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Feature

Annual Plan of the National Institute of Advanced Industrial Science and Technology for FY 2004

Planning Headquarters

Three years have passed since the inauguration of the National Institute of Advanced Industrial Science and Technology (AIST), an Independent Administrative Institute. The FY 2004 counts for the final year of the first interim-plan period. In this period, AIST has been evaluated twice by the Independent Administrative Institute Evaluation Committee. The evaluation on activities for FY2002, which was carried out in 2003, was focused particularly on the research achievements on FY 2002. The evaluation found that the research based in the "Full Research" concept was performed under the top management with advantages of independent administration system, which AIST was trying to promote since the inauguration. Consequently, AIST was highly evaluated the profession from the viewpoints of both quality and quantity (evaluated by indexes such as number of published papaers, contracted amounts based on the patents, etc.) for steady growth and progress.

In FY 2004, accomplishing the final goal of the first interim plan, AIST will promote to make rules and schemes for further development of AIST toward the second interim plan. The details are described as follows;

By increasing the amounts of budgets and internal grants for full research, as well as expanding the system to encourage the acquisition of more patents, more contracted researches, more joint researches, etc., with the private sector, AIST will proceed to advance the qualities of researches furthermore under the global competition. In embracing these aspects, AIST believes to achieve the goal of the first interim plan. Consequently, the organization and management of Research Units and Research Related Administrative Divisions should be reviewed in order to seek further efficiency of the performance and administration toward the second interim plan. To be more specific, AIST will make the administration more efficient to advance entire performance of AIST, though the establishment of the well-defined personnel who may be able to carry out the mission, in charge of his/her responsibility. AIST also performs the dissemination and advertisement of research achievements of AIST by showing them in EXPO 2005 AICHI as straightforward approach to the public. AIST tries to provide the intelligence to be widely shared with the public in easily understandable way.

It is declared that the administration of Independent Administrative Institute including AIST, shall be directed by the state minister in charge (the Minister of Economy, Trade and Industry for AIST), according to the interim goals of the period (that holds for four years between FY2001 and FY2004 for AIST). Each Independent Administrative Institute prepares an interim plan to engage in its respective achievements. In the meanwhile, an annual plan of the administration for the institution must be filed prior to the new fiscal year.

Here we introduce a summary of an annual plan for FY 2004, with focuses to research plan. For more information, please refer to AIST official website. (http://www.aist.go.jp/)

Main Features of AIST's Research Plan for FY 2004

Life Science and Technology

In the field of life science and technology, AIST has been engaged in research and development drives aimed at bringing gains in human health and contributing to the realization of recycling-driven society through the industrial application of bionomics. In particular, it will pursue the development of a range of applied biotechnologies for utilization in the post-genomic era, including bioinformatics for industrial applications of gene information, glycotechnology, RNA engineering, and aging technologies. Work will also proceed on cross-disciplinary projects for research and development, including brain-machine interfacing systems, regenerative medical engineering, and nanobio machines. As a leading center for the promotion of advanced research on biotechnology, the institute will implement researches on the establishment of intellectual infrastructure, advanced bio-processing and other themes to meet society's expectations in the areas of environmental measurement, purification, protection, and waste disposal.

In a part of the Basic Biotechnology Research Program for Health Maintenance and Improvement

Table 1 Key Projects in Life Science and Technology

- **Basic Biotechnology Research Program for Health Maintenance and Improvement**
  - Research and Development of Protein Expression and Interaction Analysis Technology
  - Technology for Analysis of Intracellular Network Dynamics
  - Glycoscience Project
  - Research and Development of Profile Diagnosis System based on Genome & Proteome
  - Development of Protein Separation Chips
  - Development of an Integrated Protein Analysis System with Bio-IT Fusion Technology
  - Advanced Bio-nanodevice Project
- **Creative Program for Recycling Manufacturing System with Biological Features**
  - Development of Analysis and Control Technology for Biodegradation-treatment Mechanism
  - Development of Highly Accurate and Sensitive Monitoring Technology for Microorganisms in the Environment
  - Development of Streamlined Industrial Materials Production Technology Utilizing Plant Energy
- **Medical Appliance Enhancement Program for Improved Health and Longevity**
  - Development Project for Physical Function Replacement and Recovery System
  - Tissue Engineering (Cell Engineering) Technology Research and Development
  - Advanced Support System for Endoscopy and other Minimally Invasive Surgical Techniques
  - Totally Implantable Artificial Heart System for Clinical Applications

nance and Improvement, FY 2004 researches will be continued on the analysis of protein structures and functions. AIST will also launch a variety of new projects on the following themes: glycoscience engineering; R&D on profile diagnosis systems based on genome-proteome; the development of protein system tips for protein isolation; the development of multidimensional protein analyzers that harness information technology; and advanced nano-bio devices. In the Creative Program for recycling manufacturing systems with biological features, various green biotechnology programs are also scheduled to proceed. Further, under the framework of advanced programs for medical appliances that will enable to prolong health and longevity, research works will be pursued on regenerative medical engineering and the development of new devices with medical and welfare applications (Table 1).

Information Technology

In the information technology field, AIST will work to help build a information society in which information technologies pervade our lives and allow anyone to create, distribute, and share information as the need arises: in other words, a society with a ubiquitously integrated information/communication network combined with easy-to-use and secure information network interface that allows digital content and other information to be accessed and utilized without the usual constraints of time or location. To this end, AIST will enlist its comprehensive strengths for research covering a broad array of technological issues on both the hardware and software fronts.

To guarantee that our information-oriented society enjoys security and reliability, AIST will build information security architectures that prevent unauthorized access over the internet and allow safe and secure communications and authentication. Also, the institute will develop and test technologies to evaluate whether software is actually designed in accordance with specifications. Additionally, desktop computers running open-source software will be tested for their practical viability. On top of this, AIST will pursue the development of appliances and robots with improved human-machine interfaces for the support of human intellectual activities as well as the functions of society at large.

To reinforce the information-oriented society's high-speed, high-capacity information lifelines, the institute will pursue work on the core technologies for high-density optical discs and ultra-fast optical communication, with an emphasis on projects for the development of high-capacity optical disc storage and femtosecond technology. It will also conduct research on grid-computing technologies whereby networks with many client computers can be operated as though they were a single computer for large-scale information transfer and processing applications.

To encourage the development of information and communication devices that boast higher performance with lower power consumption requirements, AIST will pursue the development of standardized processes and materials for next-generation semiconductors. In that undertaking, the focus will be on the MIRAI Project, part of a national strategy aimed at developing next-generation semiconductor materials and fabrication processes. Efforts will also be devoted to the development of energy-efficient, low-power semiconductor devices that incorporate innovative new circuit technologies, nonvolatile functional devices that harness spintronics technologies, and high-efficiency organic devices.

Table 2 Key Projects in Information Technology

- **Program for Next-Generation Semiconductor Device Process Technology**
  - Development of Next-Generation Semiconductor Materials and Process Technology (MIRAI)
  - Development of EUV Lithography System
- **Program for Advances in Information Infrastructure**
  - Femtosecond Technology
  - Development of Technology for Large-Scale Optical Storage
  - Development of Low-power, High-frequency Nitride Semiconductor Devices
- **Program for Development of Next-Generation Display Technology**
  - Development of Ultra-high Efficiency Organic Devices
- **Program for Development of Information Infrastructure Software**
  - Business Grid Computing
  - Development of Infrastructure for Utilization of Open-Source Software
- **21st Century Robot Challenge Program**
  - Development of Software Base for Robot Development
- **Core Technology Program for Aerospace Industry Advancement**
  - Development of Core Technologies for Next-Generation Satellites (Development of Quasi-Stationary Satellite Systems)

Environment and Energy

Driven by the goal of contributing to the establishment of a sustainable recycling-oriented society in the environmental and energy fields, AIST will conduct research and development to solve issues in global warming and environmental pollution as well as to secure stable energy resources. As a step to alleviate global warming, the Kyoto Protocol was adopted at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) in 1997. Under the first phase of that protocol, from 2008 to 2012, Japan is obligated to cut its greenhouse gas emissions by 6 percent compared to 1990 levels. This goal will demand enormous technological advances in energy conservation and other fields. In addition, there has been a strong surge in support for research and development work on technologies to assess and reduce the risks associated with chemicals in the environment, as exemplified by the environmental endocrine disrupters that have been in the news in recent years. The depletion of fossil fuels also remains a critical issue. The crucial challenge for the medium and longer term will be to shift the structure of society's primary energy dependence from oil to natural gas, and ultimately to renewable energy resources, while continuing to curb CO_2 emissions.

In view of current conditions and trends, AIST has focused its research priorities as follows. With regard to (1) technologies to fight global warming, emphasis will be on technologies that reduce the causative agents of the greenhouse effect, technologies for energy systems of high efficiency and distributed energy Systems, and environmentally friendly manufacturing processes. With regard to (2) regional environmental issues, attention will be devoted to technologies for the management and reduction of risk associated with chemical substances. With regard to (3) the goal of securing stable energy resources, research will be focused on cleaner and more diversified energy sources. Life cycle assessment (LCA) and other technologies for the integrated assessment of environmental and energy systems will be another priority research area (Table 3).

In FY 2004, AIST will utilize contract funding for new research undertakings in the following five areas. (1) Core research on information infrastructure for petroleum and natural gas resources and the development of high-precision mass analysis technologies as aids to oil and natural gas exploration; (2) core

research on standards of measurement, and R&D on flow-meter quality control technologies for streamlined petroleum distribution; (3) R&D on core energy-saving technologies for information appliances; (4) core research on standards of measurement and R&D on technologies for precision flow measurement at nuclear power generating plants; and (5) core research on energy and environmental technology standards for the establishment of standard technologies required for the society-wide popularization of new energy technologies.

AIST will also participate in the Ministry of Economy, Trade and Industry's research and development program. Development efforts will focus specifically on chemical risk assessment methods, ultra low-loss power device technologies, proton-exchange membrane fuel cell system technologies, superconducting technologies, and other areas. To promote LCA methods, AIST will launch research into regional environmental issues in cooperation with local municipalities. Other collaborative projects will focus on the development and assessment of alternative fuels such as methane hydrate and biomass resources, substitutes for fluorine compounds, and diesel exhaust control technologies.

Table 3 Key Projects in Environment and Energy

- **Program for Innovative Technologies against Global Warming**
  - Development of Energy-Conserving, Innovative Production Process Technologies
    - Development of Next-Generation Chemical Process Technology
    - Development of Low Environmental-Load Technology for Supercritical Fluid Utilization
  - Development of Technologies for Innovative Energy-Use Systems
    - R&D on Fundamental Technologies for Superconducting AC Power Equipment
    - R&D on Fundamental Technologies of Superconducting Generators
    - R&D on Superconducting Bearing Technology for Flywheel Electric Energy Storage Technology
- **Energy and Environment Program for Fixation and Effective Use of Carbon Dioxide**
  - Development of Viable CO_2 Fixation and Utilization Technology
- **Integrated Assessment and Management Program for Chemical Substances**
  - Risk Assessment of Chemicals and Development of Risk Assessment Methods
- **Program for Utilization of Solid Polymer Fuel Cells and Hydrogen Energy**
  - Development of Solid Polymer Fuel Cell System Technologies
  - Development of Core Technologies for Hydrogen Fuel Safety and Utilization

Nanotechnology, Materials, and Manufacturing

In the highly industrialized society, technologies are required that satisfy conservation of limited natural resources and the living environment as well as consumer demands for a more comfortable lifestyle.

In addition, a new technology is generally accepted in a society when the costs associated with the manufacture, use, and disposal of a product is reasonably reduced.

The nanotechnology, materials, and manufacturing field is challenging to solve the above requirements through the innovation of materials and manufacturing technologies, and establish the technological infrastructure assuring a secure, peaceful life in a demographically aging society and at the same time, realizing an advanced information society, and a society that is sustainable and environmentally sound.

AIST has drastically reorganized its framework for the practical pursuit of these challenges. In (1) the priority field of advanced materials, it has assigned four research centers to undertakings concerned with nano-carbons, diamonds, strongly correlated electron systems, and functional molecules. In (2) the arena of full-scale systematization research aimed at overcoming the weaknesses of sporadic research on elemental technologies, it has assigned three research institute and one research laboratory to projects dealing with advanced manufacturing processes, energy-conserving materials, and nanotechnology. And finally (3) to make contributions to the industrial technology base, it has assigned one research institute and one research center to projects focused in materials design and simulation and the compilation of databases of ultra-precision control, processing, and measurement technologies.

As a shared strategic objective to be pursued through this new framework for FY 2004, AIST drafted its plan for "minimal manufacturing" technologies.

The goal is to establish key manufacturing process technologies that realize "the manufacture of optimally performing products" through "minimal resource input" and "minimal energy use (in terms of manufacturing cost and environmental load)," while maintaining "minimal environmental load at the disposal stage." Research and development for this goal will be pursued in two priority domains: "green integration," for the development of manufacturing processes that hold energy consumption and environmental loads to minimal levels; and "nano integration," which harnesses nanotechnology to revolutionize the manufacture industry, featuring "on-demand" technologies for the fabrication of required goods only in required volume as designed positions. As shown in Table 4, in FY 2004 AIST will implement an array of research projects under the nanotechnology program and the programs for advanced materials and industrial technologies.

Table 4 Key Projects in Nanotechnology, Materials, and Manufacturing

- **Nanotechnology Program**
  - Nanomaterials and Processing Technologies
    - Nanostructure Polymer Project
    - Nanotechnology Glass Project
    - Advanced Nanocarbon Application Project
    - Synthetic Nano-Function Materials Project
    - Advanced Diamond Technology Project
    - Nanotechnology Material Metrology Project
  - Nano-Manufacturing and Metrology
    - Nano Structure Forming for Advanced Ceramics Integration Technology Project
    - R & D of 3D Nanoscale Certified Reference Materials
- **Material Industrial Competitiveness Strengthening Program**
  - Innovative Materials Processing Technologies
    - Integrated Development of Materials and Process Technology for High Precision Parts
    - Processing Technology for Metallic Glasses
- **Reduce-Reuse-Recycle (3R) Program**
  - 3R Key Technologies
    - Development of Recycling Technologies for Construction Waste/Glass, Etc.
- **Development of Industrial Technology**
  - Digital Meister Project

Geological Survey and Geoscience, Marine Science and Technology

AIST will conduct geological surveys for collecting and sharing basic

geoscientific data, and perform studies on marine geology, environment, and natural resources. The ultimate goal of these activities is to contribute to public safety and the utilization of national land resources for sustainable social development, environmental conservation, and the exploitation of mineral and energy resources. From a public safety perspective, it will conduct research into the geological disasters such as earthquakes, volcanic eruptions. Also, in the interests of environmental conservation, it will pursue a broad range of research on environments from local to global scale. The data obtained by the geological surveys will be shared with society at large, e.g., in the form of geological maps, geo-science maps, and databases.

In FY 2004, the institute will continue to publish geological maps (1:50,000 scale), compiled geological maps (1:200,000 scale), and digital seamless geological maps and digitize geological maps. In addition, it will release geoscience maps, ground shaking maps, geological maps of volcanoes, and other maps devoted to geophysical themes. In addition to land-based surveys, the institute will survey ocean with geological research vessels, and will prepare maps on marine geology and superficial deposits. It will also update its geological databases with the findings obtained from these undertakings.

AIST is planning to compile pre-existing data on active faults in Japan, and construct a database; in addition, it will propose a preliminary evaluation of activity of major active faults. In the arena of volcano-related research, it will proceed with studies on the Unzen and Satsuma-Iwojima volcanoes and strive for better understanding of the structure and evolution of volcanoes.

The institute is conducting study and research on deep geological environments in order to contribute to the safety of the underground disposal of radioactive waste. It will construct three-dimensional geological models and perform research into chemical reactions, rock properties, and numerical modeling techniques so that it can perform numerical analyses of radionuclide transitions.

In the field of resource-related search, AIST will move forward with research on technologies for the exploration, evaluation, development, and mining of energy resources and other natural resources in the Earth's crust, oceanic sediments, and ocean water. Furthermore, it will launch surveys concerned with the mineral and biomass resources in ocean water.

AIST proceeds with geological research for environmental problems. In particular, it will reveal the past changes of the Earth's environment with paleomagnetic measurements and other geochemical techniques. Additionally, it will pursue research on coastal environmental themes and coordinate with other countries in the environmental research field.

Among new themes in applied geological research, the institute will continue a comprehensive geological study for mitigating damage from geological disasters in metropolitan areas. Further, it will develop new methods for the investigation, assessment, and management of soil pollution.

Table 5 Key Projects in Fields of Geology, Marine Science, and Metrology

- **Pioneering Research on Global-Scale Environmental Industrial Technologies**
  - Pioneering Research on Optimal Monitoring Design Technologies
- **R&D Project for Formation of Intellectual Infrastructure**
  - R&D on Information Systems for Measuring Instruments Calibration (e-trace)
- **Nano-Technology Program**
  - Nano-Measurement Core Technology Project
  - 3D Nanometer Evaluation Reference Material Development Technology Project
- **Program for Utilization of Solid Polymer Fuel Cells and Hydrogen Energy**
  - Development of Core Technologies for Hydrogen Fuel Safety and Utilization

Measurement Standards

Measurement standards are essential for the technical evaluation of services and products destined for the international market, improvements in the reliability and efficiency of inspections and tests, and sustained and strengthened competitiveness within domestic industrial sectors. Furthermore, mutual recognition agreements (MRAs) on the standards and certification are premised on the existence of measurement standards that have guaranteed international equivalence. To ensure companies with the business climate and technological prowess that will allow them to succeed in the years ahead as frontrunners in the hotly competitive fields of international commerce and research and development, it will be essential to establish frameworks for the swift provision of high-quality standards of measurement to all industrial sectors nationwide. AIST aims to establish a basic standards accreditation framework of world-class scale and quality by the year 2010. To that end, it has formulated a detailed plan for framework development with the needs and expectations of the industrial community and society in mind, and has been moving forward with refinements through annual revisions.

As of the FY 2000 year-end, Japan had a total of around 140 different categories in effect for measurement standards. AIST's goal is to add 200 new standards categories by the end of its first medium-term plan. To achieve this goal, AIST plans to issue at least 15 new physical standards and 11 new reference materials, for a combined total of at least 26 new standards, in FY 2004. In particular, AIST has revised significantly upward its plans to issue new electrical standards, an area where Japan had significantly lagged behind the international community. By the end of its first medium-term plan, AIST is scheduled to issue at least 20 new electrical standards.

