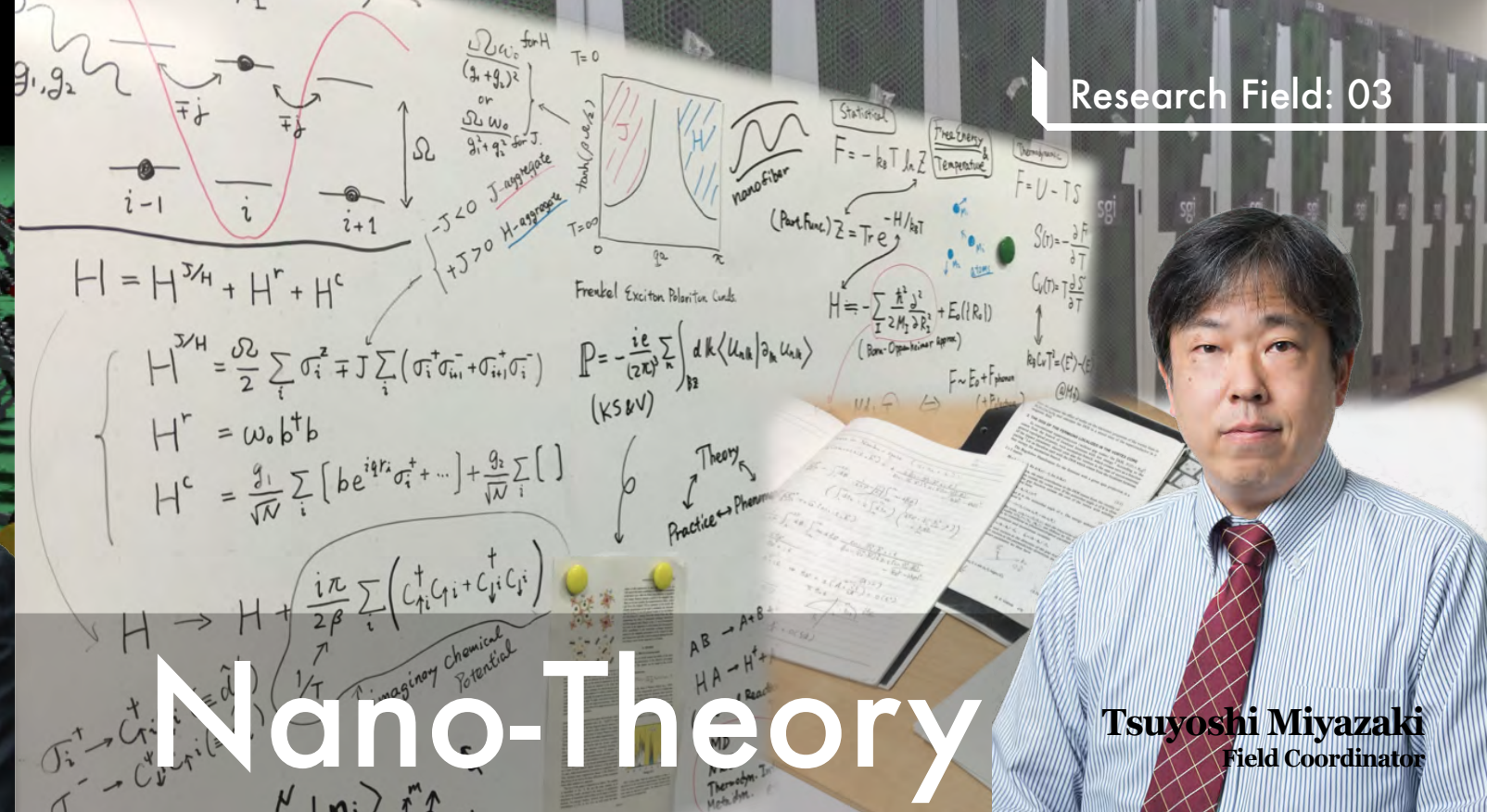
Quantum Device Engineering Group

Surface Quantum Phase Materials Group

Nanomechanical Sensing Group

Mechanobiology Group

Medical Soft Matter Group



# Nano-Theory

**Tsuyoshi Miyazaki**  
Field Coordinator

Understanding phenomena in the  
nanospace region, predicting new phenomena  
and creating novel nanostructured materials

