

AIST's Nanotec

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What is Nanotechnology?

Nanotechnology is technology to manipulate and control a substance at the nanometer (nm) level (1 nm = one billionth of a meter. The nanometer level is the level of atoms and molecules. See Figure 1), and create new materials and devices with fascinating functions making the best use of the special properties of nano-sized substances. For example, today people need devices able to store information at high densities and high speeds, using little energy. One way of realizing this is to make each component very small. However, as there are limits to miniaturizing components with existing technology, we need technology that uses a different (nanotechnology) approach to process components and systems with nanometer-level precision. Also, when the size of the matter is at the level of several molecules or atoms, certain properties (the quantum effect or the surface effect) are clarified, which are not particularly noticeable when a substance is a large mass. Therefore, the downsizing to the nanometer level can provide us not only the miniatures but also completely new devices operated by such special properties.

Metrology advancements have given nanotechnology a big boost

The rapid development of nanotechnology research in recent years is closely related to advances made in metrology. For example, in the first half of the 1980s, the IBM Group invented the scanning tunneling microscope, which enabled researchers to observe and manipulate a substance at the level of individual atoms and molecules. This opened the way for creating and verifying various nano-structures.

The two methods of controlling the structure of matter at the nanometer level are the top-down and bottom-up methods. In the top-down approach, larger masses are finely processed, as in lithography, with light or electron beams. In the bottom-up approach, structures are created by assembling atoms and molecules. Various different bottom-up approaches are being studied. In addition to the manipulation of individual atoms by a scanning tunneling microscope, methods using the self-assembly of atoms and molecules (where atoms and molecules come together to form stable structures) are being researched as well as methods using the self-organization of a substance (where nanoscale structures form spontaneously under certain conditions), as manifested in living organisms. Currently, there is considerable interest in combining top-down and bottom-up approaches to develop technologies for assembling and operating complex components and systems.

Application to industrialization

While nanotechnology is a comparatively new field of research, it has promising applications to a range of industrial fields. In the information technology area, researchers are investigating the application of nanotechnology to the development of, for example, high-density/efficiency memories, computer devices with completely new operating principles, high-luminosity devices using nano-materials such as carbon nanotubes, and high-speed optical network devices using photonic crystals. In medical area, specialists are working on drug injections to certain organs using liposomes or nanomachines. And in the environmental and energy industries, it is thought that nanotechnology can be utilized in such applications as environment remediation catalysts and hydrogen-loading materials. In this way, nanotechnology is creating new industries across a wide range of fields and attracting interest as a infrastructural technology for enriching society.

Japan's approach to nanotechnology

Six government departments carry out nanotechnology-related national projects in Japan. These are the Ministry of Education, Science, Sports and Culture (MEXT), the Ministry of Economy, Trade and Industry (METI), the Ministry of Public Management, Home Affairs, Posts and Telecommunications, the Ministry of Health, Labor and Welfare, the Ministry of Agriculture, Forestry and Fisheries, and the Ministry of the Environment. The total nanotechnology-related budget for FY2003 is expected to be more than the last year's amount (¥81.6 billion). Of this amount, most was allocated to MEXT and METI (97.5% of the FY2001 budget for nanotechnology-related projects). Both Ministries identify electronic device- and biotech-related nanotech projects as important research areas. Against this background, the nanotechnology and materials R&D promotion project team (NTPT) of the Council for Science and Technology Policy are trying to strengthen links with government departments and agencies for collaborative projects that would result in more efficient R&D useful for industrial advancement.

Through New Research Promotion Program (including so-called CREST and ERATO projects) and Nanotechnology Support Projects, MEXT is currently funding research themes that promote nanotechnology basic research (including providing nanotechnology-related facilities and constructing nanotechnology networks). Table 1 shows the Ministry's principal nanotechnology-related project proposals for FY2003. The

