TIA nano
Tsukuba Innovation Arena

AIST

NIMS

From “Tsukuba” towards
Future Industries

University of Tsukuba

KEK

TIA nano
Tsukuba Innovation Arena

Tsukuba Innovation Arena for Nanotechnology (TIA-nano)

-Reforming Japan's innovation system -

Masaharu Sumikawa

Chairperson
The Executive Board
Tsukuba Innovation Arena
for Nanotechnology

Located in Tsukuba where world-class nanotechnology research facilities and researchers are gathered, TIA-nano is Japan's largest nanotechnology research and education center. It is sponsored by the Cabinet Office, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI), and is led by core organizations including the National Institute of Advanced Industrial Science and Technology (AIST), the National Institute for Materials Science (NIMS) and the University of Tsukuba, along with participating industries. TIA-nano was founded in June 2009 when the presidents of these core organizations and Keidanren (Japan Business Federation) issued a Joint Communique. In April 2012, the High Energy Accelerator Research Organization (KEK) joined TIA-nano as a core organization member.

Nanotechnology, which controls atoms and molecules, supports all kinds of fields including materials, as well as electronics, energy/environment and life science. Also, nanotechnology is expected to stimulate innovation since it is not only useful for making micro components but discontinuous characteristics changes can also be expected from the miniaturization. Thus, TIA-nano is considered as a place to realize the concept of "Creating an environment suited for science, technology and innovation," which is provided in the plan titled "Comprehensive strategy on science, technology and innovation 2014: bridge of innovation toward creating the future," adopted by the Cabinet in June 2014. TIA-nano is expected to serve as an innovation engine at a global scale through its engagement in nanotechnology-related R&D and fostering young researchers.

Through the collaboration among the four institutes beyond ministerial frameworks as well as the participation of R&D corporations, universities and industries across Japan, we will promote the integration of different research fields and encourage a range of activities including basic research, applied research and development, demonstration and commercialization. In addition, we will establish an innovation cycle, in which scientific models are used to address issues associated with commercialization. With these approaches, we aim to reform Japan's innovation system.

Five principles

1. Creation of global value

To create innovation for new global businesses through practical demonstrations using state-of-the-art facilities

2. Under One Roof

To provide a common platform for creation (“Under One Roof”),
where researchers and research institutes from industry, academia and government collaborate
by overcoming interorganizational barriers

3. Independence/Positive cycle

To provide common infrastructures that offer globally competitive values to domestic and international researchers

4. Networking for “Win-Win”

To expand domestic and international research networks, strengthening collaboration toward value creation

5. Education of next generation scientists and engineers

To create innovation for new global businesses through practical demonstrations using state-of-the-art facilities

History of TIA-nano

1963 Construction of a science city in the Tsukuba area approved by the Cabinet

1970 Act on Construction of Tsukuba Science City enacted

1971 KEK established in the Tsukuba Science City

1972 Predecessor of NIMS relocated to Tsukuba Science City

1973 University of Tsukuba established and opened in Tsukuba Science City

1979 Predecessor of AIST relocated to Tsukuba Science City

2001 AIST and NIMS established

2009 Tsukuba Innovation Arena for Nanotechnology (TIA-nano) founded and a joint statement issued

2010 "New Growth Strategy: Blueprint for Revitalizing Japan" approved by the Cabinet;
"creation of global-level intensive industry-academia-government cooperation bases"
centering on TIA-nano to be promoted

2011 TIA-nano's phase one medium-term plan formulated; TIA Graduate School Consortium established

2011 Designation of Tsukuba International Strategic Zone
TIA-nano is one of the key projects in the zone

2012 NanoGREEN Building completed at NIMS Namiki-site

2012 KEK joined TIA-nano as a core organization member

2013 TIA Collaboration Center building completed in AIST West

2014 “Comprehensive Strategy on Science, Technology and Innovation 2014” adopted by the Cabinet;
“The field of nanotechnology and material will be a source of the country’s industrial competitiveness as a cross-cutting technology that gives support in addressing policy challenges.” Excerpts from P.69
“Developing innovation hubs that take advantage of organizational “strength” and characteristics of each local area.” Excerpts from p.99

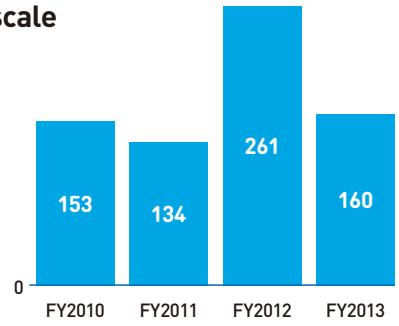
2014 Starting toward Phase 2 medium-term

Accomplishments made at TIA-nano between FY 2010 and 2013 in numeric terms

- 26 national projects (cumulative total)
- Operation scale of approx. 16 billion JPY (FY2013)
- Participation by approx. 180 companies (FY2013)
- 934 external researchers and 346 graduate students engaging in research (FY2013)

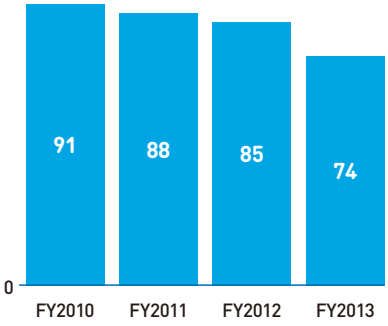
Total operation scale

(100 million JPY)



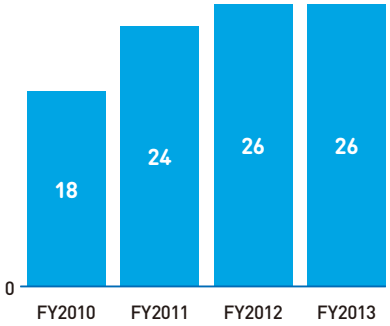
Percentage of public fund

(% to the total operation scale)



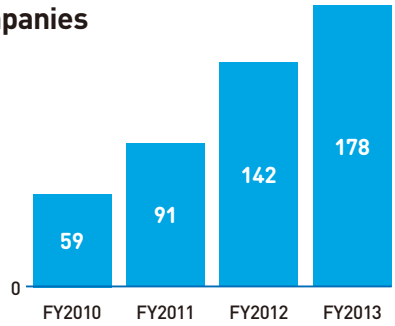
Project

(nuber of projects; cumulative total)



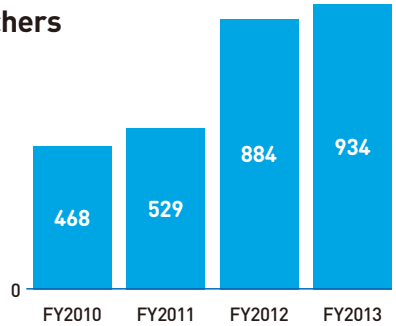
Cooperating companies

(number of companies)



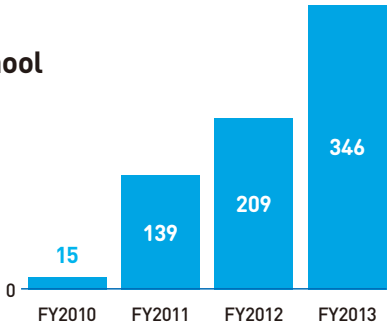
External researchers

(number of researchers)



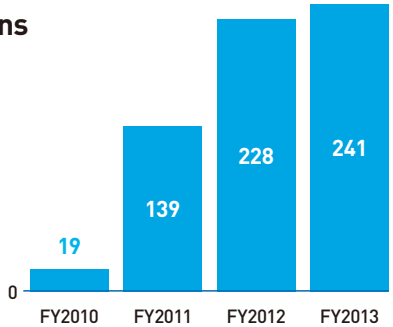
Students in TIA Graduate School

(number of students)



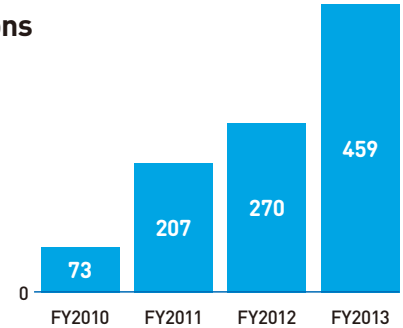
Patent applications

(number of patents applied)



Paper publications

(number of papers)



Outline of core organizations

Ryoji Chubachi,
President

National Institute of Advanced Industrial Science and Technology (AIST)

AIST is one of the largest public research institutes in Japan. It conducts research in the following diverse fields that underpin Japanese industry: environment and energy; life science and biotechnology; information technology and electronics, nanotechnology, materials and manufacturing; metrology and measurement science; and geological survey and applied geoscience.

Through its activities at TIA-nano and others, AIST enhances collaboration and exchanges various knowledge with industry and society. It engages in research and development of industrial technology centering on "green technology for realizing an affluent and environmentally friendly society" and "life technology for realizing healthy and safe living." AIST creates not only technology innovations, but also social and economic value, in its effort to solve social problems toward realizing a sustainable society.
http://www.aist.go.jp/index_en.html

Sukekatsu Ushioda,
President

National Institute for Materials Science (NIMS)

NIMS has four missions prescribed by a national law: 1) fundamental research and development in materials science and engineering, 2) dissemination of research results to industries, 3) shared use of advanced facilities, and 4) training of scientific and engineering personnel. Nanotechnology and advanced characterization techniques are used to develop innovative materials and processes that can lead to solutions of global issues such as environment, energy, and natural resources. In response to the recent national needs NIMS is expanding research on structural materials and substitution materials for strategic rare elements.
http://www.nims.go.jp/eng/index.html

Kyosuke Nagata,
President

University of Tsukuba

The University of Tsukuba makes it its mission to contribute to the world through creating advanced and creative knowledge and developing human resources with bright individuality. In particular, it takes advantage of the quality research environment of Tsukuba Science City and aims to build a new education and research center that creates outstanding research results and promising human resources. While carrying out joint research with AIST, NIMS and KEK in the respective fields on an organizational basis, the University of Tsukuba started the Cooperative Graduate School System in cooperation with such institutes as AIST and NIMS in FY1992, mainly involving the Graduate School of Pure and Applied Sciences. It also enhances collaboration in education and research with other institutes, as well as industry, through the opening of endowed courses and other activities.
http://www.tsukuba.ac.jp/english/

Atsuto Suzuki,
Director General

High Energy Accelerator Research Organization (KEK)

KEK promotes accelerator science that unlocks the mysteries of the universe, elementary particles, nuclei, materials and life by using particle accelerators as means of research. It is an inter-university research institute corporation which is opened for researchers and carries out collaborative research with researches all over the world. KEK will further promote collaboration and cooperation with related institutes to make TIA-nano an even more attractive nanotechnology research center in the world, by making KEK's large cutting-edge equipment and technology accessible to researchers in various fields.
http://legacy.kek.jp/intra-e/

Takeshi Uchiyamada,
Chairman of the Committee
on Industrial Technology

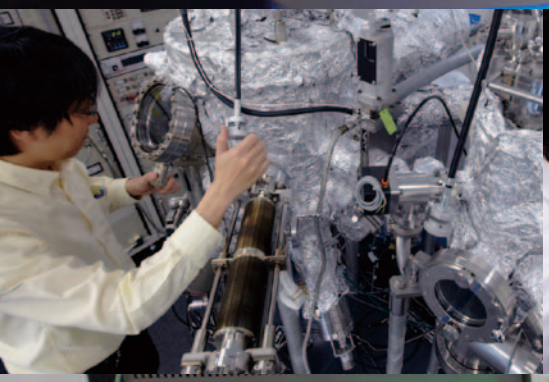
KEIDANREN (Japan Business Federation)