Nanospace is a world in which common sense does not apply, where extremely small atoms are in motion, and electrons fly about in an even smaller space. Moreover, when huge numbers of these atoms and electrons act in coordination, they come to display behavior markedly different from those of single electrons and atoms. Ways of thinking and methods that are not bound by everyday common sense—namely, quantum mechanics and statistical mechanics—are essential for a proper understanding of the phenomena that occur there, and further, for devising new materials. Key activities in the field of nano-theory, which help achieve an understanding of the myriad phenomena emerging in nanospace, include building fundamental theories behind these novel behaviors by incorporating quantum mechanics and statistical mechanics, using our supercomputing facilities to obtain quantitative numerical predictions and develop new and efficient calculation methods. Besides providing interpretations of results obtained in other nanofield areas, we aim at invoking the outcomes of our research to predict as yet unearthed phenomena and to propose new materials featuring novel properties.

## Research Groups

First-Principles Simulation Group

Computational Nanoscience Group

Emergent Materials  
Property Theory Group



Theoretical Research Building



# Globalization

## Satellite Laboratories: International Nanoarchitectonics Research Laboratories

**W**PI-MANA introduced the "Satellite Laboratories" system to implement the internationalization of our research environment. WPI-MANA invited prominent researchers as Satellite PIs, and established satellite laboratories at each research institute. These laboratories are not just for collaborative research, but they also provide young researchers at WPI-MANA an international research training ground, with satellite PIs working as their mentors.

In 2018, MANA has established two new satellite, so totally has seven satellite laboratories around the world, and the proportion of satellite PIs has exceeded a quarter of the total number of PIs of MANA.

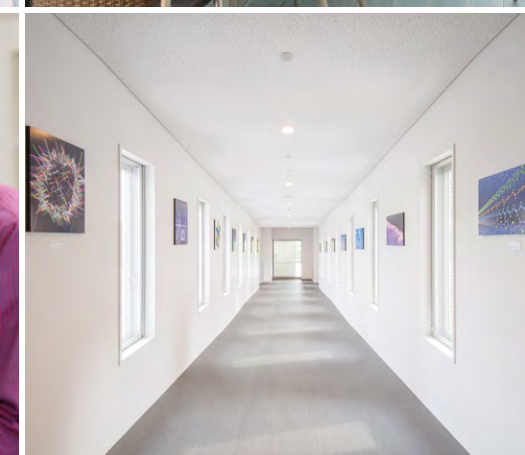
Through the international network built with satellite laboratories, WPI-MANA increases its international presence as a hub institute gathering knowledge, information, and human resources on nanotechnology.



## Melting Pot Environment: Catalysts for Interdisciplinary Research

**W**PI-MANA focuses on providing a "Melting Pot Environment" where many researchers from different research fields, cultures, and nationalities gather. This approach fosters a creative research environment by removing various barriers among researchers. WPI-MANA's research buildings feature cafeterias and interaction spaces on each floor for researchers to communicate with each other. Even in their research office and laboratory, there are no walls to hinder their communication. This free communication and exchange of opinions cultivates ideas of interdisciplinary research.

Approximately half of researchers enrolled in WPI-MANA are foreign nationals. WPI-MANA provides a variety of support for them. The administrative office is composed only of staff who can speak English, and all necessary procedures can be done in English. We also provides opportunities to deepen their understanding of Japan through Japanese language and culture classes.





