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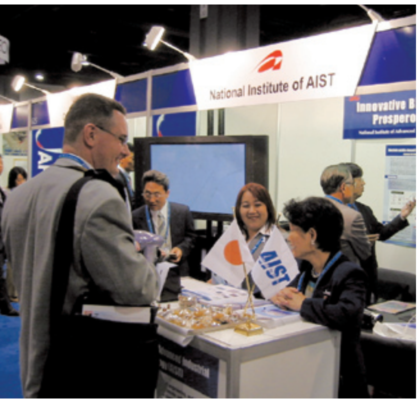

AIST Today

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National Institute of Advanced Industrial Science and Technology ***AIST***

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 the1980s, 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 wey 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 munipulation of individual atoms by a scanning tunneling microscop, 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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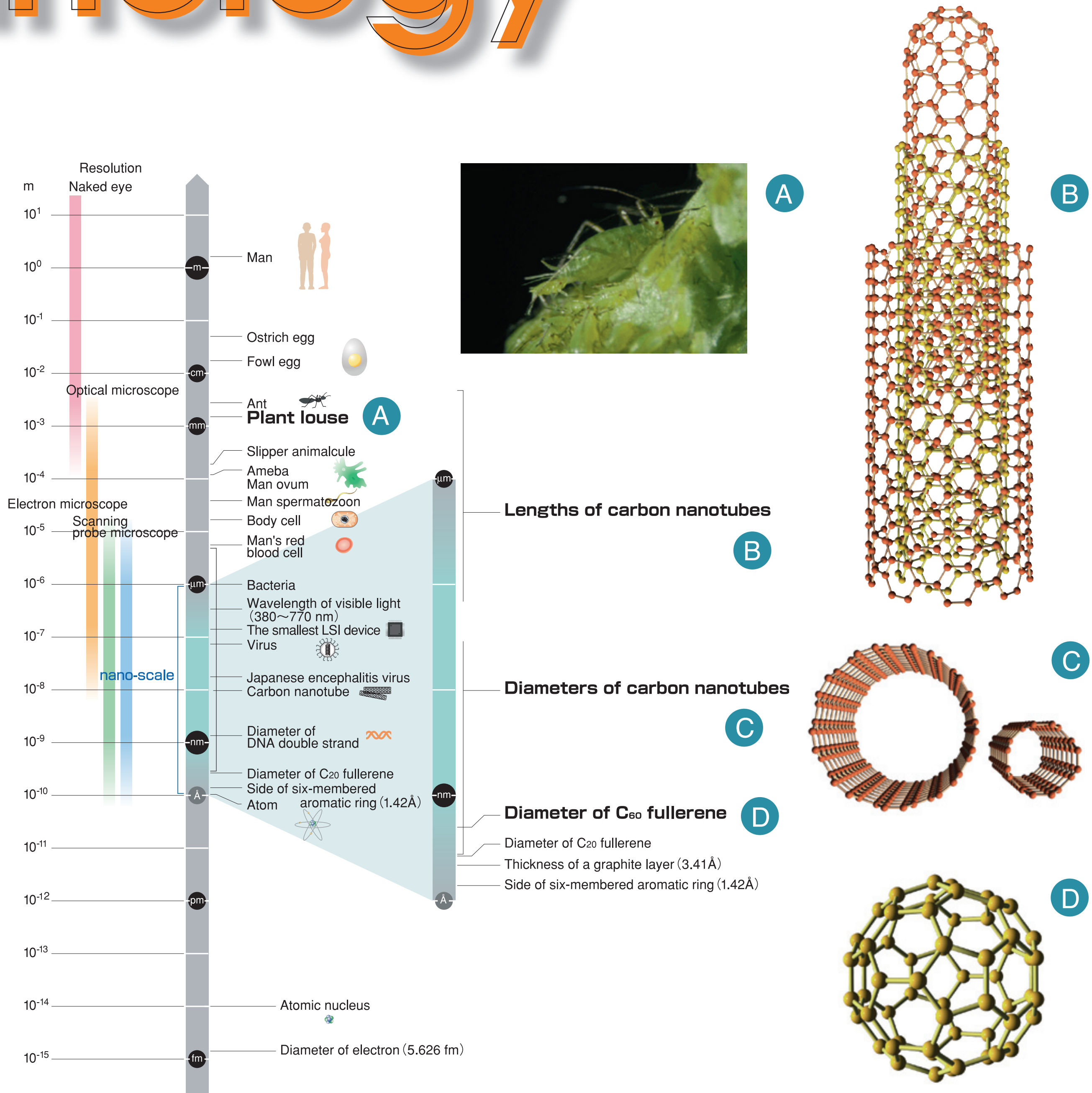

Figure 1. Size of things

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 funtional 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

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 essential 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.

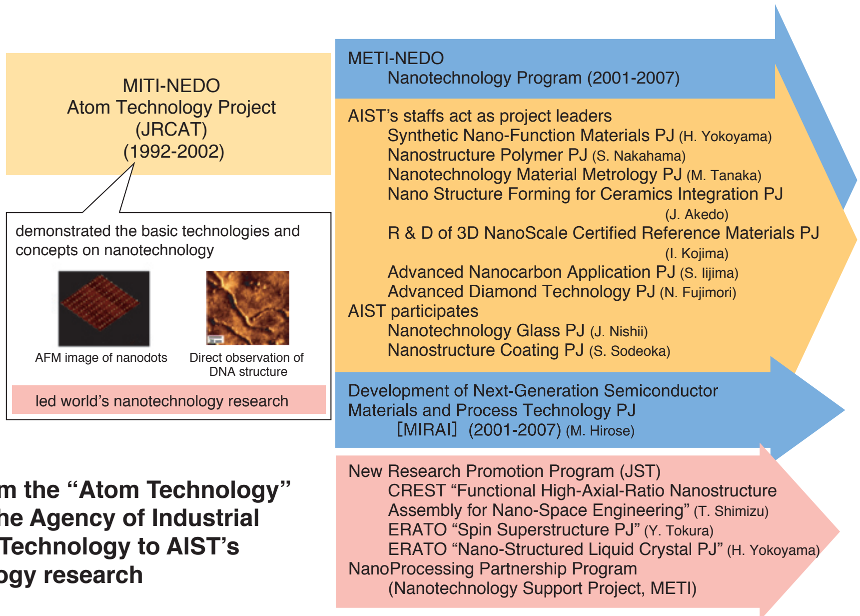

Figure 2. From the "Atom Technology" research of the Agency of Industrial Science and Technology to AIST's nanotechnology research

World Nanotech Projects

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Technology Information Department

United States

In the United States, the first country in the world which started nanotechnology-related national-scale project known as the National Nanotechnology Initiative (NNI), nanotechnology, that is nanoscale science and technology, is recognized to be not simply a field of understanding of materials and phenomena or development of technology but an intersectional, general and fundamental concept concerned with various industrial and social fields such as materials and manufacturing, electronics and computer technology, medicine and health, aeronautics and space exploration, environment and energy, biotechnology and agriculture, and national security. It is regarded as a key driver to have influence on future industrial competitiveness of developed countries. It is also recognized to have a strong character of new field-fusion science. Its implementation content is very general and widely embracing and includes education and training as well as research and development. Funding is allocated to such areas as long-term basic research, Grand Challenges, interdisciplinary nanotechnology research center, research infrastructure and equipment, technology transfer, education and training.

The NNI is managed by the Committee on Technology (CT) of the National Science and Technology Council (NSTC). The Nanoscale Science, Engineering and Technology (NSET), the CT's subcommittee, coordinates many US federal nanoscale R&D programs including the NNI, and plans, drafts and implements the NNI.

The total NNI budget is steadily increasing: US$464 million (FY2001), US$604 million (FY2002), US$774 million$ (FY2003), US$847 million (FY2004, request). While ten government departments and agencies participate in the NNI, a large portion of the budget is distributed to the National Science Foundation (NSF), the Department of Defense (DOD), and the Department of Energy (DOE). These three government bodies consume 80% of the total NNI budget.

Recently, the nanotechnology bill was submitted in both the House of Representatives and the Senate. In May, the Nanotechnology Research and Development Act was passed by the House of Representatives, and a total budget of US-2.36 billion$ has been approved for the three years starting from FY2004.

Europe

Nanotechnology in Europe includes nanotechnology and product production technology planned from beginning to end to be environmentally friendly including conservation of resources and energy all the while curbing costs.

European research is divided into Framework Programs implemented by the European Commission, in which joint research is done with several countries and National Programs carried out within each country. The Sixth Framework Program (2002 - 2006) is the latest of the framework programs. This program which includes eight priority areas will support industry and aims at true technological innovation in a wide range of fields from basic research to products. The total budget for the eight priority areas is 11.3 billion euros. Nanotechnology-related area, "Nanotechnologies and Nanosciences, Knowledge-based Multifunctional Materials and New Production Processes and Devices," is one of the eight priority areas, and is funded at 1.3 billion euros (around US$1.8 billion), or 11.5% of the total budget. It is seen as crucially important technology for a next generation industrial revolution.

In Germany, national nanotechnology-related R&D programs are actively promoted with the support of the federal government centered on the Federal Ministry of Education and Research and the Federal Ministry of Economics and Labor. A total of 18 million euros is being spent on nanocomposites and other new materials; 21 million euros on probes and other physics and chemistry areas; and 4.6 million euros on laser research, including metrology. In Switzerland, a national research plan known as "Top Nano 21" is pursuing biotech, device, materials, and other research jointly with universities and corporations. And in the United Kingdom, nanotechnology research is supported mainly through the Engineering and Physical Sciences Research Council (EPSRC) in partnership with the Department of Trade and Industry.

Asia

Trends in Korea, Taiwan, and China are attracting interest. In March 2002, Korea's Ministry of Science and Technology (MOST) announced a plan to invest 203 billion won (US$170 million, FY2002) in the nanotechnology field. In Taiwan, the government's investment in nanotechnology over the six years from 2002 is expected to total TW$23.1 billion (US$670 million). And in China, over the five years from 2001 to 2005, the central government will reportedly invest 2 billion yuan (US$240 million) in the field, while provincial governments will spend 2 – 3 billion yuan (US$240-360 million) on nanotechnology over the same period.

Nanotechnology : A Breakthrough toward a Resource & Energy Compatible Society of

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AIST's Nanotechnology Research Institute (NRI) conducts a wide range of R&D in such areas as nano-particles assembled from fixed number of atoms; ultra-small magneto-semiconductive devices utilizing electron spins; self-organizing organic materials mimicking living organisms that self-replicate based on the genetic information of DNA; carbon nanotubes with a great promise for wide applications; and the last but not the least, novel bio-assay devices.

There is much more to nanotechnology than simple miniaturization. Investigating the ultimate functionality of materials in the nanometer scale, researchers are able to discover ways to achieve maximum functions with minimum energy and resource input. Nanotechnology is a 21^{st} century technology to pave the way to a truly sustainable high-tech society. In this article, I will introduce some of the research that NRI is currently conducting with a view to resource and energy-saving.

The Super-inkjet

Inkjet printers are a common technology, familiar to people everywhere. These printers, which draw graphics by shooting jets of tiny ink droplets from a nozzle onto paper, have steadily improved in both precision and speed in recent years. Today inkjet printing is attracting new attention as an application in next-generation semiconductor nanoprocessing technology. Instead of the present highly wasteful approach of shaving off most of the thin film deposited over the whole area and leaving just the small amount needed, the new "on-demand" method places only the amount needed, where needed, through an inkjet. Naturally, this will result in a large saving of resources. The NRI has succeeded in developing a new inkjet, which we call the Super-inkjet, able to form fine patterns less than $1/10^{th}$ the size of conventional inkjet patterns. Using a liquid containing metal nanoparticles as ink, the Super-inkjet forms lines less than a micron thick without any pretreatment on the substrate's surface. (Figure 1)

Highly sensitive magnetic sensors

The explosive growth of the Internet, digital media and many other IT applications has heightened the need for rapid and accurate processing of high volumes of electronic data. Serving this demand at low cost and with minimum consumption of energy and other resources is an urgent issue today, as recent crises in electrical power supply attest. Dramatic breakthroughs are expected from such innovations as magnetic memory, which unlike semiconductor memory does not require constant power consumption; and high-density hard disks that store terabits of data per square inch. At NRI, we have discovered that nanoscale composite structures of metal and semiconductor material can provide high magnetic resistance even at room temperatures and in low magnetic fields. Through the Synthetic Nano-Function Materials Project, a nanotechnology program of the Ministry of Economy, Trade and Industry (METI), we are striving to develop advanced applications for these new technologies. Recently, we succeeded in demonstrating a rate of change in magnetic resistance of 10,000% per 100mT by building gold nanostructures on a substrate of gallium arsenide, a composite

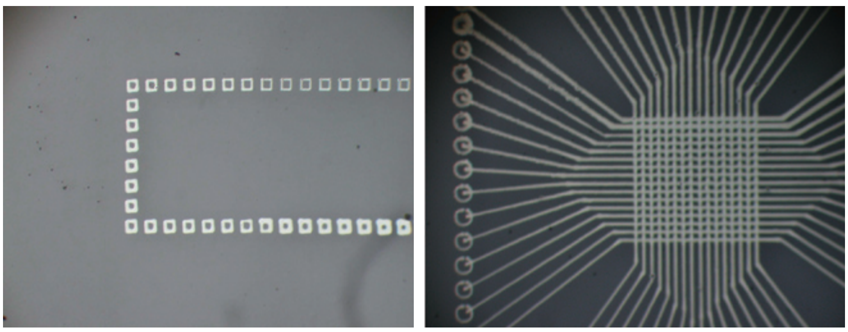

Figure 1. Ultrafine wiring plotted directly on a glass substrate with a metal NanoPaste (Harima Chemicals, Inc.), using the Super-inkjet.
(left) Squares 25μm long on each side (right) Lines 3μm wide

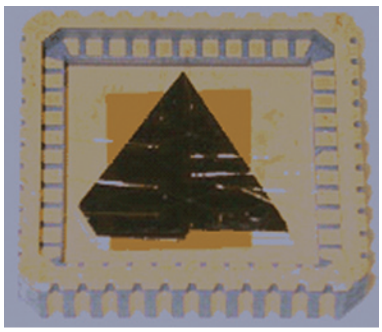

Figure 2. Ultra-sensitive magnetoresistive switching device, mounted on a device package.
Exhibited at the Nanotech 2003 + Future Exhibition, the device is attracting interest for its property of switching a light-emitting diode on and off as it is moved toward and away from a magnetic field.

the 21st Century

semiconductor. The outlook for applications of this surprising property is exciting.(Figure 2)

Liquid-crystal memory

When liquid-crystal displays (LCDs) are disconnected from an electrical power source, the picture on the screen is lost. Conventional LCDs consist of a million or so thin-film transistors (TFTs) integrated on a glass substrate. These displays must be constantly supplied with power. One of the touted benefits of LCD technology is its low power consumption, but in fact this property is not yet used to its true potential. Because LCDs harness opto-electric response characteristics of liquid crystal, it has been believed necessary to orient the liquid-crystal molecules uniformly in the same direction on the glass substrate by the treatment of the substrate surface. On this point, the Yokoyama Nano-Structured Liquid Crystal Project of the Japan Science and Technology Corporation demonstrated that, if this property is considered from a different angle, when a certain type of microstructure is mounted on the substrate, the liquid crystal acquires a multiplexed memory capability. This memory function enables the image preservation on the LCD screen even when the battery is dead, pointing the way to a new class of LCDs featuring ultra-low power consumption. This exciting discovery is expected to find applications in a wide range of mobile technologies, such as mobile telephones and electronic books.(Figure 3)

Target-oriented drug delivery systems

Finding a cure for cancer is one of the holy grails of 21st-century medicine. As the most promising solution to achieve this, researchers are now focusing on a selective drug delivery system (DDS) that concentrates delivery of anti-cancer drugs exclusively on the cancerous area.

NRI is training its sights on the cell-recognition functions of sugar chains, to develop a "guided missile attack" on cancerous cells. Currently known DDSs depend solely on sustained release of drugs in small capsules, a passive approach that targets recognizes affected areas little if at all. AIST's sugar-chain DDS has been shown in recent animal experiments to function highly selectively in targeting the cancerous area.(Figure 4)

Nanotechnology-a treasure house of discoveries and invention

The greatest thrill for a researcher is the discovery of an unexpected phenomenon that turns conventional thinking on its head. The research findings introduced here are just some of the examples, attesting to the boundless potential of nanotechnology. Nanotechnology is a dynamic field of research that combines basic scientific inquiry and industrial applications like two sides of the same coin. The day is not far off when each one of the results I have presented will find exciting industrial applications that bring great benefit to society.

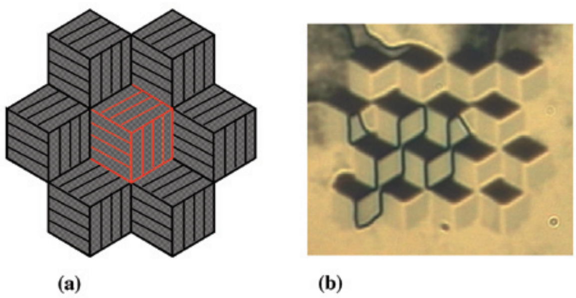

Figure 3.

(a) Microscopic orientation pattern on a substrate surface imparts a memory function to liquid crystals. (b) Microphotograph of liquid crystals aligned along the orientation pattern that is produced with an atomic-force microscope. For visibility purposes, 10 μm-sided patterns were produced, but it is actually necessary to make the less than 1 μm-sided patterns.

Because of the pattern symmetry, in this case, three different orientations were stabilized.

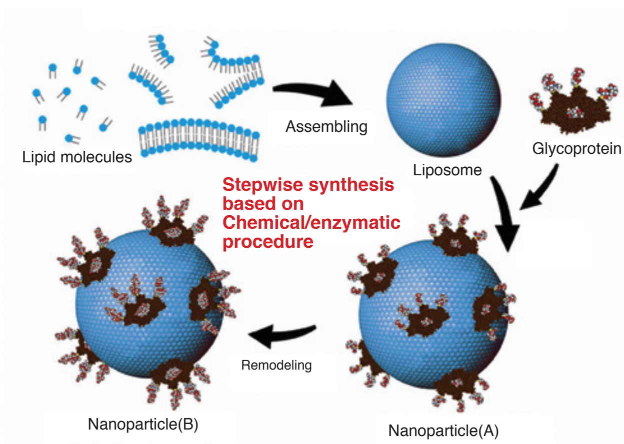

Figure 4. Process of creating a target-oriented DDS with the cell-recognition functions of sugar chains.

Carbon Nanotube Industrial Applications

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Carbon nanotubes and other nanocarbons have electrical conductivity, thermal conductivity, and mechanical strength that conventional materials cannot match. With the diversity of their structure, these characteristic values can be achieved over an extremely wide range of conditions. Nanocarbons can be used in a wide range of fields, including chemical, electrical, and mechanical, and offer great promise in the 21st century as a basic material at the core of materials nanotechnology. The Research Center for Advanced Carbon Materials develops the superior characteristics of nanocarbons and links them to the creation of innovative products in a wide range of industrial fields, including IT, the environment, and biotech in an effort to help reinforce the competitiveness of Japanese industry.