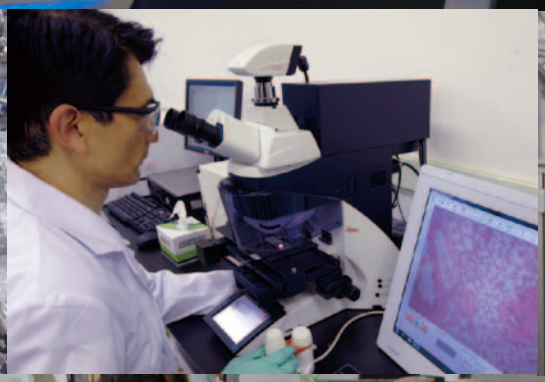
KEIDANREN is a comprehensive economic organization consisting of about 1,500 members including Japan's representative companies, nationwide industrial associations and regional economic organizations. With an aim to contribute to self-sustaining development of the Japanese economy and improvement in the quality of life for the Japanese people, KEIDANREN establishes consensus in the business community on a variety of important domestic and international issues for their steady and prompt resolution. We also strive for the resolution of international issues and the development of closer economic relations with various countries through policy dialogue with the governments and economic associations of each country as well as international organizations.
http://www.keidanren.or.jp/en/

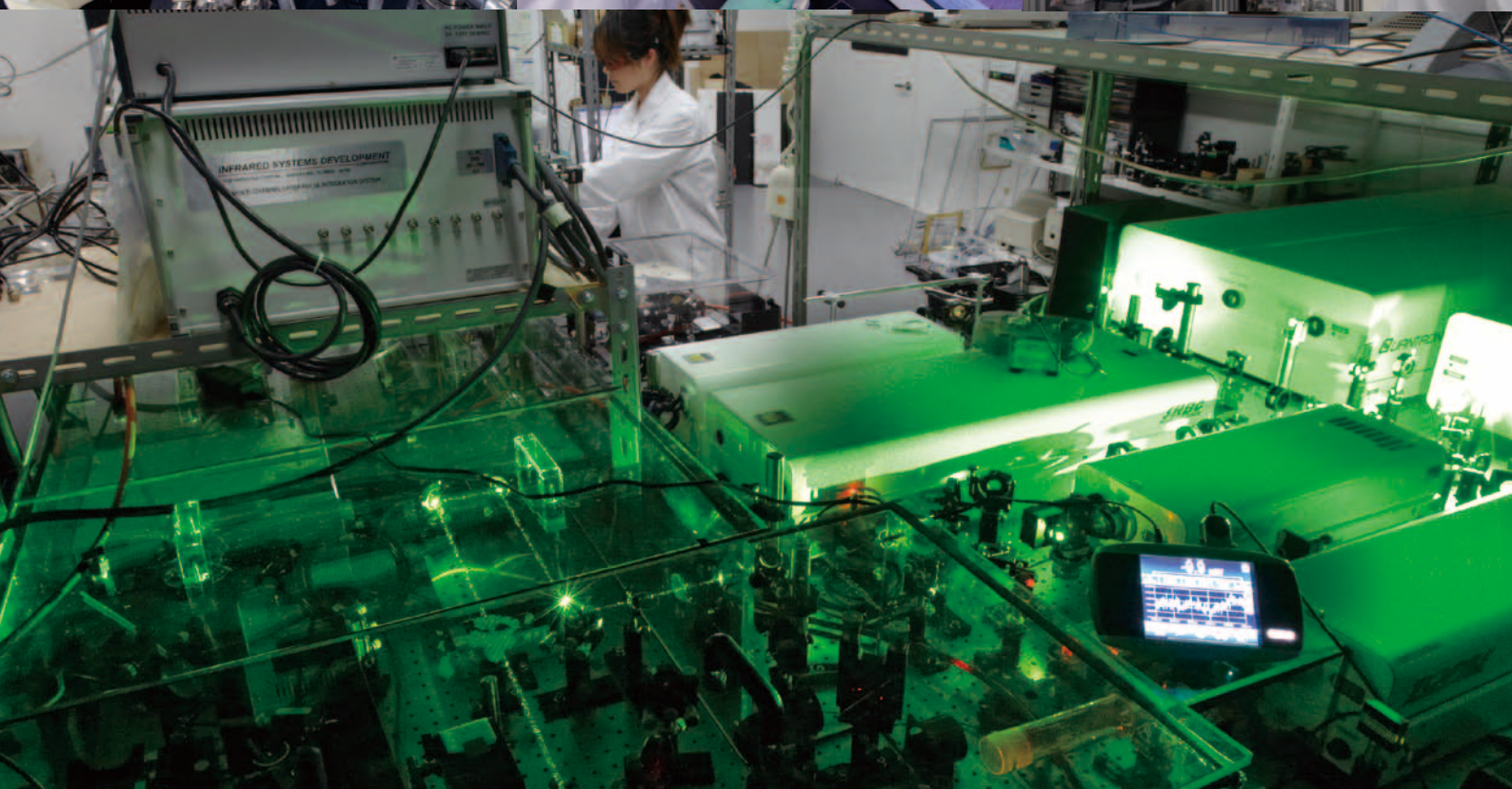
From "Tsukuba" towards Future Industries :

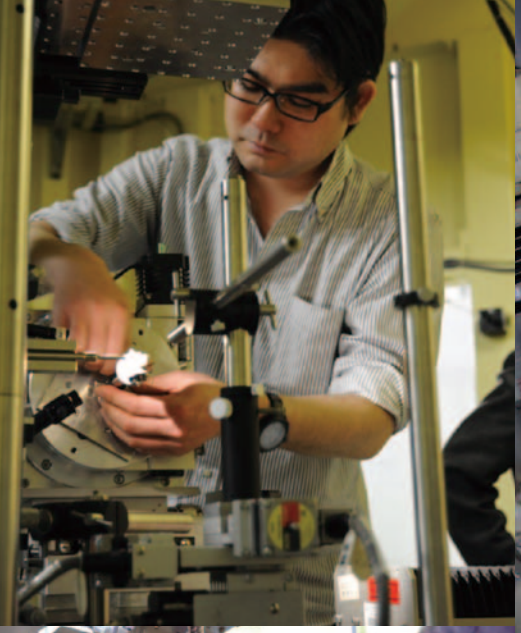
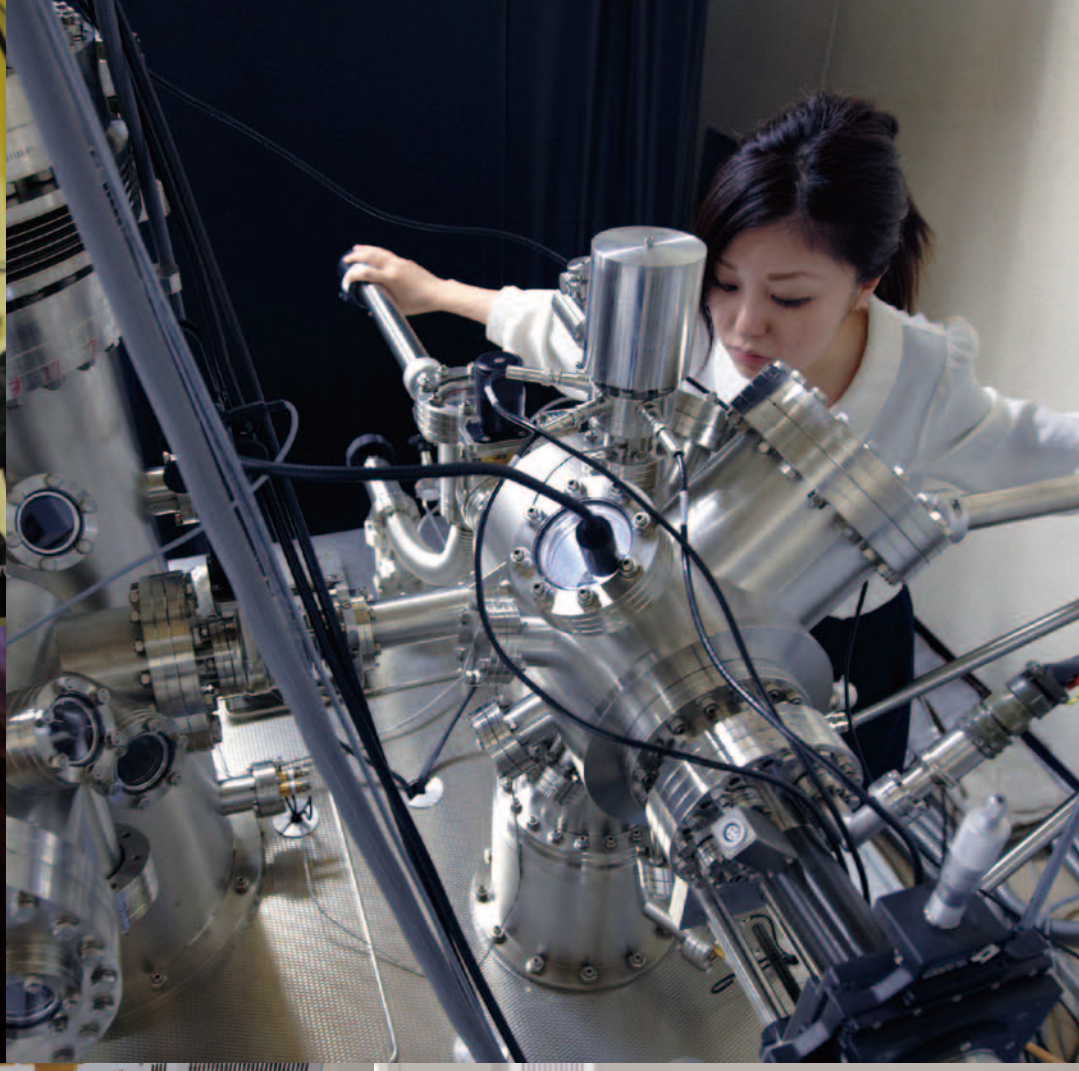
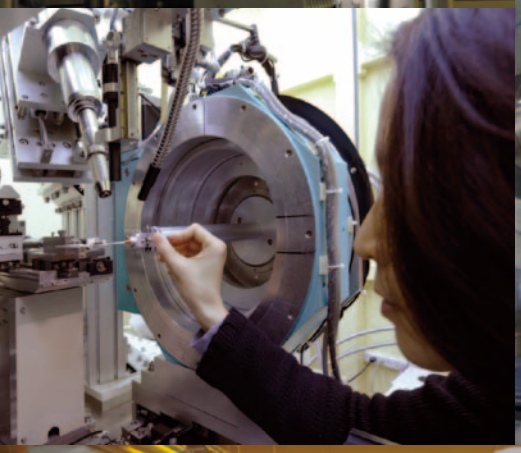
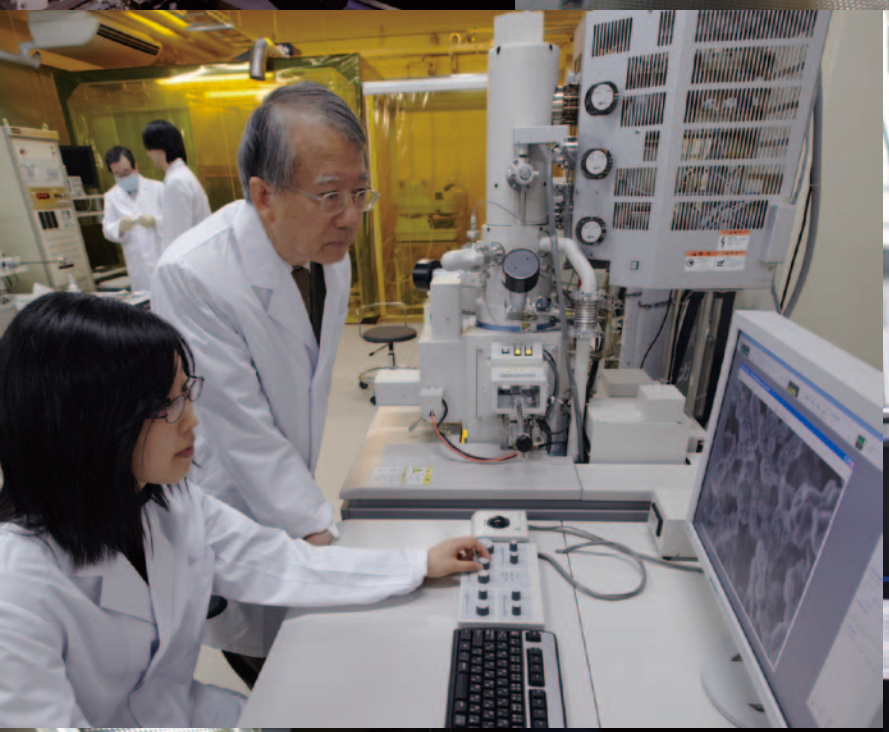
Open innovation platform for interconnection and expansion