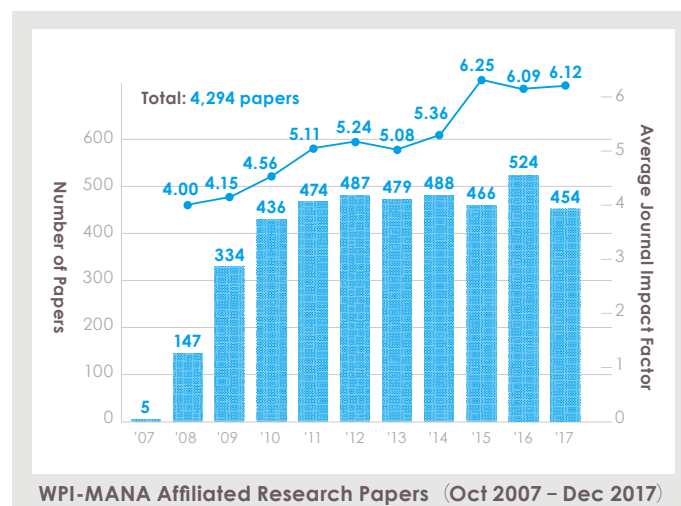
# MANA in Numbers

## Number of Papers and The Average Impact Factor

6.12

From 2007 to 2017, WPI-MANA researchers published 4,294 papers in total. In 2017, WPI-MANA researchers published a total of 454 papers. The average impact factor\* of the journals in which these papers were published was 6.12 in 2017, which reflects the high quality of research results at WPI-MANA.

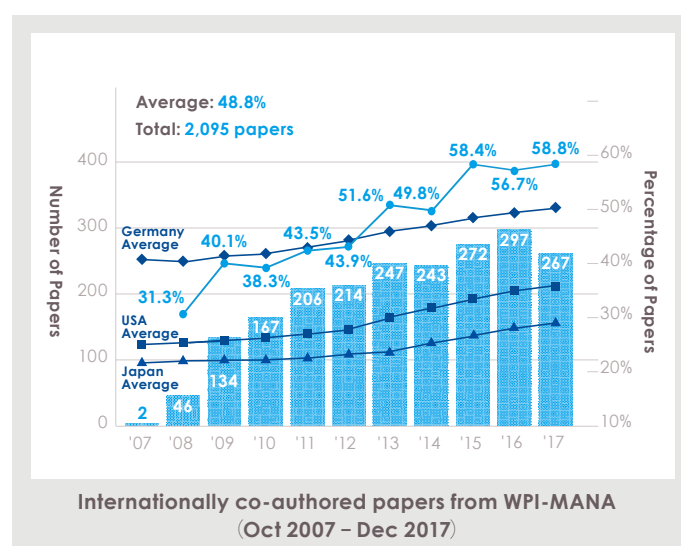
※ Impact Factor: The degree of influence is measured and numerically expressed based on the frequency of citation of published articles in scholarly journals.



58.8

## Proportion of Internationally Co-Authored Papers

The proportion of international co-authored papers of WPI-MANA has been showing an increasing trend since 2008. More than half of the total number of papers since 2015 have been internationally co-authored. In 2017, it reached 58.8% and this number represents the internationality of WPI-MANA.



154

## Top 1% Papers Highly Cited Researchers

Among the 4,293 papers published by WPI-MANA in 2007-2017, 154 papers are Highly Cited Papers (top 1% papers) based on Web of Science database. ISI Highly Cited Researchers are authors of many Highly Cited Papers in a certain research field. In 2017, 6 researchers from WPI-MANA belonged to this elite group: Katsuhiko Ariga, Yoshio Bando, Dmitri Golberg, Yusuke Yamauchi, Yoshihiko Takano and Zhong Lin Wang.

Patents 708

The total number of patents acquired by WPI-MANA reached 708 in 2017. This shows the breadth of potential in nanomaterials, and WPI-MANA's proactive approach to the development of new technology, spanning from basic research to applied research.

# How to join MANA

## Students

### Joint Graduate School Program

The NIMS Joint Graduate School Program is designed for materials science majors pursuing degrees within the latest research activities, under the supervision of NIMS researchers. As of now, University of Tsukuba, Hokkaido University, Waseda University and Kyushu University are listed as designated universities for the program. Furthermore, NIMS offers a "NIMS Graduate Research Assistantship" to excellent students in the program.

### Cooperative Graduated Program

In this program, doctoral students from globally renowned graduate schools are accepted as NIMS visiting scientist (trainee) and undergo training by NIMS researchers on research. NIMS has concluded agreement with 33 universities in Japan and 18 universities abroad.