1 Nanocarbon Technology Project

The Nanocarbon Technology Project is a five-year plan running until FY2006 and involving eight corporations, one association, and four universities as well as AIST (Figure 1). The project was started in October 2002 with the aim of advancing nanotube mass production technology and a broad range of applied research. From FY2003, it was reconstituted as one of the Focus 21 projects to invigorate economy. Two priority development themes, development of miniature, lightweight, and long-life mobile-type fuel cells using nanotubes as their electrodes, and electron device application technology using nanocarbon materials in semiconductor chip wiring, are receiving accelerated development.

The Research Center for Advanced Carbon Materials is involved in all Nanocarbon Technology Project research themes and is pursuing this research vigorously.

1-1 Development of catalysts for mass production

In the mass production of nanotubes, the catalyst holds the key. The Research Center for Advanced Carbon Materials has developed two types of catalysts. One is a nanometer-size metal particle catalyst (Figure 2). This is a new type of catalyst with many advantages: although nano-size, it can be made from a diverse range of metals, and can combine different metals. In the Nanocarbon Technology Project, this catalyst is being used in the gaseous phase reaction process under development by Nikkiso Co., Ltd. The other catalyst is based on the use of a catalyst carrier for supporting stably the 1-nm nano-particles. In the Nanocarbon Technology Project, this catalyst is being used in the fluidized bed method under development by Mitsubishi Heavy Industries, Ltd.

By the admixture of the so produced nanotubes with plastics, the mechanical strength and electrical and thermal conductivity of the material are improved. The development of applications of nanotubes as new catalyst materials, optical materials, and gas storage materials is in full swing.

1-2 Ultra-high sensitivity electron microscope

The success of the above nanocarbon technologies is underpinned by the development of an ultra-high sensitivity, high-resolution electron microscope, which has sub-nanoscale accuracy and is able to obtain information on the atomic arrangement, element identification, and electronic structure of nanocarbon materials. Our microscope, the sub-nanometer structure analysis system (Figure 3), is being improved, so that we have succeeded in

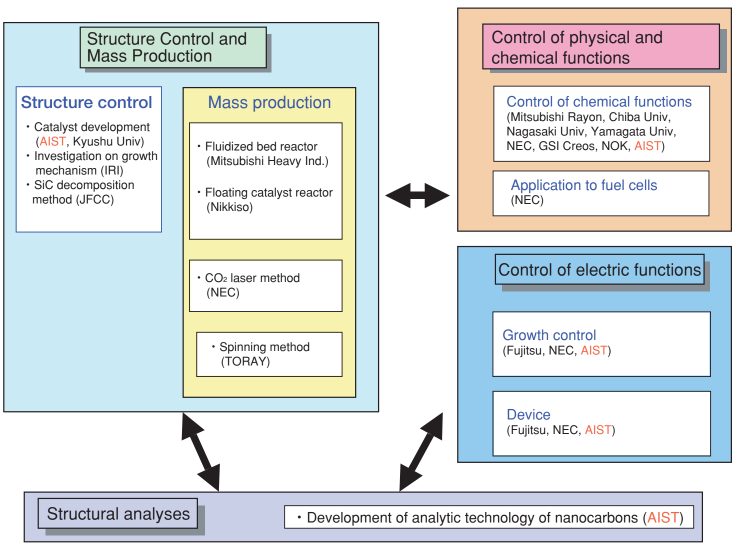

Figure 1. Nanocarbon Technology Project.

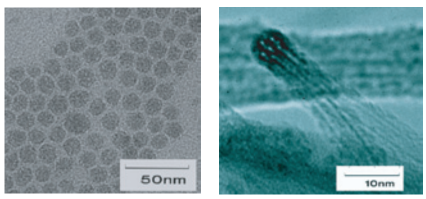

Figure 2. (left) Metal nanoparticle catalyst developed at the Center and (right) single-wall nanotubes synthesized using the catalyst.

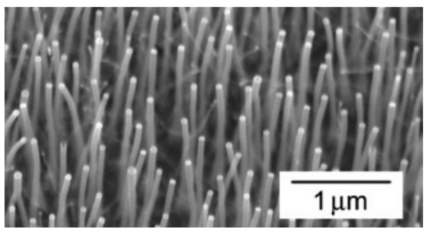

Figure 4. Oriented multi-wall nanotubes grown perpendicularly to the substrate.

revealing individual atoms on a nanocarbon.

2 Further development of carbon nanotube applications

From bulk use to using single nanotube characteristics

As research into nanotubes advances, research is shifting from methods of utilizing bulk nanotubes (in composite resins and FEDs, for example) to utilization of individual nanotube characteristics by combining with nano-processing technologies.

2-1 Application to electronics

The application of nanocarbon technologies to new transistors that surpass conventional silicon-based semiconductors holds great promise. The Center is carrying out research for realizing nanotube devices, utilizing our so far developed technology on catalyst and nanotube syntheses. By the reaction of nanometer-size catalyst with acetylene on a silicon substrate, the Center has succeeded in the fabrication of oriented nanotube film that grow vertically on a substrate, as in Figure 4. One promising application of these oriented films is as electron sources of field emission-type devices.

To extend this technology further to the development of nanotube devices, the Center has been working on developing technologies for more precise growth of nanocarbons. The Center has demonstrated that, by mixing catalysts with resist and forming catalyst patterns by lithography, it is able to selectively grow nanotubes (Figure 5). Through the development of micro-array technology using such catalyst reactions, the Center has opened the way to array nanotubes in lattice patterns on substrates for ultrafine non-volatile memories and field effect transistors.

2-2 Biotech applications

Nanocarbon tubes are 100% carbon and are compatible with cells and other organic matter. In addition, precision growth and position-direction control technologies developed for nanotube electronic device applications have potential for application in a number of areas in the biotech field.

For example, nanotubes have proved excellent characteristics as the probes of scanning probe microscopes (SPM), and application to cell manipulation technology looks very promising. Nanotubes can also be chemically modified and various molecules can be joined to give them DNA separation and protein recognition functions. In addition, expectations are also centering on such areas as the development of drug delivery systems that use nanotubes' interior space.

Toward further development

Still further development can be achieved by merging the carbon nanotube and other nanocarbon fabrication and processing technologies of the Research Center for Advanced Carbon Materials with the nano-material processing and cell processing technologies of other AIST research units. AIST hopes it can create large-scale nanocarbon business centers within AIST to help strengthen the competitiveness of Japanese industry.

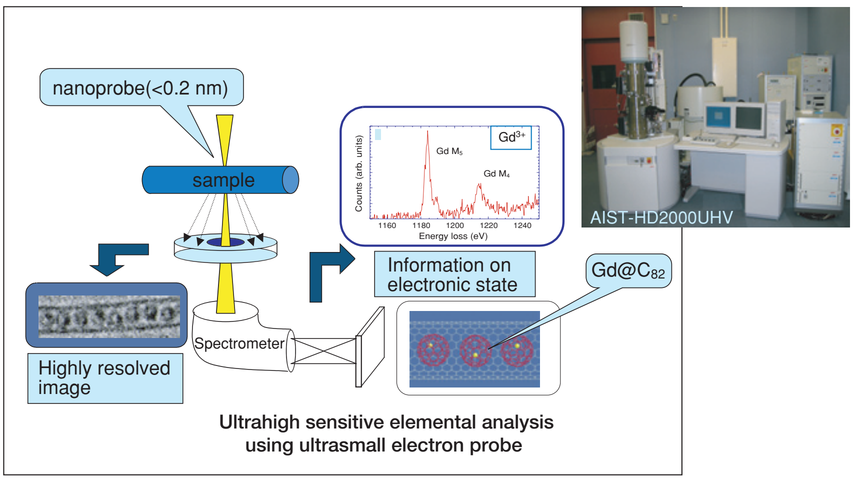

Figure 3. Sub-nanometer structure analysis system developed in the Center.

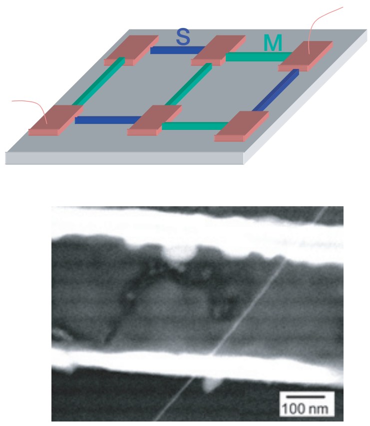

Figure 5. Towards the calculation with a carbon nanotube device.

(upper) Specimen of a carbon nanotube device (S: semiconductor nanotube, M: metallic nanotube). (lower) Nanotube grown on a catalyst pattern fabricated with lithography (a single-wall nanotube crosses over the catalyst patters)

A New Type of Nanotube Formed from Molecu

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White nanotubes

The AIST is working with Japan Science and Technology Corporation (JST) to conduct joint research into the development and utilization of organic nanotubes (properly called "lipid nanotubes") that are assemblies of millions of molecules. These nanotubes are visible as white filaments in water, and can therefore be dubbed “white nanotubes” (Figure 1). Although full-scale research into this type of nanotube has only begun, they already exhibit properties not seen in carbon nanotubes and may prove to be a valuable nanomaterial in fields such as the environment, energy and biotechnology.

Making nanotubes from cashew nuts

The raw material from which the white nanotube is produced is none other than the cashew nut, a common household food item. The tough husk that envelops the cashew nut is rich in natural, long-chain phenols such as cardanol, anacardic acid and cardol. Cashew nuts are a renewable plant resource, already used not only as a foodstuff but also in the production of industrial products such as disk pads for automobile and train brakes. Using no more than two processes, we succeeded in producing synthetic glycolipid molecules, consisting of a hydrophobic part, produced from cardanol gleaned from the cashew nut shell liquid; and a hydrophilic part, produced from glucose. This molecular structure is similar to a soap molecule, with a tadpole-shaped structure consisting of a hydrophilic component as the “head” and a hydrophobic component as the “tail.” This structure is easy to produce: Simply disperse 5mg of the glycolipid, a fine white powder, into a flask containing 100ml of water and reflux at 100℃ , then gradually cool it to room temperature and leave it. The flask will be filled with a frothy white substance filled with algae-like filaments (Figure 1). This white “algae” is really a collection of small nanotube structures.

Cylindrical structure

When this algae-like structure is observed in closer detail using a scanning or transmission electron microscope, it is clearly seen to consist of hollow, cylindrical nanotubes with open tips, having internal diameters of 10-15nm, external diameters of 40-50nm and lengths ranging from several tens of microns to hundreds of microns (Figure 2). The nanotubes are remarkably similar in dimensions, including internal diameter, external diameter and length, to multi-wall carbon nanotubes as well as microtubules, which are aggregates of tubulin protein. Whereas research into carbon nanotubes, a physically generated material, and microtubules, a biological material, are both highly active today, our project is the only project in Japan or anywhere else involving lipid nanotubes, which may be called a kind of chemically generated material.

So how do these molecules self-assembly to form nanotubes in water? The molecules push the hydrophilic parts outward, while the hydrophobic parts, which consist of long-chain hydrocarbons, insert each other into the inside to form a bilayer membrane in a three- or four-layer tubular structure, resulting in the membrane wall of a nanotube (Figure 3). If the length of the nanotubes is estimated at around 100μm, then a structure of millions or even tens of millions of molecules is generated by sheer intermolecular force alone. Moreover, the internal and external surfaces of the nanotubes provide hydrophilic surfaces with exposed hydroxyl groups, offering affinity with water in striking contrast with carbon nanotubes. In addition, the lipid nanotubes require none of the large-scale equipment, vacuum and high temperatures needed to manufacture carbon nanotubes. With nothing more than a beaker and some water, these “white nanotubes” can be generated in large volumes under surprisingly mild conditions.

Lining up gold nanoparticles with nanoholes

We were aware that a 10nm-size hydrophilic hollow cylinder serves as a favorable reaction site for the one-dimensional structure of gold nanoparticles. We succeeded in creating a one-dimensional structure by filling the empty cylinders of lipid nanotubes with an aqueous solution of hydrogen tetrachloroaurate(III), then reacting the solution with ultraviolet radiation in the nano-reaction field to form gold nanoparticles (Figure 4). When the entire periphery of the resulting gold nanowire structure was coated with an organic insulator, the structure is able to function as a nano-cable without

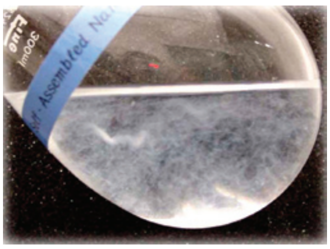

Figure 1. Lipid nanotubes generated in a flask

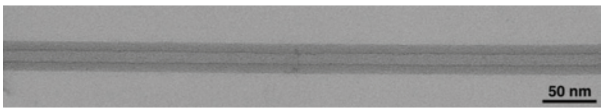

Figure 2. Transmission electron microscope photograph of a lipid nanotube

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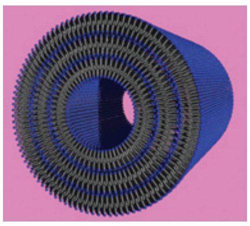

Figure 3. Schematic drawing of molecular packing of a lipid nanotube

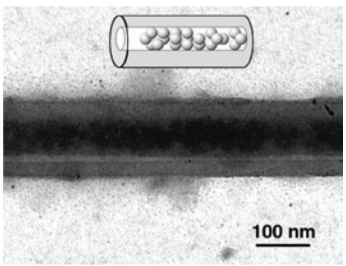

Figure 4. Organization of gold nanoparticles in a hollow cylinder

further modification. This discovery has exciting implications, as it represents a new one-dimensional nanostructural material that can produce wires under gentle conditions beyond the limit of nanolithography (50nm).

Drawing patterns using lipid nanotubes

The mechanical properties of a single, independent lipid nanotube are completely unknown. In a joint research project with Kohzo Ito, Professor of Graduate School of Frontier Sciences, the University of Tokyo, we succeeded in evaluating the bending stiffness of a single lipid nanotube underwater. It was determined that the Young's modulus for a single lipid nanotube is 700Mpa. This is much more elastic than a carbon nanotube and roughly in line with the value for a single microtubule in a living body, which is about 1000Mpa. Using the moderate elasticity exhibited by the lipid nanotubule, we developed a microinjection method that enables individual nanotubes to be extruded from ultrafine glass capillaries (with internal diameter of approximately 500nm) onto substrates and freely oriented and arranged (Figure 5). This technique enables wiring patterns to be drawn on substrates using lipid nanotubes, with any orientation and arrangement desired (Figure 6).

Creating silica nanotubes

In nanotechnology, the spontaneous organization of molecular units less than a few nanometers in size into three-dimensional structures of 10-100nm is known as the "bottom-up" technique. Upon examining a wide variety of molecular structural units, we came upon a phenomenon in which a certain glycolipid forms double-helical structures about 20nm in width. Applying this complex shape to nano-templating, we carried out a sol-gel reaction using tetraethoxysilane, a precursor monomer of silica, then calcined to remove the nano-template. In this way, we succeeded in creating a silica nanotube with a special double-helical structure. Using a variety of organic nanotemplates including rods, spirals, double cylinders and multiple cylinders, AIST is currently synthesizing a number of special, one-dimensional, inorganic nanospace materials, and evaluating properties of these structures such as supported catalysts and gas loading.

Nanochannels with diameters of 10–100nm

Lipid nanotubes have a diameter that is greater than carbon nanotubes, whose diameter ranges from 1nm to a few tens of nanometers, but smaller than the finest glass capillaries (approximately 500nm), providing a tube-diameter distribution that no other material can emulate. The use of lipid nanotubes, with their hydrophilic inner surfaces, as nanochannels, provides an instructive example. Lipid nanotubes are some 10^4 smaller in internal diameter and 10^8 smaller in volume than the microchannels (assuming the same length for both) currently used in DNA chips and electrophoresis chips (squares of substrate a few centimeters in length), whose internal diameter is roughly 100μm. Accordingly, the organic and inorganic materials we originated can be used to create hollow cylinders with diameters of 10nm to 1000nm, which can be deployed as nanochannels or nano-reaction chambers. By using these to effect the inclusion of useful bioactive nanomaterials such as DNA and protein, high-speed and high-efficient separation and high-speed reaction applications can be developed. In a joint research project with Tsuguo Sawada, Professor of Graduate School of Frontier Sciences, the University of Tokyo, we are working eagerly in research to find characteristics and applications for enclosed liquid-phase nanospaces of 10-100nm.

High expectations

The bottom-up technique described here is a key technology that enables the synthesis of tailor-made organic and inorganic nanotubes. These new nanotubes were found to demonstrate hitherto unknown properties, such as inclusion of nanostructures, gas loading and elasticity. Through close collaboration with ongoing research in carbon nanotubes, we expect AIST to uncover a wide range of promising nanotube technologies.

References

Toshimi SHIMIZU, in Kihon kara Manabu Nanotechnology (Basics of Nanotechnology) Kazuyuki HIRAO (ed) Tokyo Kagaku Dojin Co., Ltd., pp. 124-139 (2003)
Toshimi SHIMIZU, Chemistry Today; May 2003, Tokyo Kagaku Dojin Co., Ltd., No. 386, pp. 23-29 (2003)
Toshimi SHIMIZU, Kotai Butsuri (Solid-State Physics) 38, 377 (2003)

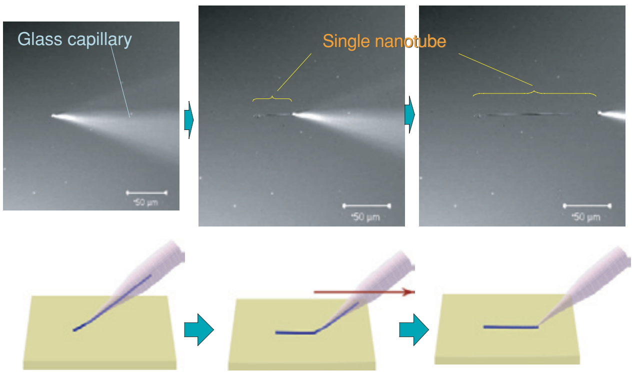

Figure 5. Microinjection of lipid nanotubes

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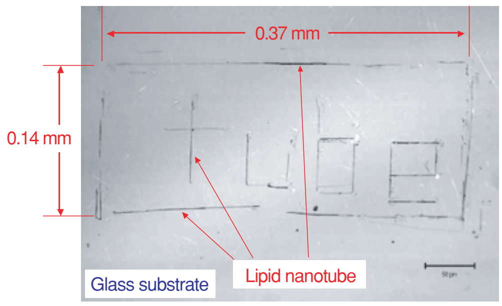

Figure 6. Letters and frame written with lipid nanotubes

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The Impact of Nanotechnology in Electron Dev

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Reducing the size of electron devices to the nanometer scale brings the following quantitative effects. First, greater integration among devices can be achieved. Second, the devices operation becomes faster, because the distance traveled by the electrons in the devices is shortened.

But what about qualitative effects? Investigating the qualitative effects of nanotechnology is not easy, since in many cases only reducing the structure is not enough to yield significant changes. When dealing with dimensions so small that individual atoms can be counted, unevenness in the surface of a single atom can obstruct the movement of electrons, preventing the realization of anticipated physical phenomena. To obtain real qualitative changes, devices must be fabricated with exacting precision at least single-atom level.

This paper describes three qualitative changes, or effects, that we at the NeRI have observed as we reduce the dimensions of devices to the nanometer scale. These qualitative effects are demonstrated for the first time when the structure and surface of the devices are carefully produced with geometrical precision at the atomic level.