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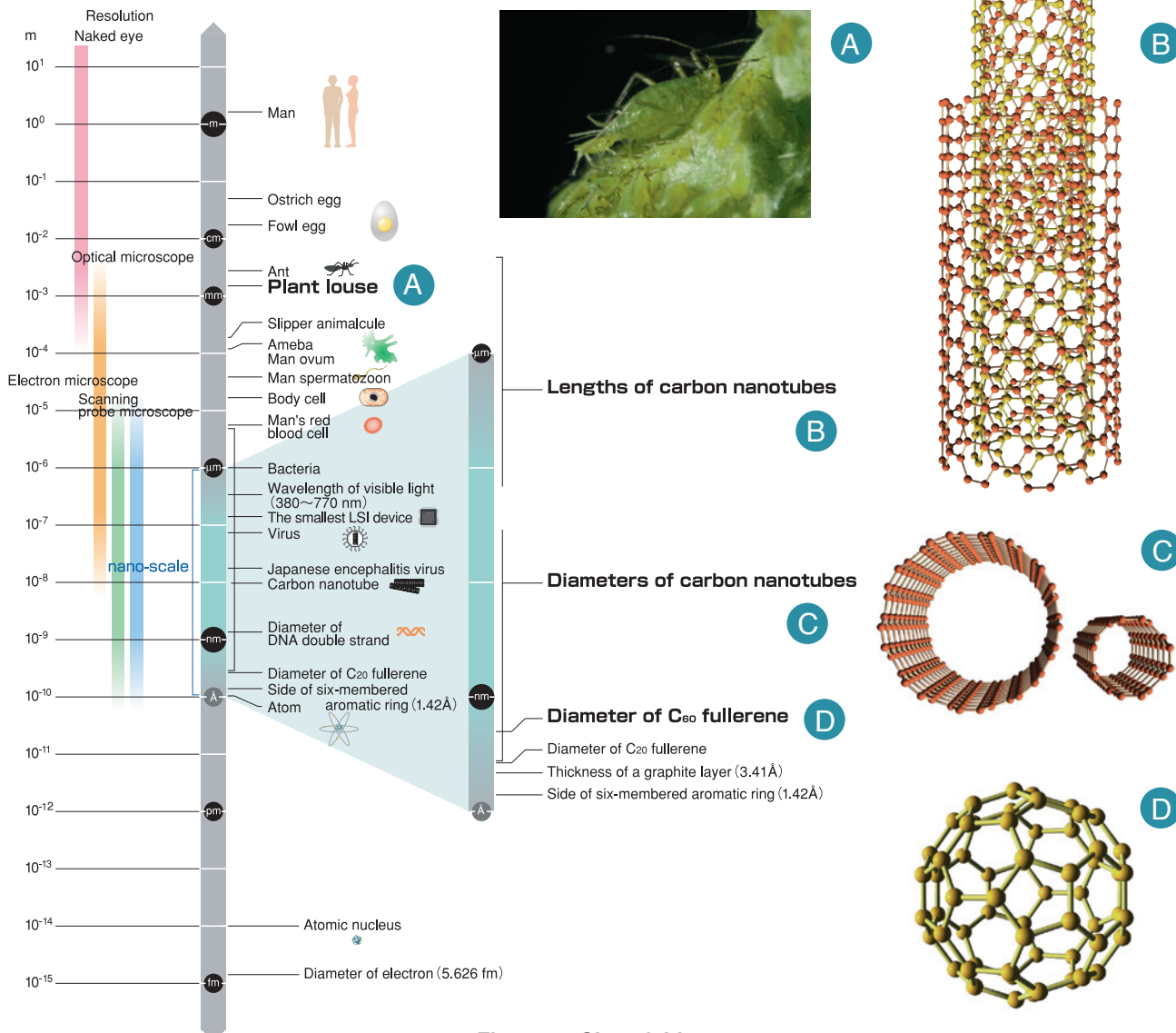


Figure 1. Size of things

Table 1. Principal nanotechnology-related project proposals of the Ministry of Education, Science, Sports and Culture (FY2003)

- Development of devices with novel principle using nanotechnology
- Development of advanced semiconductor manufacturing technology including the EUV light sources
- Development of artificial internal organs and sense organs using nanotechnology
- Next-generation fuel cells
- Project for terahertz photonics
- Development of equipments for measurements, analyses and evaluations
- Project for medical treatment according to individual's gene
- Project for regenerative medicine
- Simulation for cells and organisms
- R&D of biofunction measurement technology by photonics
- Incubation of new industries for sugar chain biotechnology
- "Protein 3000" project

Table 2. Principal nanotechnology-related project proposals of the Ministry of Economy, Trade and Industry (FY2003)

- Ultrafine structured advanced functional materials
- Microfabrication of semiconductors and novel semiconducting materials
- Semiconductor application chips
- Upgrading of telecommunication systems
- Advanced display
- Post-genome
- Amalgamation of nanotechnology and biotechnology
- Nanobiotechnology
- Development of lightweight materials and heat release technology
- Development of next generation fuel cells

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total funding sought in MEXT's nanotechnology budget is around ¥50.5 billion.