The world economy has been caught in a whirlwind of globalization for some years now, to the extent that many activities are now tightly integrated on a global scale. To eliminate technical barriers to trade and commerce at this historic juncture, more and more countries are forging ahead with mutual recognition agreements (MRAs) that mutually certify the equivalence of their tests and measurements, and that reduce the redundancy of testing in general. MRAs are global arrangements that measuring societies have devises for mutual certifications on an open and comprehensive scale. MRAs for measurement standards require two conditions for recognition: (1) verification of the equivalency of national standards through international comparisons; and (2) verification of the ability to implement calibrations on a continuous basis through the development of a quality control system. To date, AIST has performed 205 international comparisons, established quality control systems for 84 types of measurement standards, and obtained third-party certifications through reviews by experts based overseas. As an outgrowth of that effort, Japan has witnessed sharp growth in the number of its standards categories accepted under the terms of MRAs. To build a framework for the sustained and steady issuance of new standards, and to ensure compliance with international standards, in FY 2004 AIST will begin operating a quality control system for at least 30 new categories of physical standards. Further, with regard to ISO/IEC 17025 compliance, AIST intends to complete ASNITE-NMI accreditation in at least 10 categories by the end of FY 2004.

Feature

AIST's environmental research for sustainable society

Environmental and energy problems and research and development at the National Institute of Advanced Industrial Science and Technology (AIST)

Masayuki KAMIMOTO,
Research Coordinator for Environmental and Energy Technology

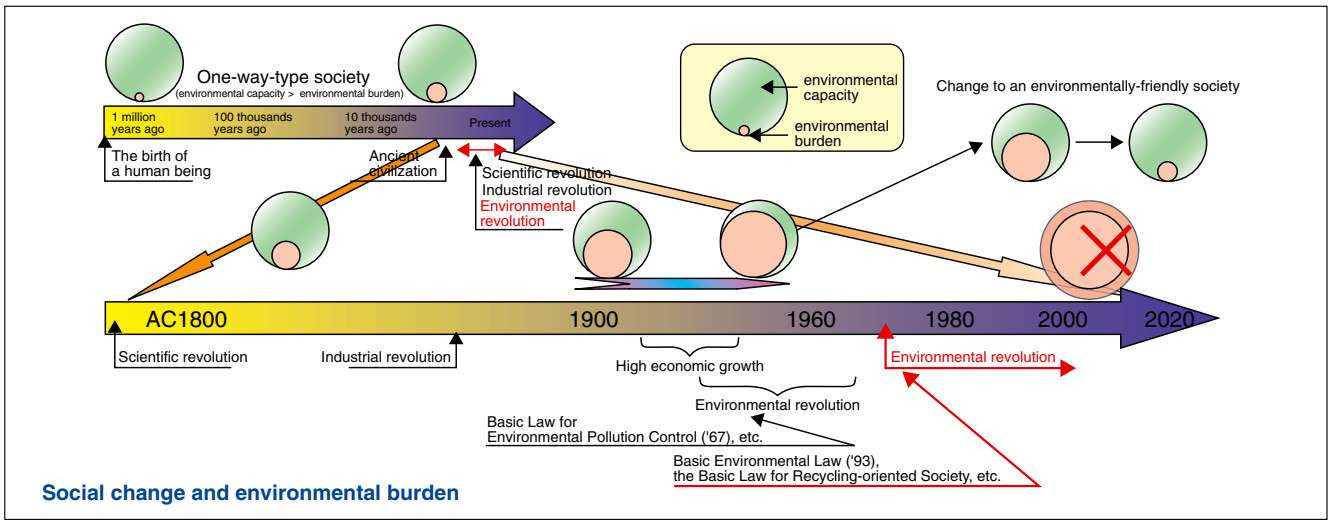
The roots of today's environmental problems lie in the Industrial Revolution of the eighteenth century

Today's environmental problems first began to appear with the coming of the Industrial Revolution of the eighteenth century. By the time of the twentieth century, the noxious and toxic substances released by factories and other sources had begun to drastically affect fish stocks and the people who relied on them for food, thus creating a social awareness of the problem of pollution. This in turn resulted in a demands being made for measures to be taken against individual sources of pollution.

As the scale and scope of industry grew in the latter half of the twentieth century, the very nature of environmental damage began to change. The spread of automobiles and the increased use of chemicals and other products caused the nature of the environmental damage being caused to change from something limited and local to something global in its scope.

As energy consumption has sharply increased since the time of the Industrial Revolution, the carbon dioxide and other greenhouse gases generated through the burning of coal and oil (i.e., fossil fuels) have made global warming an increasingly urgent issue. At the same time, in cities where large numbers of people live in concentrated areas and energy consumption is high, we have come to see the creation of urban heat island effects where local temperatures increase above those of surrounding areas. The environmental problems we face today are thus of a nature where the environmental burdens being placed upon the earth are greater than its capacity to bear, and the problems which now exist are problems of both local and global scale.

Faced with these circumstances, international efforts have begun and similar efforts have begun in Japan to create legal frameworks and formulate strategic plans for addressing these issues. Many different conferences have been held to discuss issues such as the protection of the ozone layer, stopping acid rain, preventing ocean pollution, the shipping of wastes across international borders, the preservation of forests, maintaining biodiversity, working to combat desertification, and stopping global warming, and many international treaties have been formed to address these problems.



Social change and environmental burden

The goals of AIST's environmental and energy research and development

In order to build a sustainable recycling society where both man and nature may prosper, we first have to reach the following goals:

(1) To create a safe and stable environment
(2) To establish a system for the recycling of resources
(3) To create a new environmentally friendly energy supply-demand structure

The steps which must be taken to achieve these goals are:

(1) To combat pollution
(2) To promote the practice of the three R's (Reduce, Reuse, Recycle)
(3) To act against global warming
(4) To ensure stable energy supplies

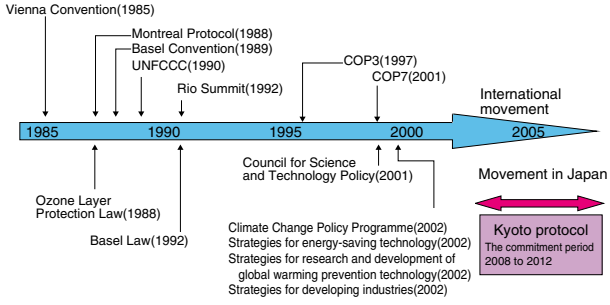
At AIST, we have defined the *maximization of environmental efficiency* as the goal of the research and development performed to achieve these objectives. Whenever a given technology is used to obtain a given benefit (e.g., electric power, heat, chemical products, etc.), in virtually all cases the benefit in question can

be obtained only at some environmental cost (e.g., carbon dioxide emissions, noise, or the release of chemical pollutants). Environmental efficiency is defined as the product obtained by dividing these benefits by their associated environmental costs. This means that in order to maximize environmental efficiency, whenever a given technology is to be applied, the system has to be evaluated as a whole from a variety of different perspectives.

An international perspective is essential to the solution of environmental and energy problems. This is not only because environmental problems exist which affect the earth as a whole, but also because the transfer of environmental and energy technologies to developing nations and the increased use of renewable energy would play a major role in eliminating the economic disparities which exist between the North and South. It is no longer possible to discuss such issues without taking into account the developing countries of Asia and Africa now experiencing explosive population growth.

Some results of the Kyoto Conference on Climate Change

At the Kyoto conference on climate change (i.e., the Third Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, or COP3), Japan pledged to reduce its greenhouse gas emissions by 6 percent from their 1990 levels over the first period of the protocol's implementation from 2008 to 2012. As one can see from the accompanying diagram, this goal of achieving a 6-percent reduction in emissions is an extremely difficult one, and in accordance with this goal the government has targets for the introduction of new energy sources for 2010. The target for solar photovoltaic power has been set at 4.82 million kilowatts, and it is also estimated that a total of 28.7 million kilowatts in generating capacity must be brought on line to achieve the targeted objective of developing the industry into a 1-trillion-yen industry by 2020. A look at other countries around the world shows that plans set forth by the National Advisory Committee on Global Environmental Problems in Germany and the G8 call for the introduction of generating capacities an order higher than this. AIST is strongly committed not only to achieving the 2010 targets set under the Kyoto protocol, but also to performing research and development of new technologies and providing assistance to promote the introduction and spread of these technologies in a way which takes into consideration the future beyond 2010 and which adopts a global perspective.



International efforts

Three core research problems: System evaluation technologies Maximally environmentally efficient production and use systems High-efficiency distributed energy systems

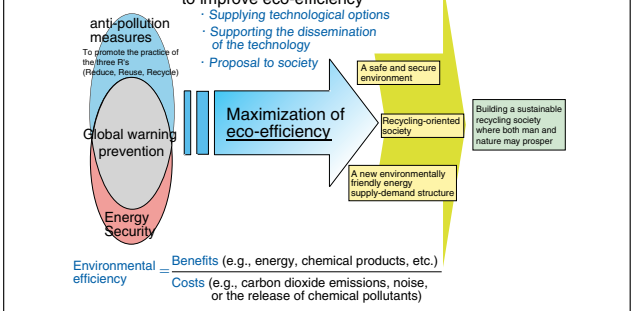
As noted above, the evaluation of environmental and energy systems present extremely complex problems, and there is a need for new methods of performing such evaluations. At AIST, we view the development of system evaluation methods as one of the core research problems which must be addressed in environmental and energy research and are working to develop new methods. Research on evaluation technologies consists of research on evaluation methods themselves and their actual application, and rather than consisting simply of the publication of ordinary research papers, our work in this regard also includes efforts to promote the increased use of these methods, providing advice for the formulation of government policy, the writing of risk evaluation reports, and other similar work. We believe this to be just the sort of typical research and development which ought to be performed by a public research institute.

Other core research problems include the development of production and use systems designed to maximize eco-efficiency and the development of high-efficiency distributed energy systems. The main objective of the first program is to create a network of technologies for the efficient reuse of materials in production and use processes. It should be noted, however, that the aim here is not an utopian and unrealistic one of achieving 100-percent reuse.

The objective of the second program is to make the most effective use of renewable energy sources and place different types of small- and mid-scale distributed energy generation systems in locations close to where energy demand exists. The aim of this program is to develop new energy systems which would make it possible to respond flexibly to different types of needs in terms of both energy supply and demand where the systems as a whole would reduce volumes of carbon dioxide emissions to their lowest possible levels.

Basic research directed towards reachable goals —Supporting research performed in cooperation between government, academia, and the private sector—

In addition to being involved in leading research di-



The goals of AIST's environmental and energy research and development

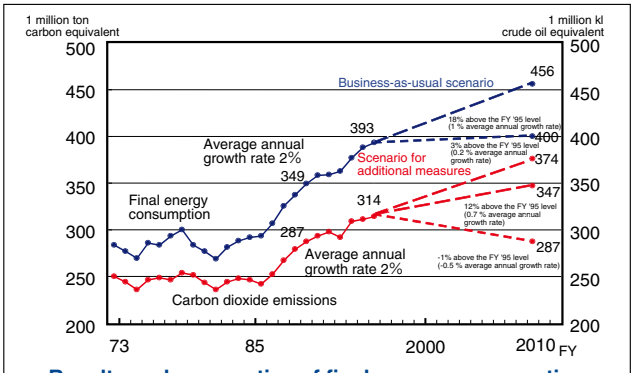
rected towards the development of technological breakthroughs and the creation of seed technologies for the development of next-generation technologies, AIST is also performs supporting research for the introduction of new technologies on a large scale. Even though our research is intended to serve as leading research it is also basic research which is naturally enough intended to result in practical applications, and for this reason cooperation with industry and academia is absolutely essential. Our research therefore includes cases of research where researchers from universities or the private sector come together at one of our research centers to participate in concentrated research programs. Examples of such research include research on supercritical fluids and research on power electronics.

One representative example of our supporting research which might be given is research on metrological and industrial standardizations. Research of this kind is absolutely essential to the dissemination of technology, and we accordingly view this research as an important part of the research we perform as a public research institution. Naturally enough, this research must be performed in consideration of the time when practical applications are developed, and for this reason it is extremely important to work together in conjunction with the private sector. It is also common for many different types of systems research to have a supporting nature.

Possibility for the growth of an industry of a scale of several dozens of trillions of yen Environmental and energy technologies

It is said that both environmental technologies and energy-related technologies could grow into an industry of a scale worth several dozens of trillions of yen. (Source: *Sangyou hakkutsu senryaku* [Strategies for Developing New Industries].) At the same time, it is also true that considerations of economic viability could make it difficult for new industries to develop.

Let us consider solar power—one of the most prototypical means for combating global warming—as an example. At the time when the Sunshine Project was first initiated in 1974, solar cells cost nearly ¥10,000 for each watt of power, but now costs have fallen to where the cost of a 3-kilowatt system for residential use is somewhere between 2 and 3 million yen (or a little less than ¥1,000 per watt for the cost of the system). The government funding provided for research and development since then comes to a total of 200 billion yen, and at the current time annual



Results and perspective of final energy consumption and carbon dioxide emission

funding levels run at about 7 billion yen per year. As a result, Japan has come to account for as much as 45 percent of the total volume of solar cells produced worldwide.

While this might cause one to suspect that there is no longer any need to perform further research and development, nothing could be farther from the truth. The cost of solar power has not yet fallen to a level where it could compete with current electricity prices. This fact serves as an clear indication of the fact that environmental and energy problems are difficult ones which must be addressed from a long-term perspective. Now and for some time to come, it will remain necessary to perform further work on research and development and to provide government subsidies, tax incentives, and other stimulus measures to promote the introduction and increased use of such technologies.

When one thinks about how energy technologies find their way into practical applications, one sees that in many cases practical applications are developed for use in aerospace or similar applications or in the private sector where such products are normally acceptable even if the cost is high because it takes a good deal of time to improve cost effectiveness. Examples of aerospace applications include fuel cells and thermoelectric conversion systems which have been used in aerospace applications for over 30 years, and examples of private-sector applications include the use of solar cells in calculators. The development of new technologies and the introduction and increased use of such technologies typically takes place in an environment where production volumes are increased while efforts are made to lower costs as markets are developed, and when the relation between costs, production volumes, and the market reaches a critical flow that an industry can stand on its own.

A new environmental industry which never before existed has been born. Examples of environmental businesses include businesses which provide other businesses with consulting services to help them in reducing energy consumption or in obtaining ISO14001 certification. AIST's proposed co-production model, life-cycle assessment system, and other similar technologies are technologies which can lead to the development of such businesses. Because the target of recent research has shifted to distributed systems, examples of technologies being put to use in private sector and other applications before the development of actual applications in the energy industry have become more common than ever before.

● The Kyoto protocol

At the Kyoto conference on climate change, or the Third Session of the Conference of the Parties to the United Nations Framework on Climate Change (COP3), held in 1997, an international framework was proposed which became known as the Kyoto protocol. At the COP7 conference held in 2001, Japan announced that it would achieve the target stated in the Kyoto protocol of reducing its carbon dioxide emissions by 6 percent from their 1990 levels by 2012 at the latest. Yet in spite of this, the current situation is such that as of 1999 emissions had increased by 9 percent over their 1990 levels, and we must accordingly make every possible effort to reduce carbon dioxide emissions over the coming years.

The main priorities of environmental policy and the development of environmental technologies

Takeshi KOYARI, METI Environment Policy Division

Environmental problems not only have a spatial aspect in which they extend from local problems with pollution to problems which exist on a global scale, but also come to have a temporal aspect as shown by the global warming issue which requires us to take a perspective that extends over periods of hundreds of years. In light of these circumstances, government must work to address not only individual problems with pollution, but rather work to develop infrastructure and formulate policies and strategies which take into account the system as a whole. Similarly, there is a growing need for businesses to move away from series of passive responses to individual regulations and other measures and instead play an active role in the implementation of environmental protection measures which take into account the need to ensure industrial competitiveness.

● General mission and policy objectives

There is a growing need for the development of environmental technologies designed in accordance with the qualitative changes which have occurred in the nature of the environmental problems we face. The technologies must meet the policy issues described below as part of an effort to construct a sustainable recycling-based socioeconomic system capable of co-existing in harmony with the environment.

(1) Dealing with global warning

In addition to working to achieve actual reductions in greenhouse gas emissions at the earliest possible stage to reach our promised goal of a 6-percent reduction of emissions as required under the Kyoto Protocol, we must also work to further reduce emissions continually over the long term through the development of hydrogen energy, carbon dioxide fixation, and other revolutionary new technologies.

(2) Constructing a recycling-based society

In order to free ourselves of the burdens placed upon us by our existing mass-production, mass-consumption, mass-waste society, we must work to develop the kind of more advanced recycling, reuse, and reduction technologies which will be needed in order to reach the goal of reducing total volumes of final disposal by 50 percent together with the other goals set forth in the Basic Law on the Establishment of a Recycling-based Society by 2010.

(3) Measures for dealing with hazardous substances

In order to construct a society in which the risk assessments are performed of the risks posed by chemicals and in which their proper controls exist over the risks posed by chemicals throughout the entire life cycle of a product or service, we must work to develop the technologies which will be needed in order to handle everything from risk assessment to achieving reductions in emissions and removing pollutants from the environment.

● Program for the development of environmental technologies (The 9R technologies)

In order to accomplish our main mission and policy objectives, we are currently working to promote the development of reduction, reuse, and recycling (3R) technologies designed in accordance with corresponding government policies. The following 3 objectives make the 3R technologies 9R.

(1) Global warming technologies

In order to achieve the goals set forth in the Kyoto Protocol and in order to achieve sustainable reductions in emissions of greenhouse gases over the mid- and long-term, we are working to achieve reductions in levels of greenhouse gases through the use of energy conservation technologies, fuel conversion technologies, and other similar technologies. We are also working to promote the development of renewable energy technologies and other technologies to replace existing energy technologies as well as the development of recovery and storage technologies including technologies for the carbon dioxide fixation and sequestration (Examples of such programs include the *Innovative Global Warming Technologies Program* and the *Program for the Development of Technologies for the Fixation and Effective Use of Carbon Dioxide*).

(2) Technologies for the construction of a recycling-based society

To reduce the total amount of waste generated during a given product's entire life cycle and to promote recovery and recycling, we are working to promote the development of reduction technologies which reduce waste by increasing the efficiency at which resources are used and by other means, the development of disassembly, decomposition, and other reuse technologies, and the development of recycling technologies designed to recover energy and raw materials from waste products (Examples of such programs include the *Reduce, Reuse, and Recycle Program*).