Finding the outermost limits of transistor performance

We are currently conducting research of a nanoscale metal-oxide-semiconductor field-effect transistor (MOSFET). Figure 1 (a) shows the structure of our proposed design for a MOSFET. In this structure, the semiconductor layer (channel), through which the electrons pass is surrounded by two gates. The structure is called a double-gate MOSFET, or XMOS, so named because of the structure's similarity to the Greek letter Ξ (X).

In the planar MOSFETs currently in use, reducing the distance between source and drain causes leak current, in which electrons pass from source to drain when they are not supposed to. The XMOS structure eliminates this problem, as the channel is surrounded by the two gates. Indeed, performance improves as the size of the device is reduced. The key here is to produce the larger drain current with the lower gate voltage. The gate voltage required to change the drain current by a factor of 10 is called the sub-threshold slope (s-slope). The smaller the s-slope is, the greater the performance of the device will be.

Recently we succeeded in fabricating a prototype nanoscale XMOS with an ideal rectangular cross-section as shown in Figure 1(b): channel thickness of 13nm and width of 82nm. The sides (the semiconductor surface through which the electrons flow) have a surface that is smooth at the atomic level. The device's characteristics indicated that, as shown in Figure 2, performance improves as the thickness of the channel decreases and the theoretically predicted performance limit is reached at 13nm. This is a qualitative effect achieved for the first time by accurately and precisely controlling dimensions, structure, and shape at the atomic level.

Seeing individual electrons

Since electrons are particles carrying an electrical charge, it should be possible to observe the behavior of individual electrons. In the ordinary world, this is generally impossible, but when devices are shrunk to the nanometer level, individual electrons become visible. The following is an example in which electrons are made visible using a simple device with silicon rods.

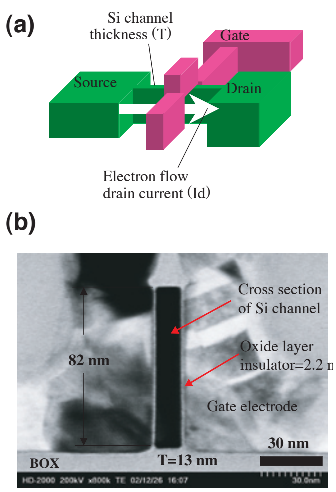


Figure 1. Structure of an ultramicroscopic Fin-type XMOS transistor

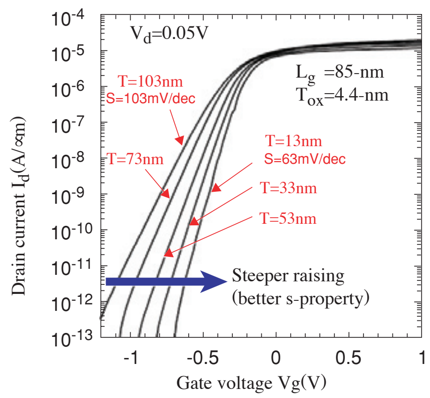


Figure 2. Electric properties of the device shown in Figure 1

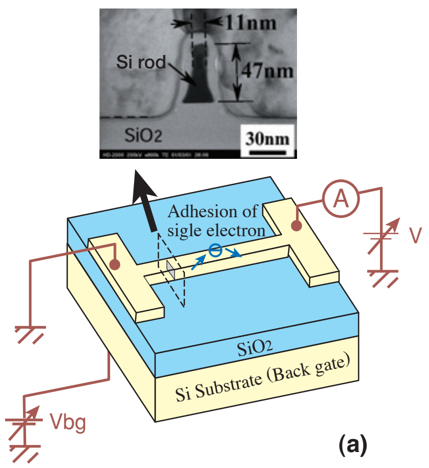


Figure 3. Structure and properties of an ultramicroscopic silicon-rod device

As Figure 3(a) indicates, the device used was a rectangular silicon rod with a cross-section width of 10nm and a height of about 50nm. When a voltage of (for example) 0.1V is applied between the ends of the rod, a current is generated. In this state, as the voltage in the silicon substrate shown in Figure 3(a) is gradually made negative, the current increases or decreases with a certain step as shown in Figure 3(b). These current steps occur because changes in the voltage of the substrate cause an electron attached to or released from the silicon rod surface. When an electron becomes attached to a point anywhere on the silicon rod surface, a repulsive force is generated between the attached electron and the electrons flowing through the inside of the rod. This repulsive force obstructs the flow of the electrons and decreases the current. This phenomenon occurs only when the rod is extremely and precisely thinned and is thus a qualitative effect of nanotechnology.

Seeing electron waves

Finally, I present an example of a device that utilizes the wave properties of electrons. When electrons are constrained between two walls and the distance between the walls is gradually decreased, the electrons reflected from the walls begin to behave as waves, reinforcing each other or canceling each other out. When the distance is integrally multiplied by the magnitude of the electron wave, the electrons reinforce each other. When multiplied by a half-integer, however, the electrons cancel each other out, so that electrons cannot be present.

This phenomenon can be visible at room temperature by utilizing another property of electrons, called spin, an ultra-small magnet. Figure 4 shows a cross-section of a prototype spin device we fabricated. The key feature of this device is that electrons enter a nonmagnetic layer are reflected by the layers above and below, which are an insulating layer and a ferromagnetic layer respectively. This device demonstrates the wave-like overlapping and canceling behavior described above. When the voltage is applied at a certain level to maintain the wave length constant, the electrical current through the nonmagnetic layer should change as a function of the nonmagnetic layer thickness. Under the condition of the thickness where the waves overlap, the current should increase; otherwise, the current should decrease.

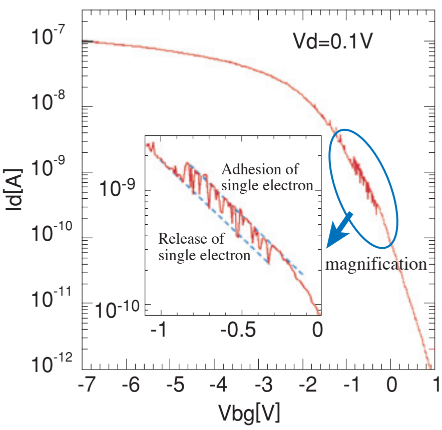
The results of our experiments are presented in Figure 5. When the thickness of the nonmagnetic layer was carefully varied from 0 to 3 nm, the current changed clearly up and down accordingly to the thickness variation. This phenomenon was rendered visible for the first time because the individual layers of metal and insulator are atomically flat and smooth, testifying once again to the qualitative changes made possible through nanotechnology.

References

(1) Y. X. Liu, K. Ishii, T. Tsutsumi, M. Masahara, H. Takashima and E. Suzuki, IEEE Electron Device Lett. 24(2003)484.

(2) T. Matsukawa, S. Kanemaru, M. Masahara, M. Nagao, H. Tanoue and J. Itoh, Jpn. J. Appl. Phys. 42(2003)2422.

(3) S. Yuasa, T. Nagahama and Y. Suzuki, Science 297(2002)234.



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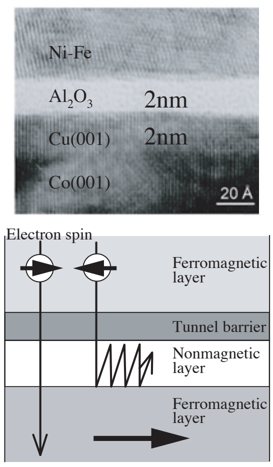

Figure 4. Structure of an electron-wave resonance device using electron spin

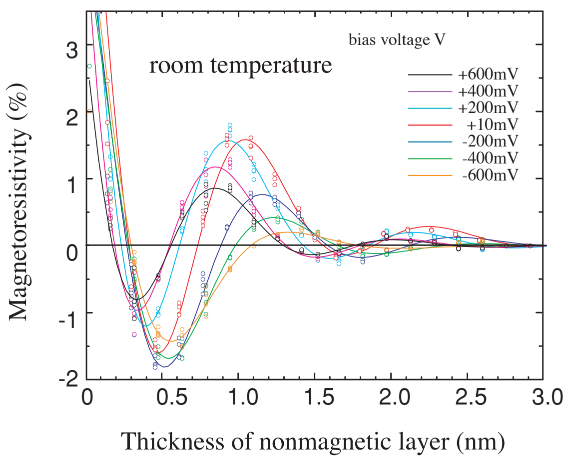

Figure 5. Electric properties of the device shown in Figure 4

Managing Chemical Risks Using Environment

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The nanotech revolution, which has made astounding progress in recent years, is spreading to the field of environmental technology. Haphazard approaches to environmental measures are a significant factor behind rising costs in manufacturing. To prevent these costs from diminishing Japan's industrial competitiveness, new ideas in nanotechnology need to be matched with the enterprises that require them, generating effective and radical technology change in the environmental field and developing the field of environmental services—a business with a huge potential market.

The essential point in general chemical risk management is to minimize the costs of management. These costs include the cost of equipment and facilities used in monitoring, measurement and processing, as well as the energy and reagents used to run and maintain systems. The following article is a review of recent developments and research trends in monitoring and measuring technologies, processing technologies applied in the use of chemicals and emission of waste, and some innovative clean-manufacturing technologies.

Development of on-site, real-time environmental measurement devices

Environmental measurement is crucial in determining how chemicals pollute the environment. For example, assessing where groundwater and soil are polluted and with what pollutants is extremely costly, as it is time-consuming and requires a great range of measuring instruments. Industries need measuring devices that are simple, flexible and compact. As Figure 1 illustrates, one instrument has been developed which consists of a quartz crystal microbalance modified with proteins and lipids that detect dioxin and trichloroethylene. When the instrument captures chemicals, the resulting increase in weight generates a change in oscillating frequency by which the chemicals are detected. This simple and highly sensitive sensor is now finding practical applications (Photo.1).

A number of approaches are being developed that aim to reproduce in microchips the molecular recognition systems of living creatures. One technology freely arrays and integrates electrodes within a microchip system. Another forms nanoscale structures on the surfaces of each of the electrodes thus arrayed; these structures are fitted with high-density arrays of substances with biological functions, such as receptors, enzymes and artificial antibodies, or are covered in inorganic catalysts. In another technology, functions such as reaction, separation and detection on the surfaces of each individual electrode are controlled electrically.

Development of environmental cleanup technologies for processes in which harmful chemicals are used and emitted

In addition to well-known pollutants such as nitrogen oxides (NOx), sulphur oxides (SOx) and carbon monoxide (CO), which are generated and released in the burning of fossil fuels, many SMEs' plants use chemicals such as toluene, xylene and dichloromethane as solvents and cleaning agents. Households use agents such as formaldehyde (adhesive solvents and resins) and p-dichlorobenzene (pesticides). Because most of these pollutants are discarded into the environment at room temperatures, the chemical industry is looking for ways of processing them as close to room temperatures

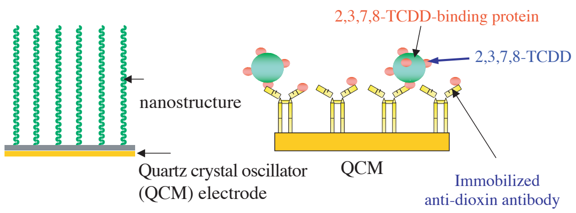

Figure 1. Development of a highly sensitive environmental measurement sensor.

Nanoscale structures are formed on the electrodes of quartz crystal microbalance. These surfaces are densely embedded with biofunctional substances such as receptors and artificial antibodies.

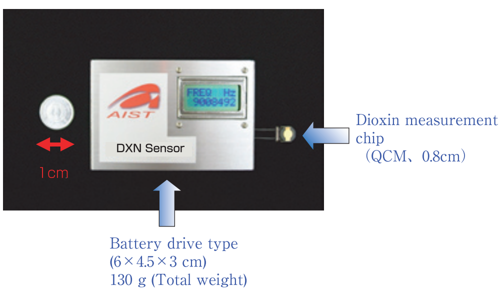

Photo 1. Simple quartz crystal oscillator–type dioxin measuring instrument

Photo 2. Photocatalytic materials spread out on a street

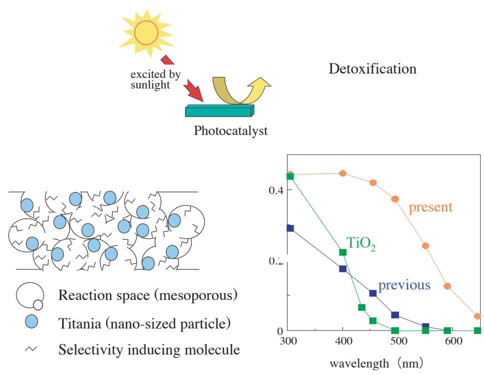

Figure 2. Detoxification of harmful chemicals using advanced functional photocatalysts

as possible, so that the requisite equipment and systems can be as compact, energy-efficient and inexpensive as possible.

In Figure 2, a photocatalyst is excited by sunlight to decompose harmful chemicals at room temperature. Through the collaboration of three research units at AIST, a new photocatalyst is being developed which uses visible light, while another photocatalytic agent under development possesses a structure that selectively adsorbs and then efficiently decomposes harmful chemicals. A battery of environmental cleanup trials are underway with these photocatalytic materials in a wide variety of locations both indoors and outdoors (Photo. 2). In the processing of cleaning agents and solvents, a technology is being developed in which fibrous activated charcoal is heated directly by electricity, providing a more compact, low-cost processing system than conventional steam-heating processes.

Research is ongoing in the synthesis of nanospace materials consisting of “mesopores” (greater than 1nm in diameter) that selectively disperse chemicals in fine pores and micropores (less than 1nm in diameter) that selectively adsorb chemicals. These materials are variously inorganic, such as silica; organic, such as cyclodextrin; or hybrid. In addition, a highly active catalyst is being developed that combines multiple metal particles at the nanoscale level (Figure 3). By conjoining these materials, we aim to construct and organize integrated, multifunctional catalytic systems that can adsorb and concentrate harmful chemicals and decompose them at room temperatures.

Innovative clean manufacturing technologies

In addition to work on microprocessing technologies and nanostructure control technologies, research is progressing to create a platform for processes that reduce the use and emission of organic solvents such as toluene and organic chlorine compounds, and minimize byproducts (unnecessary byproducts and those that carry risks). For example, as shown in Figure 4, the conventional method of synthesizing propylene oxide uses chlorine, which generates hydrogen chloride (HCl) and calcium chloride (CaCl2) as byproducts. To curtail the generation of these byproducts, a new catalyst with a carefully controlled nanostructure is being synthesized and used to create a process that uses oxygen to synthesize propylene oxide directly. In another project, nanomembranes that selectively transmit and activate hydrogen are synthesized and combined into a system which, as Figure 5 illustrates, was found to convert benzene to phenol in a single reaction. Conventional phenol synthesis requires large volumes of solvent and generates byproducts, consuming copious amounts of energy and placing a heavy load on the environment. In the new process, the catalysts produced using nanotechnology deliver a chemical process that is friendly to the environment. The researchers aim to conduct proving tests on a wide range of selective oxidation processes, to synthesize fine chemicals, specialty chemicals (medical intermediates and the like) and electronic materials with high efficiency. In one particular application, by combining microchemical processes, which provide significant effects at the microscale level, with nanotechnologies such as nanomembranes and nanostructured catalysts, researchers aim to create innovative inplant processes that greatly reduce risk.

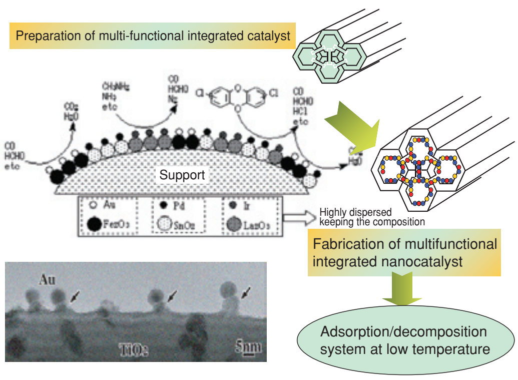

Figure 3. Processing of harmful chemicals using catalysts with controlled nanopores and nanostructures (Research Institute for Green Technology)

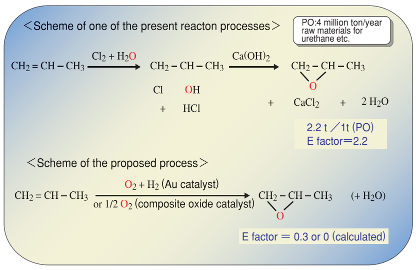

Figure 4. Development of a one-step process for synthesis of propylene oxide (PO)
(Research Institute for Green Technology)

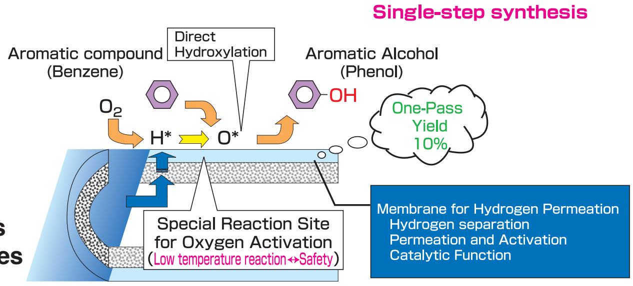

Figure 5. Development of a one-step process for synthesis of phenol using nanomembranes
(Laboratory for Membrane Chemistry)

Development of Nanotechnology Material Me

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The measurement and characterization with a high reliability not only provides a foundation for the research and development of nano-materials and devices, but also plays an important role in the fields of production process control and quality management. In order to achieve efficiency in nanotechnology-based manufacturing, the development of reliable "nano" standard materials becomes increasingly important to provide a common scale.

Currently, AIST is advancing the following two projects with regard to the development of "NanoScale", a measurement basis for nanotechnology.

1 R&D of Three Dimensional NanoScale Certified Reference Materials Project

The project focuses on the development of the "ruler" (NanoScale) which can be applied to the technologies to control, process and measure the nano structure with super-fine precision. The NanoScale is intended to offer the calibration traceable to the national measurement standards for both lateral and depth directions, and to serve as the certification reference material to which the certification value and uncertainty are assigned.

The National Metrology Institute of Japan (NMIJ) is presently providing the calibration standard for 1-D grating sample (0.2-8μm) and GaAl/AlAs superlattice reference material as the relevant measurement standard (Figure 1). The SEM (scanning electron microscope), which is integrated with the calibrated standard microscale (240nm pitch), is marketed as the CD-SEM for semiconductors. It is one of the major measurement tools developed in Japan that contributes to the field of semiconductors.

In this project, the aim is to develop a NanoScale of 25nm pitch for the lateral direction, and that of 3~10nm pitch for the depth direction. Figure 2 represents the outline of the project.

1-1 NanoScale for the Lateral Direction

By developing the calibration technology of a minute scale of nanometers that is traceable to the length standard, the lateral NanoScale of 1-D grating structure is calibrated and supplied as the certification reference material. Each of the created lateral NanoScales involves minute deviance and fluctuation from the nominal value that is caused by the incomplete fabrication process. Therefore, it is indispensable to measure (calibrate) such minute discrepancies by means of the accurate "ruler".

For this purpose, the project focuses on the development of an atomic force microscopy (Traceable-AFM) which is equipped with a laser interferometer with a resolution of about one fifth of the atomic size. Utilizing the iodine stabilized laser which is currently used as a length standard, direct traceablity to the length standard is achieved by feedback control using the laser interferometer.