- World-class advanced nanotechnology research facilities available
- Over 1,200 nanotechnology researchers involved as users of TIA-nano
- Industrial application of research results aimed at creating new industries
- Providing a platform to foster young researchers who will lead the next generation





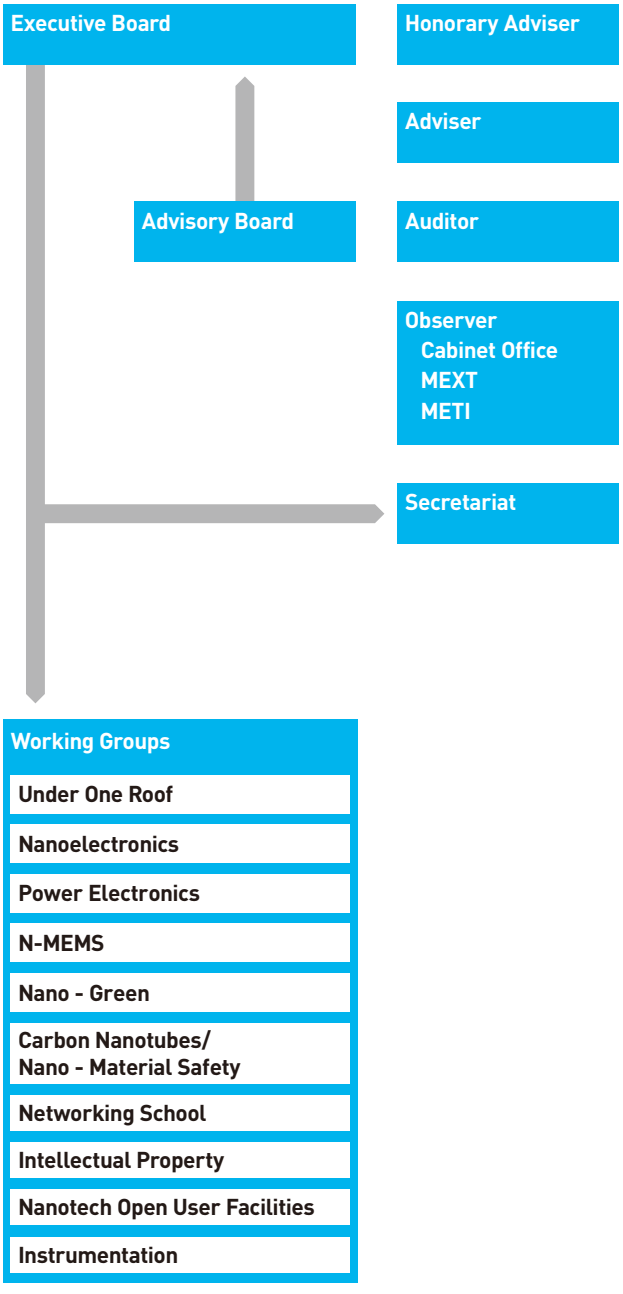


Governance structure

TIA-nano has in place an Executive Board, the highest decision-making body, consisting of seven members: the respective heads of the four core institutes, one representative from the industry, one independent expert and the chairperson of Advisory Board.
The Executive Board is responsible for deliberating and deciding policies with regard to important management matters, while supervising TIA-nano's operations.
Meanwhile, the Advisory Board consisting mainly of members from industries, is responsible for making coordination with industries, which are the main users of TIA-nano. To ensure smooth activities of the Executive Board and the Advisory Board, the Secretariat is jointly run by the four core institutes.

Organizational operation



Core domains

TIA-nano has set industry-oriented six core research domains as priority areas where capital and human resources of the public and private sectors are gathered to perform R&D, as well as three core infrastructures as systems for carrying out prototype device production and evaluation, shared use of advanced nanotechnology equipment and promotion of human resources development.
In addition, in 2014, a new domain, "research collaboration domain," with a new core domain, "instrumentation," was set in order to promote and accelerate the existing researches and create new research domains at TIA-nano by utilizing advanced instrumentation technologies based on accelerator technology, measuring technology and characterization technology using quantum beam.

6 Core research domains

1 Nanoelectronics
R&D of advanced semiconductor devices using the world's leading research infrastructure that enables verification of nanoelectronics performance

2 Power Electronics
Advanced research based on AIST's long history of SiC research

3 N-MEMS
Contributing to miniaturizing, sophisticating and improving the energy efficiency of existing components, and creating a venue for various collaborative and demonstrative research
(MEMS: Micro Electro Mechanical Systems)

4 Nano-Green
Materials research toward realizing breakthroughs in environment/energy technology

5 Carbon Nanotubes
Carbon Nanotubes (CNT) mass production prototyping and development of composite materials combining materials for various applications and CNT

6 Nano-Material Safety
Establishing safety assessment technology indispensable for new technology innovations

Research collaboration domain

Instrumentation
Innovating accelerator technology and sensing technology, as well as advancing their application researches

3 Core infrastructures

1 Nanodevice Research Foundry
The Super Clean Room handling 12-inch wafers and 4-inch wafers, using the world's highest class nanodevice manufacturing/evaluating equipment for nanotechnology research

2 Nanotech Open User Facilities
Industrial application of the cutting-edge facilities and equipment of the four core institutes and provision of facilities for shared use

3 Networking School of Nanotechnology
Developing human resources who will lead the next generation under an all-Japan framework based in the University of Tsukuba

SIP 戦略的イノベーション創造プログラム
Cross-ministerial Strategic Innovation Promotion Program

Starting a new project!

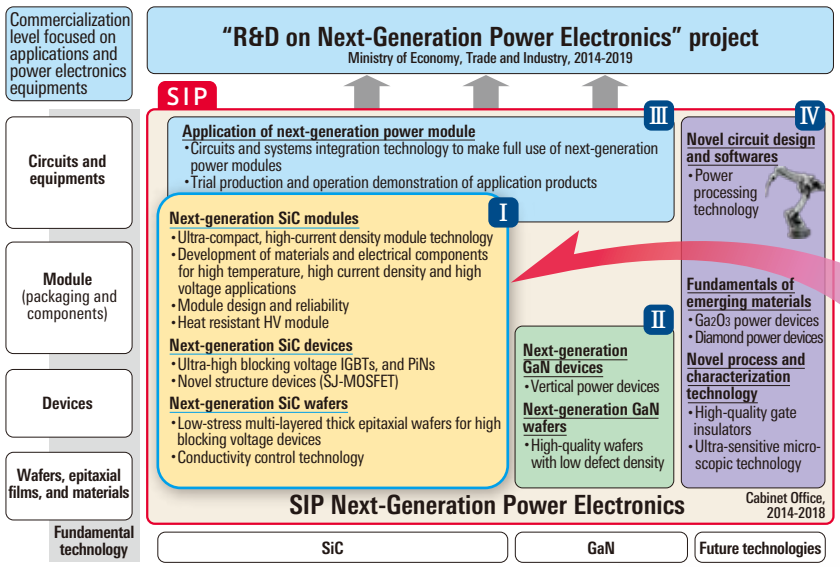
Next-generation power electronics

Consistent research and development of next-generation SiC power electronics

In October 2014, the research proposal, which was primarily prepared by the TIA-nano members, was adopted as a "Next-Generation Power Electronics" project in the "Cross-Ministerial Strategic Innovation Promotion Program (SIP)" under the Cabinet Office.

"An affluent energy-saving society by disseminating ubiquitous power electronics equipments"

Overview of R&D on the next-generation power electronics



TIA nano Tsukuba Innovation Arena

"Consistent research and development of next-generation SiC power electronics," to be conducted at the TIA-nano platform, will cover most of this part of the research project.

Power electronics

Power electronics is the technology to intentionally control voltage, current, frequency and phase in electric power using semiconductor devices, and applicable to the conversion between direct current and alternating current. It is a key technology to facilitate high-efficiency conversion of electric energy, and greatly contributes to downsizing and energy saving in applicable equipments.

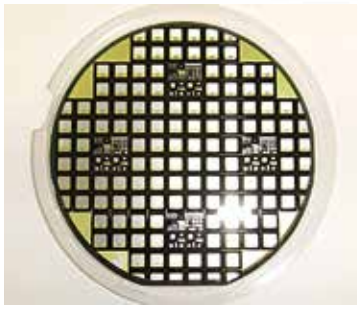
Next-generation materials

Wide bandgap semiconductors, such as silicon carbide (SiC) and gallium nitride (GaN), are considered to be next-generation semiconductor materials that will replace silicon (Si), a widely used material for electric power devices today. Owing to their superior material properties, these next-generation semiconductor materials are expected to improve the performance of electric power devices so that their electric power loss is much less than Si power devices.

Consistent research development of next-generation SiC power electronics

At TIA-nano, we will carry out the following R&D subjects in the research network framework involving 43 research organizations of universities, the private sector and public research institutes, with AIST, Kyoto University, ISIR of Osaka University and the Central Research Institute of Electric Power Industry playing a leading role. By making close coordination among different technological domains, we promote effective and efficient R&D, and foster researchers in the related research fields.

- Technological development of next-generation SiC wafers
- Technological development of next-generation SiC devices
- Technological development of next-generation SiC modules



TIA nano Tsukuba Innovation Arena
From "Tsukuba" towards Future Industries
Tsukuba Innovation Arena for Nanotechnology

SIP, the Cross-ministerial Strategic Innovation Promotion Program, is a newly-launched program by the Council for Science, Technology and Innovation (CSTI) aiming to realize Science, Technology and Innovation through promoting R&D overseeing from basic research to application and commercialization through cross-ministerial cooperation.

SIP 戦略的イノベーション創造プログラム
Cross-ministerial Strategic Innovation Promotion Program

Starting a new project!

Structural Materials for Innovation

Innovative Measurement and Analysis for Structural Materials

In October 2014, our proposal to establish an R&D center of advanced instrumentation was adopted as one of the projects for the Cross-Ministerial Strategic Innovation Promotion Program (SIP), "Structural Materials for Innovation," run by the Council for Science, Technology and Innovation, Cabinet Office, The Government of Japan.

SIP Structural Materials for Innovation

The program, SIP Structural Materials for Innovation, aims at the development and application of advanced heat-resistant structural materials for yielding innovation in energy technology, esp. making aircraft and power plants highly energy-effective, through enhancing the power of Japanese industry.

- ☐ Polymers and Fiber Reinforced Plastics
- ☐ Heat-resistant Alloys and Intermetallics
- ☐ Ceramics Coating Technology
- ☑ "Materials Integration System", tools to accelerate R&D process with a technique of computational material science

Innovative Measurement and Analysis for Structural Materials

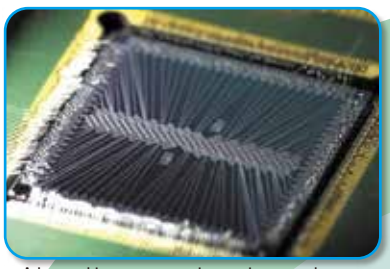
TIA-nano contributes with its advanced analytical instruments

TIA nano Tsukuba Innovation Arena

Advanced analytical instruments of TIA-nano

Four core institutions of TIA-nano, the National Institute of Advanced Industrial Science and Technology (AIST), the National Institute for Materials Science (NIMS), the University of Tsukuba and the High Energy Accelerator Research Organization (KEK), will establish an R&D center for advanced measurement and analysis utilizing their advanced instruments. The center will develop prediction technology for the performance and lifetime of structural materials by obtaining unrevealed information such as precursor states to deterioration and chemical-bonding states (electronic states) that determine the bonding strength of the constituent elements. We focus on the following four subjects, which are critical for developing innovative structural materials.

