Application for Academy Center Certification
World Premier International Research Center Initiative (WPI)

Host Institution	National Institute for Materials Science (NIMS)
Research Center	International Center for Materials Nanoarchitectonics
Host Institution Head	Kazuhito Hashimoto
Center Director	Takayoshi Sasaki
Administrative Director	Tomonobu Nakayama

1. Overall Image of Your Center

1-1. MANA background

When MANA was established, 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.

1-2. MANA: Vision, missions, and organization

MANA's guiding vision is "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

1-3. 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 nearly 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

2. Research Activities

2-1. Research Results to Date

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.

In March, 2017, MANA published a summary of 42 research achievements selected from MANA's work. The selected ones are only a part of "world-top level" achievements, such as artificial materials creation through nanosheet technology, atomic switch research from the fundamentals through to practical applications, ultrasensitive/massibely parallel molecular sensors and the development of surface/local superconductors; as well as the development of new nano-level measuring techniques. Here, we describe MANA's results by several key indicators. MANA has published 3,840 papers till the end of 2016 and, among these, A) 142 of MANA's papers are now among the top 1% most cited papers in the world (2008-2016); B) MANA has achieved an extremely high score of 2.41 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 6.25 (most recent average for 2015). MANA's scores for these indicators are superior to those of many world-class research institutions.

2-2. Research plan towards the future

MANA will generally continue to maintain and develop the present 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 creation of nanoarchitectonic perception by merging "nanotechnology", "atomic/molecular science", "informatics" and "mathematics". Therefore, these two fusional areas will be the focus of intensive research in the future.

MANA's research were divided into five fields: Nano-Materials, Nano-System, Nano-Power, Nano-Life and Nano-Theory, and now has been reformed into three fundamental fields: Nano-Materials, Nano-System, Nano-Theory. This simplification gives more freedom to create new ideas based on "Nanoarchitectonics" towards the future.

The Nano-Theory field will further 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.

Although MANA's research has thus far been conducted, in accordance with the WPI program's basic policy, under the leadership of the former Director Masakazu Aono, Dr. Takayoshi Sasaki (MANA PI of Nano-Materials Field, NIMS Fellow), has taken over the Director position from April 1st, 2017.

2-3. 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.

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

★ **Nanoarchitectonic perception systems:** This target is closely related to efforts so far to open up a new area of study within MANA. We will further try to develop nanosystems and technologies, which will eventually leads to unprecedented artificial perception. To do this, it will be necessary to make full use of MANA's original nanoarchitectonic materials and systems, which have not been achieved anywhere else. These include tailored assembly of nanosheets which exhibit exotic physical and chemical properties, multiple-probe scanning probe microscopy to analyze signaling between specifically selected points in neuromorphic network systems, and ultrasensitive / massively parallel molecular sensors that can sense stimuli at more than 1000x the sensitivity of human sensory organs. The ultimate aim of this Grand Challenge goal is to generate innovation to support future society of mankind by striving to develop sensing systems based on nanoarchitectonics concept.

2-4. Research in the fields of Nano-Materials, Nano-System, 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 experimental vs. theoretical. Below are representative examples of the challenging research that will be undertaken in these three 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-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.

3. System for Managing the Research Organization

MANA has already implemented structural reforms based on the following key points:

i) From April 2017 Dr. Takayoshi Sasaki and Dr. Tomonobu Nakayama are the new ~~Center~~ Director and the new Deputy Director of MANA, respectively. Dr. Nakayama also takes the responsibility as the Administrative Director. Dr. Masakazu Aono, a former ~~Center~~ Director, and Dr. Yoshio Bando, a former Chief Operating Officer (COO), provide advice to MANA on research and management.

ii) PIs will be replaced to breathe new life into the ranks of PIs. Associate PIs (aPIs) will be promoted to PIs, and new aPIs will be appointed from young researchers. 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) To further activate the Nano-Theory field, MANA will continue a "Theory-Experiment Pairing Program" or equivalent to enforce the fusion of theoretical and experimental research.

v) Nano-mechanical sensors and other top nanoarchitectonics technologies will be combined with other research to realize new type of perception that is unique to MANA.

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.

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

4. International Circulation of Best Brains

4-1. Participation of top-world researchers from abroad

MANA has established satellite labs (hereinafter “MANA Satellites”) at research institutions to which satellite PIs (sPIs) belong. MANA Satellites have been established at four institutions: the University of California Los Angeles (UCLA, sPI: Prof. James Gimzewski), the Georgia Institute of Technology (GETECH, sPI: Prof. Zhong Lin Wang), the Center for Materials Elaboration and Structural Studies of French National Centre for Scientific Research (CEMES-CNRS, sPI: Dr. Christian Joachim), and the University of Montreal(sPI: Prof. Francoise Winnik). These satellites play a role in MANA’s research in various fields and are also training grounds for young scientists of MANA. MANA will continue reforming MANA satellites depending on the progress of MANA’s activity.

4-2. Employment of young researchers at the Center and their job placement 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, MANA is going to create a higher position, “ICYS-WPI-MANA researcher.” This is a post-doctoral scholar who is independent of any specific group and pursue their own individual research topics. With this, MANA can keep close relationship with ICYS which is an organization that serves as a tenure-track system leading to permanent researcher positions at NIMS.