1-2 NanoScale for the Depth Direction

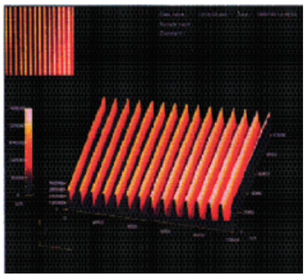
Reference materials for calibration for the depth direction is to be developed for each semiconductor system with a view to applying the standards to the structure evaluation of both compound and silicon semiconductors. In the study of the NanoScale for the depth direction, it is necessary to control not only the uniformity of the layer thickness but also other factors, unlike in the case of lateral NanoScale. These factors include the uniformity of density and composition of the substances that comprise the layer in the depth direction, roughness of both surface and interface, and a peculiar interface structure of the transition layer. For this purpose, at Ultra-Fine Profiling Technology Laboratory, it is sought to establish the method to reduce a structural transition layer to the minimum, by forming silicon-dioxide films utilizing ozone oxidization in the low temperature environment.

2 Nanotechnology Material Metrology Project

In order to establish the highly reliable measurement technology which can be applied to the field of nano material development, the project focuses on the creation of the basic nano metrologic technology including reference materials, metrology standards and so on. In practice, the project involves four major research issues: 1) physical properties (mass, size and density) of fine particles; 2) nanopores in various materials; 3) surface structure that regulates the characteristics of nano materials and 4) thermal properties of nano structure.

2-1 Physical Properties of Fine Particles

There is a requirement to accurately evaluate nano



One dimensional diffraction grating measured by AFM for calibration

GaAs/AlAs super lattice certification reference material and its structure

Figure 1. Nano Metrology Standards supplied by NMIJ

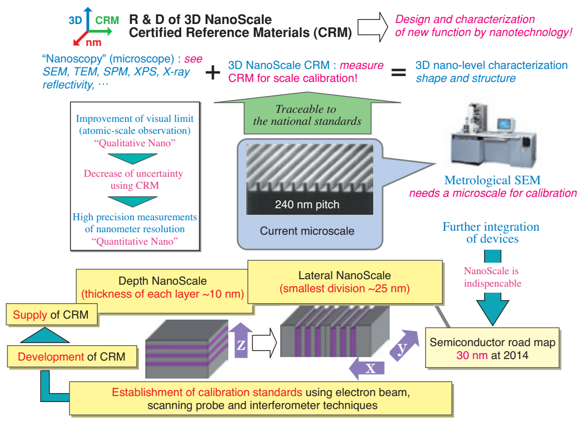


Figure 2. Overview of the R&D of 3D NanoScale Certified Reference Materials Project

particles as a building block of nano structure, as well as fine particles, for the purpose of quality management of semiconductors, environmental control for exhaust gasses and so on. One of the key technologies to attain this objective is to supply the accurate reference material for the particle diameter. AIST has been supplying the world's best precision standards for particle diameter of 100 nm and is currently striving to develop the nanoparticle reference material in the range of even smaller diameters.

In this project, the practical application of the new technique of measuring mass of fine particles is pursued by using the equilibrium between the centrifugal force and the electrostatic force both working on the particles (Figure 3). In the field of polymer materials, the diffusion coefficient of polymers and nanoparticles in the solution is measured with precision using dynamic light scattering and nuclear magnetic resonance, and the average particle diameter is determined. Furthermore, the scattering pattern measurement is implemented on the samples separated by size exclusion, by using the multi angle laser light scattering (MALLS), that leads to the establishment of the technique to accurately measure the particle distribution.

2-2 Nanopores

The porous materials with nanopores of a few nanometer diameter are attracting attention as low-k dielectrics for the wiring system of the next generation semiconductor device. In order to measure this nanopore, the development of the positron annihilation method is to be implemented. Utilizing this method, it is possible to obtain the information regarding both the average size and size distribution of nanopores, by calculating positron lifetime based on the energy distribution of gamma rays generated by positron annihilated in the samples, which is found in the nanopores of sub-nm to 10 nm scale of the material. There is also a need to measure the period of gamma ray emission.

In this collaboration project with Photonics Research Institute, it is attempted to develop a popular-type compact-size positron lifetime spectrometer (Figure 4) which utilizes the positron beam obtainable from radioisotope.

2-3 Surface Structure

X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES) are widely used as the means of characterization of surface composition, electronic state etc. of the materials that have functional surfaces, such as thin films, catalysts, sensing devices and so on. The target of the project is placed at the development of tunable photoelectron spectroscopy technology with synchrotron orbit radiation as an excitation source. Also, the objective is the establishment of quantitative reliability of conventional XPS and AES excited by Kα-ray of Mg and Al.

In addition, a database for surface analysis is to be constructed based on the collection of the standard spectrum of the samples whose physical and chemical change is kept to the minimum. The technique to eliminate background distortion of spectrum caused by inelastic scattering of photoelectron is also a subject of the study.

2-4 Thermophysical Properties

Thermophysical values of thin films such as thermal diffusion ratio, specific heat capacity, coefficient of thermal conductivity and coefficient of thermal expansion are indispensable in terms of the thermal and structural designing.

In this project, the thermal change on the reverse side of the thin film is observed referring to the change of reflectance to the laser beam, by heating the film surface using pico-second laser (pico-second thermo reflectance technique). Thereby the measurement technology is to be created for thermal diffusion ratio of thin films and the coating material, interface thermal resistance between thin films, and interface thermal resistance between the coating and the base material. By means of the laser interferometer, the technology to accurately measure the coefficient of thermal expansion of solid materials is to be established.

Summary

The above is a brief introduction of a variety of projects aiming for the establishment of nano metrology standards. The NanoScale is to be developed in the 3D Nano Project as a certified reference material which will be supplied in the final year of the project.

As part of the Nanotechnology Material Metrology Project, the standards are to be supplied for a calibration service as well as for the certified reference materials.

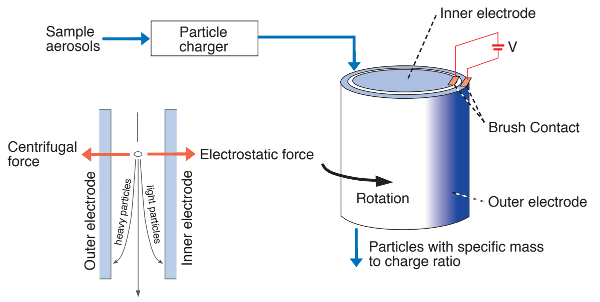


Figure 3. Principle of mass calibration method of particle reference materials

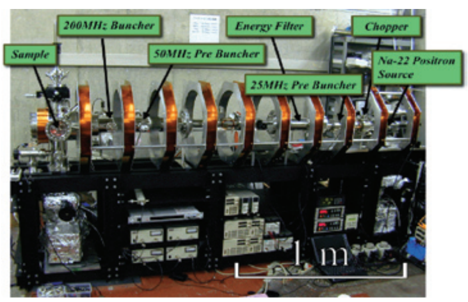


Figure 4. Popular type compact size positron lifetime spectrometer (under development)

Computational Sciences on the Frontiers of N

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Nanotechnology can be defined as technology that aims to create objects with new functions that cannot be created in bulk, such as molecular electronic devices and catalysts, from nanoscale components such as atoms, molecules or clusters thereof. Although new, non-bulk functions can sometimes be predicted through experimental work, the use of computer science to reveal mechanisms and predict nanostructures offers extremely effective support for the effort to develop these functions. We expect computational sciences to play an increasingly vital role in nanotechnology in this way.

The functions that researchers are trying to achieve through nanotechnology cover a wide range that embraces devices, catalysts, sensors and much else. Nonetheless most of this range can be approached through a relatively small set of calculation methods, such as electronic state computing and molecular-dynamics computing. The unique advantages of computational sciences are therefore expected to enable the unification of many disparate aspects of nanotechnology research.

Research Institute for Computational Sciences has made nanotechnology its highest priority and is hard at work developing highly accurate and large-scale computational methods and raising the speed of the necessary software code. We are also working to develop and publish these tools in a more user-friendly form.

Electronic state calculations -First-principle molecular dynamics-

In the first-principle molecular dynamics dynamics and stable configurations of atoms are calculated through electronic state based on quantum mechanics. To perform computing of this kind, we developed dedicated computer code called STATE. STATE is a powerful computer program with high-speed parallel processing, particularly, for calculations of high-precision surface state, the strength of vibration spectra and magnetic-field. Using STATE, the decomposition reaction of formic acid on titanium oxide (Figure 1) was possible. And reaction heat and frequency and its strength of adsorbate in some other basic catalytic reactions were also calculated. These calculations accorded closely with actual experimental results. STATE is already used in joint research by a number of groups, and was released within AIST in July as part of TACPACK, an integrated software package developed by Tsukuba Advanced Computing Center (TACC) and RICS.

Although STATE provides large-scale, high-precision computing power, computing time rises by a power of between 2 and 3 as the number of atoms increases, so computation becomes more difficult as the size of the system increases. To address this problem, the Institute developed, for the first time in the world, a unique order *(N)* method based (ABRED) on the recursion method, which reduced the computing load to a power of 1 to the number of atoms. Although parallel programming of this method has not yet been conducted, it is now possible to compute electronic state of systems for a few hundred atoms on a single PC. The method has already been applied to problems in carbon nanotubes and manganese polynuclear complexes. One difference between this method and other order *(N)* approaches is that it can be applied to metals. The program has been optimized to enable calculations on up to the fourth row of atoms. After further parallelization of the code, the Institute plans to release it for general use.

To provide methods of electronic state computing, we are currently developing a density functional method using finite element bases (FEMTECK) as well as a fragment molecular orbital method (FMO) for large molecules such as proteins. All of these calculations are performed using AIST's Hitachi SR8000 supercomputer, which has been proven to offer highly efficient parallel processing using 512 CPUs. Within two or three years, we expect to be able to use the fragment molecular orbital method, on a large PC cluster, to calculate the structures of proteins composed of thousands of atoms.

High-precision electronic state computing -Electron correlation-

The density functional method is extremely effective and widely used. Because it generally uses local density approximation, however, this method is unable to address some problems of electronic correlation. This shortcoming introduces many qualitative and quantitative problems into the results of calculation of such practically

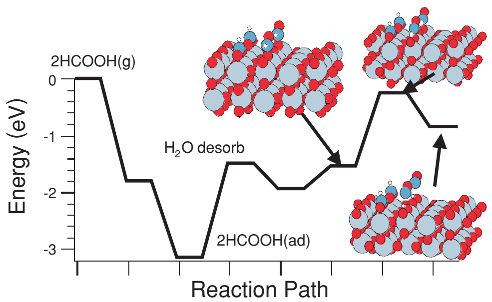


Figure 1. Energy diagram produced using first-principle molecular dynamic calculations of a decomposition reaction of formic acid on titanium oxide, with the structures of various intermediate forms
(collaboration with The University of Tokyo)

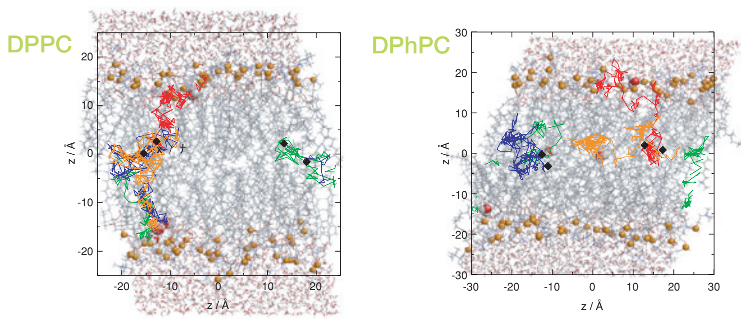


Figure 2. Simulation of molecular dynamics in the transport of water molecules through a lipid bilayer
Several water molecules were placed in hydrocarbon (central area of cell) and the path of their diffusion to the surrounding water is indicated in colored lines. Diffusion was rapid through the film formed with DPPC, which has no side chain, but slow through DphPC, which has side chains. (Collaboration with the Nanotechnology Research Institute)

important features as luminescence characteristics, light-absorption, band gap and magnetic field. We are currently developing a theoretical method for these problems of electronic correlation. The required computing time is still too long as a practical computing technique, but we have already been able to reproduce some important experimental values using this approach. The method has proven an important tool in running computer simulations of the electronic and optical properties in the fields of strongly correlated electronic system, spin electronics and optoelectronics.

Molecular dynamics simulations

To create organic field-effect transistors (FETs) and molecular sensors, the molecules must first be lined up on the surface in a certain pattern. One method of doing this is to make the molecules line up automatically by self-organization. Such methods have been developed in areas of "wet chemistry" such as supramolecular chemistry. It is, however, difficult to know what structures are obtained from what molecular structures. In this case, molecular dynamics is applied to predict structures and functions of the resulting aggregations. To apply classical molecular dynamic to structural prediction, however, several problems must first be solved; sufficiently accurate intermolecular forces must be obtained. Efficient sampling methods are required. And the accurate time-integration method for a long-time calculation must be developed. The Institute was able to use these methods to develop high-speed, high-precision code. Figure 2 illustrates an example in which this code was applied: a description of the dynamics of different molecule transportation in lipid bilayers. Using these technologies for the molecular assemblies, we are collaborating with experiment groups with the aim of developing systems for the design of nanostructures.

Nanoscale conductance

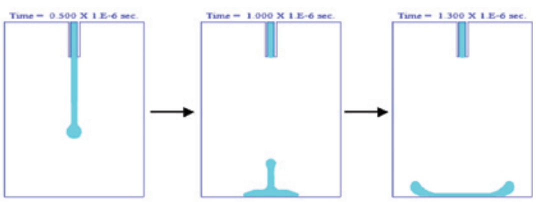
Thanks to the development of atomic and molecular processing technologies such as semiconductor micromachining, researchers have been able to produce a wide variety of nanoscale structures. In the field of nanoscale electronic devices, electrical conductance has revealed in some materials a number of unique behaviors that could not be discovered using electron-state computing alone. For example, unlike ordinary copper wires, carbon nanotubes are predicted in theoretical simulations to display the behavior of an electrical wire with a kind of no electrical resistance. In recent experiments, carbon nanotubes have been observed to demonstrate a “ballistic” conductance, and this theoretical prediction has since been confirmed. In the nanosclaes a quantum interference effect is expected to exert an important influence on electrical conductance, as explained here. We developed a theoretical simulation methods that fuses the appropriate modeling with electronic state computing. In future efforts, we intend to develop this theory into a form of circuit-design CAD that we expect will prove important in opening up the field of nanoelectronics.

Continuum simulation

If we apply the term “nanoscale” a little large system where atomic and molecular interactions are replaced by a mean field, we can use the method of calculating continuum media. Examples include the phase field method and vertex model, which are used in computing the organization in metals and ceramics. If we “zoom out” a little further, in simulations of microscopic electronic machines (MEMs) and the machines to construct nanostructures, simulations of continua in solid and fluid mechanics become most useful. In these microscopic domains, however, computing requirements are usually too rigorous to be handled by commercially available software. For example, in the super-inkjet now being developed by the Nanotechnology Research Institute, the problem of high-speed two-phase flow occurs when the ink is ejected from the nozzle. Our Institute have developed an alternative solution; A shown in Figure 3, the simulation impact spot of the ink droplets closely matches the actual experimental results.

Toward original softwares

Recent versions of commercially available software, and even freeware and shareware, can perform surprisingly accurate simulations. In this paper, I have described the motives behind some of the new computational methods being developed and how they are intended to be used. Most of the commercial software available now was once developed in similar ways. The computing methods I have described will probably be incorporated into commercial software packages or be marketed as stand-alone applications.



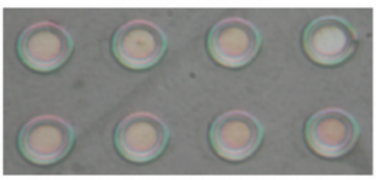


Figure 3. Finite-element computation using a new stabilization method and the VOF method for eject and impact of ink from the inkjet nozzle

(This simulation matched closely with the experimental results on formation of piezoelectric devices using the inkjet. Collaboration with the Nanotechnology Research Institute and Smart Structure Research Center)

The Nanotechnology Program Projects and NEDO's Project Management

Kyouhei NISHIDA
Nanotechnology and Materials Technology Development Department,
New Energy and Industrial Technology Development Organization (NEDO)

The Nanotechnology Program was launched in 2001 to create a platform technology that will contribute to the sustainable development of Japan's economy and to incubate new businesses that will lead the world market in nanotechnology and nanomaterials in 10 years' time. The Nanotechnology Program consists of a number of projects, including nine projects involved in the Nanomaterials and Processing Sub-Program Projects and four projects involved in the Nano Manufacturing and Metrology Sub-Program Projects. NEDO manages these projects as the entrusted mission from the Ministry of Economy, Trade and Industry (METI). The Nanotechnology and Materials Technology Development Department (NMTDD) is in charge of all the Nanomaterials and Processing Sub-Program Projects; two of the Nano Manufacturing and Metrology Sub-Program Projects; and four of "Focus 21" projects started this fiscal year of 2003 (for details, please see the illustrations below).

The NMTDD is tasked with management of the project in accordance with the following management policies, as is reflected in the agreements signed with each of the project contractors.

1 Promoting the commercialization

(1) By the end of the third fiscal year of the project, at least one prototype (sample material, database, or simulation software, etc) that can be used for trial purposes must be produced and it will be furnished to outside observers after closing a contract.
(2) Each participant of the project may request the consent of other participants for the use of said participants' patents or expertise if it is required for carrying out the project.

2 Promoting the dissemination of information

(1) The NMTDD operates a domestic mailing list called the Nano-Tech Mailing List, to provide information exchange on nanotechnology to persons interested in nanotechnology, both within and outside the Nanotechnology Program. As of June 2003, this mailing list has approximately 760 members. Every effort will be made to provide comprehensive disclosure on the NEDO website.
(2) Forums, workshops, exhibitions and similar kinds of events will be held every year. Research activities are also conducted for aiming at developing practical applications and commercialization of nanotechnology.
(3) An international network of professionals will be formed to promote R&D and commercialization of nanotechnology through the free and open exchange of views and information among people.