(3) Technologies for dealing with hazardous substances

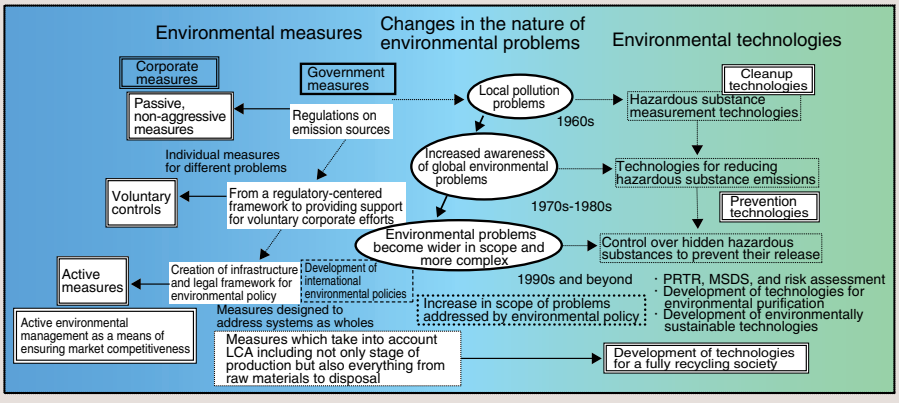
To promote reductions in emissions of hazardous chemicals and the detoxification of such emissions, we are working to promote the development of reduction technologies designed to reduce levels of emissions of hazardous substances through the use of new production processes and other means, replacement technologies designed to replace toxic materials through the development of alternative materials, and remediation technologies through pollution treatment and other means (Examples of such programs include the *Chemicals Risk Assessment and Control Program*).

(4) The construction of an intellectual infrastructure

In order to develop the assessment tools and other parts of the intellectual infrastructure which will be needed for the development of the technologies described in (1) through (3) above, we are working to promote the development of life cycle assessment (LCA) technologies, to develop assessment technologies for chemical hazard, risk, etc., and to construct a chemical hazard information database and other elements of a risk communication infrastructure.

● Future issues

As environmental policy and environmental technologies have become more advanced, there has been a particularly strong growth in the demand for policy decisions to be made appropriately in accordance with scientific opinion especially in cases where the objectives of different measures exist, e.g., as in recycling measures like thermal and material recycling vs. anti-global warming measures. Not only is there an urgent need to develop the 9R technologies needed to address the three core research problems related to global warming and other related issues, but an urgent need also exists to promote the development of LCA technologies and other elements of the necessary intellectual infrastructure and to foster the development of risk communicators and other personnel able to put this technological foundation to work. It is for reasons such as these that we believe that the expectations held of the AIST, with its strong personnel and technological potential, will only grow stronger in the future.



PROJECT

Construction of a recycling-based economic system in harmony with the environment

Problems with current system

Limitations of our socioeconomic system based on mass production, mass consumption, and mass disposal

○Mass consumption of limited resources and increasing volumes of waste
- Growing shortage of sites for final disposal and illegal dumping of waste

○Environmental pollution and limits in the ability of nature to clean itself
- Environmental pollution and destruction of natural ecosystems from hazardous substances
- Possibility of increased risks from hazardous substances

○Increased concern about effects of waste and hazardous substances on the environment and health
- Reconsidering present-day economic practices and consumption-orientation
- Hopes for technological innovations needed for sustainable development of society

Changing from a mass-disposal to a recycling society

Because energy and other resources are finite and because there are limits to how far the earth can absorb the environmental stresses placed upon it, we must reform our current socioeconomic system into a recycling-based system which can coexist in harmony with the environment and which can allow for sustainable development.

- Switching from a unidirectional system to a circular recycling system
- Viewing discarded goods as valuable resources instead of as wastes
- Moving away from the conception of ownership and towards that of the use of functions
- Working to prevent environmental pollution instead of dealing with it after the fact

View of the 21st century recycling society

○A recycling society where wastes are reused as valuable resources
- Maximizing resource usage efficiencies and minimizing the dumping of wastes

○A society which prevents damage from occurring from hidden hazardous substances before it occurs
- Reducing the use of toxic substances and providing advice concerning their risks

○A safe and secure society able to manage all wastes and organic materials
- Development of substances of managing all aspects of the chemical substances cycle and product life cycle and of evaluating characteristics

The society as it should appear in the 21st century

Development of an society where we can reduce wastes to a minimum while still allowing for economic development

Reducing the amount of waste generated during the entire life cycle of a product and promoting the practice of the three R's (reduce, reuse, recycle)

○Reduce: Reducing the amount of waste generated during the product life cycle as a whole
- Reducing the amount of raw materials consumed by increasing resource usage efficiencies
- Switching to the use of biomass or other easily recycled materials through chemical treatment and resource reclamation
- Designing products which can be easily decomposed or disassembled for recycling or reuse
- Zero-waste production facilities (i.e., cleaner production)

○Reuse: Promoting the reuse of whole products or the reuse of reusable parts and components
- Development of technologies for the breakdown and disassembly of used equipment (i.e., creation of "inverse factories")
- Development of techniques for evaluating the quality, durability, and other aspects of parts and components for their reuse
- Technologies which make it possible to upgrade products through repairs or replacement of parts
- Promoting the use of returnable containers
- Development of standardized and inter-replaceable products and materials

○Recycle: Promoting the recycling of wastes as raw materials or energy resources
- Development of waste recycling technologies (e.g., sludge, plastics, slag, and construction wastes)
- Development of recycling technologies using biotechnology or supercritical fluids
- Efficient reclamation of energy from wastes (i.e., thermal recycling)
- Increasing distribution efficiencies in the reclamation of used products
- Creation of markets for recycled products and increasing use of same
- Construction of recycling plants, waste treatment plants, and distribution facilities

Development of an society which reduces global warming

Development of technologies designed to enable us to achieve the targets set in the Kyoto Protocol-i.e., reducing greenhouse gas emissions by 6% from their 1990 levels (promoting the three R's)

○Reducing global warming while taking steps to deal with wastes and toxic substances
Reduce: Greenhouse gas emissions (an issue for the energy sector)
- Promoting conservation of energy
- Use of food conversion technologies to minimize volumes of emissions of greenhouse gases
- Minimizing volumes of emissions of greenhouse gases through the development and widespread use of fuel cells and other technologies
- Building of urban infrastructure (e.g., ITS)

○Replace: Greenhouse gases (an issue for the energy sector)
- Development and widespread use of solar power technologies and other renewable energy technologies
- Use of wind power and other forms of natural energy
- Use of nuclear power
- Development of alternatives to the three gases HFC, PFC, and SF6

○Greenhouse gases: Recovery and sequestration
- Development carbon dioxide fixation technologies which would be efficient from a LCA point of view as related to energy consumption
- Development of methods of assessing the environmental impact and evaluating the technological and economic considerations involved in carbon dioxide fixation
- Development of ways of using hydrocarbons through biological or chemical methods which make use of CO_2
- Development of technologies for the effective use of trees and plant life which act to store CO_2

Development of an society where we can reduce the risks associated with toxic materials and have a full understanding of all such risks

Properly assessing the risks associated with toxic materials to reduce the amount of such materials generated through the entire product life cycle and working to eliminate toxicity in waste materials (Promotion of the three R's)

○Reduce: Reducing the amount of toxic materials created throughout the entire product life cycle by switching to the use of different raw materials, reforming production processes, or by other means
- Development of production and treatment processes which generate and release no toxic materials (e.g., through use of biotechnology)
  Development of alternative materials technologies (e.g., green chemistry, biochemical technologies, complex organism technologies, or new bio-materials)

○Replace: Replacement of current products with new products of a similar quality and function but which have a lower environmental impact in terms of things such as the generation of toxic materials
- Development of materials which do not release endocrine-disrupting chemicals (EDCs) or other toxic substances
- Development of materials to replace toxic metals
- Development of high-performance biodegradable materials

○Remediation: Reclamation, detoxification, and cleaning of toxic materials
- Development of remediation technologies
- Development of technologies for detoxifying toxic materials (e.g., supercritical fluid technologies or plasma-usage technologies)
- Development of standards for biotechnologies used in cleaning up pollution

Providing judgment criteria and developing assessment methods and other intellectual infrastructure needed in order to ensure that we can achieve our goal of creating a recycling society

A safe and secure society of this kind can be created by assessing and controlling the circulation of materials throughout society and the economy, by evaluating the characteristics of chemical materials, and by providing guidelines for such assessments

○Ensuring the performance of proper life cycle assessments (LCA)
- Development of LCA methods for use in assessing the environmental impact of a product in terms of factors such as recycling and the generation of waste and the construction of databases for use in performing such assessments
- Development of methods for assessing factors such as environmental impact and the circulation of materials in all facets of economic activity
- Assessment and control of economic activity in accordance with LCA methods
- Introduction of environmental labeling

○Construction of the intellectual infrastructure needed for the control of chemical materials
- Establishment of methods of assessing the hazards and risks associated with chemical materials
- Construction of databases on chemical toxicities (creating an improved PRTR system)
- Development of technologies for analyzing and measuring toxic materials (biosensors)

○Creation of Information infrastructure for improved risk communication
- Collection and publication of PRTR data
- Development of standards for the labeling of chemical materials
- Construction of MSDS library

Anti-global warming technologies

Water and carbon dioxide are two key materials which govern the future of the global environment. The reason why this is so is because while both existence in abundance all over the planet, they circulate around the earth in many different forms, and their presence and form influence the global environment and determine whether or not the human race is capable of sustained development. AIST is involved in a program of research designed to learn about the behavior of such critical materials and discover ways of addressing the environmental problems which occur as a result of their movement.

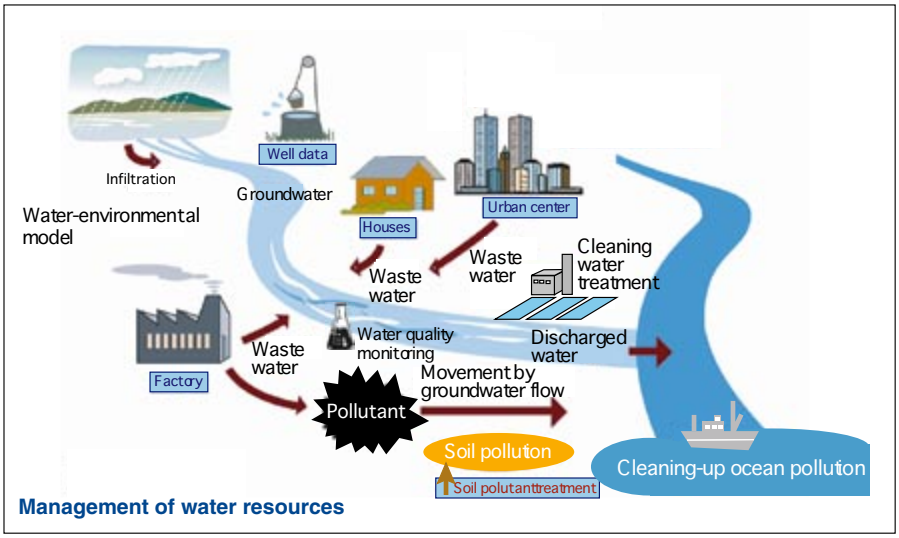
The twenty-first century as the century of water

It has been said that the twenty-first century will be the century of water. At the World Water Forum held in March 2003 in Kyoto, a statement was issued which said that the prioritization of water issues was an urgent global requirement because water is a driving force for sustainable development and the eradication of poverty and hunger and because it is indispensable for human health and welfare. The ministerial declaration issued at the WWF states that it is necessary to each country to act on its own in regards to the management of water resources and the sharing of benefits, ensuring safe drinking water and sanitation, providing water for food and rural development, preventing of water pollution and conserving local ecosystems, and disaster mitigation and crisis management.

The importance of developing forecasts of underground water resources in the Yellow River basin

As part of the Ministry of Education, Culture, Sports, Science and Technology's Kyousei Project, AIST has been assigned the task of constructing a model of the circulation of underground water in the Yellow River basin and developing forecasts of future underground water resources. In this project AIST will perform local hydrological surveys, construct models of underground water flows, and develop forecasts of future underground water resources to assess the role played by underground water basins in the circulation of water in this massive river system. The remarkable economic development of China which has made it come to be referred to as the world's factory, together with the movement of the population to urban centers, the transformation of the land, and the accompanying increase in the demand for water and the fragility of underground water resources are all such that when these factors are viewed in relation to their possible economic effects there is a danger that events in China could seriously affect Japan and eventually the entire world. Forecasting the future of underground water resources in the Yellow River basin is important as a basic element in considering global issues such as these.

One of the databases maintained at AIST is a database on underground water resources called the *Idojibiki*, or Well Database. This database has been constructed by collecting data on well water properties, boring cores, water quality and geological properties of bedrock formations and by creating links to databases of other organizations to provide a richer variety of data. AIST is also working together in conjunction with geological survey institutes and water resource authorities in Southeast Asia to create an underground water and hydrological database for the region which is expected to be completed in 2004. These basic research data could prove useful in addressing global environmental problems, managing water across national boundaries, evaluating the effects of urbanization, and infrastructure planning.



Management of water resources

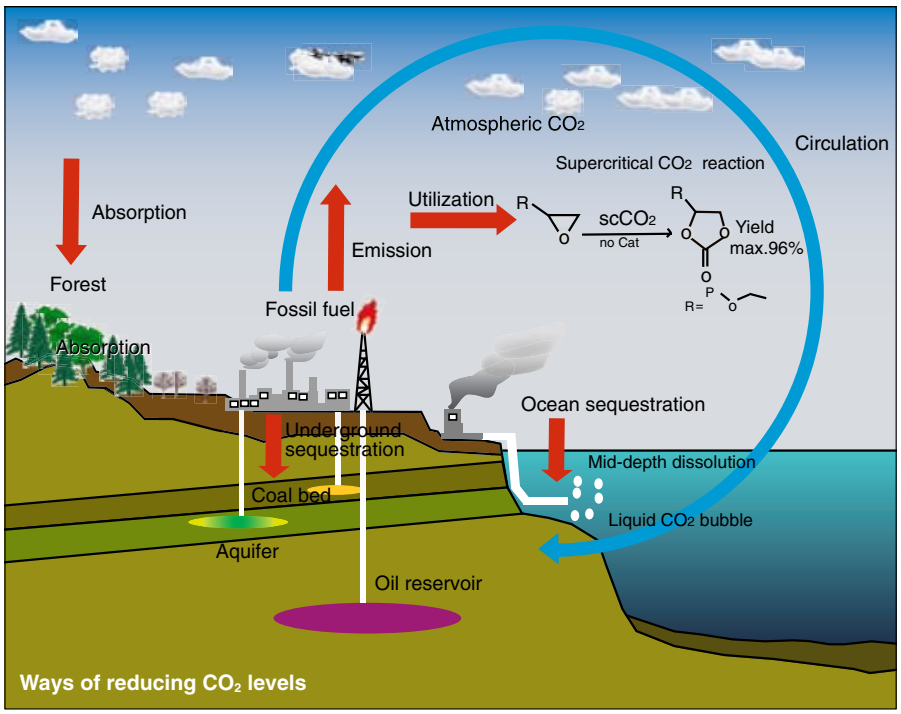
Water quality monitoring as a means of learning about watersheds

Water quality monitoring is an basic and central method for use in learning about changes in watersheds. To develop more advanced monitoring technologies for use in monitoring the ionic water contaminants which serve as indices of water pollution, we are developing a water quality monitoring system which uses new dissolution methods together with an on-site ion chromatography system to identify hydrogen ions, anions(e.g., sulfur, nitric acid, nitrous acid, phosphoric acid, chloride, fluoride, silicic acid, and hydrogen carbonate ions), cations (e.g., sodium, ammonium, potassium, magnesium, and calcium ions), and organic acid ions. Current plans call for this system to be put to use in monitoring watersheds in Japan and abroad to prove its effectiveness and for the system to be introduced as part of JIS, ISO, and other official standards.

Cleaning up water pollution

To maintain our rich and comfortable lifestyle, we continue to release large amounts of persistent pollutants into the environment, and these pollutants result in the pollution of underground water systems and many other water environment problems. Ozone has the ability to transform materials into a form which makes it possible for living organisms to easily decompose such pollutants, and by making use of this property together with bio-processing, we have found that it is possible to efficiently decompose persistent pollutants in waste water containing dyes to remove its total organic carbon (TOC) content. This technology is a promising one which might make it possible one day to purify and restore watersheds throughout the world.

Mention has been made about the major effects that the trace chemical pollutants that have been a subject of wide concern could have on ecosystems, and many different methods for reducing the quantities of such pollutants in the environment have been studied. While biologically based methods of decomposition are known to place less of a burden on the environment than physical chemistry methods, in recent years particularly strong attention has come to be given to methods which make use of biocatalysts found in living organisms. One example of such an effort can be seen at AIST, where we developed a new ceramic catalyst carrier with nanoscale pores to hold catalysts and where we are now working to develop ways in which this could be put to actual use in a minimally compact advanced water treatment system which would be more sustainable and provide higher levels of efficiency than previous such systems. This in turn would make it possible to develop systems which use oxygen to improve



Ways of reducing CO_2 levels

the circulation of water.

Cleaning up ocean pollution is also an important part of global environmental preservation. The coast along the Ariake Sea in Kyushu is one of Japan's major sources of seaweed. Although the ocean water used in the production of seaweed products is polluted in many ways, it is released back into the sea without being treated in any way, and this has resulted in major environmental problems in the regions surrounding production centers. To address this problem, we are currently working to develop a complete treatment system for use in the treatment of seawater used in processing seaweed products based on technologies for the production of environmental cleaning agents which have already been developed. If this system can be completed, we believe that it could be used in other applications as well and prove useful in treating water in many applications.

Carbon dioxide released into the oceans

Since the time of the Industrial Revolution, the production and consumption of energy which has accompanied human activity has resulted in the release of vast amounts of carbon dioxide into the atmosphere. A variety of different data and calculations made using models indicate that roughly 25 percent of the total amount of carbon dioxide released has been absorbed into the oceans. In order to quantitatively investigate this behavior, we have used models of ocean flows and carbon circulation to calculate the distribution of anthropogenic carbon dioxide in the oceans. From these distributions we have learned that the anthropogenic carbon dioxide which has been absorbed into the oceans plays a major role in determining the concentration of carbon dioxide in the atmosphere, these calculations should prove useful in predicting future concentrations of carbon dioxide in the atmosphere.

Ways of reducing carbon dioxide levels Methods of carbon dioxide sequestration

Carbon dioxide in the atmosphere is absorbed by forests through photosynthesis. Methods have already been developed capable of continuously and quantitatively measuring over long periods of time the capacity of forests in severe climactic environments such as those found in the tropics to absorb carbon dioxide. Based on outdoor tower observations performed using these methods, we are working to investigate the relationships which exist between climactic conditions and the net volume of carbon dioxide exchange (i.e., carbon absorption capacity) between the atmosphere and forest ecosystems and to learn about seasonal and year-by-year changes in carbon absorption capacity. From observations of some representative forest ecosystems in East Asia performed in cooperation with different research institutions and universities, we have found that forest ecosystems have a capacity to absorb from the atmosphere as much as from 1.3 to 5.7 tons of carbon per hectare per year, or an average of 3.2 tc/ha/yr. In addition to having made it possible to identify actual conditions, these results may also be used as basic data for use in the trading of carbon dioxide emissions rights between Japan and other Asian nations.