- Stress and cracking
- Trace light elements and additive elements
- Interface between different phases and base material structure
- Lattice defects and nanovoids



Advanced instruments using positrons and superconductivity, and establishment of representative center

TIA nano Tsukuba Innovation Arena

Expansion to the measurement and analysis of pre-deterioration and electronic states from morphology after crack generation and development!

Photon facility and materials structure science

Social implementation of innovative structural materials with nanostructure

Nano-characterization instruments and structural materials research

Ion-beam analysis facility and development of human resources

TIA nano Tsukuba Innovation Arena
From "Tsukuba" towards Future Industries
Tsukuba Innovation Arena for Nanotechnology

SIP, the Cross-ministerial Strategic Innovation Promotion Program, is a newly-launched program by the Council for Science, Technology and Innovation (CSTI) aiming to realize Science, Technology and Innovation through promoting R&D overseeing from basic research to application and commercialization through cross-ministerial cooperation.

Core research domain 1

Nanoelectronics

Toward the formation of center of excellece for the development of innovative nanodevices

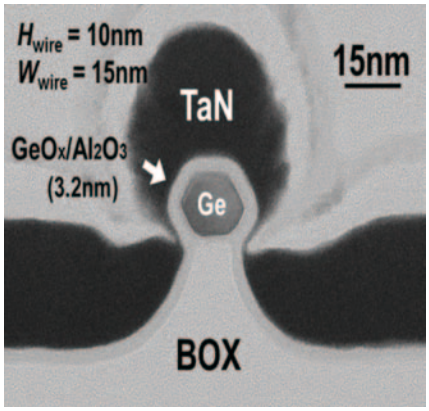
In the nanoelectronics research core, cutting-edge R&D is conducted, including R&D on innovative nanodevices, the development of next-generation semiconductor nano-fabrication/evaluation technologies, and research on convergence between photonics and electronics, using AIST's Super Clean Room (SCR) as the research base.
A large number of researchers gather from industries, universities and research institutes at home and abroad, and work on a broad range of R&D projects involving the development of devices, materials and equipment. The research core provides a venue for researchers from diverse backgrounds to hold discussions and explore new businesses and new technologies. In addition, highly skilled engineers who can flexibly provide common fundamental technologies of nanoelectronics are in place to support the projects.

Point 1

Leading-edge research on ultra-low voltage devices

Toward realizing a low-carbon society, various researches are carried out for substantially reducing the power consumption of LSIs (Large-Scale Integrations).
Projects are implemented on the combining of CMOS (complementary metal-oxide semiconductor) and nanocarbon materials, the development of LSIs with embedded superlattice phase change materials with superlattice-like structures or variable resistive materials, and R&D on spintronics logic integrated circuits for achieving normally-off operation.

- Development of Core Technologies for Green Nanoelectronics (completed in March, 2013)
- Ultra-low Voltage Device Project for Low-Carbon Society
- Research and Development of Ultra-low Power Spintronics-based VLSIs (completed in March, 2013)
- Development of obstacle sensing devices for vehicles



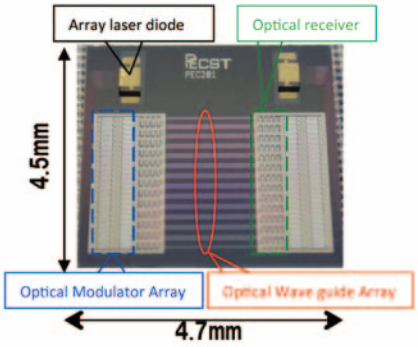
Nano Wire-Ge-Transister (prototype)

Point 2

Leading R&D center for photonics and electronics

Researchers engage in projects for research on innovative fundamental technologies for photonics-electronics convergence aimed at optical interconnection between LSI chips, the development of devices and packaging technologies for realizing optical interconnection of information-communication technology (ICT) equipment, and research on optical switches and transmission for realizing ultra-low power, innovative information and communication networks.

- Research on Photonics-Electronics Convergence System Technology (completed in March, 2013)
- Photonics Electronics Convergence Technology for Power-Reducing Jisso System
- Vertically Integrated Center for Technologies of Optical Routing toward Ideal Energy Savings



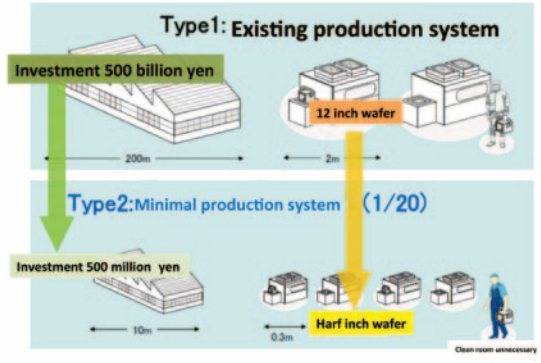
Optical semiconductor integrated device (prototype)

Point 3

Development of next-generation semiconductor manufacturing technologies

Projects are under way to develop sub-10 nm patterning technology using EUV (extreme ultraviolet) lithography, which is a promising next-generation lithography technology, and to develop the necessary elemental technologies for "Minimal Fab," which dramatically reduces the investment cost for semiconductor fabrication by using half-inch wafers.

- Minimal Fab
- Development of Next-Generation Semiconductor Micro-Fabrication and Evaluation Infrastructure Technologies



Concept of "Minimal Fab"

Core research domain 2

Power Electronics

Promoting advanced research and industrialization based on AIST's long history of SiC research

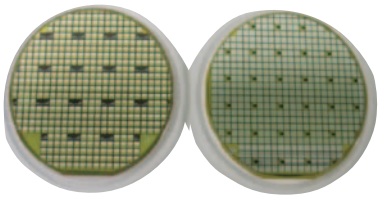
Power electronics is a field in which Japanese industry still maintains high competitiveness in the global market. The core technology is SiC (silicon carbide) power semiconductor devices, which are considered highly promising innovative devices that will contribute to creating a low-carbon society.
TIA-nano's power electronics research domain is based on R&D on SiC crystal growth, wafer processing, epitaxial film growth and SiC device manufacturing which AIST has been the world leader in R&D of SiC for over 30 years. Companies, universities and research institutes have come together and are playing the central role in Japan's world-leading SiC R&D.

Point 1 Building an SiC power device research environment and promoting state-of-the-art research

AIST, which has a large clean room for producing SiC prototype devices, has been working to establish evaluation technologies through accumulation of various data concerning wafers and devices and to increase the efficiency of the manufacturing process.
At TIA-nano, AIST and universities conduct a wide range of basic research (defect evaluation, study of new structural devices, simulation, etc.), and further, the results of such research are used for carrying out applied research that meets the needs of industry. Particular focus is placed on R&D for the manufacture of next-generation large-diameter wafers, high-breakdown voltage devices, etc. in which companies such as automobile, materials, processing and device manufacturers cooperate in an integrated manner.

A new project launched in October, 2014
- SIP Next-generation power electronics
  Consistent research and development of next-generation SiC power electronics

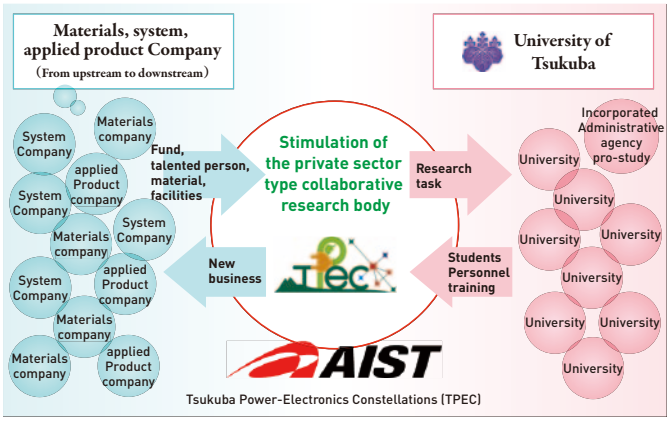
Clean room for producing SiC power device prototype



SiC devices prototype on 3inch wafer

Point 2 Industry-funded open innovation consortium TPEC (Tsukuba Power-Electronics Constellations)

Under the initiative of AIST, the Tsukuba Power-Electronics Constellations (TPEC) has been operated as a new industry-funded consortium for promoting open innovation in power electronics since April 2012.
TPEC is operated in a self-sustaining manner, with global companies related to power electronics and SMEs possessing advanced technologies sharing the research costs and covering most of the R&D funds.
In addition to promoting R&D for industrial applications, developing capable human resources who will lead the next generation in power electronics is also an important mission of TPEC.



Concept of "TPEC"

Core research domain 3

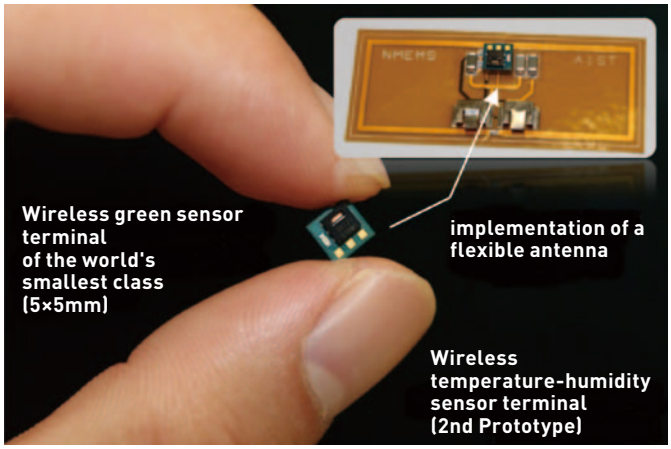
N-MEMS

Creating a venue for various collaborative and demonstrative research with an aim to contribute to miniaturizing, sophisticating and improving the energy efficiency of existing components in the industrial sector through application of N-MEMS technology

The research core promotes realization of open innovation through industry-academia collaboration, such as supporting the development of application-oriented, advanced MEMS devices that are internationally competitive. It integrates relevant universities and industries and provides a venue for various collaborative research, as well as a venue for Green MEMS demonstrative research.

Point 1 Creating a venue for various collaborative research and demonstrative research where N-MEMS-related universities and industries come together

With a pilot foundry for 200–300 mm diameter integrated N-MEMS established within AIST Tsukuba East, the research core provides a venue for various collaborative and demonstrative research where N-MEMS-related universities and industries come together. The research core also provides the MicroNano Open Innovation Center (MNOIC), which offers research support services using the world's most advanced MEMS facilities.



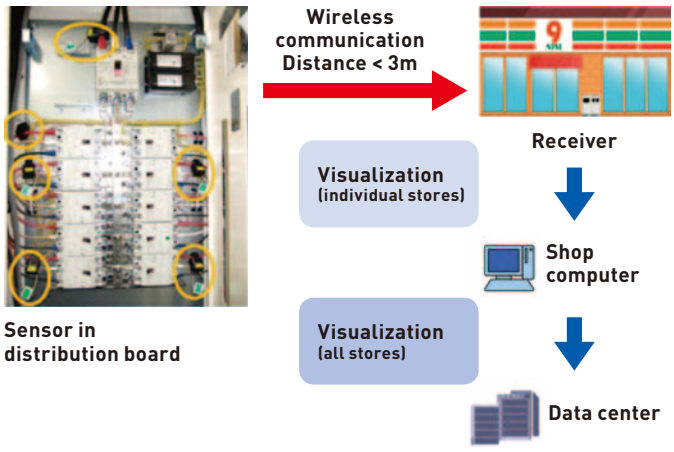
Wireless sensor network terminal prototype

Point 2 Development of integration technology for lower-power, ultra-compact wireless green sensor terminals

The research core developed a 5×5 mm square wireless temperature and humidity sensor with a function to collect and process signals from a MEMS sensor and transmit the result by wireless communication, and realized a high-function, low-power and low-cost wireless sensor network terminal of the world's smallest class. It is expected to spread dramatically through a wide range of applications including environment monitors and energy consumption monitors.