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 March 2017, 298 MANA’s young researchers have “graduated” MANA. 4.7% of them were selected for permanent research positions at NIMS and 35% became faculty members (professor, associate professor and so on) of universities inside and outside Japan. Also, 43% have advanced in their careers to become researchers at universities and research institutions, and 11% have moved to private companies. 36% of those who made research at MANA found employment within Japan, and the remaining 64% 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.

4-3. 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.

4-4. Holding International Symposia, Workshops, Research Meetings and Others

Each MANA international symposium brought over 400 participants and 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.

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. Furthermore, MANA is contributing in training PhD candidates through “Nanotechnology Students’ Summer School” co-organized by UCLA, UCL, Flinders University and other overseas organizations for educating and encouraging younger generations and for expecting future international collaborations.

4-5. System for Supporting the Research Activities of Overseas Researchers

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.”

4-6. Others

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. Also, 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, 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. Support by Host institution

For sustaining and advancing MANA as a World Premier International Research Center, NIMS has promised to provide MANA with the following supports and to 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 kept assigned to MANA as "permanent employees of NIMS assigned to MANA."
As of April 1st, 2017, MANA has a total of 98 permanent staff.

ii) R&D expenses required to sustain basic and fundamental research at MANA such as research project 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.

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

iv) A part of programs characteristic of MANA—such as young researcher training programs (ICYS-MANA, independent scientist, etc.) and—will be transferred to and implemented at NIMS to ensure sustainability of the programs.

v) NIMS keeps technical support that are of especially high quality developed in MANA.

vi) NIMS established the Materials Open Platform which provides opportunity to work with external institutions especially with private companies. Also, NIMS helps international networking of MANA through Materials Global Center for sustainable operation of MANA.

6. Financial Measures

NIMS plans to maintain the MANA research workforce of about 90 permanent staffs (scientists, engineers and administration staffs) after the WPI program concludes. 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. NIMS keeps allocating these buildings and facilities to 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.

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Appendix 1. List of Principal Investigators for Progress Plan

Name	Age	Current affiliation (organization, department)	Academic degree and current specialties	Notes (Enter "new" or "ongoing")
1. SASAKI, Takayoshi*	61	Director, International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. (Science) University of Tokyo, 1986 Nanosheet and soft chemistry	Ongoing
2. NAKAYAMA,Tomonobu	55	Deputy Director / Administrative Director, International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. (Physics) University of Tokyo, 1999 Scanning probe microscopy	Ongoing
3. OSADA, Minoru	47	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Tokyo Institute of Technology, 1998 Nanosheet Functionality	Ongoing (FY2016~)
4. YAMAUCHI, Yusuke	36	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Waseda University, 2007 Mesoscale Materials Chemistry	Ongoing (FY2016~)
5. GOLBERG, Dmitri*	56	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Moscow Institute for Ferrous Metallurgy, 1990 Nanotubes and nanowires	Ongoing
6. ARIGA, Katsuhiko*	54	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Tokyo Inst. Tech., 1990 Supramolecular chemistry and surface science	Ongoing
7. CHIKYOW, Toyohiro	58	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Waseda University, 1989 Semiconductor and electric materials	Ongoing
8. TERABE, Kazuya	54	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Nagoya University, 1992 Nanoionics	Ongoing (FY2016~)
9. TSUKAGOSHI,Kazuhito	49	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Osaka University,1995 Nano electronics	Ongoing
10. HU, Xiao	55	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. (Physics) University of Tokyo, 1990 Condensed matter physics	Ongoing
11. TAKANO, Yoshihiko	51	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Yokohama City University, 1995 Superconducting materials	Ongoing (FY2016~)

12. 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
13. 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
14. YE, Jinhua*	54	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. University of Tokyo, 1990 Photocatalyst, eco-materials	Ongoing
15. MORI, Takao	50	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. University of Tokyo, 1996 Thermoelectric materials	Ongoing (FY2016~)
16. TATEYAMA, Yoshitaka	46	International Center for Materials Nanoarchitectonics (WPI-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. 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
19. SASAKI, Taizo	58	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Tohoku University, 1987 Condensed matter theory	Ongoing (FY2016~)
20. MIYAZAKI, Tsuyoshi	50	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. University of Tokyo, 1995 First-principles calculations	Ongoing (FY2016~)
21. BOWLER, David	46	Condensed Matter and Material Physics, University College London, UK	Ph.D. Oxford University, 1997 Condensed matter theory and calculations	Ongoing (FY2016~)
22. NAGAO, Tadaaki	50	International Center for Materials Nanoarchitectonics (WPI-MANA)	Ph.D. Waseda University, 1995 SurfaceNanophotonics, Condensed Matter Physics, Infrared NanoTechnology	New (FY2017~)

World Premier International Research Center Initiative (WPI)
The number of Center personnel

	FY2017（as of April 1）
Principal Investigators	22
Other Researchers	83
Post-Doctor researchers	55
NIMS Junior Researchers	41
Research Support Staffs	49
Administrative Staffs	27

World Premier International Research Center Initiative (WPI)
Diagram of management system