Project	FY2000	FY2001	FY2002	FY2003	FY2004	FY2005	FY2006	FY2007
Nanostructure Polymer Project		1300	1150	950				
Nanotechnology Glass Project	300	600	620	430				
Nanotechnology Glass Project for Display				250				
Nanotechnology Glass Project for Electron Device				260				
Nanotechnology Metal Project		300	670	490				
Nanocarbon Technology Project/Advanced Nanocarbon Application Project			750	1270				
Carbon Nanotube FED Project				810				
Advanced Diamond Technology Project				810				
Nanotechnology Particle Project		900	910	640				
Nanostructure Coating Project		500	520	360				
Synthetic Nano-Function Materials Project		250	360	250				
Nanotechnology Material Metrology Project		230	230	160				
Systematization of Nanotechnology Materials Program Results Project		220	270	190				
Sum of the budgets (million yen, 100yen=8.4USD	**300**	**4300**	**5480**	**6870**				

Table. Nanotechnology Program (Nanomaterials and Processing Sub-Program and Nanodevice and Materials Sub-Program)

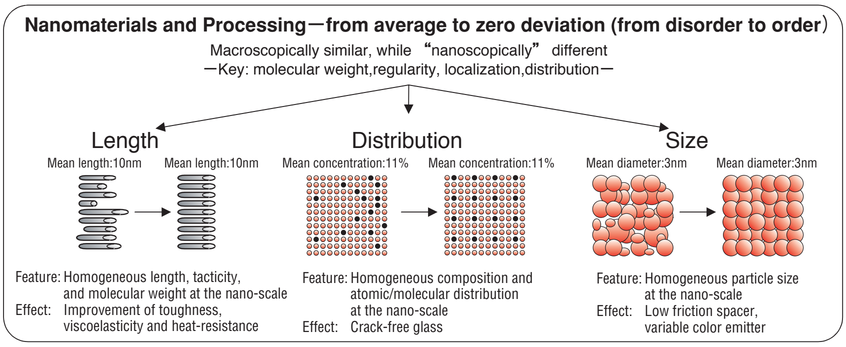
3 Thorough research management and promotion of liaison among projects

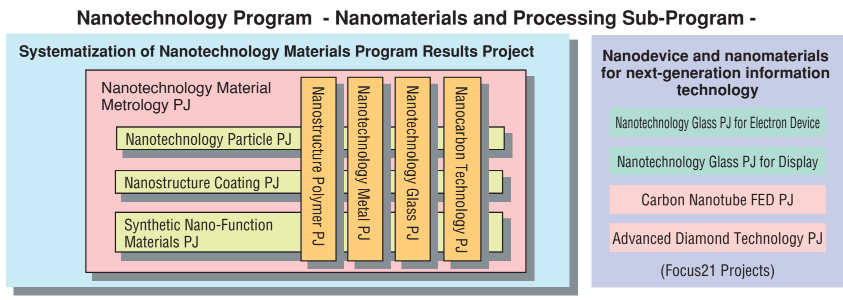
(1) Considerable authority will be conferred on project leaders and clear numerical targets will be set, to ensure responsible and effective research management.
(2) Effective liaison among projects will be maintained through "Systematization of Nanotechnology Materials Program Results Project".

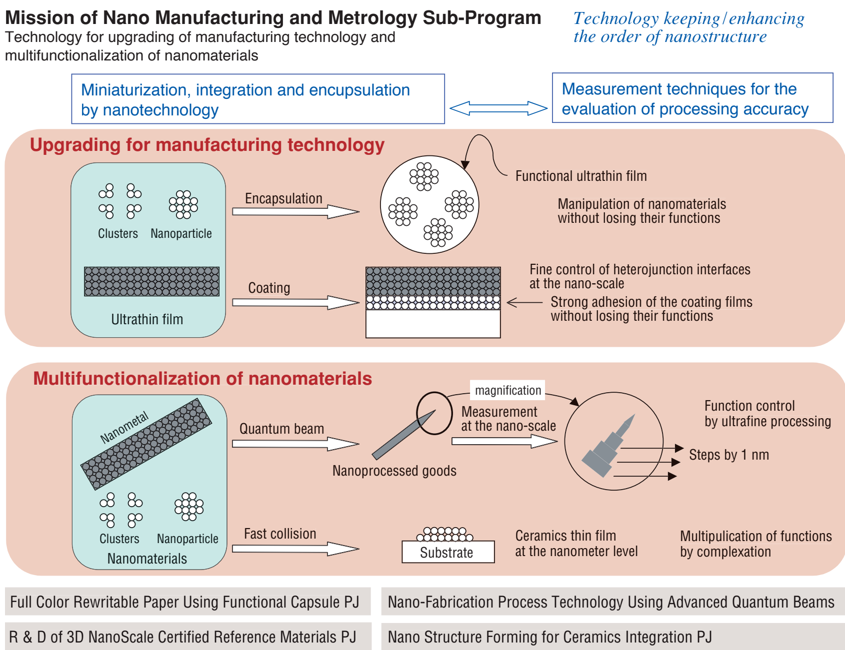
During the current fiscal year, five projects will be subject to an interim evaluation: Nanotechnology Metal Project; Nanotechnology Glass Project; Nanotechnology Particle Project; Nanostructure Coating Project; and Synthetic Nano-Function Materials Project. Moreover, most of the projects under Nanomaterials and Processing Sub-Program are subject to the third fiscal year, when the submission of prototypes will be required. This year is thus designated as an evaluation year, when progress in each project is verified and reviewed and future management policies and directions are determined.

Full and comprehensive sharing and publication of information is of crucial importance, as the commercialization of nanotechnology research results requires timely and rapid response. Currently moves are afoot in industry in Japan to establish a nanotechnology business promotion council, which NEDO believes will provide much-needed support. This fiscal year, the evaluation year, NEDO will be involved in "nano tech 2004", as "nano tech 2003 + Future". "nano tech 2004", scheduled for March 2004 at Tokyo Big Site, is the world biggest international exhibition and conference on nanotechnology providing the resources necessary to launch new and exciting nanotechnology industries. NEDO is also keenly active in promoting exchanges of views through overseas expositions, including Nanofair 2003 in St. Gallen (Switzerland) slated for September 2003.

Four projects under Nanomaterials and Processing Sub-Program and two under Nano Manufacturing and Metrology Sub-Program are led by researchers from National Institute of Advanced Industrial Science and Technology (AIST). In many other projects, AIST is a key participant, playing important roles in each of these efforts. I would like to close by thanking all of the researchers in advance for their valuable work in furthering each of the projects that make up the Nanotechnology Program.







The Propagation Effect of Nanotechnology on the Economy

Naoki IKEZAWA
Nomura Research Institute, Ltd.

The materials and devices that nanotechnology has given the world are used in a wide range of systems and machines today. One of the most exciting features of nanotechnology is its astounding breadth of real and potential applications. Thus the propagation effect of nanotechnology is immense, and the business opportunities it creates are both numerous and diverse. If the size of the nanotechnology market were calculated based on the breadth of its influence and the extent of the commercial opportunities, it renders feasible. Depending on the assumptions used, the market could be worth between ¥20 trillion and ¥30 trillion by 2010. A number of possible trial calculation results are presented below.

In the electronics field, a vast potential market can be tentatively calculated for such products as new types of displays, secondary batteries and fuel cells, replacements for today's general-purpose semiconductor memory (for example, magnetoresistive random access memory, or MRAM), magnetic recording devices and wiring materials. New displays are being aggressively pursued through the development of carbon nanotube applications. By 2010, the market for such displays may be on the order of ¥180 billion. Carbon nanotubes and nanohorns are expected to be applied in the development of secondary batteries, used in mobile telephones, and fuel cells, which should be used in power vehicles and even at homes in the future. The market for such secondary batteries is forecast to reach ¥150 billion, while a figure of ¥120 billion is anticipated for fuel cells. Another prominent example of a nanotechnology application is MRAM, which may replace existing DRAMs to create a market on the scale of ¥120 billion. This forecast covers only replacement of the latest generation of DRAMs; the figure may well grow larger if MRAMs cast into the market and enter a true growth phase.

In biotechnology area, nanotechnology will open vast opportunities for such applications as drug delivery systems. For example, microcapsules developed using nanotechnological techniques could deliver medicines to affected areas within a patient's body. This is an especially exciting field for Japan, with its eminence in polymer chemistry. Even in fields of existing materials such as iron and glass, nanotechnology is expected to be applied to effect quantum improvements in function and performance, blazing the trail to a multitude of fresh opportunities and sizeable new markets. For example, fine ceramics to which nanotechnology is applied is forecasted to reach production of ¥100 billion by 2010. Many nanotechnology products will be goods used in the everyday lives of consumers, such as photocatalysts and cosmetics. A trial calculation of the market for photocatalysts and other environmentally friendly catalysts suggests a figure of ¥70 billion. Nanoscale particles can be used in transparent sunscreen and foundation powders, generating a market of some ¥45 billion.

The products to which the above trial calculations apply incorporate a great deal of processing, which implies a high price in many cases. The above-mentioned market size of nanotechnology reflect this value-added as well as the large size of the markets for the products in question. The trial calculation reflects the direct economic effects of nanotechnology; the actual range of the propagation effect of this technology is much broader. For example, as the markets described above are realized, a wide range of business opportunities are sure to emerge in the fields of related processing and measurement equipment. Moreover, many themes exist in which research institutions among industry, government bodies, and universities can give free rein to their own unique talents and capabilities. As they develop those abilities, new synergies should arise among the industry, government bodies, and universities, leading to a many exciting new high-tech joint ventures. This, too, is an important economic propagation effect of nanotechnology.

The Nanoprocessing Partnership Program: AIST as Incubator for Nanotech Japan

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Nanotechnology is a highly ambitious field, which seeks to usher in one of the most sweeping technological transformations in human history. It is a world of ideas, an exciting and dynamic field of inquiry where one researcher's passing insight can spark a quantum leap in applied technology. Yet because nanotechnology seeks to manipulate objects beyond the grasp of the five senses, it requires apparatus of vast scale and expense, as well as exceptionally sterile clean-room environments. The difficulty and cost of acquiring the sophisticated equipment needed often means that the most worthy ideas never see the light of day. To derive full benefit from the strengths of Nanotech Japan, everyone involved must have access to the equipment they need, when they need it and as much as they need it, so that researchers can quickly put ideas to the test. This scientific community requires a shared platform of nanotechnology research equipment.

At the Nanotechnology Research Institute, we have clearly recognized this aspect of nanotech R&D since the foundation of AIST in 2001. We were instrumental in the establishment of the AIST Nano-Processing Facility (AIST-NPF), a shared facility that any researcher could use to conduct nanoprocessing and nanomeasurement, and worked closely with other units to open it up for all AIST researchers to use.

In 2002, the Ministry of Education, Culture, Sports, Science and Technology launched the Nanotechnology Support Project. The Nanotechnology Research Institute and AIST-NPF, in their joint capacity as the governing body of the Nano-Foundries Group, is in charge of an initiative called the Nanoprocessing Partnership Program (NPPP), a part of the Nanotechnology Support Project. The Nano-Foundries Group is a support network consisting of AIST, Waseda University, the Tokyo Institute of Technology, Osaka University and Hiroshima University.

NPPP makes a wide range of leading-edge nanoprocessing and nanomeasurement equipment available at no charge to researchers in government, industry and academia. Some 30 types of advanced equipments are provided, ranging from electron-beam etching equipment to probe microscopes, along with nano-foundry services to cater to each user's requirements. With a staff of 11 nanotechnology professionals, NPPP responds swiftly to requests for operation and engineering consulting and for made-to-order fabrication. The project currently boasts a roster of over 100 registered outside users.

NPPP will continue to offer cutting-edge equipments and services and to contribute to the support of Japan's nanotechnology community through a wide range of training and other initiatives.

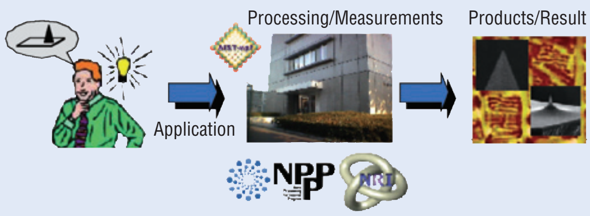

Figure: Schematic view of NPPP's nano-foundry support.

(Photos of results of NPPP support provided by the Japan Advanced Institute of Science and Technology)

http://www.nanonet.go.jp/japanese/
http://www.nanoworld.jp/nppp/

Nanotech Ventures

Hiromichi MAENO, *Department Head, Nanotechnology Dept. Mitsui & Co., Ltd.*

The Japanese economy is faced with the need for radical reforms of truly seismic impact. Many of the organizing systems in Japan today require reforms that have no precedent in history. As someone who has great expectations of AIST, as a member of the Tsukuba community who helped to found the Center for Collaborative Research, Tsukuba's "nanotech park," I would like to say a few words on this subject.

Mitsui is earnestly searching for new business models and industrial mechanisms that leverage the results of scientific and technological research. In this spirit, we founded a research and development subsidiary to develop successful models for an interdisciplinary approach to R&D, which is one of the guiding themes in today's nanotechnology boom.

Many excellent researchers and engineers in a wide array of fields have joined Mitsui, forming a team of 110 professionals. About two years ago, a friend of mine came to us from AIST to assist in the launch of this project. Since then, joint researches between Mitsui and AIST have been one of the core axes of our projects.

Many existing companies are losing their former drive. One prescription for revival that is currently raising expectations is to use new technologies to formulate fresh and innovative business models. Such business models may be developed through partnerships among government, industry and academia; the reinvention of Japan as an "intellectual property nation"; and the formation of up to 1,000 university-based joint ventures. These are all excellent ideas in themselves. However, any frank assessment must concede that dependence on universities is an unwise policy, since universities are concerned with learning. Businesses based on intellectual content have so far proven a phantom, as they lack the human resources to deliver what they promise, and I see no reason to expect a great wave of new small businesses to emerge from these university-based ventures. There is no such thing as quality without quantity. AIST possesses such critical mass, as does Tsukuba. What Japanese enterprises need to do is to construct compelling business models and take concrete steps toward their fulfillment, sweeping the nation with powerful new ideas.

A technology strategy is not sufficient in itself. What is essential is a "knowledge strategy" that fuses internal and external sources of knowledge. Japan needs to cultivate a highly active community through the efforts of many sectors, including the school system, public agencies, local government, associations, NPOs and private enterprise. Such an active community would have the capability to construct systems that put knowledge to work, fostering mechanisms for the use of intellectual property with a broad view, casting aside narrow, self-centered viewpoints. Such a system of knowledge management would also support a comprehensive network that gives meaning to broad-based collaboration both within and across organizations. As a member of the community and the center of Tsukuba's nanotech park, our XNRI Group (www.xnri.com) aims to contribute in every way it can.

The Future of Continuously Developing Nanocarbons

Sumio IIJIMA, *Director of the Research Center of Advanced Carbon Materials* s-iijima@aist.go.jp

Nanocarbon cross-field technologies

At the beginning of July, the NT03 international conference on carbon nanotubes (CNT) was held at Seoul National University in South Korea. This conference emphasized on the fundamental research of carbon nanotubes such areas as carbon nanotube growth and simulations; structural evaluation using Raman spectroscopy, photoabsorption and emission spectroscopies; electronic properties; electron transportation; processing and evaluation of electronic devices; characteristics of gas and bio-molecular adsorption, and also discuss some applications to field emission displays (FEDs); scanning probes; and fuel cells. Carbon nanotube-related conferences in general tend to be characterized by interdisciplinary research across a range of fields from basic to applied research.

Report on the formation of 6-mm long and 2-nm diameter nanotubes

Both theoretical and experimental research has revealed the variation of electronic properties of carbon nanotubes depending on their diameter or helical structure. This feature is quite characteristic for carbon nanotubes and is not seen in ordinary materials. As well as being of interest as a natural phenomenon of molecular devices, it also has potential for the future of the electronics industry. One of the research projects that attracted interest at NT03 was a report by Liu et al. from Duke University on the growth of single-wall carbon nanotubes that reach lengths of 6 mm with diameters of around 2 nm. These carbon nanotubes, whose growth direction can be controlled, represent a revolutionary breakthrough. It was shown that the application of this carbon nanotube can lead to more accurate electronic property and transportation experiments, and production of multiple-array of transistors. In addition, there is a sense that structural materials that use the superior mechanical properties of carbon nanotubes (for example, bundled rope out of carbon nanotubes) are now very close. Applications that utilize the nanospace at the inside of carbon nanotubes would include light waveguides and super-ionic conductor tubes. While it is not yet clear when these industrial applications will be realized, carbon nanotube science is advancing steadily.

Top runner of carbon nanotube display

In the recess halfway through the conference, four American professors and I were invited to the Samsung Advanced Institute of Technology (SAIT), where we took the opportunity to observe at first-hand R&D into field emission displays (FEDs). Our guide was SAIT's vice-president Dr. Jong Min Kim, who has overall responsibility for FED development. While this was my third visit to SAIT, the six-inch FEDs that I had observed two years before had now developed into 32-inch full-color television screens. Samsung said it hoped to commercialize these within two years, and I am convinced that carbon nanotube FEDs are viable. Plasma displays (PDPs) generate heat similarly to electric ovens but we confirmed that it was naturally possible to touch the glass of a FED screen without getting burned.

Development of special electron microscope

To show the perspective of nanotechnology, I would like to briefly introduce research that I am personally interested in. In nanotechnology, it is essential to develop nanoscale material metrology methods in tandem with the nanotechnology development. This is why we develop special electron microscopes that we call "ultimate elemental analysis device". We have already succeeded in detecting single atoms inserted into the nanospace of carbon nanotubes.

Expanding fields of nanotube applications

Finally, in the nanotech materials field, research is being carried out into fabrication and application to fuel cell electrodes of carbon nanohorns that resemble carbon nanotubes. Applications to biotechnologies that utilize good affinity of nano-carbon material with organisms also fall within the scope of my research. Specifically, I am working on adsorbing bacteriophages that present certain DNA base sequences into the nano-carbon surfaces and evaluating their selective adsorption characteristics.

AIST's Nanotechnology : Technical Development Outlook

Kazuo IGARASHI, *Research Coordinator*

"Full-Research" from nanotechnology

AIST is developing a policy of merging subdivided areas of knowledge and establishing an integrated system in which a wide range of researchers from different fields can work on specific research topics. With "Type-II Basic Research"[1)] as the core axis, continuous research, from "Type-I Basic Research"[2)] up to development, will be performed as "Full-Research". By relating this to its liaison functions with industry, government, and universities, AIST hopes to boost the development of industrial technology. "Full-Research" is involving in the integration of a wide range of research fields, so that AIST is advantageous. Nanotechnology holds out great promise as one of the core technologies of this approach.

From nanotechnology, to nano-industry

In nanotechnology research, there are three main needs: a strong need to produce new concepts by merging different research fields together, the need for a concentrated approach focused on clear goals, and the need for close collaboration among researchers under strong leadership. In addition to the nanotechnology, materials, and manufacturing fields, AIST embraces such fields as life-science, information technology, energy, environment, standards and metrology, and has developed an environment conducive to cross-field joint research with researchers from outside the nanotech field. Promoting interdisciplinary joint research with researchers in the above areas, AIST aims to establish an industrial infrastructure — nano-industry — from nanotechnology. AIST also promotes the establishment of the special research style in nanotechnology, the computer-aided nanotechnology, by encouraging its talented human resources in computational science to participate in nanotechnology-related research.

Fierce development competition needs smooth technology transfer

Technology licensing is an important issue for AIST. Because that nanotechnology is regarded as one of the "aces in the hole" reinforcing the competitiveness of Japanese industry, it is vital to promote nanotechnology research with concrete views for practical and industrial applications. Nanotechnology includes many research fields that need long-term perspective and a considerable period to come to fruition, but there are also many fields where basic research can find quick practical application. By the liaison of its research departments, Intellectual Property Division, TLOs (AIST Innovations), and the Innovation Center for Start-ups, AIST is building a system that can provide rapid support across the whole spectrum, from the search for promising research results, to their implementation.

Rapidly boosting nanotech development

To rapidly boost nanotechnology development, we believe it is necessary to train nanotech personnel and actively appeal to industry. Through the Nanoprocessing Partnership Program and the Innovative MEMS Business Support Program, we are stepping up technical support of researchers in industry, providing with the latest nanoprocessing and measurement equipments and as well showing the operation know-hows. We also plan to exhibit in various nanotechnology-related trade fairs and actively organize nanotechnology seminars.

AIST has been a world-leading pioneer in nanotechnology through pursuing several nanotechnology-related projects such as the Atom Technology Project, accumulating a range of results and know-how. In its history, AIST has made it clear that nanotechnology is not only for the hi-tech world but also extends to energy-saving and environment friendly technologies, new biotechnologies, and innovative production processes that result in high-quality component materials. Based on the research results achieved to date, AIST will continue to aim for further breakthroughs that contribute to the development of the nanotechnology industry.