Point 3 Development of a green sensor network system for smart convenience stores

The research core has introduced a wireless current sensor network in about 2,000 convenience stores since March 2012 to collect electric power data and examine the possibility of saving energy by 10%. Since the network can be used to easily acquire the data necessary for taking energy-saving measures, such as power consumption and environmental information (temperature, humidity, etc.), it is expected to contribute significantly to building an energy-saving society.



Network system of smart convenience stores

Core research domain 4

Nano-Green

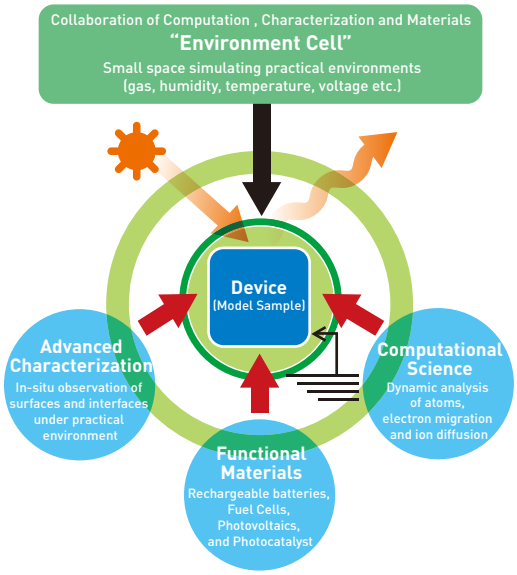
Contributing to resolving environment/energy issues through the materials research technology accumulated at NIMS

With NIMS playing a leading role, TIA-nano has been providing opportunities for research collaboration that will facilitate the creation of innovative environmental and energy technologies using nanotechnology.
Primarily focusing on three major activities, and based on the collaboration guidelines, TIA-nano has been promoting research collaboration that will expand domestic and global partnerships and lead to open innovation. We are accommodating various forms of collaboration in a flexible manner based on users' requests.
We have been carrying out R&D of high-performance energy conversion and storage materials (such as secondary batteries, fuel cells, photovoltaic materials, thermoelectric conversion materials and heat-resistant materials) using advanced computational science and technology and measurement technology, while making sure to bring things back to basics.

Activity 1 Global Research Center for Environment and Energy based on Nanomaterials Science (GREEN) *1 <TIA-nano utilization project >

GREEN is a research center for industry and academia to collaboratively promote fundamental R&D on environmental technology so as to drastically resolve global environment issues and build a sustainable society. The center works to solve problems commonly faced in research on a series of materials including photovoltaics, rechargeable batteries and fuel cells, which are associated with energy flow starting from sunlight, by integrating computational science technology, advanced measuring technology and materials research.
From FY2013, the center has specified all solid-state rechargeable batteries and lithium air rechargeable batteries as priority themes, and has promoted research under an "all-Japan" industry-academia-government collaboration framework.

*1 Established in October 2009 as a research center for conducting the MEXT program for the "Development of environmental technology using nanotechnology," with NIMS as the core institute.



Activity 2 Center of Materials Research for Low Carbon Emission <TIA-nano utilization project >

In the center, there are 28 advanced equipment*2 units related to creation, processing and evaluation of materials available for use by research institutes and researchers in and outside Japan. There are five categories of research support (see Table 1): "collaborative research," "technical support," "technical surrogate," "use of equipment," and "technical consultation." As needed, NIMS staff in charge of each unit of equipment provides precise research support by applying expertise and know-how.
Since the start of its service in April 2011 until the end of October 2014, the center has provided support for a total of 644*3 research themes of 92 research institutes (universities, national research institutes and private companies), and contributed to the creation of a large number of research results including articles and patents.

*2 The 28 advanced equipment units were introduced under the FY2009 supplementary budget of the Ministry of Education, Culture, Sports, Science and Technology (MEXT).
*3 Research theme is counted as one even if the theme involves repeated use of the equipment. Use by the equipment manager is excluded from the count.

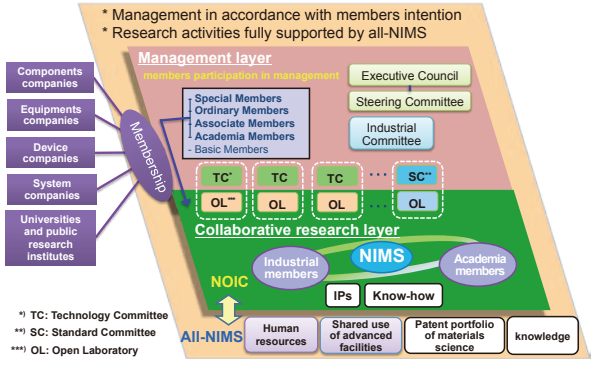
Research Support Menu of the Center of Materials Research for Low Carbon Emission

Support Type	User	Contract	Intellectual Property	User Fees
Collaborative research	Applicant/ Equipment administrator	Collaborative research agreement	Follow the collaborative research agreement	Follow the collaborative research agreement
Technical support	Applicant/ Equipment administrator	Duty of confidentiality/ User policy	Deal individually	Charged
Technical surrogate	Equipment administrator	Duty of confidentiality/ User policy	Deal individually	Charged
Use of equipment	Applicant	Duty of confidentiality/ User policy	Deal individually	Charged
Technical consultation	-	Duty of confidentiality/ User policy	Not claim	Free

Activity 3 NIMS Open Innovation Center (NOIC)

At NOIC, companies, universities and public research organizations have been participating as members and are collaboratively conducting research on certain materials NIMS has expertise on. These materials were mutually selected by NOIC members including NIMS based on common themes they agreed upon. In addition, with the participation of NOIC members, NIMS is aiming to find the optimum way of operating NOIC.
Since its establishment in April 2012, people with various specialties have joined NOIC, and during fiscal 2014, we have been working on three research themes: battery materials, thermal energy conversion materials and magnetic energy conversion materials, under the international collaboration framework.

Operation Scheme in FY2014



Core research domain 5

Carbon Nanotubes

Fundamental research for the development of technology for industrial mass production of the Tsukuba-originated new material "single-walled carbon nanotube" and the development of composite materials aimed at early commercialization

The research core supports the creation of new businesses through the establishment of mass production technology based on the Super-Growth method—a technology developed by AIST, which can synthesize high-purity single-walled carbon nanotubes (SWCNT) over 1,000 times more efficiently than the conventional method—and provision of the SWCNT obtained thereby.
Toward realizing a low-carbon society, the research core aims to achieve early commercialization of application products of SWCNT, which has properties such as being 20 times higher strength than steel, with 10 times higher thermal conductivity compared with copper, half the density of aluminum, and 10 times higher electron mobility than silicon.

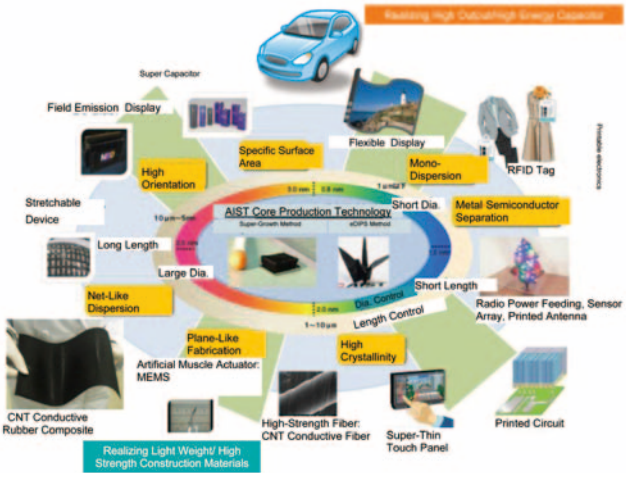
Point 1 Development of technology for industrial mass production of SWCNT based on the super-growth method

The research core has promoted the development of mass production technology for SWCNT using the super-growth method as the fundamental technology. By optimizing the process, it has succeeded in continuous synthesis of a large-area (500 mm square) SWCNT forest (bulk). Furthermore, to promote application development, the research core provides samples of the SWCNT manufactured by this mass production technology, and has already distributed such samples to more than 100 companies in Japan.

Reactor of continuous synthesis of large area

Point 2 Fundamental research for the development of composite materials aimed at early commercialization of SWCNT <TIA-nano utilization projects >

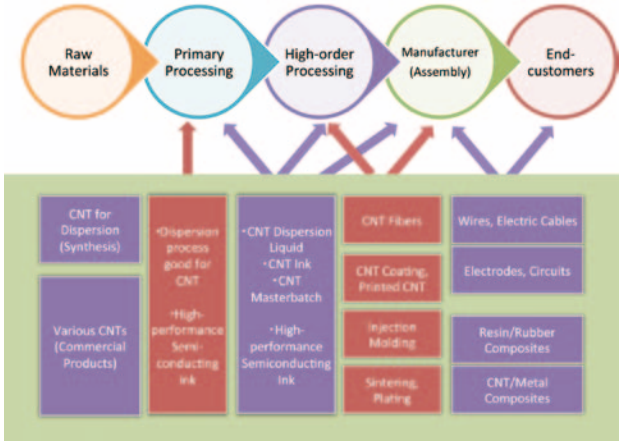
In the "Nanocarbon application project to realize a low-carbon society, " a NEDO project using TIA-nano's research base, the research core develops technology for creating semiconducting SWCNT inks and technology for combining SWCNT with existing materials such as resin, rubber and metal.



Application image of CNT composite materials

Point 3 Supporting the creation of new businesses through providing SWCNT and composite materials

CNT is only a raw material; therefore, the development of every process, such as synthesis, dispersion, composite manufacture, required to transform the raw material to everyday applications need to be developed. In order to increase the speed of industrial development, the Technology Research Association for Single Wall Carbon Nanotubes (TASC) is working with companies to establish supply chain and processing technologies (dispersion, molding, coating, sintering, plating, etc.). We will continue to provide these newly developed functional materials.



Core research domain 6

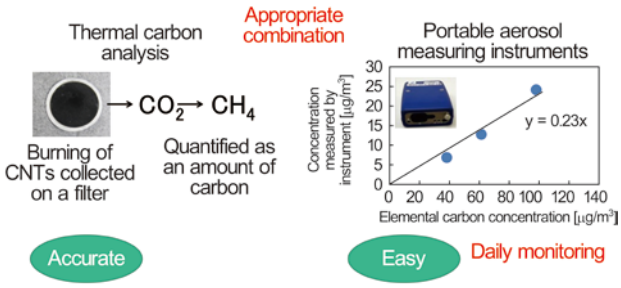
Nano-Material Safety

Establishment of safety assessment methods indispensable for technological innovations

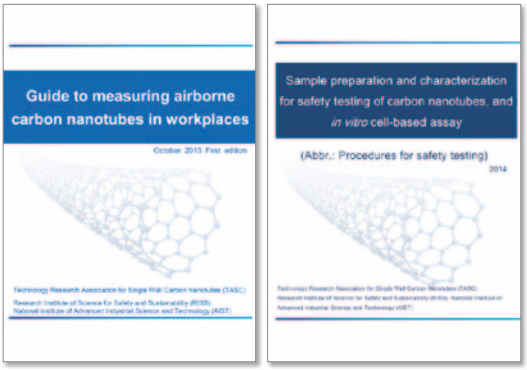
Regarding the health effects of nanocarbon materials such as carbon nanotubes (CNT) on workers who handle these materials, we assist business operators in conducting voluntary management of such issue. In this effort, we have been developing and encouraging the use of inexpensive and simple emission and exposure assessment methods and quick and easy hazard assessment methods. In addition, we study the global trends concerning individual types of nanocarbon materials, conduct case studies to acquire safety assessment data and know-how about safety management, and publicize the results.