Sequestration is one method which might be used to reduce the amount of carbon dioxide in the atmosphere. Broadly speaking, there are two ways in which carbon dioxide could be sequestered: through underground storage or through ocean sequestration. The two main methods being considered for underground storage are a method whereby carbon dioxide would be stored under pressure in aquifers covered by caps of rock to prevent the carbon dioxide from escaping and a method whereby carbon dioxide would be stored under pressure in coal beds, which have a high degree of adsorption with respect to carbon dioxide. The first method would make use of technologies developed for the underground storage of natural gas or for improved oil recovery, and the second method would have the advantage of making it possible to recover methane at the same time that carbon dioxide is injected underground. If either one of these methods could be made practical, it would serve as a tremendous contribution towards directly reducing carbon dioxide levels.

The mid-depth and deep areas of the oceans are also viewed as a promising place for the sequestration of source-reclaimed carbon dioxide. However, because the waters of the oceans circulate these waters eventually come into contact with the atmosphere and it is feared that any sequestered carbon dioxide would be released into the atmosphere or that sequestered carbon dioxide could have a serious effect on the marine environment which would alter its ecosystems. Moreover, our knowledge of the oceans at intermediate and extreme depths is poor, and no predictions have been made about the effects or the behavior of carbon dioxide after ocean sequestration. To address these questions, using data from on-site observations and indoors testing obtained using methods developed over the past few years, we are working to develop ways to identify the dynamics of carbon dioxide after sequestration and to develop methods of predicting the environmental effects of sequestering carbon dioxide in the oceans. The ability to make such predictions should make it possible to determine whether ocean sequestration can be made feasible.

Making use of organic synthesis to consume carbon dioxide

We are also trying to find ways of actively using carbon dioxide as a way of reducing its effects on the environment. Some of the technologies now being developed which have gained the greatest amount of attention in this area include technologies for phenol and other selective hydrogenation reactions which use supercritical carbon dioxide as a substitute for toxic organic solvents and technologies which use carbon dioxide fixation as a means of synthesizing carbonates. Multi-phase systems which use combinations of solid catalysts which accelerate reactions with supercritical carbon dioxide not only improve reaction efficiencies but also perform both reaction and separation in the same step, thus making this a pioneering new process which makes it possible to reduce overall process times. This method is accordingly viewed as both an environmentally friendly and economically attractive organic synthesis technology with a promising future.

Environmental management

Measurement of chemical substances

Spectrometry-based measurement technologies

Of all the greenhouse gases, there is a particularly strong demand for measures to be taken to reduce the amounts of emissions of carbon dioxide, methane, nitrous oxide, and other gases generated from anthropogenic sources. To ensure that effective measures are implemented, we must study the actual emissions of these gases and measure and create records (i.e., an inventory) of the quantities of emissions from what are known as 'fixed sources'.

At AIST, we are working to develop a variety of technologies which use spectrometric systems for measuring concentrations of gas emissions.

Figure 1 shows an absorption spectrum of nitrous oxide in the far-infrared region measured using AIST's terahertz spectrometer. Here measurements were taken at a large number of different pressures of a gas mixture of oxygen and nitrous oxide. When precision measurements are performed, the spectral lines assume a shape which may be represented as an overlaying (i.e., a convolution) of a Gaussian and Lorentzian function like that shown in Figure 1. Since the central wavelength possesses a value unique to a given material, this value may be used to determine the type of material in question. The strength of absorption or emission may also be used to calculate the quantity and temperature of a material along the path traveled by light. Since the width of the Gaussian function represents the Doppler effect caused by the thermal motion of molecules, this enables us to determine the kinetic temperature of molecular motion. Since the width of the Lorentzian function is determined by the frequency of molecular collisions, this can be used to obtain information about the pressure of the gas.

If a spectrometer is placed in a location like that shown in Figure 2, then it is possible to measure and monitor the quantities of carbon dioxide and nitrous oxide being emitted from the exhaust ducts of an electric power plant, factory, or waste processing plant without needing to collect gas samples. This method for measuring emissions is known as the path monitoring method. If one uses a path monitoring system which uses lasers, then it is possible to monitor gas emissions continuously and in real time, thus making it possible to implement measures designed to reduce emissions of greenhouse gases. Methods which make use of diode lasers which oscillate in the near-infrared region of the spectrum have been cited as a promising possibility for use in simple, high-performance automatic path monitoring spectrometry systems for use in the automated measurement of concentrations of gas emissions.

Chemical sensors using quartz oscillators

Because the frequency change of a quartz oscillator is proportional to the weight of the material adsorbed on the surface of the oscillator (e.g., by 1 Hertz for 10^{-9} grams), when a host molecule is fixed to the surface of an oscillator to selectively adsorb a guest molecule (an analyte) it causes only the analyte to be adsorbed and changes in mass can be transduced to changes in concentration. If the adsorption/desorption reaction is reversible, then adsorption occurs at high concentrations and desorption occurs at low ones, thus making it possible to perform monitoring continuously over time. We are currently working on developing sensors for chemical substances including trichloroethylene, benzene, acetaldehyde, and bisphenol A. For dioxins, antibodies are used instead of synthetic host molecules to selectively adsorb dioxins. Although minute amounts of polycyclic aromatic hydrocarbons are also adsorbed because of cross-reactivity, strong correlations have been observed with respect to conventional GC/MS methods, thus making this a promising screening method.

Development of other types of analytical instruments

Other simplified methods for performing analyses now under development include a so-called lab-on-a-chip method whereby micro-fabrication techniques are used to create flow channels in a glass substrate to detect the chemical substances electrochemically. We are also working on the development of a hyphenated technique for elemental speciation by coupling a high-performance liquid chromatograph and other separation devices to an inductively coupled plasma (ICP) mass spectrometer and other detection devices. One example for the need for such systems is that while it is necessary to identify the chemical species of elements in order to understand their behavior in the environment and their biological effects, with conventional analysis methods we have measured only the total quantities of elements. At AIST, we are using the integrated analytical system described above to know the species in which arsenic exists in the environment and in living organisms at parts per billion levels. (See Figure 3.) We are also working to develop the photoreactors and methods of hydride generation which will be needed for trace analysis. In addition, we are currently developing an interface which will be used to develop an integrated gas chromatography and ICP mass spectrometry system for the determination of chemical species of organic tin and mercury compounds.

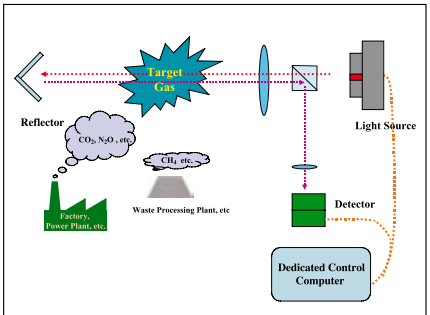


Fig. 2 The prinple of the automated measurement of the emission gases is illustrated.

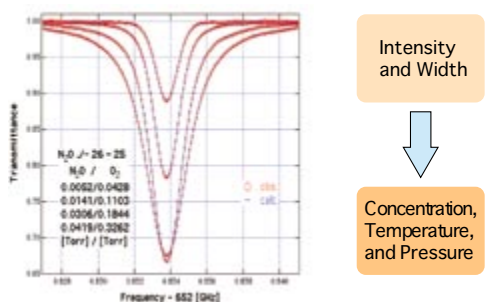


Fig. 1 The line profiles of a rotational transition of N_2O diluted by O_2 are shown for various mixing ratios.

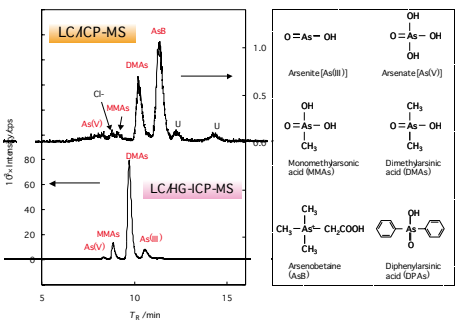


Fig. 3 Arsenic Species and Chromatographic Separation

Technologies for the identification and separation of chemical substances

Separation technologies using hydrates

Today, every year about 10,000 tons of additional fluorochemical waste which contributes to global warming is disposed of in the form of styrofoam waste. Since these fluorochemicals are becoming increasingly absorbed into the atmosphere, to recycle and reuse these waste materials we must separate and refine them first. Here we will describe technologies which use hydrates to separate global warming agents.

Hydrates are a type of inclusion compound which display a unique structure in which gas molecules are enclosed within a container formed by water molecules. The molecules enclosed in this container are called 'guest molecules', and compounds consisting of water and carbon dioxide, nitrous oxide, methane, chloro-fluorocarbon (CFC), hydrochlorofluorocarbons (HCFC), or hydrofluorocarbons (HFC) and other global warming agents all form hydrates when under the necessary temperatures and pressures.

While advances have been made in recent years in terms of separation technologies using functional materials which can be used to perform molecular recognition, in addition to being able to be used in the same way as crown ethers, cyclodextrins, and other functional extractants to perform molecular recognition based on molecular diameters, hydrates have the property of being able to be used to perform molecular recognition to a greater precision using methods based on differences in the potentials of guest molecules and water molecules. In addition, the pressures required to generate hydrates are lower than the saturated vapor pressures of global warming agents, thus reducing the amount of energy required for extraction and making this a superior method in terms of cost.

Figure 1 shows the conditions required for the generation of hydrates from HFC134a, a representative global warming agent. Hydrates may be generated from HFC134a at normal atmospheric pressure if it is cooled to a temperature of about 4°C. The conditions under which hydrates like these may be generated differs for different global warming agents.

Figure 2 shows the results obtained when hydrates are used to separate HFC134a from a gas mixture of HFC134a and nitrogen. For instance, in a case where the exchange with air is proceeding at a rate of about 40 percent and the system is operated at a temperature of 5°C and a pressure of 2 atmospheres, it is possible to refine up to about 97% of the HFC134a shown in the first row.

In addition to this, we are also hard at work performing the measurements needed in order to obtain the basic data which will be needed in order to design a global warming agent separation system like this which use hydrates to perform separation, and with the aim of developing actual working systems, we are performing research and development work on high-efficiency separation systems using static mixers, continuous separation systems using porous materials, and other similar systems. Figure 3 illustrates the principles underlying the working of such systems. The gas mixture from the intake which has been separated by passing it through the porous material and the water from the transmission layer are fed in, the water and gas come into contact within the porous material, and the pressure of the intake is set to the pressure needed in order to generate hydrates to cause hydrates to be formed at the gas-liquid phase boundary. By setting the pressure of the transmission layer to the pressure required for hydrate decomposition, it becomes possible to decompose the hydrates and continuously extract the separated gas.

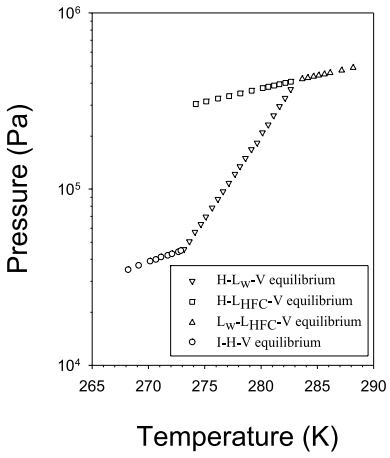


Fig. 1 Three phase equilibrium lines of HFC134a hydrates

Separation and identification of microorganisms

It is important to be able to identify not only chemical substances, but also microorganisms found in the environment. Microorganisms play a major role in determining the behavior of chemicals released into the environment. The actual degradability of biodegradable plastics and similar materials varies depending on the types of microorganisms present. It is necessary to have an understanding of both chemicals as materials and the environment as a place for reactions to take place, and we are accordingly performing the research needed in order to rapidly separate and identify different types of microorganisms. Electrophoresis is a well-known method for use in separating different chemical substances, but we have discovered that it can also be used with microorganisms and that it is possible to separate microorganisms over short separation times by adding certain polymers to the electrophoresis solution. We are also developing a method of identification which uses the soft ionization mass spectrometry method (MALDI-TOF-MS) to measure the concentrations of proteins and lipids found in microorganisms. (See Figure 4.) It has been found that this method makes it possible to easily distinguish between different types of microorganisms even when they consist of microorganisms which are extremely similar to each other at the genetic level.

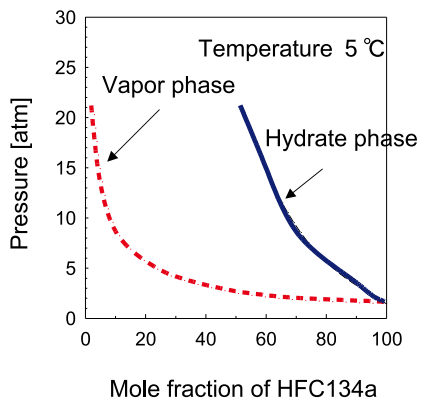


Fig. 2 Mole fraction of HFC134a in vapor and hydrate phases

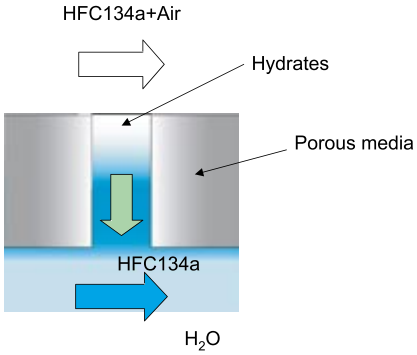


Fig. 3 Mechanizm of continuous separation

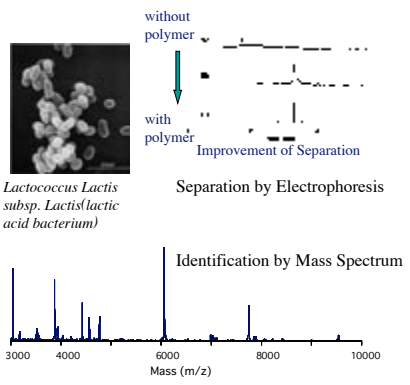


Fig. 4 Separation and Indentification of Microorganism by Electrophoresis/ MALDI-TOF-MS

Technologies for reducing hazardous chemical emissions

Tens of thousands of different types of chemicals are being produced and sold on a commercial basis and they are valuable in our daily lives. Among these chemicals, some have the potential (i.e., present the risk) of adversely affecting human health or natural ecosystems. However, as reducing all the risks to a level of zero would cost immense amount, it is required to assess the relative risks in accordance with the benefits to be gained in exchange for those risks, select those risks which are particularly high and monitor such chemicals to take appropriate measures (i.e., measures to reduce risk levels) to realize a sustainable recycling society in harmony with the environment (See Figure 1).

Below we introduce some of the researches now being performed at AIST on technologies for reducing hazardous chemical emissions.

Reducing emissions of volatile organic compounds

(1) Using electromagnetic heating in adsorption recovery

Although over half of all emissions of benzene and other volatile organic compounds (VOCs) released into the atmosphere come from small- and mid-sized sources, existing emissions control technologies are hardly used in practice because of the expensiveness and large-scale systems. Although technologies which use adsorption have gained attention as a means of controlling emissions on the grounds that VOC is reusable, these technologies are impractical for use at small- and mid-sized emissions sources without improvement of the heating desorption process after adsorption. For this reason, AIST is currently conducting research on ways of using electromagnetic fields to perform heating desorption with the aim of developing simpler, less expensive, and more compact systems. This may be rather unexciting research, however if it succeeds, it would be the most effective technology available. We believe that this method would make it possible to handle emissions from almost all sources where the emissions consist of high concentrations of a single material. Field tests are already being conducted of electric heating systems with the aim of developing a practical working system. The basic research work on radiofrequency heating has already been completed and we have now entered the stage of working on the research and development of an actual device. Since the radiofrequency heating is a very unique technique in terms of partial heating and temperature control, its application can be put to use not only in heating desorption but also in a wide variety of others as well, and the new range of applications of the technologies might be too numerous to even guess at.

(2) Nonthermal plasma decomposition

Nonthermal plasma, which is also known as non-equilibrium plasma, an unique reaction media where only the motions of electrons are accelerated. In nonthermal plasma, strong covalent bonds of hazardous air pollutants can be broken within a short reaction time using the energy of the high-speed electrons even when gas temperature is not higher than average room temperature. It is also possible to generate high concentrations of free radicals with high decomposition reactivities toward hazardous air pollutants. Recently, nonthermal plasma has attracted much attention as a key technology in various applications such as air cleaners, systems for decomposition of VOCs emitted from stationary sources, and disinfection and sterilization devices. Investigations have been initiated on the development of actual working systems using this technology. Since such systems require no high-temperature furnaces and can be operated simply by turning a power switch on and off, nonthermal plasma technology is viewed as a compact and low-cost technology ideal for reducing environmental risks. To make this technology a more feasible one, it is important that we find ways to promote oxidation and decomposition of hazardous air pollutants and further improve energy efficiencies, and we are accordingly making much effort in the research and development on the hybridization of nonthermal plasma, oxidation catalysts, and photocatalysis. (See Figure 2).

(3) Environmental purification through photocatalysts

As environmental purification technologies using photocatalysts (mostly titanium dioxide, or TiO_2), which can use sunlight or indoor lighting as energy sources, have been highly regarded as a means of removal of nitrogen oxides (in concentrations on the order of parts per billion) along roadsides, we have now expanded our research objectives to include aldehydes, BTX (benzene, toluene and xylene), polycyclic aromatic hydrocarbons, organics in particulate matter, and other air pollutants. It has been found out that, in the decomposition of aldehydes or BTX, it is possible to improve the rate of decomposition and increase the effective life of the catalysts by illuminating at temperatures of over 100 °C and by having the reactions take place upon a photocatalyst under a minute platinum load. We are also working on the development of new photocatalysts. While normal titanium dioxide photocatalysts can only use light in the ultraviolet range with wavelengths of 400 nm or shorter (see Figure 3), our research group has developed a nitrogen-doped titanium dioxide catalyst using a nitrogenous titanium complex which can use light with wavelengths up to 650 nm. This catalyst has been shown to be much more efficient than other nitrogen-doped photocatalysts in the oxidation of NO, and we are now conducting further research to improve this photocatalyst for practical applications.