1) Type-II Basic Research: Motivated by certain economic and social needs, research that combines various pieces of already established universal knowledge (including theories, natural laws, principles, and theorems), performs repeated observations, experimentation, and theoretical calculations, and by these methods and results derives regular and universal knowledge and a specific path to realize certain goals.
2) Type-I Basic Research: Research to discover, interpret, and form universal theories (including natural laws, principles, and theorems) through observation, experimentation, and theoretical calculation of unknown phenomena.

AIST RESEARCH HOT LINE

UPDATES FROM THE CUTTING EDGE

(Jul. — Sep. 2003)

The abstracts of the recent research information appeared on the Vol.3 No.7-No.9 of "AIST Today" are introduced and classified by research area. For inquiry about the full article, please contact the author directly.

Life Science & Technology

Molecular Dynamics Simulation of Prion Protein

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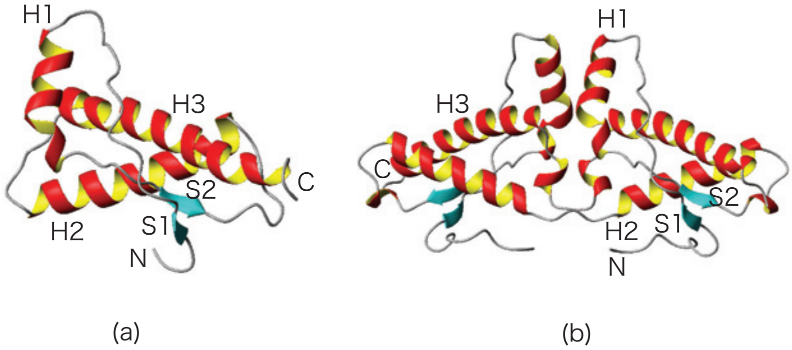
AIST Today Vol. 3, No. 8 (2003) 35

A central theme in prion protein research is the detection of the process that underlies the conformational transition from the normal cellular form (PrP^C) to its pathogenic isoform, PrP^{Sc}. Although the three-dimensional structures of monomeric and dimeric human prion protein (HuPrP) have been revealed by NMR spectroscopy and X-ray crystallography, the process underlying the conformational change from PrP^C to PrP^{Sc} and the dynamics and functions of PrP^C remain unknown. The dimeric form is thought to play an important role in the conformational transition. In this study, we performed molecular dynamics (MD) simulations on monomeric and dimeric HuPrP to investigate the differences in the properties of the monomer and the dimer from the perspective of dynamic and structural behaviors.

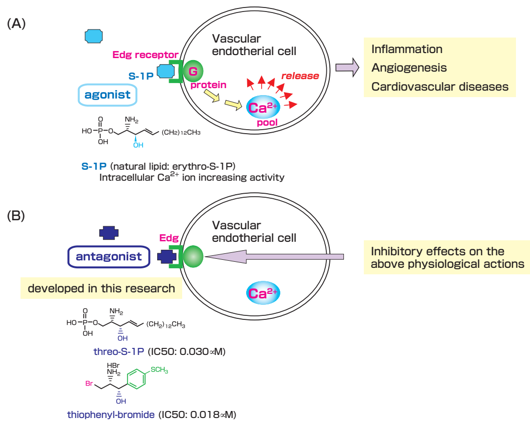


Schematic ribbon diagram of HuPrPc. (a) monomer, (b) dimer

Synthesis and Physiological Activity of Novel Sphingolipid Analogues

- Development of potent antagonists for natural sphingosine-1-phosphate -

Recently sphingosine-1-phosphate (S-1P), one of the sphingolipids metabolites, has attracted considerable attention as an extracellular mediator. It has been shown that S-1P binds to cell surface Edg receptors to cause Ca^{2+} ion release from intracellular stores. The search for agonists and antagonists toward Edg would provide the basis for development of novel therapeutic agents. We have synthesized novel S-1P analogues such as *threo*-S-1P, which is C-3 stereoisomer of natural *erythro*-S-1P. Bioassays of the S-1P analogues using HL60 cells have indicated that the *threo*-aminoalcohol derivatives (3 kinds) inhibit the Ca^{2+} ion increasing activity of natural S-1P at low concentrations (IC_{50} = 0.02-0.18 μM) by competitive binding to Edg receptors.



Cellular Responses to Agonist (A) and Antagonist (B) for Edg Receptor

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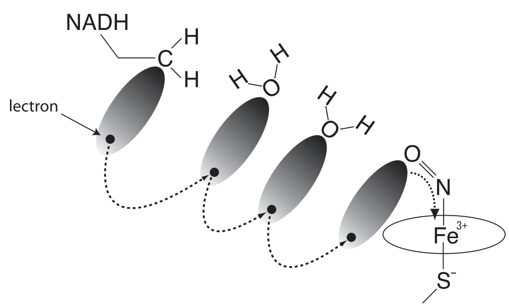
AIST Today Vol. 3, No. 8 (2003) 36

Numerical Computation of Enzyme Function

Nitric Oxide reductase (NOR) isolated from the denitrifying fungus *Fusarium oxysporum* is a cytochrome P450-type heme enzyme [1-3]. NOR catalyzes a nitric oxide (NO) reduction reaction in which two NO molecules are converted into a nitrous oxide molecule using two electrons directly transferred from NADH [4].

The reaction path for NO reduction in NOR was obtained using the semiempirical method SAM1 [5].

We analyzed the two electron transfer system that supported the function of NOR using the docking simulation and the quantum chemical calculation. Then, we propose the system that the two electrons transmit as a charged soliton (Figure 1).



Schematic representation of the two electron transfer system, the charged soliton as illustrated by the dashed line

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AIST Today Vol. 3, No.9 (2003) 17

Protein Engineering using Cellular Quality Control System

- Improvement of productivity of proteins by removing S-S bonds -

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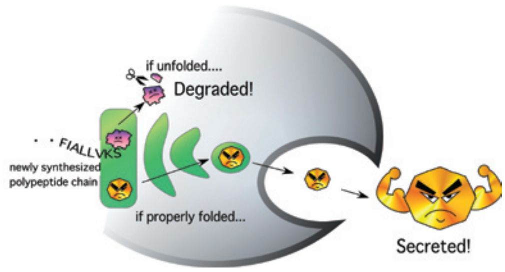
AIST Today Vol. 3, No. 9 (2003) 18

As renaturation of disulfide (S-S) bonds is difficult issue in a large-scale production of proteins, the method to remove S-S bonds with minimum stability loss will be a useful tool to increase the productivity of recombinant protein. We are developing a screening method utilizing a cellular quality control system to identify stable protein mutants from a large number of sequences. This method was used to screen amino acid pairs substituted for the disulfide bond (S-S bond) between positions 14 and 38 in bovine pancreatic trypsin inhibitor. The mutants selected by this screening showed higher stability than simple Ala/Ala substitution and retained inhibitory activity at physiological condition.



Schematic representation of “cellular quality control system” in yeast. Newly synthesized polypeptide chains with secretion signal are first inserted in to ER membrane and transferred to the ER. In ER, the quality control machinery recognizes the structural status of the synthesized polypeptide chains. If these polypeptides fail to fold into the native structure, these are transferred to cytosol and degraded. If the synthesized polypeptides form rigid native structure, they go through the secretory pathway. Using this cellular recognition mechanism, we can know the “foldability” of a certain sequence by monitoring its secretion efficiency.

Information and Communication Technology

Active Role of Motor Function in Human Communication

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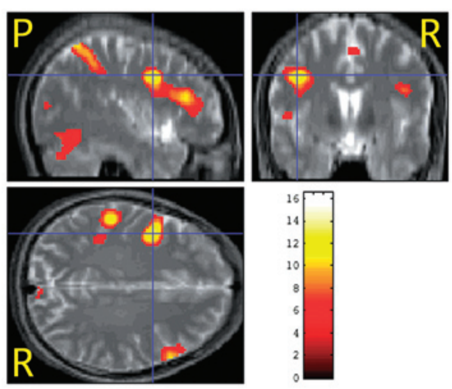
AIST Today Vol. 3, No. 7 (2003) 10

Human communication employs every means available to be realized. Using functional magnetic resonance imaging (fMRI), we revealed that motor function plays an important role for character/letter processing. Exner’s area, a language area located at the left premotor area, was found to be important for association between character and sound. This suggests that the character-sound association may share its mechanism with that of motor generation. We also revealed that motor execution reduced activation in visual areas and Exner’s area during character processing. These findings can be utilized for designing new information systems for input-output units such as character-oriented portable terminals.



Sagittal, axial and coronal views of activation in Exner’s area

Voltage-Imaging of Association in Perirhinal Cortex

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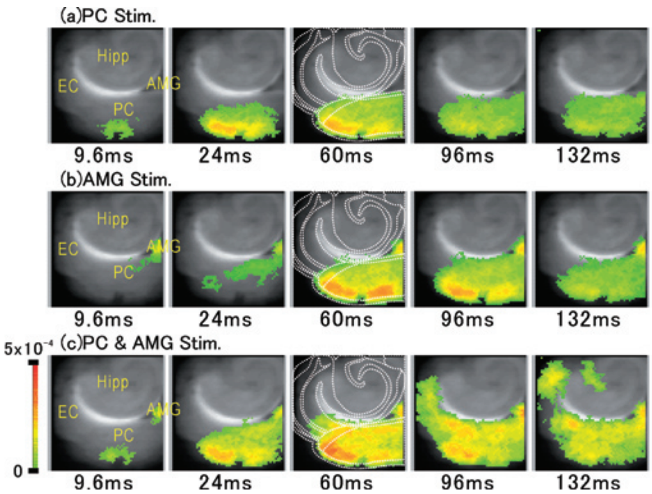
AIST Today Vol. 3, No. 7 (2003) 9

To investigate the potential associative function of the perirhinal cortex with respect to sensory and motivational stimuli and the influence of the association on the perirhinal/entorhinal/hippocampal neurocircuit, we prepared rat brain slices including the perirhinal cortex (PC), entorhinal cortex (EC), hippocampal formation (Hipp), and amygdala (AMG). We used an optical imaging technique with a voltage-sensitive dye to analyze the effect of associative inputs to the PC from both the AMG and the PC on the perirhinal-entorhinal-hippocampal neurocircuit. Our observations suggest that a functional neural basis for the association of higher-order sensory inputs and emotion-related inputs exists in the PC, and that transfer of sensory information to the entorhinal-hippocampal circuitry might be affected by the association of that information with incoming information from the AMG.



Optical recording of neural activity elicited by stimulation of the PC and/or the AMG.
Depolarization is measured as the fractional changes in fluorescence in each pixel, this value is encoded in "pseudocolor" as indicated in the scale and is superimposed on a bright-field image of the slice. The brain slice includes the hippocampus (Hipp), entorhinal cortex (EC), perirhinal cortex (PC), and lateral amygdaloid nucleus (AMG).

Two-Dimensional Particle-Mesh Ewald Method

- Fast and accurate molecular dynamics simulations for surfaces and membranes -

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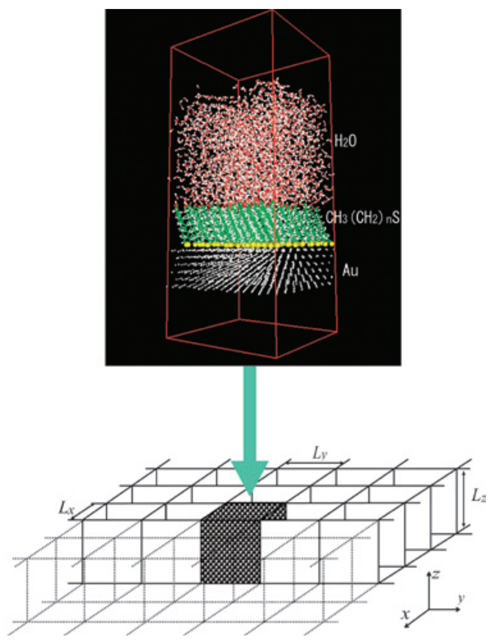
AIST Today Vol. 3, No. 7 (2003) 11

We developed a fast and accurate algorithm for calculating Coulomb interactions for three-dimensional systems with two-dimensional (2D) periodicity, i.e., quasi-2D systems, and built a numerical library that can be easily combined with molecular-simulation programs in widespread use all over the world. We refer to this new algorithm as the 2D-PME method. We present overview of the 2D-PME method, focusing on the advantage over the previous methods. The 2D-PME method is useful for the molecular simulations for surfaces and membranes.



(Top) Self-assembled monolayer membrane system. (Bottom) Quasi two-dimensional simulation system, Original particles are contained in the central box and images of the box are repeated in the (x,y) directions.

Preparation of 10μm-Thick-PZT Films for Piezoelectric Film Devices

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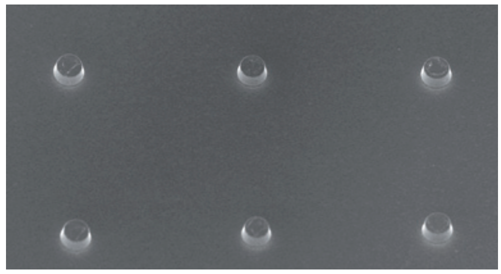
AIST Today Vol. 3, No.7 (2003) 12

A combination of the preparation techniques for the ferroelectric films and the micro machining of Si is considered to be an effective way to fabricate micro-electromechanical systems (MEMS), such as piezoelectric micro-transducer devices for applications in the electrical and medical fields. In this study, disk shape lead zirconate titanate (PZT) thick films were successfully fabricated. More than 10-μm-thick PZT films were deposited onto Pt/Ti/SiO_2/Si substrate using a chemical solution deposition (CSD) process. Pt top electrode and PZT layer were etched by reactive ion etching (RIE) process, and 20 to 500-μm-diameter PZT micro disks were fabricated.



SEM micrograph of fabricated PZT micro disks by RIE process

Implementation of a CFD Portal System by the Grid PSE Builder

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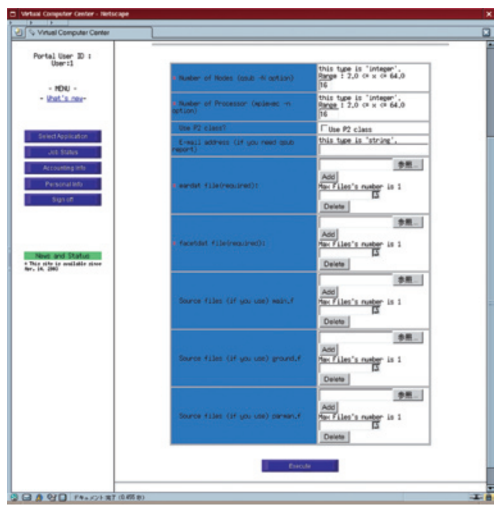
AIST Today Vol. 3, No. 9 (2003) 16

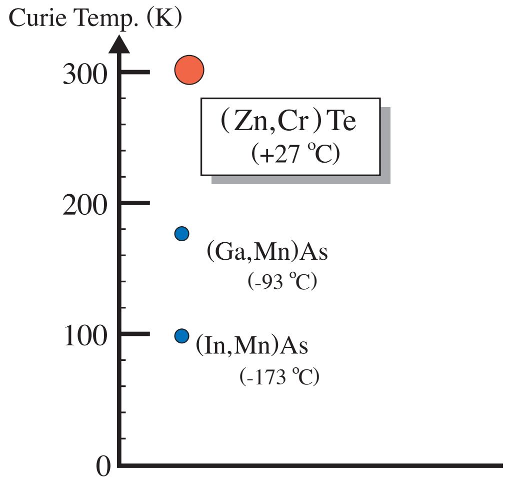
We are constructing an ASP portal system for CFD simulations on the Tsukuba WAN network which has 10Gbps connections in Tsukuba, Ibaraki local area. The Grid PSE Builder, which is developed by our center and an efficient tool to build a portal system, is used in this construction. A user can submit his job with appropriate parameters and initial data files to a remote supercomputer through the portal server. The portal has a capability to obtain the results onto the local PC. Figure 1 shows a job submitting page of the portal system.



A job submitting page of the portal system.
A user can set job parameters and/or upload input data file from local PC in this page.

Success in Synthesis of a (Zn,Cr)Te Room-Temperature Ferromagnetic Semiconductor

The Nanoelectronics Research Institute (NeRI) of the National Institute of Advanced Industrial Science and Technology (AIST) has developed a (Zn,Cr)Te ferromagnetic semiconductor that functions at the highest temperatures seen to date. Thus far, scientists have only been able to produce ferromagnetic properties at temperatures below –100ºC, but this research has significantly increased this temperature to +27ºC (300K) (Fig.1). The research team also observed semiconductor-like electrical and optical properties that are vital for use in technology applications. (Zn,Cr)Te is a promising material for new semiconductor devices with magnetic memory functionality (spintronics device).



Curie Temperature of ferromagnetic semiconductors

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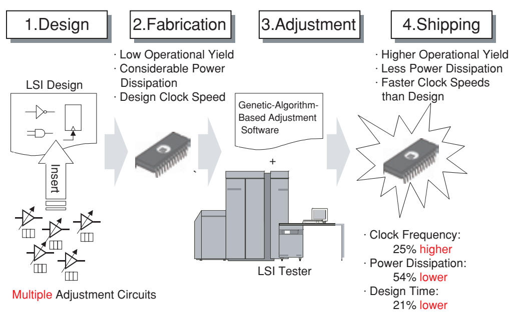
AIST Today Vol. 3, No.8 (2003) 26-27

Reducing Power Dissipation of LSIs using Genetic Algorithms

The Advanced Semiconductor Research Center at the National Institute of Advanced Industrial Science and Technology (AIST) and the Association of Super-Advanced Electronics Technologies (ASET) are collaborating under the Semiconductor MIRAI Project. Together they have developed a Genetic-Algorithm-based method to adjust clock timing that allows enhanced up to 25% of working clock frequencies and reduced 54% of power consumption by high-speed LSIs operating at the GHz level, and also reduced 20% of design time on the design process for a high-speed memory DDR-SDRAM controller. Details of this research were presented at the 2003 Symposium on VLSI Circuits (12–14 June 2003).



Genetic-Algorithm-Based Adjustment

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AIST Today Vol. 3, No. 9 (2003) 4-6

Synthesis of a Novel Disordered Rocksalt-Type Manganese Dioxide

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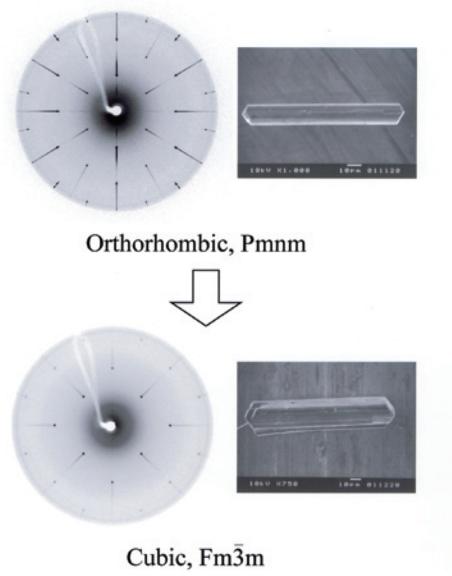
AIST Today Vol. 3, No. 7 (2003) 14

Layered lithium manganese oxides have attracted intense research interest as prospective cathode materials in secondary lithium batteries not only because of the low cost and low toxicity of manganese, but also becaude of their high theoretical capacities. Recently, we have succeeded in the synthesis of the electrochemically delithiated Li_xMnO_2 crystals with $x < 0.1$ from the parent orthorhombic $LiMnO_2$ single crystals. We also revealed the disordered rocksalt-type structure by single-crystal X-ray diffraction method. The mechanism of the structural transformation from the parent $LiMnO_2$ to the rocksalt-type MnO_2 was well explained by the manganese ion migration accompanied with Li^+ extraction. We believe that the rocksalt structure is a key to understanding the good and stable characteristics of the charge-discharge cycles in the $LiMnO_2$ electrodes for the battery use.