### NIMS Internship Program

The NIMS Internship Program gives students in universities, graduate schools and technical colleges in Japan and other countries opportunities to experience research at NIMS for up to 90 days. Especially at WPI-MANA, a globally open research center, the possibility of obtaining wide-reaching human networks is an important merit for students. NIMS also offer financial support to students who are recognized as particularly outstanding.

Please visit NIMS website for details.

<http://www.nims.go.jp/eng/hr-development/>



## Companies

NIMS, the host institute of WPI-MANA, are engaged in activities to bridge NIMS's technology to the industry with the aim of realizing our philosophy, "material becomes material when it is used." We set up a "place of information circulation" that matches needs and seeds, a "joint research place" that develops NIMS's technology with the industry toward practical application through patent licensing, technical consulting, collaborative research, etc.

Technical Consulting

Licensing

Collaborative Research

Commissioned Research

Sample Evaluation

## Researchers

WPI-MANA wants researchers who conduct fundamental research with high originality under the concept of "nanoarchitectonics." We update the recruitment information through WPI-MANA website: MANA Postdoctoral Fellows, Independent Scientists, ICYS Researchers and various research posts.

Please visit WPI-MANA website for details.

<http://www.nims.go.jp/mana/recruit/>





# MANA Member List

## Principal Investigators (PIs)

**Nano-Materials**



T. Mori T. Sasaki Y. Yamauchi D. Golberg K. Ariga J. Ye N. Fukata J. Takeya Z. L. Wang

**Nano-Systems**



G. Decher T. E. Mallouk K. Terabe T. Nakayama K. Tsukagoshi X. Hu Y. Takano T. Nagao J. K. Gimzewski

**Nano-Theory**



C. Joachim F. M. Winnik T. Miyazaki D. Bowler Y. Tateyama

Field Coordinator  
Satellite PI

## Research Groups

### Nano-Materials

**Thermal Energy Materials Group**



T. Mori T. Aizawa Y. Michiue N. Tsujii I. Ohkubo  
Group Leader Chief Researcher Chief Researcher Principal Researcher Senior Researcher

**Functional Nanomaterials Group**



R. Ma T. Taniguchi D. Tang  
Group Leader Senior Researcher Researcher

**Mesoscale Materials Chemistry Group**



Y. Yamauchi J. Henzie Y. Ide  
Group Leader Senior Researcher Senior Researcher

**Soft Chemistry Group**



T. Sasaki N. Shirahata Y. Ebina N. Sakai S. Tominaka  
Group Leader Associate PI Principal Researcher Senior Researcher Senior Researcher

**Nanotubes Group**



D. Golberg M. Mitome N. Kawamoto  
Group Leader Chief Researcher Senior Researcher

**Photocatalytic Materials Group**



J. Ye M. Oshikiri T. Kako  
Group Leader Principal Researcher Senior Researcher

**Supermolecules Group**



K. Ariga J. Takeya J. Hill L. K. Shrestha  
Group Leader PI Chief Researcher Principal Researcher

**Frontier Molecules Group**



T. Nakanishi K. Tashiro S. Ishihara K. Nagura  
Group Leader Principal Researcher Senior Researcher Researcher

**Nanostructured Semiconducting Materials Group**



N. Fukata W. Jevasuwan R. Matsumura  
Group Leader Senior Researcher Researcher

**Nano Electronics Device Materials Group**



T. Nagata M. Yoshitake S. Yagyu Y. Yamashita J. Chen  
Group Leader Chief Researcher Principal Researcher Principal Researcher Senior Researcher

### Nano-Systems

**Nanoionic Devices Group**



K. Terabe Y. Okawa M. Sakurai T. Tsuruoka T. Tsuchiya  
Group Leader Chief Researcher Principal Researcher Principal Researcher Senior Researcher