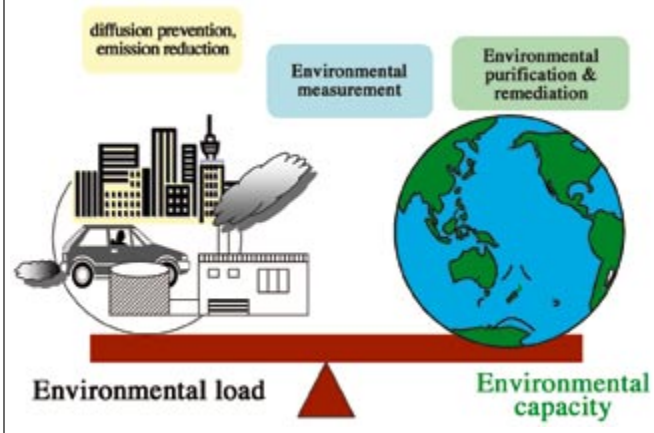


Fig. 1 Sustainable recycling society in harmony with the environment

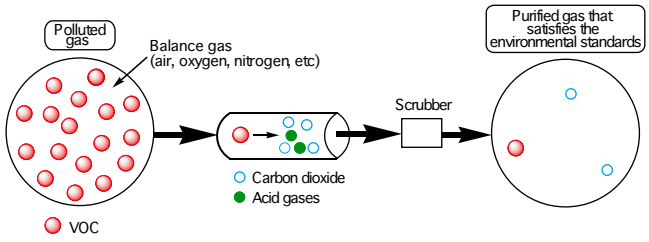


Fig. 2 VOCs treatment by low-temperature plasma

Development of technologies for controlling exhaust emissions from diesel vehicles

The particulate matter (PM) released by diesel vehicles is considered to be a highly hazardous substance in view of the degree of risk to human health, therefore, steps are now being taken to enact much stricter sets of regulations concerning PM emissions. The use of diesel particulate filters (DPFs) is thought to be promising as a method of reducing such emissions. In order to maintain the effectiveness of a DPF, the collected PM must be burned and removed, and to do so, a DPF would normally have to be heated to a temperature of 600 °C or higher. At AIST, we have developed a catalyst consisting of platinum, titania and silica (Pt/TiO_2-SiO_2) which can be used to promote the combustion (i.e., complete oxidation) of PM, thus making it possible to burn PM at temperatures around 320 °C. As such temperatures are still higher than those normally found in diesel vehicle exhaust emissions, we are also working on the development of new types of DPFs which, when used in combination with this catalyst, would be able to burn PM without using extra amounts of energy (See Figure 4).

Reduction of dioxins through waste incineration

Up until now, dioxins have been generated as a result of mainly the waste incineration and released into the environment. Today, measures have been taken in accordance with tightened regulation, and the volume of such emissions has become extremely smaller, especially the emissions from large-scale waste incineration plants. This does not mean, though, that no dioxins whatsoever are being generated, and there is a tendency to use excessive amounts of energy and money to reduce the volume of emissions. The reason for this is because how dioxins are generated during incineration is not completely understood and because many of the techniques which have been used to reduce emissions are based on empirical rules alone. Through research performed at AIST, we have learned that degradations in combustion conditions in incineration furnaces increase the volumes of soot and other pollutants which are thought to form the base material for reactions, thus resulting in an increase in dioxins generated. While temperature, chlorine contents, and many other factors are considered to be involved in the generation of dioxins, virtually all of these affect the process of combustion and the amounts of dioxins generated. If we learn to understand the mechanisms by which dioxins are generated and put the understanding to use in development, then the better technologies for reducing dioxin emissions should be available (See Figure 5).

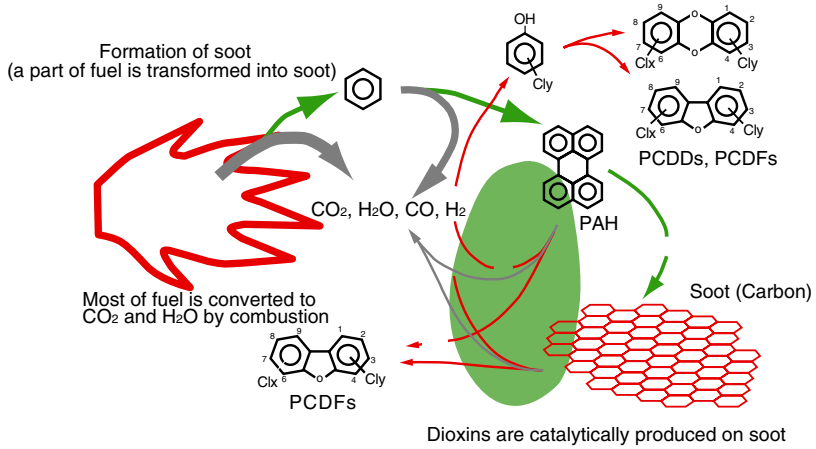


Fig. 5 Estimated formation scheme of dioxins in combustion processes

Hazardous chemicals

Among those chemicals artificially produced to address given needs, there are some whose effects on human health or natural ecosystems become apparent only as a result of the ways in which they are used or as a result of long-term exposure. The sources from which these chemicals are generated are varied in nature, and in order to reduce exposure on the part of human beings and natural ecosystems we must take steps to reduce the volumes of such chemicals released into the environment. Standards exist for reducing emissions of such chemicals including benzene, trichloroethylene, dioxins, and suspended particulate matter (SPM).

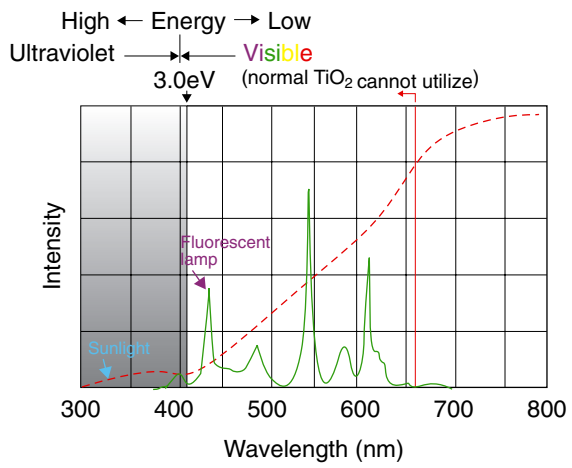


Fig. 3 Wavelength range utilized by photocatalysis

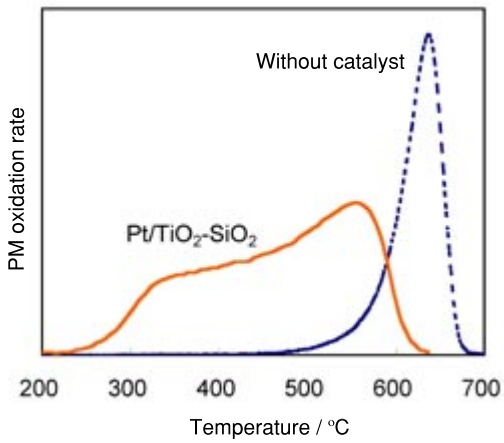


Fig. 4 Performance of the catalyst developed for PM combustion
(results based on temperature-programmed reaction)

Denitrification of industrial waste water

While nitrogen regulations have grown stricter over the past few years, the presence of biological inhibitors, the lack of sufficient organic materials for use in denitrification, and other similar problems mean that there are many cases where industrial waste water cannot be treated using biological methods. At AIST, we are currently working on the problems of waste water treatment, aiming for improvement of technologies for using microorganisms in cleaning up pollution and wider applications of such technologies.

Using a membrane separation activated sludge system, we have proved that it is possible to maintain high concentrations of nitrifying bacteria with slow reproduction rates, stimulate denitrification, and reduce the amount of excess sludge generated. We are also studying ways of performing nitrogen removal under conditions biological inhibitors exist.

Phenols are frequently found in industrial waste water, and it is said to have a strong effect as an inhibitor towards nitrifying bacteria at low concentrations of 10 mg/L. We have demonstrated the effectiveness of a system which confirms the existence of nitrifying bacteria in activated sludge acclimated to the presence of phenols and simultaneously removes phenols and ammonium from waste water in which both (phenols and ammonium) are found. A view of this system is shown in Figure 1. We were successful in achieving complete decomposition of phenols and the removal of 60% of the nitrogen under a phenol load of 0.3 g/L/d and an ammoniac nitrogen load of 0.2 g/L/d.

Dimethylformamide (DMF) is a persistent substance which requires acclimatization in activated sludge treatment. Furthermore because it is a nitrogenous compound, ammonium and nitric acid remain in the waste water, and it is necessary to add nitrogen treatment. We treated synthetic DMF waste water with a concentration of organic materials of 910 mg/L (nitrogen concentration: 122 mg/L) by a membrane separation nitrification/denitrification process with intermittent aeration using acclimated activated sludge. By adjusting the number of times processing was performed and setting an upper limit on the concentration of dissolved oxygen at the time of aeration, we demonstrated that it is possible to remove nitrogen using DMF as an organic source. In this way, the effective use of organic materials in waste water, which are not normally utilized, would also make it possible to reduce the cost of treatment.

Plans now call for these experimental results to be used in an attempt to develop an actual water treatment and control system.

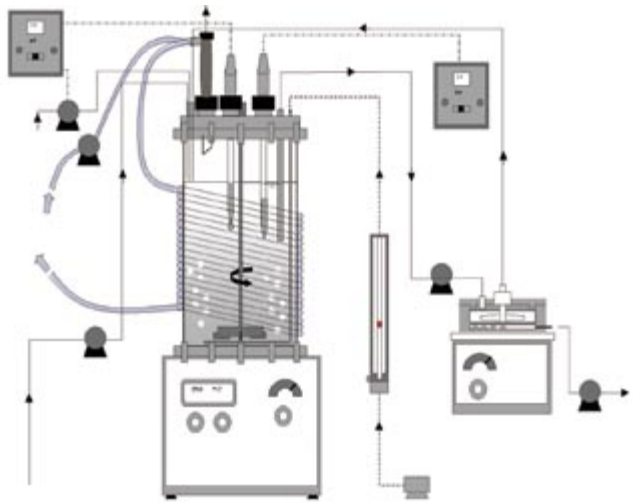


Fig. 1 An experimental setup of membrane separation reactor

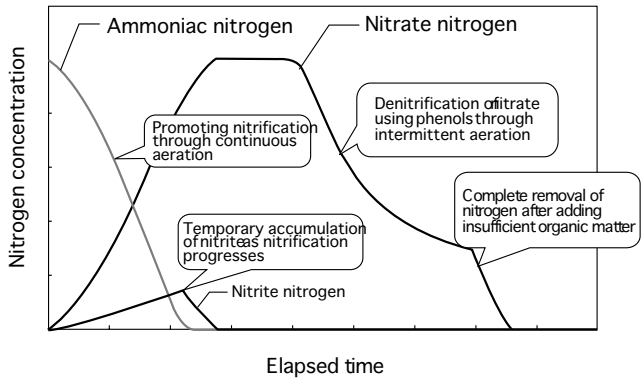


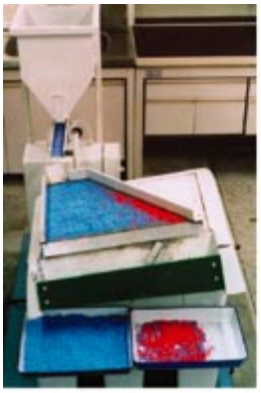
Fig. 2 Removal of nitrogen by modification of aeration methods using a single-vessel reactor

Experimental results obtained by phenol-ammonium treatment reactor

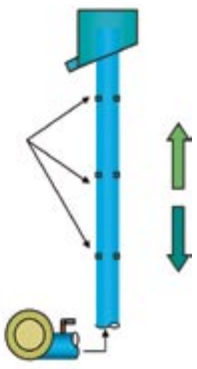
Recycling technologies

Particle separation technologies

While technologies for the separation and recovery of particles are used in a wide variety of production processes, such technologies are also important in the field of environmental preservation for the recycling of useful materials from wastes or used products or for the waste water treatment to remove particles and purify water. One example of this need can be seen in dry particle separation technologies, which present advantages such as being energy-saving and which require no post-processing waste water treatment and are thus suited for use in recycling but which are also considered to be inferior to wet process in terms of their efficiency in separating fine particles. It is



(a) An air table type separator



(b) A pneumatic column separator

Fig. 1 Dry particle separators

therefore important to develop dry separation technologies which could be used for the removal of fine particles too, and we are accordingly conducting research and development work on separation technologies using an air table type separator or a pneumatic column separator. (See Figure 1(a) and 1(b).)

Metal recycling technologies

The development of energy-saving technologies for the separation and recovery of metals is essential to the construction of a metal recycling-oriented society. AIST is currently working on the development of a process like that illustrated in Figure 2 which recovers copper from metal waste by reducing univalent copper-ammine complexes in an ammonia-alkaline solution to metallic copper. Because it uses ammonia, this method makes it possible to selectively dissolve copper, and it is promising in terms of the possibility of being able to greatly reduce the amount of electric power required for recovery.

Re-utilization technologies

There is a strong need to develop new technologies which would enable us to understand the behavior of toxic materials and energy consumption in recycling processes and enable us to build a sensible and economically stable model for the recycling and re-utilization of waste products. We have conducted studies of materials re-utilization technologies using hydrothermal treatment for the removal of toxic metals from incineration residues and for the molding or solidification of such residues, and we have learned that with respect to fly ash, which has a high heavy metal content, we can remove over 90% of the lead from such ash through alkaline hydrothermal treatment. We have also succeeded in treating incineration ash through hot hydrothermal pressure molding to obtain a molded product possessing a strength comparable to that of mortar or cement while inhibiting the elution of heavy metals (See Figure3) .

Assessment of environmental impact and the design of eco-materials

To assess the environmental impact of recycling systems and to design eco-materials which are both easy to be recycled and friendly to the environment are an important issue which must be addressed to create a recycling-oriented society. (See Figure 4.) To make it possible to perform assessments of the environmental impact of recycling systems, we are collecting inventory data from recycling processes for waste automobiles, waste household appliances, and other waste products, and we are working to develop new recycling systems in accordance with the assessments. We are also conducting research on ways of comparing these data to inventory data on production processes for steel, copper, lead, and plastics to develop ways of assessing the environmental impact of such systems on society as a whole.

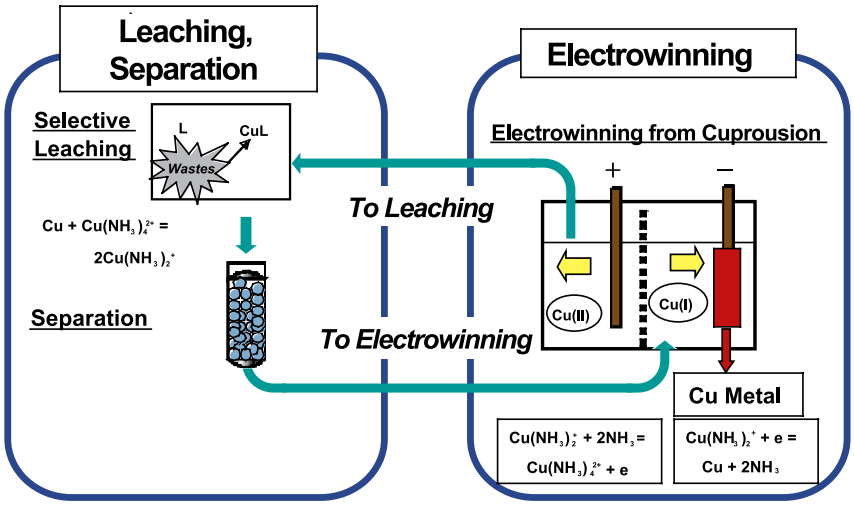


Fig. 2 New copper recycling process
This is proposed as a new process with the innovative refining techniques using solvent extraction process or adsorption process for copper recycling.

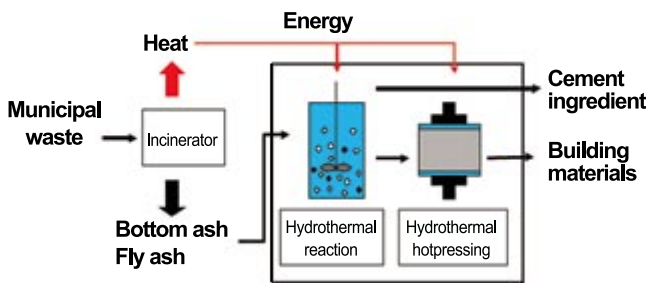


Fig. 3 Schematic flow of the treatment and re-utilization of incineration ashes

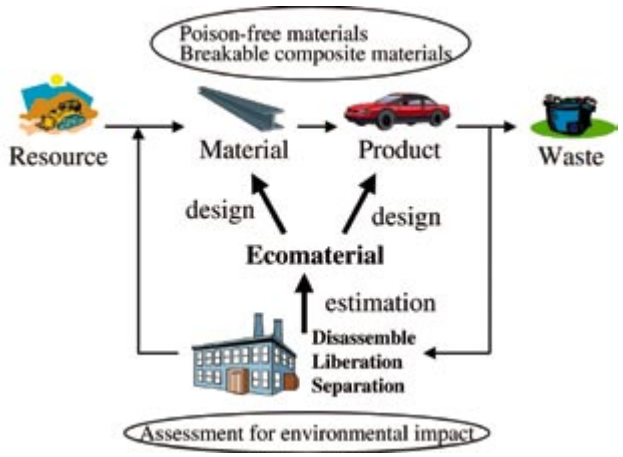


Fig. 4 Assessment of recycling processes and design of eco-materials

Technologies for Green Processes

Research and Development on Green and Sustainable Chemistry The five major programs

Research programs in green and sustainable chemistry (GSC) may be divided into five main categories: raw materials, reaction processes, end products, recycling, and waste processing. There has been a global shift in raw materials from current technologies based on petroleum towards biomass conversion and other renewable resources. We are seeking a way how we should proceed research on biomass in Asia as well as in Japan. As for end products, there is a growing demand to new chemical products and materials which are friendly to both people and the environment. In regards it is especially important that R&D be performed in conjunction with industries. Concerning reaction processes, innovations need mid- and long-range R&D covering a wide range of research from basic to applied. AIST accordingly regards this as a high-priority work and plays a leading role in R&D in Japan. Reaction processes include the three main component technologies of catalysts, separation membranes, and non-organic solvents, and AIST has many years of accumulated technological experience in these areas.

Innovations in Reaction Processes for Saving Energies and Resources, and Poison-free Materials

(1) Halogen-free, energy and resource saving selective oxidation processes

To produce functional chemical products from petroleum, namely, or hydrocarbons, it is necessary to selectively add oxygen, and this oxidation reaction processes occupy the second largest market in chemical industry after polymer synthesis. At the present time, however, the major industrial processes consist of multi-stage reactions using halogen or costly organic peroxides. It would be desirable if we could develop processes which enable us to selectively synthesize desired organic oxygenate compounds (e.g., unsaturated alcohols, aldehydes, expoxides) using hydrogen peroxide (where the only by-product would be water) or, ultimately, using only molecular oxygen.