Point 1 Development of exposure assessment and hazard assessment methods to assist voluntary safety management of CNT

We evaluated the effectiveness of a few types of compact and simple measuring equipment and carbon analysis in measuring airborne CNT in workplaces, and calculated response factors and appropriate measurement conditions for individual types of CNT. In addition, we established a standard method of dispersing CNT applicable to hazard assessment studies using cultured cells or animals. We compiled the measurement and testing methods we developed in two documents, “Guide to measuring airborne carbon nanotubes in workplaces” and “Protocols of preparation, characterization and in vitro cell based assays for safety testing of carbon nanotubes," and published them in Japanese and English.



Proposal of practical methods for measuring airborneCNTs



“Workplace environment measurement guide” and “safety testing protocols”

Point 2 Information gathering and dissemination of results to promote voluntary safety management of CNT

We acquired safety assessment data and know-how about safety management with reference to super-growth single-wall CNT and single-wall CNT manufactured using the eDIPS method, which are provided by AIST or the Technology Research Association for Single Wall Carbon Nanotubes (TASC). We then published “Safety data and TASC’s voluntary safety management.” In addition, we set up a website called Nanosafety that provides regulatory information concerning the handling of nanomaterials in Western countries and by international organizations. Furthermore, we provided our samples and test data to the Organisation for Economic Co-operation and Development (OECD) and the International Organization for Standardization (ISO), thereby contributing to the process of international standardization related to CNT.

Nanosafety Website
(http://www.nanosafety.jp)

“Safety data and TASC voluntary safety management”
(available only in Japanese. http://www.aist-riss.jp/assessment/)

Research Collaboration Domain

Instrumentation

Promotion of the "light and quantum beam application research initiative" Innovation of light and quantum beam generation and sensing technologies and advancement of their application research

Tsukuba leads the world in pioneering academic research for elucidating the origins of the universe and the roots of substance and life, using cutting-edge, sophisticated light and quantum sensing technologies with large accelerators.
Under TIA-ACCELERATE, three "Squares" are set up for open collaboration, mobilizing the advanced light and quantum sensing technologies of the four core institutions of TIA-nano, with an aim to create new science fields and industries. The three Squares (Accelerators Square, Sensor & Imaging Square and Nano-Materials Square) are respectively designed to carry out the following: development of high-performance light and quantum beam generation technologies; development of high-sensitivity, high-precision and high-resolution light and quantum detectors and advanced sensing technologies; and research for elucidating the origins of material functions and fundamental development of new functional materials by using newly developed light and quantum sensing technologies.

Light and quantum beam application research initiative (TIA-ACCELERATE)

Accelerators Square
(Development of light and quantum beam generation technologies)

(Main themes)
- Development of high-performance accelerator power supply using SiC semiconductors
- Development of ultra-compact accelerators

Sensor & Imaging Square
(Development of light and quantum sensing technologies)

(Main themes)
- Silicon on insulator (SOI) technology
- Superconductive detectors
- Imaging of large structures

Nano-Materials Square
(Elucidation of nano-material structures with light and quantum beam)

(Main themes)
- Structural materials
- Environment and energy
- Electronics materials
- Fundamental physical properties

Activity 1 Development of compact, lightweight and portable light and quantum beam sources installable in research and industrial settings

The Square aims to create accelerators that are more high-performance, compact and energy-saving overall, through such means as transferring the technology for development of large accelerators and adopting SiC power semiconductors.
Portable ultra-compact accelerators that can be brought into research and industrial settings will be developed as new artisan tools for such settings. This effort is expected to expand the use of light and quantum beam sources (X-ray, neutron and muon sources) employing compact accelerators.

Electrostatic ion storage ring
(Biomolecular ions such as DNA are stored as they are circulated within an accelerator ring, and the electron capture dissociation process of biomolecules is studied.)

Activity 2 Development of high-sensitivity, high-precision and high-resolution detectors and establishment of innovative sensing technologies

The Square develops new high-sensitivity, high-performance and high-resolution detectors such as superconductive detectors and Silicon-On-Insulator (SOI) detectors.
Innovation will be achieved in sensing and diagnostic technologies in diverse fields from fundamental physics research and medical research to infrastructure diagnosis applying cosmic rays, radiation and quantum beams generated by accelerators (e.g., technologies for imaging large structures applying cosmic ray muons).

Activity 3 Exploration of the origins of material functions and fundamental development of new functional materials

The Square promotes fundamental physical property research for exploring the origins of material functions through application of light and quantum beams.
By directly linking research laboratories using light and quantum beams and laboratories developing materials, fundamental research and development will be accelerated in the fields of "structural materials," "electronics materials" and "environment and energy materials" where the emergence of world-leading new materials is expected.

A new project launched in October, 2014
- SIP Structural Materials for Innovation
  Innovative Measurement and Analysis for Structural Materials

Core infrastructure 1

Nanodevice Research Foundry

World's highest class prototype production and evaluation equipment for nanotechnology research

The TIA-nano's Super Clean Room (SCR) is one of the largest clean rooms for nanotechnology research use in Japan with a floor area of 3,000 m^2. TIA-nano also has a SiC clean room and N-MEMS foundry (wafer diameter: 200/300 mm). They are equipped with research and prototype production lines consisting of the world's highest class nanodevice manufacturing equipment and cutting-edge evaluation equipment, which enable verification of new nanodevice operation and new materials' potential.
By effectively taking advantage of the prototype production and evaluation equipment, a large number of research projects are under way in collaboration with private companies and research institutes in and outside Japan. With regard to the SCR and the N-MEMS foundry, TIA-nano is actively encouraging industrial use of its world's highest class equipment not only by making them easily accessible for external users as facilities for shared use but also by reinforcing its information management system.

Point 1 Promoting integration of diverse nanodevices using a 3,000 m^2 SCR

The SCR has a semiconductor line and equipment handling 12-inch wafers, and constitutes TIA-nano's cutting edge nanoelectronics research infrastructure, with line quality for verification of integration and flexibility that enables verification of new nanodevice operation and new material's potential. The process platforms, for CMOS transistors, Cu-wiring by dual-damascene process, and Si photonics, are configured based on ArF immersion lithography tool, as well as various process equipment and sophisticated elemental process technologies. Based on these, TIA-nano efficiently supports the R&D of a large number of projects that are promoted toward the creation of new nanodevices by using the SCR.

Point 2 Promoting practical application of SiC power devices through prototype production, verification, and evaluation

TIA-nano provides dedicated equipment for prototype production, verification and evaluation of SiC power devices for use in power electronics research projects.
It has established a "research system with vertical cooperation" where advanced technologies in which Japan can demonstrate its strength are gathered from the entire stream of R&D from materials development to development applied technologies, centering on the mass production prototype line for SiC device chips. As industries and public institutes jointly concentrate their research resources in this research base, technical and business risks can be reduced. As a result, the development period can be dramatically shortened, and society will be able to benefit from the research results more quickly.

Point 3 Contributing to commercialization and development of new technologies of N-MEMS devices based on various needs and seeds

TIA-nano has established an N-MEMS foundry (wafer diameter: 200/300 mm) to be used for R&D of advanced integrated MEMS and for the fabrication of prototype devices with a general-purpose large-diameter line. It aims to make the foundry a shared facility center for a network of MEMS-related industries.

Core infrastructure 2

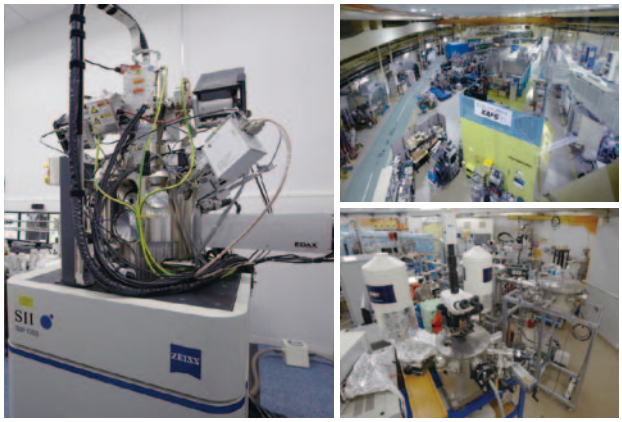
Nanotech Open User Facilities

Contributing to promoting efficient research activities by shared use of advanced nanotechnology equipment

Thirty-two public research institutes, accounting for one-third of all public research institutes in Japan, are located in Tsukuba City, Ibaraki Prefecture, where research facilities, including those developed at TIA-nano, and research environments are prepared for various types of studies. In particular, TIA-nano's four core organizations: AIST, NIMS, the University of Tsukuba and KEK, possess an array of leading-edge facilities and equipment that supports nanotechnology research. Various state-of-the-art facilities and equipment have been used for materials synthesis, microfabrication, fabrication of prototype devices, physical property measurement and nanoscale measurement and analysis, in various forms of services such as technical consultation, technical surrogate, use of equipment, and collaborative research (chargeable services).
Besides these chargeable services above, Photon Factory (PF) at KEK is opened for public use of nonproprietary research at universities etc. (free of charge) and supports "trial use" for novice industrial researchers (free of charge). TIA-nano holds training sessions and encourages shared use of the equipment to shorten the time used for development.

Point 1 State-of-the-art equipment

TIA-nano provides state-of-the-art equipment for enabling the world's latest, leading-edge nanoscale measurement and analysis, such as microscopes including "positron defect-detecting microscopes," "scanning helium ion microscopes," and "electron microscopes for single-atom analysis" as well as 3D multi-scale triple-beam analytical microscopes as equipment for shared use. In addition to those fundamental equipment, TIA-nano also offers equipment for experiments with fluorescent XAFS, etc. using synchrotron radiation of the Photon Factory (PF), and equipment that enables nano-scale elemental analysis, ultrasensitive accelerator mass spectrometry (AMS), and space radiation tolerance testing using ion accelerators, to be put to shared use for a variety of purposes ranging from academic research to the development of industrial technology.



Point 2 Development of nanotechnology human resources and trial use for industrial application

TIA-nano offers various seminars and training courses for developing nanotechnology human resources in a variety of fields ranging from R&D of the world's latest, leading-edge nanoscale processing, measurement and analysis technologies and academic research to the development of industrial technologies.
Also, at the Photon Factory (PF), material evaluation/analysis technologies using synchrotron radiation (XAFS, SAXS, XRD, photoelectron spectroscopy, imaging, topography, etc.), and, at the University of Tsukuba, measurement/processing techniques using ion beams, are available for trial use (free of charge) aimed at their application in industrial R&D.

Point 3 Database of Open Research Facilities in Tsukuba http://oft.tsukuba-sogotokku.jp/

As part of the Tsukuba International Strategic Zone projects, a database has been created for allowing a batch search of open research facilities in the Tsukuba area. At present, about 280 units of equipment for shared use installed at the four core institutes of TIA-nano (AIST, NIMS, University of Tsukuba and KEK) are registered. The database allows users to find out the location, specifications and the application method for the equipment they want to use by conducting a keyword search. Also, users can search data by combining the analysis, measurement or processing object and technique, and can identify the equipment that best serves their purpose.

Core infrastructure 3

Networking School of Nanotechnology

With the University of Tsukuba as the base, high quality human resources are developed in coordination and cooperation with universities and industries in and outside Japan.