Single-crystal X-ray diffraction patterns of the parent $LiMnO_2$ and the delithiated MnO_2

DME Fueled Courtesy Bus

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AIST Today Vol. 3, No. 7 (2003) 15

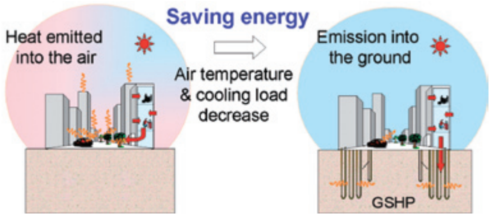
Figure shows DME powered mini-bus with a wheelchair lift. This vehicle represents the outcome of several projects, such as “Research and Development of Retrofit DME Diesel Vehicle”. The major areas modified include (1) Changing seal materials for DME compatibility, (2) Use of a pressure resistant fuel supply system, (3) Injection pump cooling system with fuel circulation, (4) Post-shutdown fuel purge system, (5) Use of a suitable lubricant additives with the DME fuel. With a fully-developed retrofit system, the cost is expected to be reduced, and it may be installed on in-use vehicles. This mini-bus will be licensed and operated in the near future.

DME powered mini-bus with wheelchair lift

A Countemeasure for Heat Island Effect using a Ground Source Heat Pump System

Heat island effect in summer becomes now one of the most serious social issues in Tokyo. More energy is required for cooling systems, when air temperature rises.

We proposed a new countermeasure for the heat island effect such as a district heat supply and air-conditioning system using a ground source heat pump (GSHP). GSHP suppresses the emission of exhaust anthropogenic heat and thereby acts as a possible countermeasure against the heat island effect. The GSHP system is expected to decrease the maximum air temperature in office area by 1°C compared with the present temperature level in Tokyo.



A new countermeasure for heat island effect

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AIST Today Vol. 3, No. 7 (2003) 16

Evaluation of Greenhouse Effects for Building A Sustainable Society

- IWE and ITWE as new evaluation methods -

New and convenient global warming evaluation methods for a sustainable society are proposed. One method is the Integrated Warming Effect (IWE: 1 IWE = 1 kg of CO_2, ITH = 100 years) instead of Global Warming Potential (GWP: 1 GWP = 1 kg of CO_2). Another method is Integrated Total Warming Effects (ITWE). ITWE is calculated the same way as TEWI, but using IWE instead of GWP. Long-term warming evaluations are made using these new evaluation methods.

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	ITH (year)	CO_2	CFC-12	HCFC-22	HFC-134a	CF_4	HFE-245cb2	HC-C5
IWE	20	0.3	3039.7	1383.8	995.7	1140.9	574.7	0.9
	100	1.0	10600.1	1700.5	1300.8	5700.0	580.9	3.1
	500	3.2	16657.0	1702.0	1303.6	28386.4	582.8	10.1
	1500	7.2	16771.5	1704.1	1307.1	84314.5	586.4	22.7
	∞	60.0	16778.5	1728.1	1347.2	2850000.0	631.1	186.7

IWE values of several greenhouse gases in a different Integrated Time Horizon (ITH)

Long-Term Monitoring of CO_2 Flux Over Forest Ecosystems

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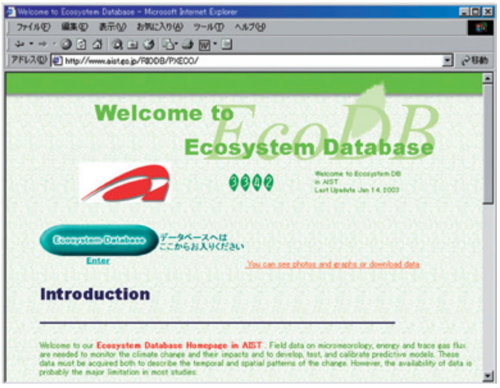
AIST Today Vol. 3, No. 8 (2003) 29

Forest plays an important role on the global carbon cycle. We have developed a measurement system for a long-term monitoring of CO_2 flux over forest ecosystems. The CO_2 flux is measured by the eddy covariance method, which is one of the micrometeorological methods based on a theory of atmospheric turbulence. We have now several monitoring sites in the East Asia, such as Japan, China, Thailand, and Indonesia. Observational networks of greenhouse gas fluxes have been established for global (FLUXNET) and for Asian countries (AsiaFlux). We are now trying to clarify the carbon budget of Asian forests in collaboration with participants of the flux-monitoring network.



A database of greenhouse gas fluxes over terrestrial ecosystems

Direct Production of Hydrogen from Woody Biomass

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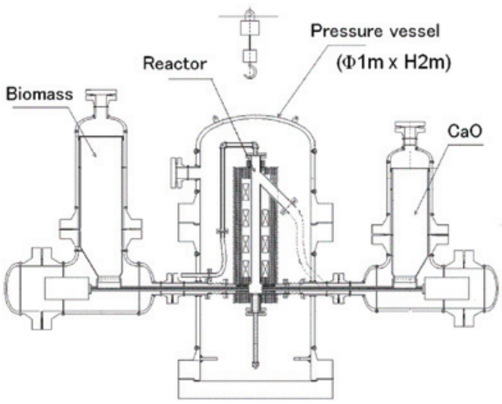
AIST Today Vol. 3, No. 8 (2003) 30

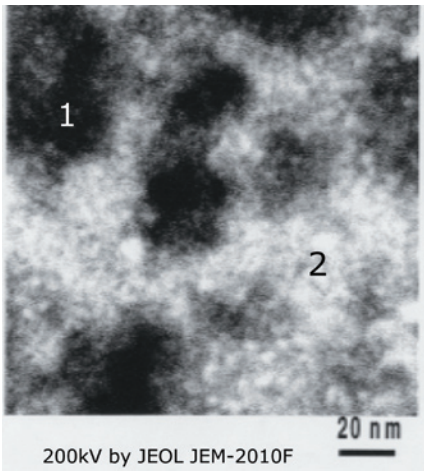
Biomass is a renewable and carbon neutral. The project, funded by METI, aims to develop the technical feasibility of hydrogen production from woody biomass by steam gasification using CO_2 absorber. The theoretical formula of the reaction is $C+2H_2O+CaO \rightarrow 2H_2+CaCO_3$, and AIST and CCUJ (Center for Coal Utilization, Japan) observed this phenomenon. Until now, a continuous bench scale unit of 10 – 20 kg biomass per day was designed and is being constructed (see Figure). It will be operated from the summer, 2003. At laboratory scale batch-test, obtained product gas consisted mainly of hydrogen (>80 mol%) and methane (<20 mol%), and all of CO_2 was absorbed in CaO as CO_2 absorber; no CO_2 was detected in the product gas. The clean gas could be produced in close to theoretical yield.



Continuous bench scale unit (reactor is set in a pressure vessel)

Organic/Inorganic Molecular-Hybrid Polymer Electrolytes for Intermediate Temperature Operation

Polymer electrolyte membrane fuel cells (PEFC) are one of the attractive energy conversion systems to be used in many industrial applications including electric vehicles, mobile telephone, and on-site power generations. Recently, the operation of PEFC at higher temperature (100 - 200°C) has been considered to provide many advantages, such as improved carbon monoxide (CO) tolerance of the platinum electrode, the higher energy efficiency, simplified heat managements, and co-generations. High temperature proton conducting polymer electrolytes have been synthesized through the sol-gel processing of organic /inorganic molecular hybrids. The membrane doped with inorganic acidic clusters shows large proton conductivities up to 160°C under humidified conditions. Proton conductivities of larger than 10^{-2} S/cm at elevated temperatures have been achieved and the conductivity can be correlated with the nano-phase separation to form bicontinuous inorganic channels in the flexible polymer matrix.



Nano-phase separated structure of the organic/inorganic hybrid membranes synthesized with octane bridging groups, where bicontinuous channels are observed

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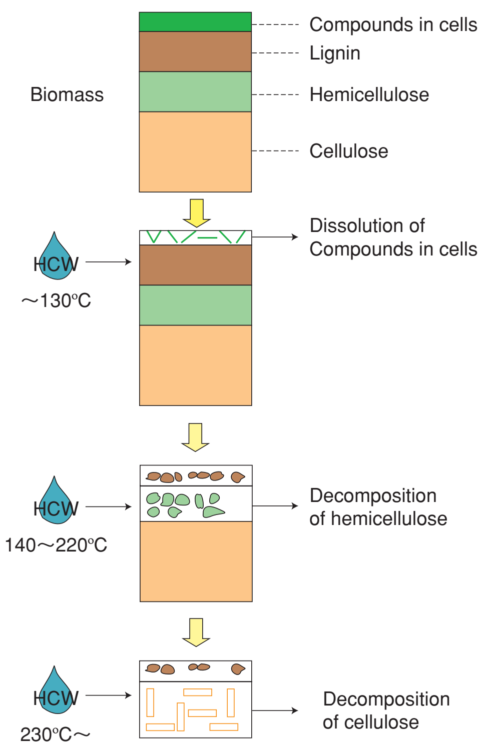
AIST Today Vol. 3, No. 9 (2003) 14

Development of Environmentally Friendly Hydrothermal Conversion Process of Biomass

- Biomass provides functional food, ethanol, and bio-degradable polymer -

Fractionation process of plant biomass using water alone was proposed as an environmentally friendly conversion process for a maximum utilization of biomass. If water is heated in a closed vessel, the ion product of water increases with increasing temperature and pressure, and the hot compressed liquid water in the vessel comes to have a hydrolysis-ability. Hemicellulose in plant is hydrolyzed to oligomers at temperatures 140-220˚C, being functional food which keeps the intestines in healthy state. Then, cellulose is hydrolyzed to glucose and its oligomers above 230˚C. These products from cellulose can be converted to ethanol or poly-lactic acid that are used as a clean energy and bio-degradable polymer, respectively.



Fractional of biomass using not-compressed-water

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AIST Today Vol. 3, No. 9 (2003) 15

Novel Nanoporous Carbon-Silica Composite

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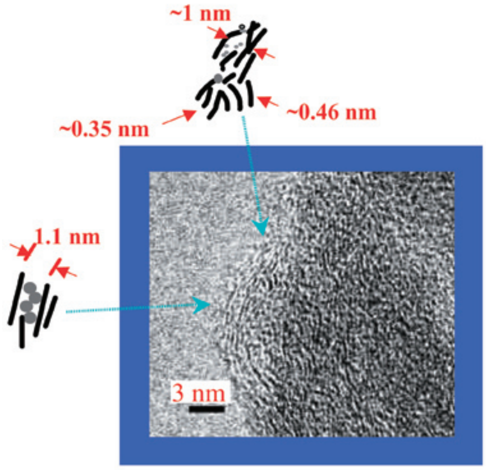
AIST Today Vol. 3, No. 8 (2003) 31

The objective of this research is to create nanoporous materials ideal for CH_4 storage by physically and chemically functionalizing the layered compound precursors with very thin walls via the modern nanoprocessing technology such as intercalation, soft chemical template method, etc. Recently, we succeeded in synthesizing a novel nanoporous carbon-silica composite by this route which has medium hydrophilicity and could be expected for applications which require both hydrophobic circumstances and the role of intercalated active species.



TEM image of nanoporous carbon-silica composite

Organic-Inorganic Hybrid Materials for VOC Gas Sensors

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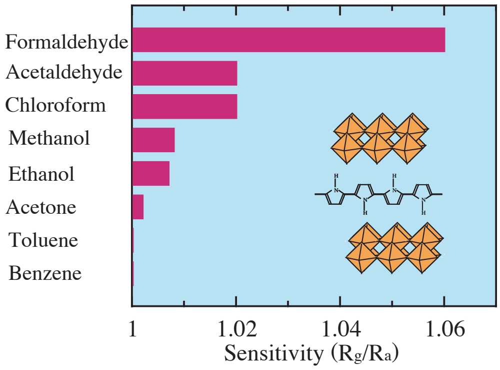
AIST Today Vol. 3, No. 8 (2003) 32

We have proposed intercalative type organic-inorganic hybrid materials as the chemical sensors for detection of volatile organic compounds (VOCs). The organic and inorganic components take part in molecular recognition and transduction of chemical signals to measurable resistance changes, respectively. We tested this idea with polypyrrole intercalated MoO_3 hybrid materials, $(PPy)_xMoO_3$, with a layered structure. The $(PPy)_xMoO_3$ pressed pellets show a distinct response to VOCs by increasing in their electrical resistivity. $(PPy)_xMoO_3$ exhibits higher sensitivities to polar analytes such as formaldehyde and acetaldehyde, whereas it showed almost no response to toluene and benzene.



VOC gas sensing properties

Isomer Determination for Individual Molecules by High Resolution Electron Microscopy with Atomic Sensitivity

Intra-molecular structure of the scandium di-metallofullerene ($Sc_2@C_{84}$) has been clearly revealed by high resolution transmission electron microscopy (HR-TEM) with the single atom sensitivity. Direct observation of two Sc atoms inside each fullerene molecule has led to a successful determination of the molecular symmetry among the three possible structural isomers for the $Sc_2@C_{84}$. The present work introduces a new electron microscopic approach to investigate individual molecular structures and demonstrates the possibility for determining the molecular isomer on a single-molecular basis.

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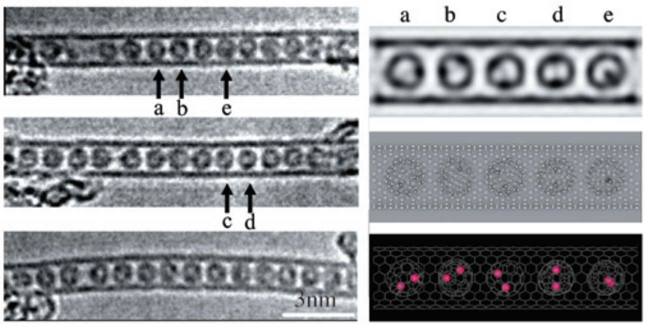
AIST Today Vol. 3, No. 9 (2003) 10

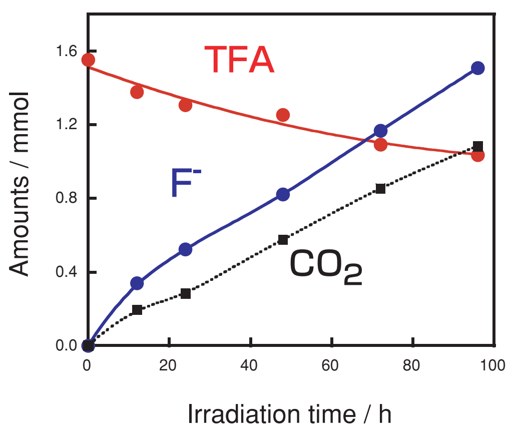


(Left) HR-TEM images of the $Sc_2@C_{84}$ metallofullerene inside SWNTs. Dark spots seen in each molecule correspond to the individual Sc atoms. (Right) Simulated HR-TEM image (top) for various orientations of $Sc_2@C_{84}$ molecules inside SWNT. Projected atomic potential (middle) and models used for simulations (bottom) are also presented. Legends (a-e) correspond to those in the observed HR=TEM images.

Decomposition of Environmentally Persistent Perfluorinated Compounds by Heteropolyacid Photocatalysts

Fluorinated compounds have been widely used in industrial applications such as surfactants. The use of these compounds has steadily increased, and some of them have detected in the environment. Hence, it is desirable to develop an artificial method for decomposing these compounds to environmentally harmless species under mild conditions as a measure against stationary sources.

We developed the effective decomposition method for perfluorinated compounds such as trifluoroacetic acid (TFA), using a homogeneous system consisting of the heteropolyacid photocatalyst, water, and oxygen. Most of the F and C atoms in the decomposed TFA are transformed into F- and CO_2.



Irradiation-time dependence of the TFA decomposition [Reprinted with permission from Environ. Sci. Technol. 2003, 37, 418. Copyright 2003 American Chemical Society].

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AIST Today Vol. 3, No. 9 (2003) 11

Roles of Mesopores of Y-type Zeolite Catalysts

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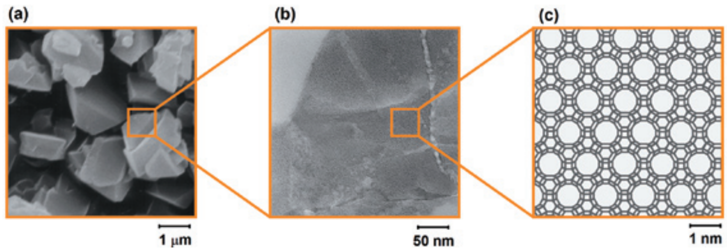
AIST Today Vol. 3, No. 9 (2003) 12

Y-type zeolite-based catalysts have many advantages for the hydrocracking of the petroleum fractions. In the case of the hydrocracking of heavy oils, however, the diffusional limitation of large size molecules into the micropores of Y-type zeolite occurs. Therefore, active catalytic sites are limited to the external surface, that is, the external surface of zeolite particles and the mesopore surface. In this study, the roles of mesopores of Y-type zeolite catalysts for the hydrocracking of heavy oils were investigated.



Bimodal structure of Y-type zeolite. (a) zeolite particles observed by scanning electron microscopy (SEM), (b) mesopore structure observed by transmission electron microscopy (TEM), (c) micropore structure.

The Highest Efficiency of NO_x Decomposition by Nano-Structurally Controlled Electrochemical Cell

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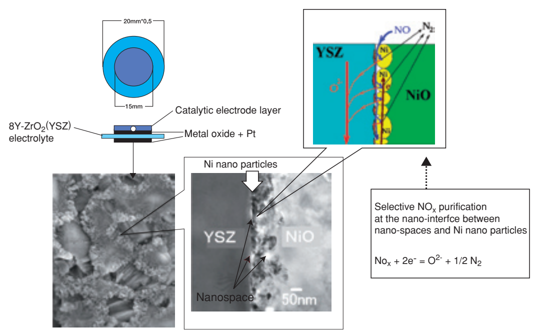
AIST Today Vol. 3, No. 9 (2003) 13

Electrochemical cells have become an important technology which contributes to environmental aspects of human life and industry. The Environment Purifying Materials Team of Synergy Materials Research Center has successfully fabricated high performance electrochemical cells for reduction of NO_x gases emitted from diesel engines and so on. Nano-structural control in the catalytic electrode of the cells has been proposed and optimised. A nano-reaction space composed of catalytic reduction phase of Ni nano particles with oxygen defects in YSZ surrounding nano-pores enhanced NO_x decomposition reaction drastically. Efficiency of NO_x decomposition to consuming energy of the newly developed electrochemical cell reached twice of it for the catalytic system, which is practically used in vehicles.