**Nano-System Theoretical Physics Group**



X. Hu T. Kariyado  
Group Leader Researcher

**Nano Frontier Superconducting Materials Group**



Y. Takano H. Takeya  
Group Leader Chief Researcher

**Photonics Nano-Engineering Group**



T. Nagao S. Ishii  
Group Leader Senior Researcher

**Nano Functionality Integration Group**



T. Nakayama S. Kawai Y. Shingaya T. Minari  
Group Leader Principal Researcher Senior Researcher Principal Researcher

**Quantum Device Engineering Group**




Y. Wakayama S. Nakaharai R. Hayakawa S. Moriyama  
Group Leader Principal Researcher Senior Researcher Senior Researcher

**Medical Soft Matter Group**



K. Kawakami C. Kataoka Y. Shirai  
Group Leader Senior Researcher Principal Engineer

**Thin Film Electronics Group**



K. Tsukagoshi S. Kato T. Nabatame  
Group Leader Senior Researcher Chief Researcher

**Mechanobiology Group**



J. Nakanishi M. Ebara T. Ueki C. Yoshikawa  
Group Leader Associate PI Senior Researcher Senior Researcher

**Surface Quantum Phase Materials Group**



T. Uchihashi R. Arafune K. Nagaoka T. Yamaguchi  
Group Leader Senior Researcher Senior Researcher Senior Researcher

**Nanomechanical Sensing Group**



G. Yoshikawa K. Shiba  
Group Leader Senior Researcher

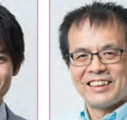



**Managing Researcher**



H. Kobayashi  
Managing Researcher







### Nano-Theory

**First-Principles Simulation Group**






T. Miyazaki A. Nakata J. Nara R. Tamura  
Group Leader Senior Researcher Senior Researcher Senior Researcher

**Computational Nanoscience Group**



M. Arai T. Ohno W. Hayami J. Inoue K. Kobayashi S. Suehara J. Shimizu  
Group Leader Senior Scientist with Special Missions Principal Researcher Principal Researcher Principal Researcher Principal Engineer

**Emergent Materials Property Theory Group**



A. Tanaka Y. Nonomura I. Solovyev  
Group Leader Principal Researcher Principal Researcher




## Independent Scientists



G. Imamura T. Konoike J. Labuta A. Okamoto D. Umeyama L. Sang  
Independent Scientist Independent Scientist Independent Scientist Independent Scientist Independent Scientist Independent Scientist

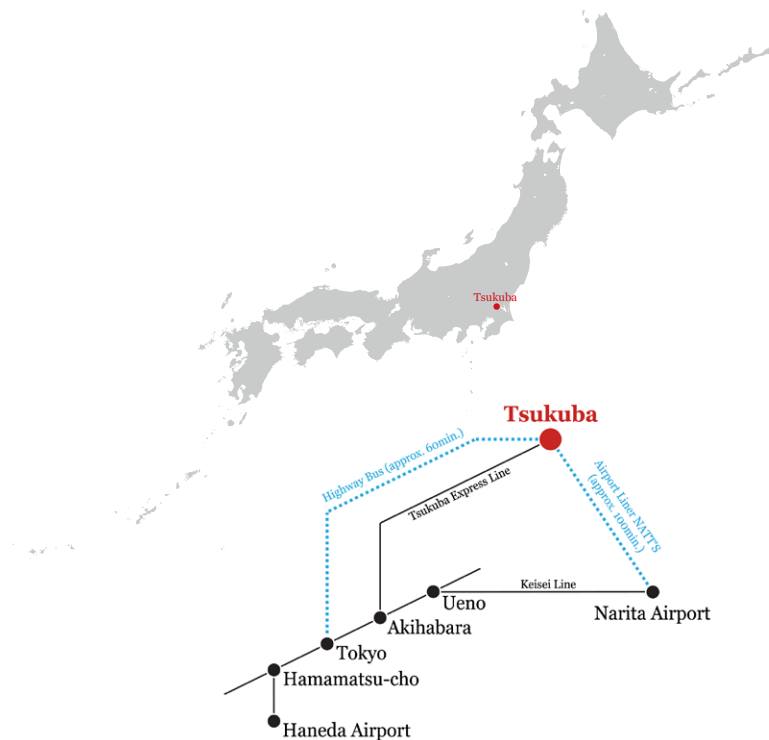
## ICYS Researchers

ICYS-WPI-MANA Researchers  
Former ICYS-MANA Researchers



T. Iwasaki T. Subramani K. Uto  
ICYS Researcher ICYS Researcher ICYS Researcher





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