TIA-nano has been preparing a "Networking School of Nanotechnology" for promoting human resources development. With the University of Tsukuba as the base, a "TIA Graduate School" framework is being built, using high quality human resources and education-research resources, in coordination and cooperation with universities and industries in and outside Japan.

Activity 1 TIA Graduate School Summer Open Festival and the TIA Graduate School Consortium

TIA Graduate School holds the "TIA Graduate School Summer Open Festival" as a comprehensive event and collaborative project that links the "human resources development programs" of the core research groups of TIA-nano. In addition, with an aim to construct a collaborative management system open to industry, academia and government, the "TIA Graduate School Consortium" has been established, with the University of Tsukuba, Tokyo University of Science, Shibaura Institute of Technology, AIST, NIMS and KEK as the key institutes. It is an organizational system whereby education and research are conducted under collaboration in all university in Japan.

Activity 2 Power electronics endowed courses

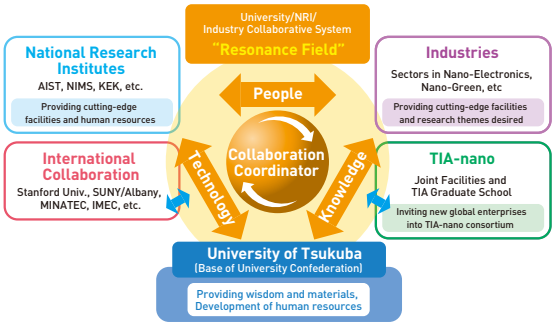
As graduate school education provided through industry, academia and government collaboration, a "TIA Graduate School power electronics course" was opened in April 2013, combining two endowed courses at the University of Tsukuba (the Toyota Motor-Denso power electronics endowed course and the Fuji Electric power electronics endowed course) and dispatch of AIST researchers as instructors (Cooperative Graduate School System)*1. Through systematically learning power electronics as an academic discipline and conducting collaborative research and working in close cooperation with company researchers, students who have experienced practical research in this course are expected to play an active role in companies, and succeed to and further develop Japan's advanced power electronics technologies. The human resources development under this course is implemented with the cooperation of an industry-funded consortium which is operated under industry-academia-government collaboration and based on the Tsukuba Power-Electronics Constellations (TPEC)*2.

*1 A system at the University of Tsukuba to provide education at its graduate school by employing researchers from research institutes as instructors at the University of Tsukuba while keeping their status as institute researchers, and using the research environments of those research institutes

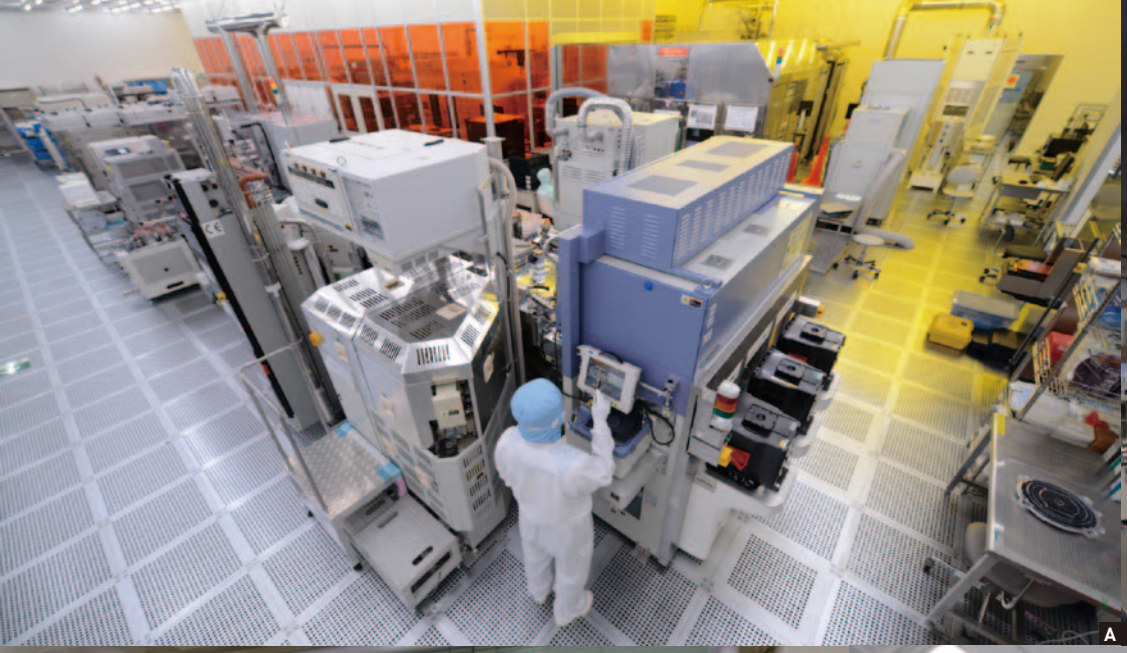
*2 An industry-funded consortium operated in a self-sustaining manner, with Japanese global companies related to power electronics covering most of the R&D funds.

Activity 3 Honors Graduate Program: Tsukuba Nanotechnology Human Resource Development Program*3 <TIA-nano utilization project >

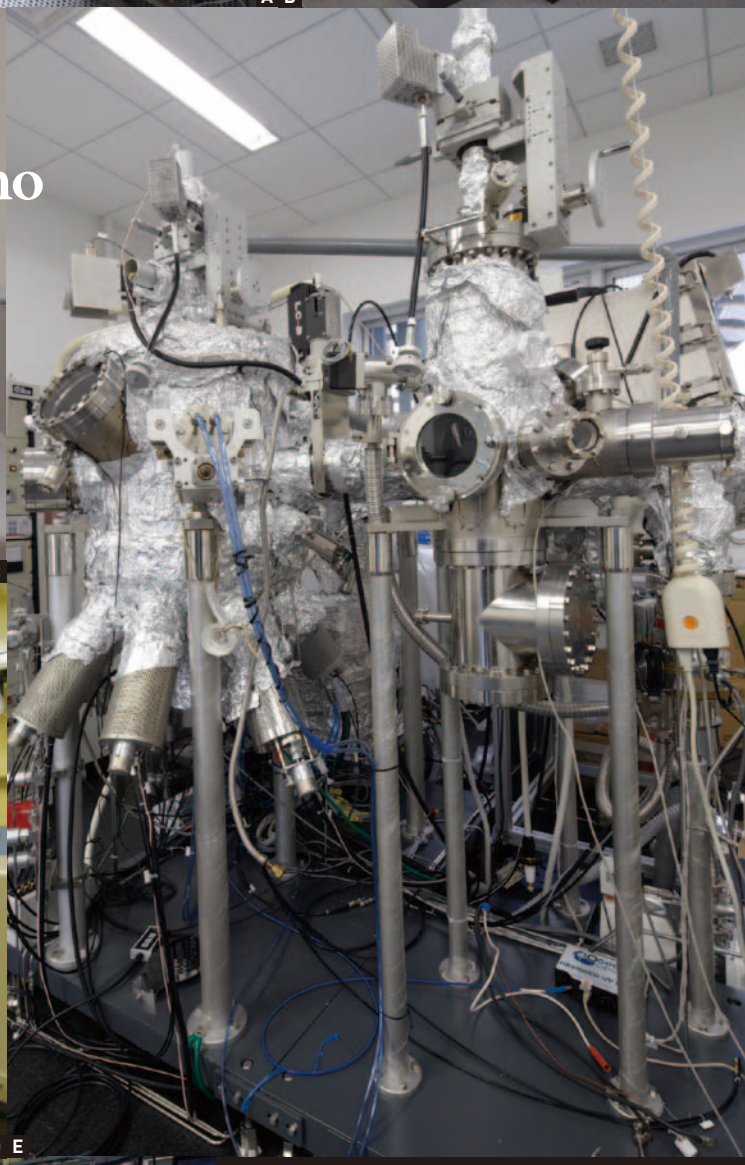
This program was launched in FY2010 at the University of Tsukuba with an aim to develop doctoral students who will lead the next generation in nanotechnology, making the most of the geographical advantage of Tsukuba. “Collaboration Coordinators” with outstanding research achievement and business experiences are allocated in seven major fields of nanotechnology to facilitate needs of Industry and research skills of Honors Graduate Students to support their research agenda to break down research topics into education/research themes founded on basic science, and forms a resonance field which gives rise to a flow of "technology, knowledge and people." By using this resonance field to promote collaborative research and human resource development, students can acquire a global perspective and practical problem-solving skills. Furthermore, the program provides opportunities for the students to receive widespread acclaim from outside through such as a short-term overseas Knight-Errantry at worldwide nanotech arenas for about four months, Summer Lectures by prominent professors of the world, and international symposiums to actively transmit research results.

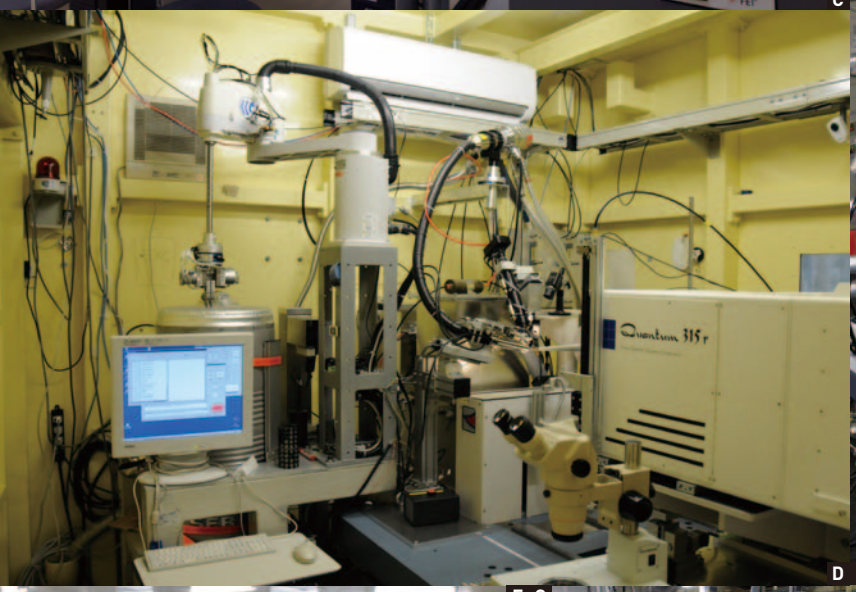


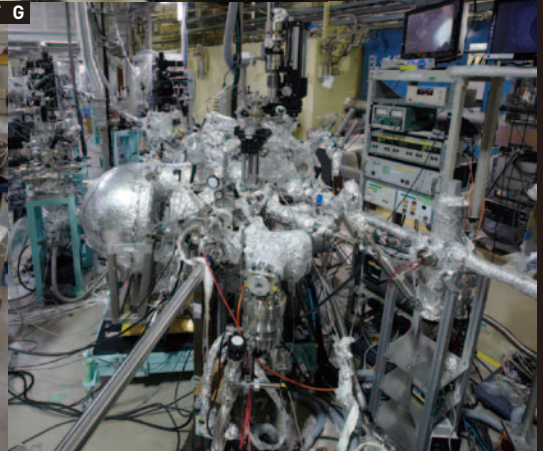
*3 MEXT fund for University-Industry Collaboration Project (2010~2015) entitled