One example of such a process is shown in Figure 1, which illustrates an attempt to synthesize adipic acid, which is used to make nylon-6,6, using hydrogen peroxide. The current method of producing adipic acid is to react cyclohexanone and cyclohexanol with nitric acid, but this produces nitrous oxide as a byproduct. While this nitrous oxide could be used as an oxidizing agent, in actual practice it is often transformed into N2 through decomposition. At AIST, we have discovered a new sodium tungstate catalyst for the synthesis of adipic acid in a simple route shown at the bottom of Figure 1.

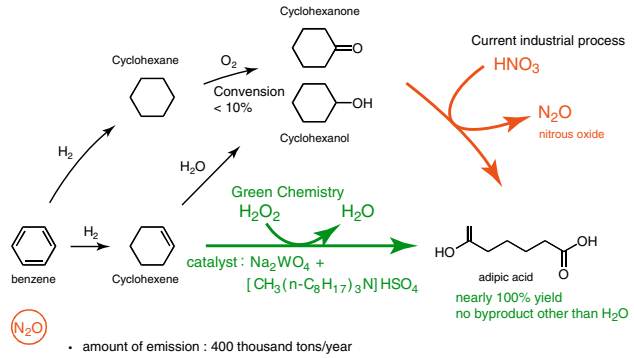


Fig. 1 New route for the synthesis of adipic acid (row material for nylon –6,6)

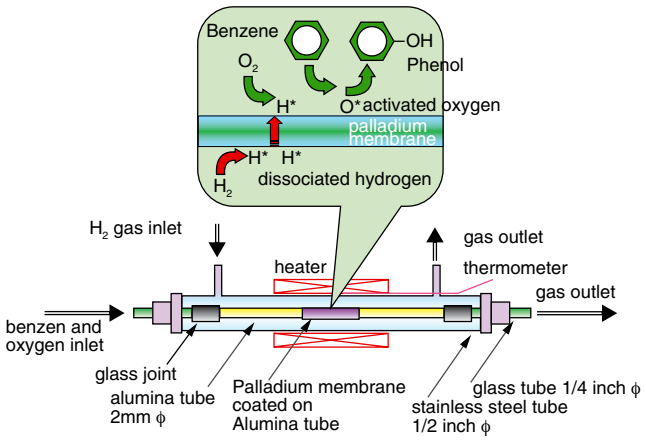


Fig. 2 Palladium membrane reactor and its application to direct phenol synthesis

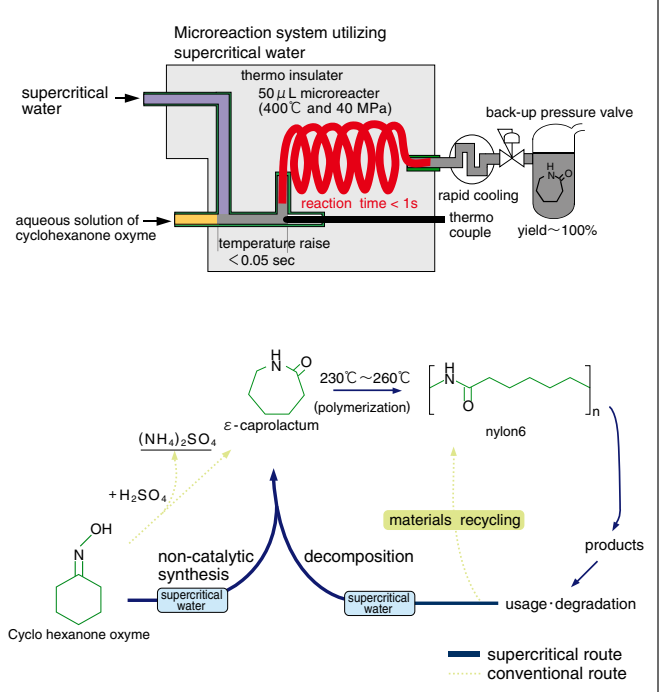


Fig. 3

(above) Synthesis of ε-caprolactum with microreaction system utilizing supercritical water

(below) Environmentally-friendly material recycling system utilizing supercritical water –nylon 6 synthesis

(2) Energy-saving separation and concentration techniques using separation membranes

In chemical industry, it is said that over 50 percent of all energy consumed is used in separation and concentration processes, but if separation membranes were applicable to these processes it would lead to remarkable reduction in energy consumption. Moreover, a reaction chamber equipped with separation membranes can overcome the limitations of chemical equilibria (e.g., in dehydrogenation reactions), leading to increased conversion and selectivity. An example of this has recently been presented by AIST, where we have succeeded in direct synthesis of phenols from benzene in a single-stage reaction by sending dissociated hydrogen atoms through a palladium membrane and controlling the reactivity of oxygen molecules reacting with the benzene. (See Figure 2.)

(3) Simplified synthesis reactions using supercritical fluids

In order to innovate reaction processes, changing solvents in which reactions take place is one effective mean of doing so. Interest has also grown in methods where carbon dioxide or water is used in a supercritical state, because supercritical fluids impose environmental burden than organic solvents less vapor pressures of which at room temperature are relativily high and the vapor is often toxic. An example can be seen in the synthesis of ε-caprolactum, which is used to make nylon-6. Reaction can be completed in a short time within a second with an ε-caprolactum selectivity of 99% if a supercritical water micro-reaction system is used. This method eliminates the need for acid catalysts and the recovery and reuse of solvents and is therefore a very interesting environmentally-friendly method for the synthesis of a raw compound for making nylon. (See Figure 3.)

Green and Sustainable Chemistry

In Japan, green and sustainable chemistry is defined as chemistry which "ensures the health and safety of people and the environment and conserves energy and resources through technological innovations which take into account the entire lifecycle of a product from its design to the selection of raw materials, means of production, means of use, and recycling." Green and sustainable chemistry is both an idea and a movement designed to strengthen the development of chemistry, which is sometimes regarded not only as one of the main causes of environmental problems but also as the principal means by which such problems can be addressed.

Participation in Green and Sustainable Chemistry Network

Green and sustainable chemistry: A worldwide movement

Green and sustainable chemistry, which means a type of chemistry friendly to both people and the environment and capable of supporting a sustainable society, would represent a major innovation in production in chemical industry, and work directed towards making GSC a reality is being performed all around the world. This work has begun since the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 (*i.e.*, in accordance with Chapter 19 on the management of chemicals in *Agenda 21*), with this work being performed by Organization for Economic Co-operation and Development. At the Risk Assessment Steering Group's Venice Workshop on Sustainable Chemistry held in October 1998, an agreement was reached which stated that the participants recognized that green and sustainable chemistry would contribute to the improvement and advancement of environmental management programs and that governments, industries, and academia in all nations should initiate programs to make GSC a reality and strive to promote GSC. Under a restructuring of the OECD which took place in June 1999, work on GSC began to be performed by an organization placed directly underneath the OECD joint meeting (*i.e.*, meeting of representatives of member nations of the OECD).

In response to these global developments and in recognition of the fact that an organization ought to be formed in Japan, Green and Sustainable Chemicals Network (GSCN) was established in March 2000 under the direction of what was then Chemicals Office of Ministry of International Trade and Industry to make GSC a reality in Japan. Including what was then National Institute of Materials and Chemical Research, a total of ten organizations participated in GSCN: three academic associations (The Society of Chemical Engineers, Japan, The Society of Polymer Science, Japan and The Chemical Society of Japan), Japan Association for International Chemical Information, The Association for Progress of New Chemistry, Japan Chemical Industry Association, Japan Chemical Innovation Institute, Chemical Evaluation and Research Institute, and Japan Bioindustry Association. National Institute of Advanced Industrial Science and Technology (*i.e.*, AIST) has continued to serve as a member of GSCN since it was reestablished as an independent administrative institution.

Serving as a main member of the GSCN

The main activities of the GSCN are divided into two types: domestic activities and international activities related to the OECD. Just as it is stated in Chapter 19 on the management of chemicals in *Agenda 21*, the initiating force behind the green and sustainable chemistry movement, in recognition of the importance of education and providing the public with information in order to gain the understanding of the people about GSC activities, in domestic activities GSCN has devoted a great deal of effort to public information and education activities. Of course work is also being done to promote the performance of research directed towards making GSC a reality. In September 2002 we published *Initiative GSC21: Challenge of Chemical Technology*, a document which set forth general guidelines concerning the future of GSC research.

Presently, the main activities of GSCN consist of (i) the organizing of annual GSC symposium, and (ii) granting GSC awards. The first international conference on green and sustainable chemistry, *GSC Tokyo 2003*, was held in March 2003 at Waseda University with 760 participants including 120 participants from twenty nations not including Japan, and the conference proved a huge success. AIST has helped to support the international conference by serving as members on the action committees for the conference, and amongst the research presentations, 22 of the 129 presentations consisted of presentations of research performed at AIST, thus resulting in a substantial contribution to the success of the conference. As for the GSC awards, three ministers' awards (*i.e.*, the Ministry of Economy, Trade and Industry Minister's Award, the Ministry of the Environment Minister's Award, and the Ministry of Education, Culture, Science, Sports and Technology Minister's Award) have been granted since 2002, and Dr. Akira Sekiya of AIST's Research Center for Developing Fluorinated Greenhouse Gas Alternatives was given the honor of sharing the MoE Minister's Award with the Zeon Corporation.

GSCN is currently composed of five working groups including GSCN Operating Committee. AIST researchers serve as members on all of the GSCN's working groups and committees, and AIST itself serves as one of the main organizations working towards the realization of green and sustainable chemistry. Finally, it should be noted that over 20 organizations are now the members of the GSCN.

Research and development of photovoltaic power generation technologies

Achieving higher efficiency to develop cost-effective systems

The cost of generating electricity using solar energy systems, which have long been regarded as one of the most representative forms of renewable energy capable of preventing global warming and reducing carbon dioxide gas emissions, has fallen by over one-fifth of its original cost over the past ten years, and it has made great strides in its progress, with 637 MW of generating capacity coming on line throughout Japan by 2002. While original targets call for the introduction of 4.8 GW of capacity by 2010 as set by the government, work on research and development will have to be increased even further in order to introduce the large amounts of capacity which will be required in order to make solar energy capable of serving as a major source of energy by 2030. There are two main issues which must be addressed in research and development: increasing the efficiency of solar cells (currently available products only provide efficiencies of around 15%) and reducing their cost, and developing ways of making effective use of their output, which varies greatly over time.

Solar cells are a green technology which use sunlight to generate electricity, and several divisions at AIST have been involved in playing a leading role in conducting pioneering research and development on crystalline silicon cells, amorphous silicon cells, CIGS solar cells and other compound solar cells, and dye-sensitized solar cells.

Crystalline solar cells account for the majority of all solar cells on the market today, and while they have a high conversion efficiency of over 20 percent over a small area, they are also expensive, and research and development work is accordingly being performed to develop thin-film solar cells with film of a thickness of under 100 microns and to develop low-temperature production process technologies in order to reduce their cost by developing energy- and resource-saving production processes.

Photo 1 Photovoltaic Power Generation System (1 MW) installed in AIST Tsukuba Central Area

Amorphous silicon cells are inexpensive, can be mass-produced, and can function at a thickness of just a few microns, but they are relatively low in efficiency and research is being done to develop microcrystalline silicon cells with laminated structures to improve their efficiency. CIGS, or Cu InGa Se_2, cells are high-efficiency solar cells which also function at a thickness of just a few microns and make it possible to obtain efficiencies near 20 percent over a small area, but with current technology when these cells are spread over larger areas their efficiency drops sharply, and research is accordingly being performed to develop high-precision production process technologies and find the optimal gallium concentration for such cells to improve their efficiency. Dye-sensitized solar cells are low-cost cells with a structure where electrodes are connected by electrolytic fluid, and they have gained attention because of the rapid progress in their development which has been made in the past few years and because their efficiencies now exceed over 10 percent over small areas. The problems which remain to be addressed in their future research and development are those of increasing their efficiency and increasing their effective life.

The remaining issues which must be addressed for all types of cells are that innovative new systems and low-cost process technologies must be developed to produce cells with thinner films capable of being spread over wide areas in order to reduce their cost to the level required to allow their widespread introduction, and to further improve their efficiency, it is essential that they must be capable of making use of the wide spectral range of sunlight, and they must be therefore, multi-junction solar cells with various materials. Furthermore, as the use of solar cells becomes more widespread, it will become necessary to have the means to accurately and objectively evaluate their performance in a way compatible with internationally established methods, and AIST is currently working to establish systems for doing so.

Another problem of growing importance is how to make effective use on a large scale of the electricity generated by solar cells, which varies greatly as it is influenced by weather or time of day. If excess power not consumed by the end user were simply returned to the energy grid in the same way that such systems are used today, then there would be a possibility of voltage increase or other problems in the power grids of areas with high concentrations of solar power systems. Solar power has many things in common with wind power because there is a need for technologies which make it possible for large numbers of modules to work together in conjunction with existing systems while combining those modules together with the minimum necessary power storage systems, thus making research on such an energy network is a very challenging subject theme. In addition, when calculated in terms of peak capacity and the annual amount of electricity generated, solar energy systems in Japan are operating at only about 1/8 of their total capacity (as a result of decreases in the amount of sunlight due to factors such as rain or time of day), and there is a need to clearly identify the most meaningful way in which such power generation systems is used.

AIST has established a research center dedicated to performing research on photovoltaic power generation to study all of these different types of solar cells, integrate the research performed on them and develop a common standard of evaluation, evaluate their efficiency, and promote system research, and significant progress is expected in research on the next generation of solar power systems.

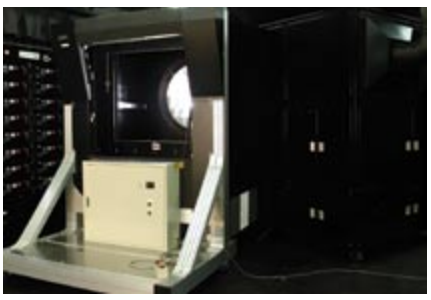


Photo 2 Large area solar simulator for indoor characterization of PV module (1m x 1m)

It is also our aim to play a role in objectively and accurately evaluating the performance of different new types of solar cells developed in the future.

AIST is currently working to establish a research center dedicated to performing research on solar power systems to study all of these different types of solar cells, integrate the research performed on them, evaluate their efficiency, and promote system research and general research and development, and significant progress is expected in research on the next generation of solar power systems.

Fuel cells and hydrogen energy

Working towards a clean hydrogen energy society

Fuel cells

Fuel cells present a number of advantages, advantages which include the fact that even compact fuel cells provide high power generation efficiencies, that it is possible to attain even higher levels of usage efficiency when used in conjunction with heat, and that in the ideal case they use only hydrogen as fuel and produce no carbon dioxide emissions, and they are accordingly viewed as a highly promising technology for ensuring the effective use of energy and helping to prevent global warming.

Of the many different types of fuel cells which exist, polymer electrolyte fuel cells (PEFC) can be produced in compact form because they use fluorinated polymer films as electrolytes for carrying hydrogen ions and use electrocatalysis to make it possible for them to be operated at relatively low temperatures of about 80°C, and they are viewed as a promising type of fuel cell which can be used in a wide variety of applications including automobiles stationary power systems in homes and officies or portable devices. Long term durability and system cost are the issues to be addressed for the real use of PEFC. In the AIST, research on the cause of degradation of PEFC and searching for new inexpensive and high performance electrolytes and catalysts are being performed mainly in Kansai Center. In order to use these fuel cells in high-added-value portable devices, research and development work is also being performed mobile power generation systems which would consist of a combination of compact fuel cells, fuel storage systems, and compact, high-performance secondary batteries.

Solid oxide fuel cells (SOFC) operate at high temperatures near 1000°C and use ceramics made from yttria stabilized zirconia or other oxygen-ion conducting materials as electrolyte, and in addition to providing high power generation efficiencies of over 50 percent, they provide a number of other advantages such as that their design is simple and robust and that fuel can be easily converted to hydrogen within the high-temperature fuel cell. Hybrid systems where the high-temperature exhaust gas from the SOFC is used to drive a power generator provide the highest overall efficiency in the power generation systems. Over the past few years, a number of prototype SOFC systems with capacities of several hundreds of kilowatts have been created, and work has also been done to develop systems which shorter startup times or more compact systems with operating temperature of under 700°C. At AIST, in addition to developing technologies for accurately evaluating the performance of SOFC systems nearly ready for the market, we are also doing research on low-operating-temperature materials for compact SOFC systems on methods to use a wider range of fuels and on hybrid systems. Figure 1 shows a view of a compact, low-temperature (tubular) SOFC together with the electrode pattern used in performing a detailed analysis of the behavior of oxygen ions.

Hydrogen

Just as with electric power, hydrogen is a secondary energy source which can be used to store and transport energy, and it has many advantages like the fact that it provides high energy densities per units mass, that it produces only water vapor when burned, and that the electrolysis of water or fuel cells may be used to both convert hydrogen to electric power or do the reverse. Fuel cells are one of the most important possible uses for hydrogen. It is expected that the amount of hydrogen which is required to the government targets for the introduction of PEFC systems by 2010 (targets calling for their use in 50 thousand fuel-cell automobiles and 2.1 gigawatts of capacity in fixed power generation systems) can be met by using the hydrogen produced as a byproduct in the making of steel and other processes, and the important issues which must first be addressed are finding ways of storing, transfering, and supplying hydrogen at high densities. While the first generation of fuel-cell automobiles will be equipped with high-pressure gas tanks (with pressures from 30 to 70 MPa), there is a need to develop materials which would be able to hold large amounts of hydrogen within a small volume, and current targets call for the development of materials capable of holding from 5 to 6 percent of their own weight in hydrogen. To achieve this goal, a great deal of work is being performed at AIST. Completely new types of materials are being produced by using many different types of methods, and analyses of the nanoscale structures of these materials are being performed. Figure 2 shows an alloy with a body-centered cubic lattice structure which achieves high levels of hydrogen storage together with a view of a fuel-cell automobile built using this material.

In order to reach the target of getting 5 million fuel cell automobiles onto the road by 2020 and achieve the long term objective of creating a hydrogen-energy-based society using larger quantities of hydrogen, it will be necessary to ensure safety in the use of hydrogen, and to find ways of producing large amounts of hydrogen from renewable energy resources. AIST is also conducting research on these subjects.