Scheme of nano-structurally controlled electrochemical cell for selective No_x decomposition

Suppression of Charge Build-up during Ion Bombardment into Insulators using a Cluster Ion Beam

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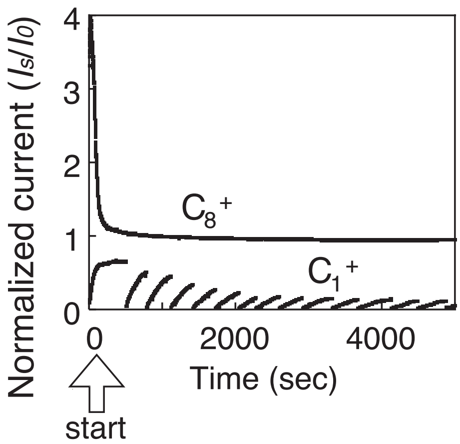
AIST Today Vol. 3, No. 9 (2003) 19

The charge accumulation processes of an organic insulator during monoatomic ion C_1^+ and cluster ion C_8^+ bombardments were studied by simultaneously measuring the target and secondary emission currents as functions of atomic dose. A series of abrupt changes in the currents was observed during C_1^+ bombardment, indicating repeated charge accumulation and electric breakdown. In contrast to the C_1^+ bombardment, the emitting current was equilibrated with the injecting current and the electric breakdown was not observed for C_8^+ bombardment. Combining the cluster bombardment with the application of the external electric field eliminates the charge accumulation problem. Cluster ion beam is expected to be useful for the processing and analysis of materials having low electric conductivities.



Variations of secondary emission current I_s normalized to incident beam current I_0 (I_s/I_0) with irradiation time for monoatomic ion C_1^+ and cluster ion C_8^+ bombardments to polycarbonate.

Silicon Nanoblocks Pave The Way for A New Conceptual Nanoarchitecture

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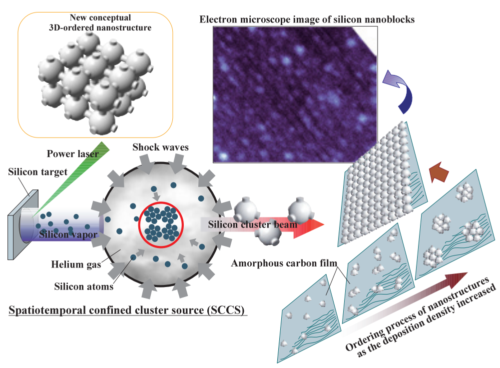
AIST Today Vol. 3, No. 7 (2003) 4-6

"Nanoarchitecture" in blocks of atomic clusters uniquely enables one to construct new conceptual three-dimensionally ordered nanostructures efficiently. Spatiotemporal confined cluster source (SCCS) has been newly developed to realize the nanoarchitectures using stable clusters which have characteristically narrow size distributions. Electron microscopic images of well-defined silicon clusters deposited on an amorphous carbon film revealed that silicon nanoblocks of 2-3nm in diameter lined up spontaneously to form a tetragonal structure by the interaction potential working on between adjacent silicon clusters. The empirical establishment of spontaneous ordering of nanoblocks paves the way for the three-dimensional nanoarchitecture in blocks of clusters, which particularly extends electronic, optical, and mechanical functions of nanomaterials.

3D-ordered silicon nanoblocks possibly generate a monochromatic electron emitter, which would lead to the increase of resolution of electron microscopes or lithography systems, and also possibly turn ultra thin accumulators with a high electric capacity into reality. The accumulator integration system with a solar cell can change the concept of autonomous energy supply systems which are now expected as a short term operating system.



Cluster beam nanoprocesses to realize nanoarchitecture in blocks of atomic clusters.

The World's Largest Epitaxial Superconducting Film (30cm×10cm)

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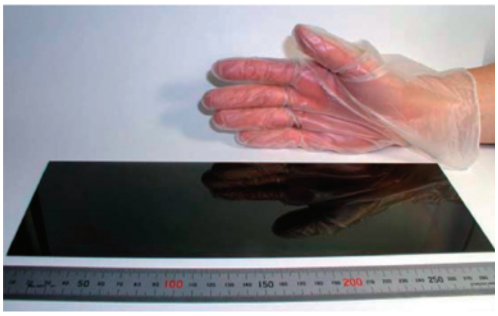
AIST Today Vol. 3, No. 9 (2003) 7-9

AIST has succeeded in preparing the world's largest (30cm×10cm) epitaxial superconducting $YBa_2Cu_3O_7$ film on CeO_2-buffered sapphire substrate by coating-pyrolysis process. This process produces $YBa_2Cu_3O_7$ film by "applying and then burning" a coating solution, so that mass production can be realized at a far lower cost than that of vapor-phase processes. This film is epitaxially grown with preferentially oriented particles, and shows a very high superconducting characteristic that the average critical current density at liquid nitrogen temperature is over 1,000,000 A/cm^2. This large-area superconducting film can apply to passive microwave devices such as filters or antennas, and fault current limiters.



Photograph of the epitaxial $YBa_2Cu_3O_7$ film (30cm×10cm)

Mechanical Engineering and Manufacturing Technology

Recycling of Waste Colored Glass

- A new type of fluorescent glass obtained from waste glass -

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AIST Today Vol. 3, No. 7 (2003) 7

A new method to decolorize the waste colored glass is newly proposed. In this method, the colored waste glass is converted to colorless transparent porous glass employing similar method for preparing conventional porous glass. To obtain more valuable recycled product, a fluorescent glass is prepared by loading small amount of metal ions in the porous glass followed by sintering.

Waste colored glass (left) and porous transparent coloreless glass botained from the waste glass (right)

Study on Metal Core-Assisted Piezoelectric Complex Fiber

In an attempt to develop piezoelectric sensors and actuators for smart boards, complex piezoelectric fibers with metal core were fabricated by hydrothermal method and extrusion method. The insertion of metal core was significant in view that the fragility of ceramics can be overcome and electrodes are not required in the use as sensors and actuators. In order to evaluate the sensing and actuating abilities of these new-type fibers, a cantilever structure was constructed by embedding the fiber into the surface layer of CFRP composite board. In addition, it is shown that this board can make the vibration and detect the vibration.

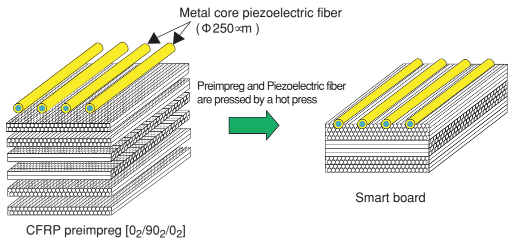

Fig.1 Fabrication prosess of the smart board

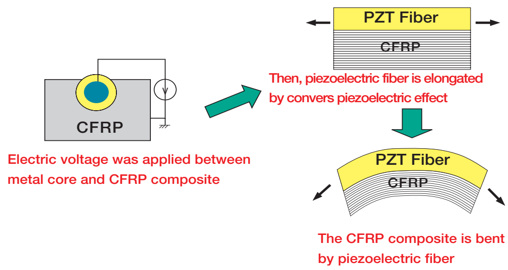

Fig.2 Application to the Actuator

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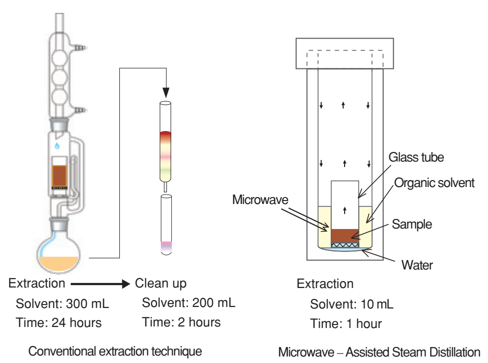
AIST Today Vol. 3, No.7 (2003) 13

Standards and Measurement Technology

Extraction Technique for Simple Determination of PCBs and Pesticides

Polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) are representative persistent pollutants. We have developed a novel sample extraction technique (Microwave-Assisted Steam Distillation) for PCBs and OCPs analysis. The analytes were effectively vaporized with water vapor which was generated by microwave irradiation. Because only volatile compounds were recovered in the solvent, the obtained extract could be analyzed with gas chromatograph-mass spectrometers without any cleanup process. The technique gave comparable analytical results with the values obtained by other extraction methods. Smaller organic solvent consumption (10 ml or less) and shorter process time (60 min) would be advantages over other methods.



Comparison of Microwave-Assisted Steam Distillation (MASD) andconventional sample pretreatment technique.
In the case of MASD, effective extraction of PCBs and OCPs was driven by water circulation. Water vapor was generated from the microwave irradiated sample, then the condensed water permeated into the sample by capillary action repeatedly. Through this process, PCBs and OCPs carried by water vapor were trapped into the organic solvent without direct contact between the solvent and the sample.

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AIST Today Vol. 3, No. 7 (2003) 8

Development of a Sub-Micron Resolution EUPS (EUV Photoelectron Spectroscopy) System

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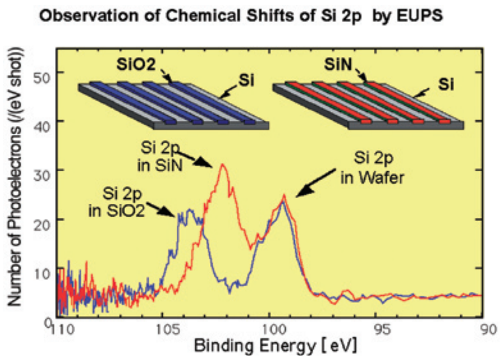
AIST Today Vol. 3, No. 8 (2003)33

Photoelectron spectrum (PS) has been obtained from a sample irradiated with a sub-micron EUV beam. In EUPS devised at AIST, a sample is irradiated by a narrow line-emission from a laser-plasma source and the energy of emitted photoelectrons is analyzed by Time-Of-Flight. High efficiencies in the use of a photon source and electron energy analysis enables us to acquire high-spatial-resolution PS. As seen in the Figure, the energy resolution of EUPS is high enough. By forming a micro beam with a multilayer coated Schwarzschild optics, we can achieve sub-micron spatial resolution. By collecting photoelectrons with high efficiency by employing a magnetic bottle, we succeeded in obtaining a decent PS.



Chemical shift of Si 2p is easily observed in EUPS using a 4.8nm line emission.
The irradiated area on sample was several millimeter in diameter.
Energy resolution better than 0.5 eV has been confirmed in other spectra.

Realization of the Triple Point of Equilibrium Hydrogen using New-Generation Sealed Cells

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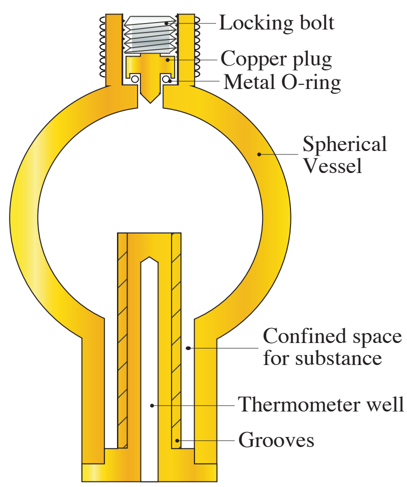
AIST Today Vol. 3, No. 8 (2003) 34

New generation sealed cells have been developed at AIST, which are used for realization of low temperature fixed points of the International Temperature Scale of 1990. The triple point of equilibrium hydrogen (e-H_2), one of the fixed points, is realized using the sealed cells containing ferric oxy-hydroxide as a catalyst for the ortho-para equilibration. The reduction of the amount of the catalyst suppresses a heat-capacity anomaly due to an interaction between hydrogen and catalyst at temperatures just below the triple point and allows one to obtain more reliable melting curves for e-H_2.

references

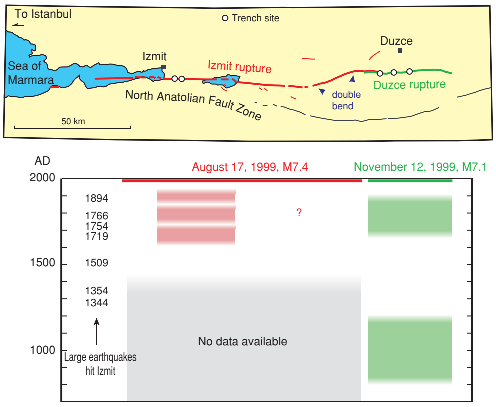
[1]Nakano T., Tamura O. and Sakurai H., in: Temperature, its Measurement and Control in Science and Industry, Vol. 7, 2003, American Institute of Physics, (in press).
[2]Nakano T., Tamura O. and Sakurai H., T. SICE 38, 2002, pp. 947-951.
[3]Nakano T., Tew W., Tamura O. and Sakurai H. in Proceedings of 15th Symposium on Thermophysical Properties, 2003, Boulder (to be submitted).
[4]Nakano T., Tamura O. and Sakurai H., in Proceedings of 2nd International Seminar on Low Temperature Thermometry, 2003, Wolclaw (to be published).



Schematic side view of new-generation sealed cell

History of Large Earthquakes on the North Anatolian Fault

To identify one or multiple fault segment that corresponds to one large earthquake, we develop an evaluation technique. As a case study, we have been studying the North Anatolian fault, Turkey that produced 12 M≥6.7 earthquakes in the twentieth century. We excavated several trenches along the Izmit and Duzce segments that had produced large earthquakes in August and in November 1999, respectively. We then found that the recurrence intervals of the paleo-earthquakes on both faults are totally different. Thus, the boundary between two segments that characterizes a double-bend has worked as a persistent barrier to stop rupture propagation.



(upper panel) Distribution of the North Anatolian fault zone and surface ruptures due to the 1999 Izmit and Duzce earthquakes.
(lower panel) History of large earthquakes produced by the Izmit and Duzce faults. Each box corresponds to one large historical earthquake.

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AIST Today Vol. 3, No. 8 (2003) 37

Prince and Princess Hitachi Visited AIST Tsukuba

On the 23rd of July, 2003, AIST Tsukuba had an honor to welcome His and Her Imperial Highness Prince and Princess Hitachi, who attended the 45th Natural Park Festival. The visit was a part of the inspection tour of Ibaraki prefecture.

Despite the gloomy rainy season weather, the Imperial Couple took a tour of the Geological Museum affiliated to AIST, following the introduction of the Museum by Dr. Masahiro Aoki, the director. The exhibitions included “History of the Earth”, “Mineral Resources and Marine Geology” and “Geological Phenomena and Our Living”.

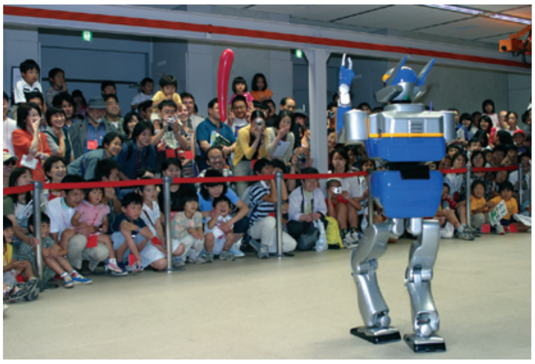
AIST Tsukuba Public Open Day

AIST Tsukuba was opened to the public on July 23, 2003 and the center was bustling with 4,012 visitors. This number exceeds that for last year, partly thanks to the cool weather during a rainy season.

The research achievements were on display and some were demonstrated at “Hot Topic Corner”, whereas “Dream Labo” and “Challenge Corner” allowed the visitors to experience scientific experiments. Everyone from primary school children to senior citizens had fun with the mysteries of science.

As a special event, Dr. Hideki Shirakawa, honorary professor of Tsukuba University, made a lecture on his endeavors, that led him to win the Novel Prize in Chemistry. The audience included many children fascinated with his talk given in an easy to understand manner with a hint of humor.

A number of primary and junior high school students were tackling the challenge of scientific experiments, eagerly asking questions to the instructors. The public open day of this year was a great success, providing the opportunity to inject the “Science DNA” to the younger generation.



Dr. Shunso Ishihara, AIST Emeritus Advisor, Appointed as Academician of Russian Academy of Sciences

On May 22, 2003, Dr. Shunso Ishihara, Emeritus Advisor of AIST, was elected as an academician of Russian Academy of Sciences at the general conference of the Academy, in recognition of his longstanding and internationally distinguishedachievements in the field of study of mineral deposits and granite petrology. As of 2003, there are 244 academicians outside Russia and 13 of them are Japanese researchers including Prof. Ryoji Noyori, Dr. Masatoshi Koshiba and Dr. Shunso Ishihara, all of whom were nominated on this occasion.

Among the achievements of Dr. Ishihara was his proposition of "granite series". This had an exceptional influence over the international community of granite studies and is highly acclaimed as one of the outstanding developments that have been produced in Japan and disseminated to the world. The method to classify granites into magnetite and ilmenite series, as Dr. Ishihara proposes, is based on the state of oxidization and reduction of granite magma, which can be recognized by the quantity of contained magnetite. Therefore, these two series can be easily identified in the open field, by means of measuring magnetic susceptibility.

In addition to this, the clarity of classification methodology in terms of both component recognition and recording, was largely influential on the research of granites not only of the Japanese archipelago but also of circum-Pacific magmatic zone. Dr. Ishihara himself has been advancing his research to the earliest part of the Earth histry in order to verify the classification theory of granite series in collaboration with geologists from Chile, China, Australia and other countries.

Dr. Ishihara was appointed as an emeritus advisor of AIST in April 2001 and has been publishing a number of academic papers and giving guidance to junior researchers.

US Biotechnology Industry Exhibition [BIO 2003 ANNUAL CONVENTION]

The world largest exhibition of biotechnology industry, BIO 2003 ANNUAL CONVENTION was held at the newly erected Washington Convention Center in Washington, D.C. from 22nd to 25th of June in 2003, hosted by US Biotechnology Industry Organization (BIO). The event was joined by approximately 1,000 exhibiting companies and received 16,000 visitors. President Bush made a speech during the day-time seminar.

AIST ran a booth with six Japanese bio-venture enterprises at JETRO Japan Pavilion, where a video was shown to present the outline of the relevant research projects and venture businesses in the field of biotechnology. Moreover there were displays of the research achievements which were aimed at technology transfer. The research activities were introduced to a number of visitors through the exhibitions at both the AIST booth and the Japan Pavilion, and some discussions were made to further cooperative research in order to nurture and develop one of the most promising technologies.

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Trustee

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AIST Fellow

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General Administration Headquarters

Evaluation Department

Safety and Environmental Protection Department

Research Coordinator

Superintendent

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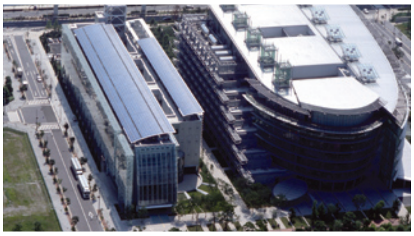

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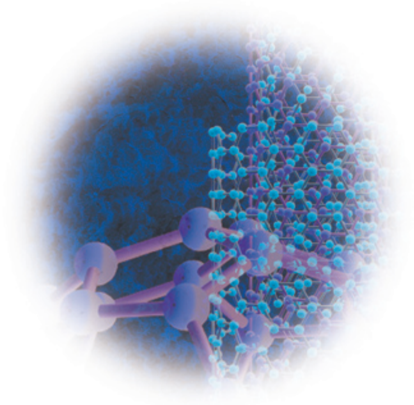

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