The METI, on the other hand, focuses on nanotechnology industrialization. It aims, for example, to establish the nanotechnology business promotion council in September 2003 to promote links among industry, government bodies, and universities. The Ministry's nanotechnology-related projects also seek to quickly develop practical and industrial applications for nanotechnology. Table 2 shows the Ministry's principal nanotechnology-related project proposals for FY2003. The total funding sought is around ¥62.4 billion.

AIST's world-leading approach to nanotechnology

This feature introduces some nanotechnology-related research topics pursued by AIST. AIST, the National Institute of Advanced Industrial Science and Technology, is an integrated research institution that employs around 2,400 (full-time) researchers and covers a wide range of research fields, including materials, manufacturing technology, life-sciences, information technologies, energy and the environment. The field we apply nanotechnology therefore ranges in wide ways.

The special characteristic of AIST's nanotechnology research is strong links with researchers in the computational science and standards/measurement technology fields. By combining actual experimental research of nano-materials with the computer simulations of their structure and physical properties, we can achieve more efficient R&D that takes us beyond the trial-and-error research methods used in the past. AIST also develops sophisticated measurement technologies that are essen-

tial for applying nanotechnology to industry, and standard nano-materials that give greater reliability.

From 1992 to 2002, the National Institute of Advanced Interdisciplinary Research (NAIR) (a research institute of the Agency of Industrial Science and Technology, the forerunner of today's AIST) carried out the Atom Technology Project on the ultimate technology for manipulating of atoms and molecules. This was a world-leading project, which gathered together researchers from industry, government, and universities in Tsukuba to break new ground in nanotechnology research. AIST also leads such projects as the Nanotechnology Program (of the New Energy and Industrial Technology Development Organization or NEDO) and the Semiconductor MIRAI Project (NEDO), seeking to strengthen Japan's international competitiveness and create new industries (Figure 2).

Some of AIST's staff also act as project leaders in a number of New Research Promotion Program (MEXT). In addition, AIST provides various resources for the Nanoprocessing Partnership Program (a MEXT Nanotechnology Support Project: see the article in this feature) centered on AIST's Nanotechnology Research Institute, and the Innovative MEMS (Micro-Electro-Mechanical Systems) Business Support Program (METI) centered on the AIST Institute of Mechanical Systems Engineering. In these programs, AIST supplies researchers from industry, government, and universities with the latest leading-edge systems, technical advice, and prototyping services and provides support so that researchers' ideas can be quickly turned into reality. In this way, AIST contributes to the acceleration of Japan's nanotechnology R&D.

I hope that this feature will successfully convey something of AIST's nanotechnology-related activities.

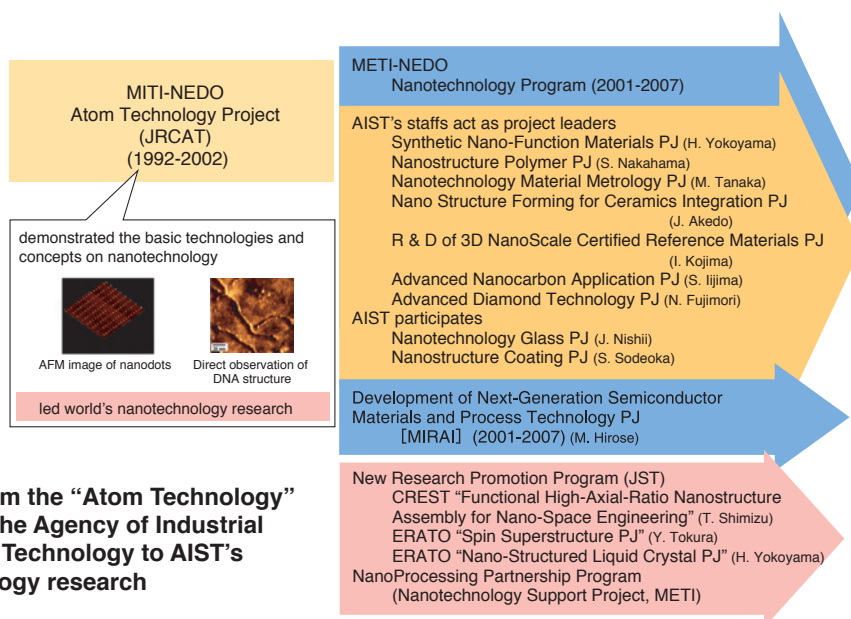


Figure 2. From the "Atom Technology" research of the Agency of Industrial Science and Technology to AIST's nanotechnology research