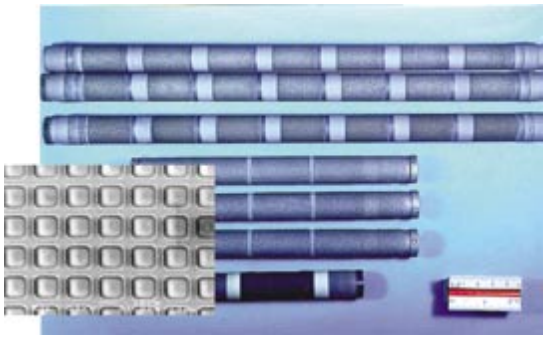


Fig. 1 SOFC (tubular type) developed by AIST, and electrode pattern on planar SOFC for ion dynamics analysis

Fig. 2 An alloy with body centered cubic structure which achieved high density hydrogen storage, and fuel cell vehicle with it

Technologies for the production and the use of clean fuels from organic resources

The design and development of the HyPr-RING system for the production of hydrogen gas with a in-situ carbon dioxide removal

Under the present circumstances where Japan still relies on fossil fuels for 81 percent of its energy, development of new technologies is required for the efficient utilization of fossil fuels and unused organic resources as well as the conversion technologies of these organic materials into clean and lower carbon content fuels. These developments will help us to solve global environmental issues such as global warming and ensure stable energy supplies for sustainable economic growth.

At AIST, we have developed a new hydrogen production process from water by thermo-chemical decomposition of organic materials (HyPr-RING: Hydrogen Production by Reaction Integrated Novel Gasification). This process utilizes the chemical energy contained in coal, biomass, sewage sludge, and other organic resources. The main features of this method are that the carbon dioxide produced as a byproduct is fixed using calcium or other metals. The heat of the absorption is efficiently supplied to a gasification reaction and no carbon dioxide is detected in the gaseous product. Then, it is possible to produce hydrogen efficiently. In addition to basic research results such as reaction rate, the composition of the gas produced, and so on, we have also performed process verification based on the results obtained from a small size continuous reactor; for various organic materials, about 80% of the produced gas is hydrogen and 20%, methane with only trace amounts of carbon dioxide and nitrogen. Hydrogen sulfide and chlorine contents are below detectable limits.

Fundamental principles of the process

One of the novel features of this process is that both a water gasification reaction (Eq.1) and a shift reaction (Eq. 2) take place within a single reactor (See Figure 1), while the conventional gasification process requires two reactors.

(1) $C + H_2O \rightarrow CO + H_2$

(2) $CO + H_2O \rightarrow CO_2 + H_2$

When these reactions are combined with a carbon dioxide absorption reaction using a metal, the overall reaction equation becomes equation (3):

(3) $C + 2H2O + CaO \rightarrow CaCO_3 + 2H_2$

The $CaCO_3$ is calcined at high temperature to produce CaO. This heat is released when calcium oxide absorbed the carbon dioxide and supplied to the water gasification reaction; strong endothermic reaction. Pure carbon dioxide will be withdrawn at the calcination process of the $CaCO_3$, if new technologies are applied to the process.

HyPr-RING process has been originally developed here in Japan and will contribute to the global environmental issues and energy resources issues, though we have to find the solution for some peripheral issues; such as powder handling.

The Center for Coal Utilization Japan and the five private-sector companies have jointly conducted the research and development for the commercial plant utilizing coal. In 2004FY, 50 kg/day bench plant will be operated to verify the feasibility of the system.

The HyPr-RING system can be used to produce hydrogen from a various kinds of organic materials. (See Figure 2.) However, the characteristics of the reaction depend on the properties of the organic material used, so the technologies developed for coal might not be applied to all other organic materials. In order to cover these aspects, a new project has been started to utilize wooden biomass to produce hydrogen. Biomass is renewable energy and considered as the eligible energy resources for global environmental issues. AIST Chugoku has conducted this biomass project. At this moment, it has been found that even at lower pressures, a larger amount of hydrogen is generated from biomass than that from coal.

Further development of hydrogen production processes

The conventional thermochemical hydrogen production processes partially oxidize the organic materials to maintain the reactor at high temperature and high pressure to produce CO, CO_2, and H_2. To obtain pure hydrogen, the separation process is required. While large scale commercial plants have been developed and already at work, the efficiency of the system is not so high because the conventional systems consume large portion of enthalpy of organic materials to keep the reactor at high temperature. There is also a need for a process to separate of the carbon dioxide.

In just five years since the Hy-Pr-RING system was first proposed in 1998, a project was started in the EU using biomass and brown coal together with the similar principles of the Hy-Pr-RING system. This process, in which carbon dioxide is withdrawn during the production of hydrogen, will be tested in the world using various kinds of organic materials. Now, we have come to the stage to discuss how we dispose and utilize the withdrawn carbon dioxide.

Gasification of biomass for the production of liquid fuels

Biomass was recognized as one of new energy sources in amendment of governmental ordinances in January 2002 in Japan. Among many biomass-to-energy conversion processes, gasification is considered to be one of the most practical and promising processes. Here we introduce a gasification research now conducted at AIST as part of a NEDO High Efficiency Biomass Conversion Project.

The purpose of this project is the development of biomass gasification and liquid or gas fuel synthesis. In this project, Mitsubishi Heavy Industries (MHI) and Chubu

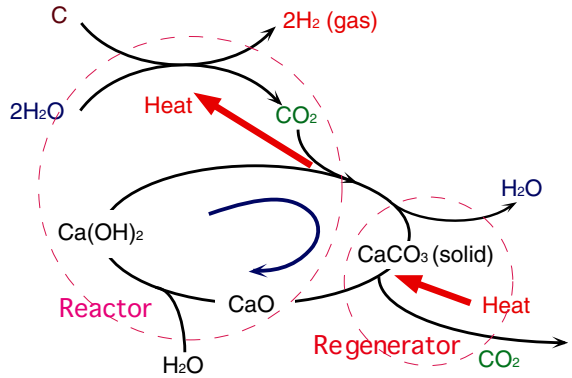


Fig. 1 Concept of HyPr-RING Process

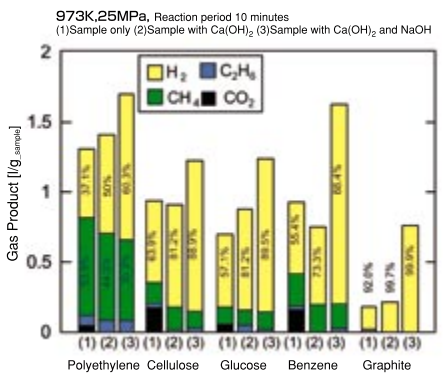


Fig. 2 Gas products from various organic materials

Electric Power Company (CEPCO) built a 2-ton/day scale test plant in Mie prefecture, and operate it to demonstrate a comprehensive system. AIST is responsible for performing the basic research which will be needed for the test plant to verify and to study various biomass gasification characteristics.

In this research we use an entrained type gasifier, which is quite simple in structure and, therefore, is usable for from small to large scale depending on the circumstances. It also has advantages of quite low tar yield without catalyst and low cost because of simplicity of structure. We built a small-scale entrained type gasifier, designed to provide similar gasification conditions as the test plant, and gasified a variety of biomass using it.

Figure 3 shows the results of gasification of Japanese cedar. Steam and oxygen were used as gasification agents and under various combinations of gasification agents' parameters biomass was gasified. In all runs, the gasification rate (carbon equivalent) was 0.89 to 1.01 and tar yields were under 0.02%. The proportion of gas in recovered products (gas, solid residue, tar and aqueous phase compounds) was more than 98%, indicating that gasification had proceeded very well.

In the absence of O_2 and in the case of relatively small amount of O_2 was added ($[O_2]/[C]$ = 0.1, 0.2), both H_2 and CO_2 increased, but CO decreased, when $[H_2O]/[C]$ ratio was increased from 0.5 to 5. However, at $[H_2O]/[C]>5$, no salient change was observed. When the $[H_2O]/[C]$ ratio was small (about 2), we obtained a gas composition suitable for synthesizing liquid fuels ($[H_2]/[CO]$ = 2.5-3) with high gasification rate. On the other hand, even in case of high $[O_2]/[C]$ ratio (0.35) condition, which is comparable to that in a large scale thermally isolated system, the results were interesting that gas with a high portion of CO was obtained when $[H_2O]/[C]$ ratio was small (0.5).

These results obtained from the research show that a high gasification ratio of over 95% could be obtained of a composition well suited to the later stage of liquid fuel production and enabled us to identify the optimal conditions. In addition, almost none of the tar that usually presents problems in gasification was generated, thus indicating that this is a promising technology for use in the development of an actual commercial system.

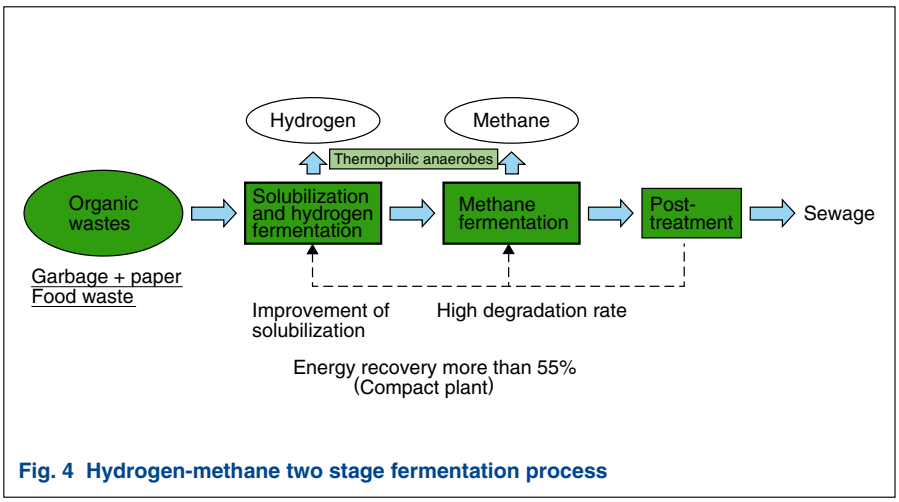


Fig. 4 Hydrogen-methane two stage fermentation process

Two-stage hydrogen/methane fermentation process

While methane fermentation is a well-known method for use in treating raw sewage or fecal and urine waste, in this research we are working to develop a new process designed for use in the processing of kitchen refuse, old paper, and food wastes which have thus far proved resistant to treatment by methane fermentation and used thermophilic microorganisms to gasify the waste in two stages, subjecting it first to soluble hydrogen fermentation and then to methane fermentation with the objectives of improving the energy reclamation ratio, increasing the variety of waste materials which can be processed, and reducing the amount of residues produced. (See Figure 4.) More specifically, a plant near that of an actual test plant will be constructed at AIST West Tsukuba which will use as its raw materials waste foods discarded in the AIST cafeteria (50-70 kg/day), and this plant is expected to start operation in May 2004.

DME-powered automobiles

In those engine technologies used primarily in private transportation and shipping, the development of cleaner, higher-performance engines and the development of technologies for engines using new fuels are extremely important issues in terms of environmental preservation and the diversification of energy resources.

One example of the work that is being done to develop technologies for the use of clean fuels with lower carbon content or carbon-free fuels is that being done on using and converting to the use of dimethyl ether (DME) and other types of liquid synthetic fuels. AIST is currently involved in research and development such fuels as diesel fuels which would generate no soot particles, and we have developed technologies for use in DME-powered engines, performed driving tests with actual test vehicles using these technologies, and are now working to develop technologies which would contribute to the actual introduction and widespread adoption of clean vehicles using low-carbon fuels. We are also conducting research surveys directed towards the formulation of quality standards for the use of this fuel as an automotive fuel, i.e., towards the creation of a set of DME standards.

AIST is thus involved in a wide range of research inspired by a variety of different concepts which range from the development of technologies for the production of clean fuels to the study of ways in which clean fuels produced from unused organic resources can be put to practical and effective use and the study of systems using those fuels.

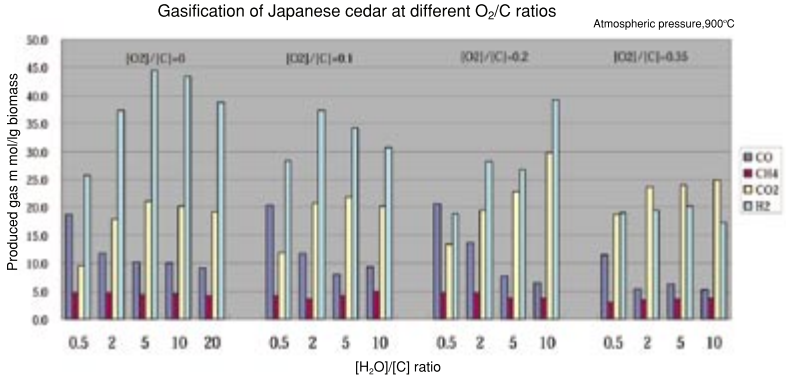


Fig. 3 Results in gasification of Japanese cedar

Photo DME minibus

Work being done by AIST on the development of energy and environmental assessment techniques

● AIST research facilities

While many examples can be seen of technologies or products which bill themselves as being 'environmentally friendly', we need some sort of yardstick against which such claims can be measured to determine what is and what is not really so. A yardstick of this kind would also be useful in determining the direction in which we should proceed in energy and environmental research and development. This is why at the time of its foundation AIST established evaluation research centers designed to play a central role in responding to government needs and building a scientific foundation, and this is why we devote a good deal of effort and resources in our research institutes to the development of techniques for use in evaluating actual individual examples of such products and technologies. These evaluation techniques are not only indispensable in the fields of energy and the environment, but are also essential tools for use in trying to achieve a broader balance between science technology and society the environment as a whole.

● Managing the risks associated with chemicals

A wide variety of different chemicals play an important role in industrial activity and in our day-to-day lives. While we use these chemicals directly or we unexpectedly produce hazardous chemicals as a byproduct of the introduction of a given technology, at AIST we believe that in order to make effective use of these chemicals it is absolutely essential that we learn about, assess, and properly manage their concomitant impact on the environment (i.e., their associated risks), and it is with this in mind that we are working to develop procedures for risk assessment and management.

Learning how chemicals disperse through the environment and what impact they have on local residents is an effective means of managing risk in order to maintain communications with large numbers of people and to arrive at a consensus. One examination tool which AIST has developed for this purpose is the Atmospheric Dispersion Model for Exposure and Risk (ADMER), a model designed for use in estimating atmospheric concentrations of chemicals (See Figure 1). ADMER may be used to simulate the dispersion of chemicals over time on a regional scale for the Kanto region or other regions (spatial resolution: 5 × 5 km), and this model makes it possible to assess possible exposure and risk from data on the distributions of the sources of the chemicals, their concentration, and deposition. More recently, we have also released a simple risk assessment model for Tokyo Bay.

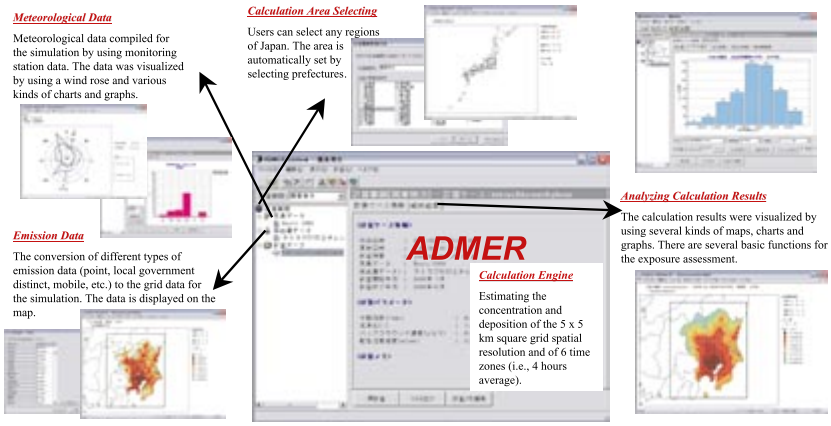


Fig. 1 The user interface and major functions in the ADMER ver. 10

For chemicals regarded as particularly hazardous, we have drawn up detailed risk assessment reports, and we have already released a risk assessment report on 1,3-butadiene. The estimation models and these reports may be accessed from the website of the Research Center for Chemical Risk Management.

● The impact of fluorocarbon substitutes on the environment

Fluorocarbons have played a major role in many industries as refrigerants, foaming agents, and cleaning agents. Yet it has been found that some of these fluorocarbon products contribute to global warming and to the depletion of the ozone layer of the stratosphere. While practical alternative compounds which do not harm the ozone layer have already been developed, there is still an urgent need to develop materials which restrict greenhouse effects and achieve a balance in terms of the other criteria by which they are measured.

This is why in addition to develop ways of performing environmental assessments, i.e., ways of measuring with precision the life of new alternative compounds in the atmosphere and develop methods for calculating their greenhouse effects—including computational science methods—we are also performing research to find economically viable methods of synthesizing new compounds. This has already resulted in the proposal of the Integrated Warming Effects (IWE) index as a new index designed to replace the global warming coefficients currently in use (See Figure 2). In addition to this, the criteria used to assess alternative materials include a wide range of criteria from the energy efficiencies of different applications to evaluations of the combustibility of materials and other safety-related criteria, and we are now working to create a general set of evaluation guidelines to make it possible to assess these criteria centrally using a single system.

This work is being performed in close conjunction with industry through joint research programs and other similar efforts. Information on these activities is available for viewing on the AIST website.

● Life cycle assessment

Life cycle assessment (LCA) is a technique for assessing impact of a product or service on the environment. Beginning from the mining of the resources needed to manufacture a product, an LCA takes into account the entire life cycle of a product including the production of the materials used in that product, to the time of its use and disposal, as well considering resources, the energy chain, and environmental impact. At AIST, we are working to develop LCA methods designed in accordance with ISO standards, to develop an inventory database with detailed analyses of inputs and outputs of materials affecting the environment, to provide assistance in low-environmental-impact product design (i.e., 'eco-design'), to perform assessments of energy technologies and of heating and air conditioning systems and waste usage in urban and local rural areas, and to conduct research on supply and demand as well as developing and providing software systems for use in these

areas (See Figure 3).

In terms of life cycle impact assessment (LCIA) used to represent the amount of damage caused to people or to natural ecosystems as a result of a product's environmental impact, we have developed our own set of procedures using quantitative indices based on environmental economic methods for calculating damage from environmental impact. These procedures have attracted a great deal of interest not only in Japan but also from other countries abroad as well.

As opposed to the environmental impact of a product as calculated using the LCA method, there is also the environmental efficiency of that product used to indicate what degree of services (i.e., functionality) the product will provide; it is believed that this will serve as a quantitative index of the degree of environmental compatibility of industrial activity. In addition to working to develop environmental efficiency indices, we are also studying how to attain the goal of 'sustainable consumption' in an effort to reduce environmental impact when considered from the point of view of consumers and what sort of functionality they demand from products.