The world's most advanced research facilities of TIA-nano



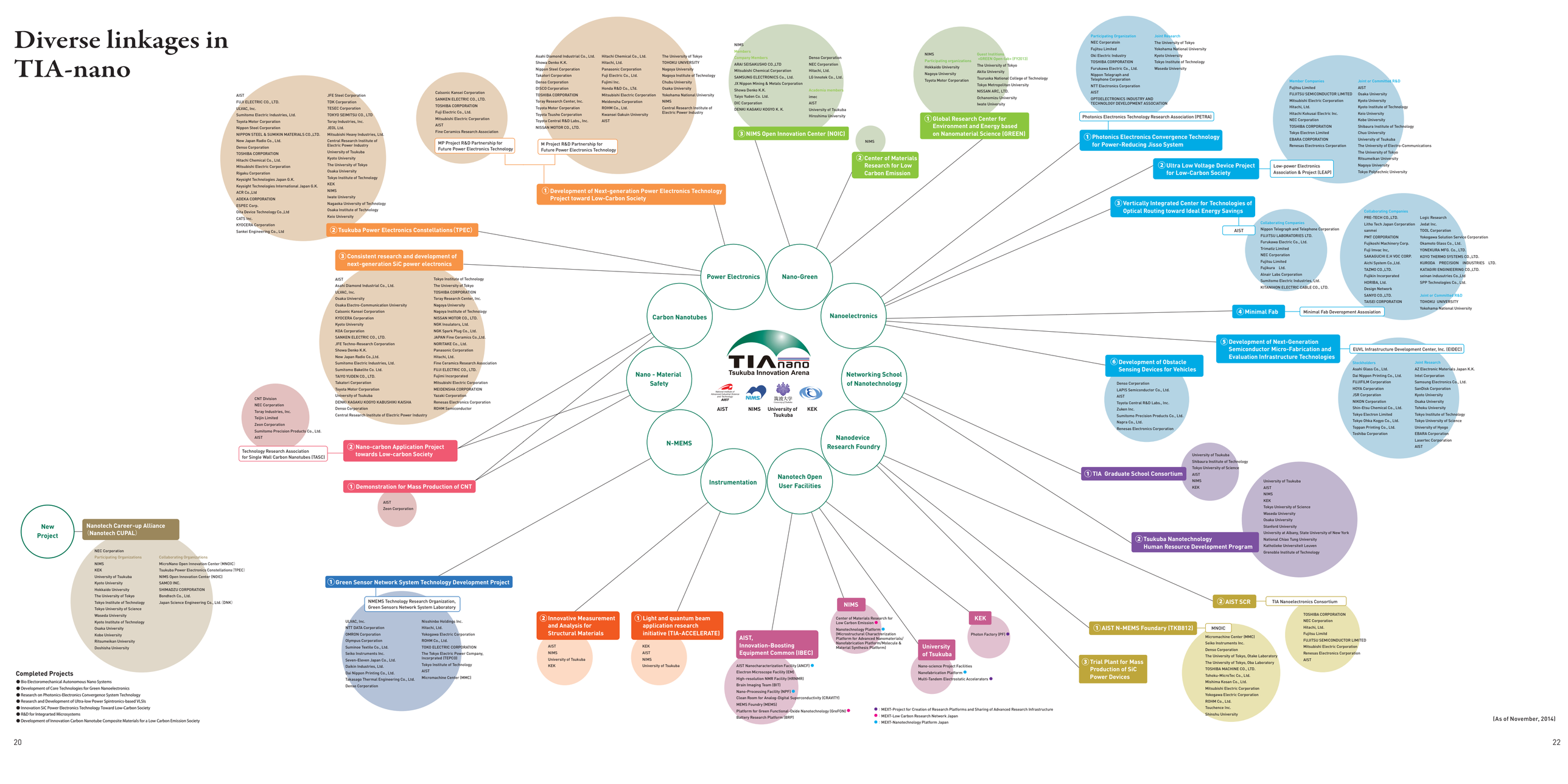




Research facilities

- **A** Nano-carbon deposition system
- **B** Electron microscope with aberration correction
- **C** FIB-SEM
- **D** Protein crystallography station
- **E** MBE quantum well thin film fabrication apparatus
- **F** 1 MV Tandetron accelerator
- **G** Angle-resolved photoemission spectroscopy (ARPES) station for surface chemistry

Diverse linkages in TIA-nano



(As of November, 2014)

Projects

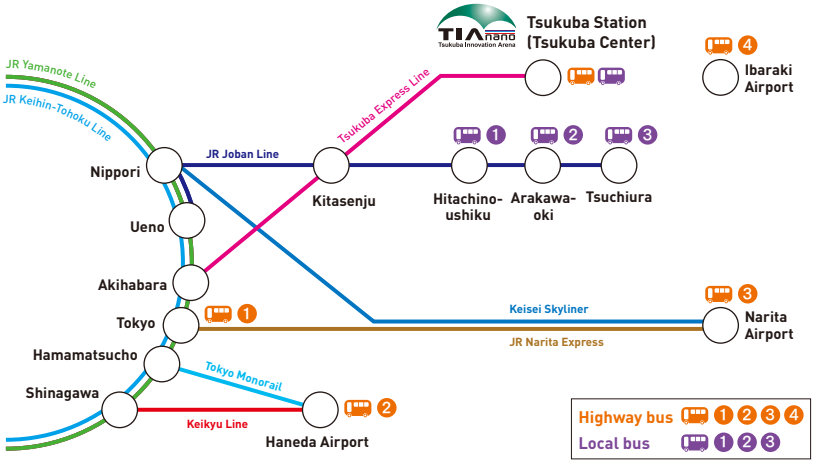
Nanoelectronics	
① Photonics-Electronics Convergence Technology for Power-Reducing Jisso System	Develops photonics-electronics convergence integrated circuits and devices and their packaging technology, toward realizing optical interconnection between/within information equipment
② Ultra-low Voltage Device Project for Low-Carbon Society	Develops ultra-low power BEOL devices with phase change materials embedded in the LSI's interconnect layer and charge-information storage changed to resistance-change information storage
③ Vertically Integrated Center for Technologies of Optical Routing toward Ideal Energy Savings	By building a technology center aimed at realizing innovative information and communications networks with ultra-low power consumption, develops optical switch devices and transmission and network technology
④ Minimal Fab	Develops necessary elemental technologies, such as minimal equipment, wafers and ultra-compact components, for realizing semiconductor fabs (minimal fabs) requiring 1/1000 plant investment cost by using half-inch wafers
⑤ Development of Next-Generation Semiconductor Micro-Fabrication and Evaluation Infrastructure Technologies	Develops basic technologies (mask technology and resist technology) of EUVL (extreme ultraviolet lithography), which is a promising next-generation lithography (exposure) technology
⑥ Development of obstacle sensing devices for vehicles	Using 3DIC technology, with which a sensing device chip and a signal processing circuit chip are stacked and connected, we have been developing a technology to miniaturize the device with automotive quality, which is space-saving and capable of high-speed signal propagation.
Power Electronics	
① Development of Next-generation Power Electronics Technology Project toward Low-Carbon Society	Develops SiC power semiconductor materials and devices (second generation) for automobile, railway and industry equipment
② Tsukuba Power Electronics Constellations (TPEC)	Industry-funded consortium promoting Japanese-style open innovation engaged in R&D and human resources development aimed at industrial application of SiC power semiconductors
③ Consistent research and development of next-generation SiC power electronics	We will develop materials, devices, and packaging and system technologies related to next-generation power electronics such as SiC.
N-MEMS	
① Green Sensor Network System Technology Development Project	Develops innovative sensors with wireless communication, stand-alone power supply and lower power consumption functions, and conducts demonstration testing of a sensor network that visualizes and optimizes energy consumption
Nano-Green	
① Global Research Center for Environment and Energy based on Nanomaterial Science (GREEN)	Works to solve problems commonly faced by solar-based energy flow systems such as photovoltaics, rechargeable batteries and fuel cells, while integrating theories and experiments by making full use of computational nano-science and advanced nano-characterization techniques and returning to the basics
② Center of Materials Research for Low Carbon Emission	Makes 28 advanced equipment units related to the creation, processing, evaluation and design of materials available for use for a fee, and with the support of NIMS experts, actively supports advanced research on carbonization
③ NIMS Open Innovation Center (NOIC)	NOIC is a membership-based collaborative research center with the aim of achieving breakthroughs in materials science through interactions of researchers among industries, academia and public institutions. Notable features of NOIC include members' participation in the operational aspect, the fact that each organizational unit manages its own information, the use of leading-edge facilities in material evaluation, and sharing of know-how about materials technology.
Carbon Nanotubes/Nano Material Safety	
① Demonstration for Mass Production of CNT	Establishes mass production technology for single-walled carbon nanotubes (SWCNT) based on the super-growth method
② Nanocarbon application project to realize a low-carbon society	We are developing innovative materials by mixing existing materials with nanocarbon materials (e.g., carbon nanotubes and graphene).
Instrumentation	
① Light and quantum beam application research initiative	The four core institutions of TIA-nano collaborate to drive innovation in the light and quantum beam technologies such as the accelerator and instrumentation, and to promote the research for advanced materials. The main themes are the down-sized accelerator, SOI-sensor, inspection for the decrepit social infrastructure, structural materials and so on.
② Innovative Measurement and Analysis for Structural Materials	We establish an R&D center of advanced measurement and analysis instrumentation for structural materials. The latest instruments provide synchrotron-radiation-based analysis, ion beam analysis, superconducting X-ray spectroscopy, atom probe analysis, and positron probe microanalysis.
Nanodevice Research Foundry	
① AIST N-MEMS Foundry (TKB812)	N-MEMS foundry (wafer diameter: 200/300 mm) conducting R&D on advanced integrated MEMS and fabrication of prototype devices with a general-purpose large-diameter line
② AIST Super Clean Room (SCR)	With the world's highest class nanodevice manufacturing/processing/evaluation equipment equipped in one of the largest super clean rooms in Japan with a floor area of 3,000m^2, conducts operation verification of new materials and new structure devices and supports a large number of projects
③ Trial Plant for Mass Production of SiC Power Devices	Provides dedicated equipment for prototype production, verification and evaluation of SiC power devices for use in TIA-nano power electronics research projects
Networking School of Nanotechnology	
① Tsukuba Innovation Arena (TIA) Graduate School Consortium	Forms an organizational system for developing human resources in the nanotechnology field, aiming to build a collaborative management system open to industry, academia and government
② Tsukuba Nanotechnology Human Resource Development Program	Develops doctoral students and postdoctoral researchers who will lead the next generation in nanotechnology using the Tsukuba Science City as a campus
New project	
① Nanotech Career-up Alliance (Nanotech CUPAL)	To improve the careers and mobility of Japan's nanotechnology researchers, we will foster the type of professionals who will lead the creation of new knowledge (nanotech research professionals or NRPs) and specialists to create innovation by use of accumulated high level expertise and advanced equipment (nanotech innovation professionals or NIPs).

(As of November, 2014)

NIMS Nano Green Building (completed in March 2012)

AIST TIA Collaboration Center (completed in March 2013)

Access to TIA-nano from Tokyo



TIA nano
Tsukuba Innovation Arena

Tsukuba Innovation Arena for Nanotechnology
National Institute of Advanced Industrial Science and Technology
National Institute for Materials Science
University of Tsukuba
High Energy Accelerator Research Organization
KEIDANREN (Japan Business Federation)

Contact
Secretariat, Executive Board,
Tsukuba Innovation Arena for Nanotechnology
http://tia-nano.jp Email: tia-nano_info@tia-nano.jp

Tsukuba Innovation Arena Headquarters
National Institute of Advanced Industrial
Science and Technology (AIST)
Tsukuba West, 16-1 Onogawa, Tsukuba, Ibaraki 305-8569, Japan
Tel. +81-29-862-6123

Tsukuba Innovation Arena Promotion Office,
National Institute for Materials Science (NIMS)
1-2-1 Sengen, Tsukuba, Ibaraki 305-0047, Japan
Tel. +81-29-860-4955

Tsukuba Innovation Arena Promotion Office,
University of Tsukuba
1-1-1, Tennodai, Tsukuba, Ibaraki 305-8571, Japan
Tel. +81-29-853-5891

Tsukuba Innovation Arena Promotion Office,
High Energy Accelerator Research Organization (KEK)
1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan
Tel. +81-29-879-6253