● Relationships between society and technology

For technology to play a role in the sustainable development of society, it must strike a balance between the needs of people, society, and the environment and come to be accepted by society to play its role. To make this possible, we must do more than create new scientific and technological knowledge and instead assess and predict the effects of science and technology on society, the economy, and the environment and properly manage the risks involved.

Working from research performed both inside and outside the institute, AIST is currently working to develop a new form of sociological research for the study of technology. This research, which involves gaining an understanding of social and economic needs, making forecasts about social and economic effects, and designing the systematic framework needed for new technologies to become accepted in society is referred to as research on the social aspects of technology, and this too is an important part of research on society and technology.

We have performed surveys of research performed in other countries on the social aspects of technology and related systems existing there and studied ways of introducing the same kinds of systems in Japan. Systems have been put in place in many countries abroad for new types of technology assessments and for the study of ethical, legal, and social issues (ELSI), and many expect that similar work will begin in Japan in the very near future.

F-center

Evaluation of Warming Effect for Solvents Use.

Building a Sustainable Society

Useful solvent CFC-113 was phased out because of destruction of the ozone layer. New solvents are being developed to replace CFC-113. Current LCA, TEWI, LCCP analyses evaluate global warming effect of solvent cleaning system by using GWP 100-year integrated time horizon (ITH). In order to construct a sustainable society, an integration of 100 years is too short to evaluate as the global warming gases such as carbon dioxide have much longer lifetimes. It means new evaluation method is necessary for selection of alternative solvent.

New concept (S-GWP), Evaluation No. (IWE), and Evaluation method (ITWE) is reported as replacing GWP, TEWI, LCCP, and LCA.

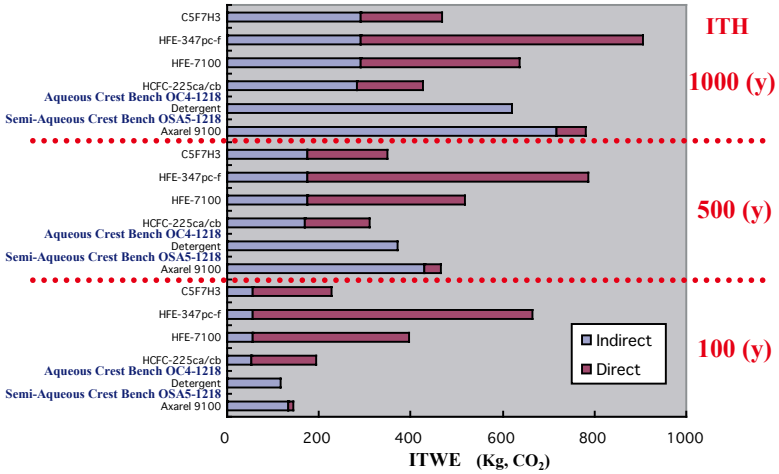
New evaluations:	Current analyses:
New concept: Sustainable GWP (S-GWP)	Global Warming Potential (GWP)
Integrated Warming Effects (IWE)	Total Equivalent of Warming Impacts (TEWI)
Integrated Total Warming Effects (ITWE)	Life Cycle Climate Performance (LCCP)
	Life Cycle Assessment (LCA)

New analysis using the unit of global warming effects for 100-year global warming of CO_2.
Current analysis using the unit of global warming effects for ITH year global warming of CO_2.

The evaluation results shows that HFC is better solvent than water cleaning.
It is opposite conclusion compared with current evaluations.

The some of the evaluation data is listed below:

ITWE : Batch Precision Metal Cleaning Processes



Calc. from the data in AFEAS 1994, p.5-5

A. Sekiya, Solvent Expo、2003, Tokyo

Fig. 2 Example of the proposed global warning index applied to cleaning agents

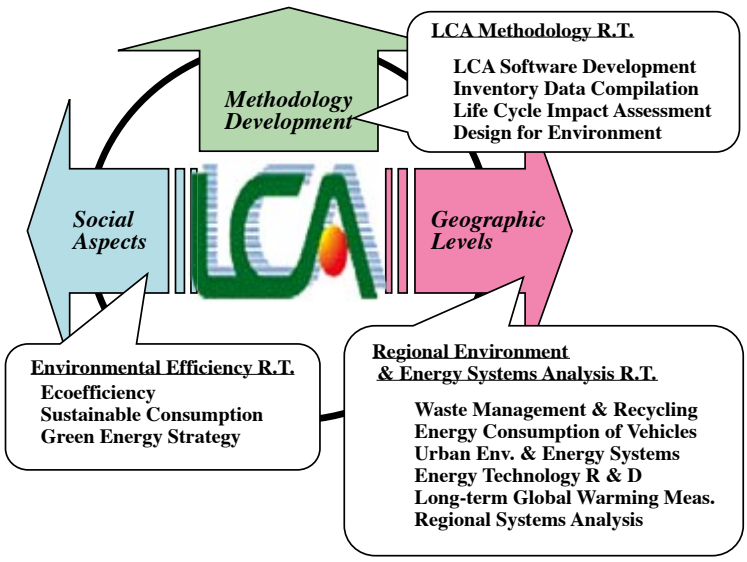


Fig. 3 Research Teams (R.T.) and their main research at LCA Center

Examples of cooperation between government, industry, and academia

The development and use of methods of assessing environmental impact in terms of a product's life cycle

Life-cycle assessments, where the environmental impact of a product or service is evaluated over its entire life cycle, are widely used as a tool for developing effective strategies for environmental improvement. Amongst different stages of the LCA process, the most important stage is that of performing life-cycle impact assessments designed to provide an evaluation of the environmental impact (e.g., on health or in terms of degradation of ecosystems) brought about by different types of environmental stresses (e.g., volumes of pollutants released or the amount of consumption of a depletable resource).

● Developing reliable and transparent methods of performing environmental impact assessments

In 1998, NEDO and the Ministry of Economy, Trade and Industry initiated a national project centered at the Japan Environmental Management Association for Industry to construct a database for use in performing life-cycle assessments. (The project was later completed in March 2003.) AIST formed a research group of environmental scientists involved in different areas (i.e., from universities and research institutions) to study ways of effectively introducing the results of leading research in different areas into the LCIA process, and this resulted in the development of a new LCIA method known as LIME, or the Life cycle Impact assessment Method based on Endpoint modeling.

● Promoting the increased use of LCA methods

It is only when they are put to use in the real world that LCIA methods begin to have any meaning. We should also always continue to work to improve the methods of impact assessment used in accordance with changes in environmental conditions and advances in environmental science. To ensure that the methods used are properly subjected to ongoing review and improvement, it is extremely important that we listen to the needs of those who actually perform LCIA assessments with regards to the methods used.

Working in conjunction with Nikkei Business Publications, in November 2003, AIST established the LCIA Special Research Group. We have performed reviews of the results obtained by participating businesses through LIME assessments, and these reviews are now being used to perform a study aimed at improvement the reliability of the LIME method.

As many as nineteen different companies—a figure which greatly exceeds our original expectations—have applied to join the LCIA Special Research Group, and we are now considering establishing two separate research groups. The results obtained will be released in environmental reports, research presentations, exhibitions, and other media and used to publicize the role of the participating companies as leading environmental businesses.

● Cooperative relationships between AIST and government, industry, and academia

As noted above, the promotion and operation of the national LCA project has provided a forum for a large number of environmental scientists to become involved in LCIA research. The LCIA methods developed will be made available to industry, and forward-looking companies will put them to work in evaluating their own business practices and products, make the results found publicly available, and provide feedback to researchers in the form of requests for ways of improving these methods. AIST will be responsible for developing new LCIA methods and coordinating all of these activities, and it is expected that providing this kind of strong support for cooperation between government, industry, and academia will lead to the early development of more advanced LCIA research and hasten the widespread adoption of the use of the LIME method and other LCIA methods.

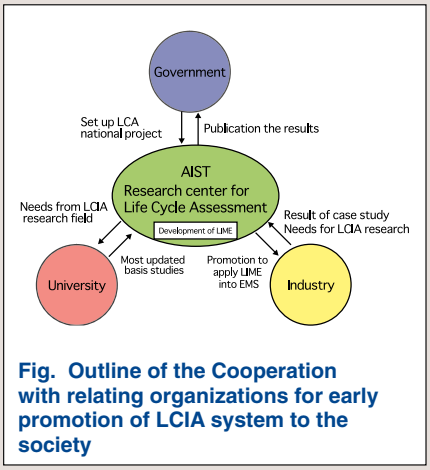


Fig. Outline of the Cooperation with relating organizations for early promotion of LCIA system to the society

An advanced industrial wastewater treatment reagent making it possible to recycle heavy metals in sludge – Joint development being performed with the Mitsubishi Environmental Resources Research Institute –

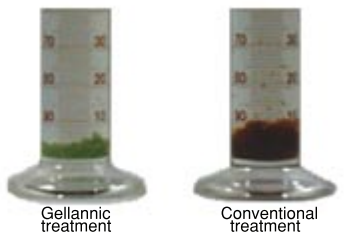
● Gellannic: From the first to the third generation

To reduce the amount of sludge generated by the treatment of wastewater containing heavy metals, working in conjunction with the Mitsubishi Environmental Resources Research Institute, AIST has developed a new advanced coagulant known by the name of 'Gellannic'. The first version of Gellannic developed consisted of a combination of alginic acid and modified chitosan as its active ingredients. An improved version was later developed in which alginic acid was the main constituent, and it is this version which is referred to as the first-generation version of Gellannic. Because the main active constituent of the product consisted of a gelling agent made from natural polysaccharides, the name 'Gellannic' was chosen as an abbreviation for 'Gel Landslide for Nixing Cation'. A second generation of Gellannic was then developed containing no natural polysaccharides. Because Gellannic can convert copper ions in wastewater into copper oxide, it can be used to obtain easily dryable sludge containing little water when compared to the types of sludge obtained using the conventional hydroxide sedimentation method. Moreover, the sludge obtained has high copper content levels of from 15 to 20 percent, and chlorine content levels are conversely extremely low in the range of 1 percent. While Japan imports massive quantities of copper ore, the average copper content of this ore is at best several percent, and this provides an indication of just how high the copper content of the sludge obtained using this method is. Finally, the sludge obtained contains little of the chlorine which would normally interfere with copper reclamation, thus making it possible to make fully effective use of copper resources. A third-generation version of Gellannic effective for fluorine and boron treatment was then developed in 2002. This third version of the product makes it possible to process fluorine (for

which regulations were strengthened in 2001) and boron (for which new regulations have been introduced) while generating only small amounts of sludge.

● A new environmental business

This joint research is being performed with not only the aim making it possible to make effective use of the waste generated by wastewater treatment, but also developing the technologies needed to do so. For some time now, the sludge generated during the treatment of wastewater containing heavy metals have been shipped to refineries to reduce the amount of sludge generated and make it possible to reclaim and reuse the heavy metals. However, the fact that the heavy metal content of sludge containing large amounts of calcium compounds is low and the fact that sludge also contains phosphorus, chlorine, and other materials which make it difficult to smelt has thus far made it impossible to reclaim heavy metals from sludge on a profitable basis. By making it possible to increase the content of heavy metals in sludge and reducing the amount of impurities contained possible was the development of a new treatment agent made from inexpensively obtained materials. We have done the work by jointly conducted development program between the National Institute of Advanced Industrial Science and Technology and the Mitsubishi Environmental Resources Research Institute, and by making effective use of the power of a general trading company, which had been previously performed separately by chemical companies, water treatment companies, and industrial waste contractors. Finally, we have made it possible to recycle heavy metal in wastewater and effluents as a resource.



Difference of the sludge amount

A compact, high-efficiency, biogas-fueled cogeneration system
– Development of a low-cost 6-kW gas engine cogeneration system –

One approach towards addressing the problem of global warming and working towards the creation of a recycling society which has gained attention is that of using methane fermentation (i.e., anaerobic digestion) technology. The use of methane fermentation makes it possible to produce organic fertilizers and biogases (with a methane content of about 60-65% and a carbon dioxide content of about 35-40%) from waste biomass from sources such as food wastes, livestock waste, and organic sludge. Some of the problems facing methane fermentation include that of using and processing the fermentation fluid and the cost-effectiveness and energy efficiencies needed in order to make effective use of biogases. There have been problems with such systems in that none of the biogas electric power generation systems developed thus far have been compact, and their manufacturing cost has been high.

To address these problems, AIST and the Aisin Seiki Co.,Ltd. embarked upon a joint research and development project to develop a cogeneration system which would be able to operate on biogas based on a 6-kW gas engine cogeneration system released by AISIN in February 2002 designed to operate on natural gas or propane. Air-fuel ratio adaptability tests of the gas engine were then performed using a low-calorie model biogas, and these tests showed that the cogeneration system could be successfully operated at a ratio of 60% methane and 40% carbon dioxide. These results showed that it would be possible to run the cogeneration system using biogas as fuel and that it would be possible to develop a cogeneration system with a 6-kW power generation capacity and the ability to use waste heat.

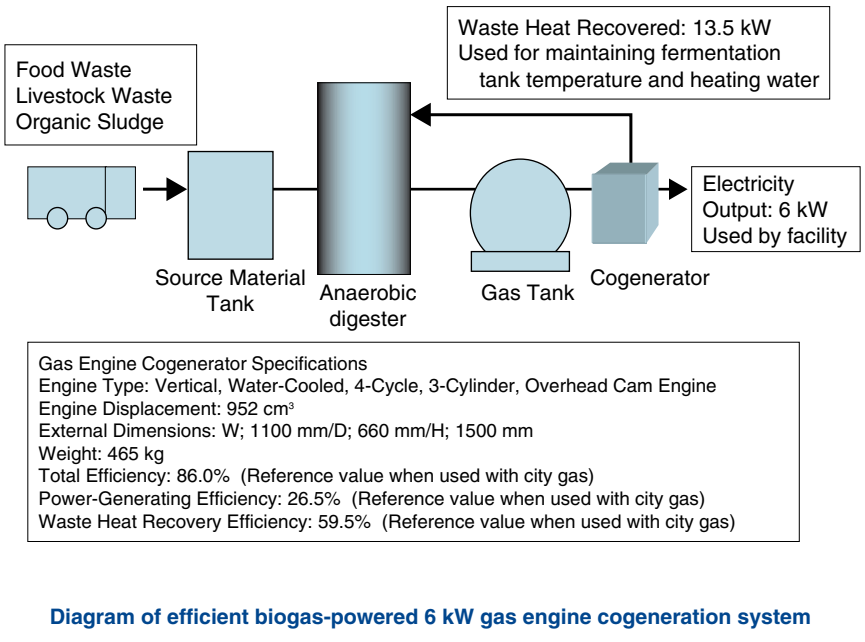


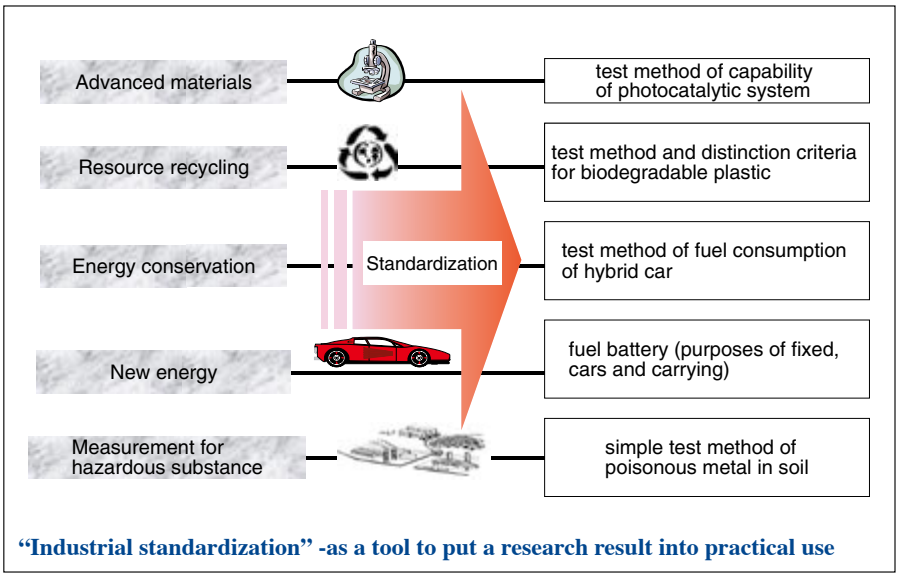
Diagram of efficient biogas-powered 6 kW gas engine cogeneration system

6kW biogas-powered gas engine cogeneration system

Work on the establishment of industrial and international standards

The ISO and IEC have published international guidelines for the inclusion of environmental aspects in product standards (ISO Guide 64 and IEC Guide 109). In Europe individual nations are now developing their own domestic guidelines for each industrial sector designed in accordance with these guidelines. European standards organizations are also taking a systematic approach to the establishment of product standards with relation to the three principles of reducing, reusing, and recycling. It is important for Japan to put more efforts in setting up standards systematically to increase the demand for recycled products, products designed with reduce, reuse, and recycling in mind, and environment-conscious products. Setting up standards is also important to provide accurate product evaluations and information in order to encourage active participation of consumers such as by purchasing environment-conscious products. Japan is currently working on devising environmental-conscious standards based on the *Action Program for Promoting Formulation of Environmental JIS Standards* published in April 2002 by the Japan Industrial Standards Committee. AIST is engaging actively in the standardization activity of environmental measurement technology which has high research potential. To be more precise, AIST is trying to promote the standardization for the safety assessments of chemicals concerned to be harmful to human health or to the environment and also for the measurement methods of the greenhouse gases dealing with the issue of global warming.

Several AIST researchers are also serving as chairs of the working group assigned with the task of preparing drafts of the initial ISO and IEC international standards recommendations or as coordinators involved in work where Japan is serving as the coordinating country for the establishment of standards. They are also providing positive contributions in order to set up the international standards.



"Industrial standardization" -as a tool to put a research result into practical use

Nonylphenol analysis methods as an example of international standardization

With respect to nonylphenol, a material which is used as a basic material in the chemical industry at the rate of 50,000 tons per year, it has been noted that the accuracy of the exhaustive extraction method currently used is insufficient because nonylphenol consists of a mixture of large numbers of isomers. Because nonylphenol has also been found to affect living organisms and has been designated as a Class 1 chemical substance under the *Law Concerning Reporting, etc. of Releases to the Environment of Specific Chemical Substances and Promoting Improvements in Their Management*, there is an urgent needed to obtain the data needed for submitting reports in accordance with the Pollutant Release and Transfer Register (PRTR) system. Since there would always be a possibility that the reliability of the analysis data used to manage the emission volumes reported by businesses could be called into question, there is a growing need for an standard method of analysis which would guarantee high levels of accuracy in the measurement of the quantities of individual substances found in these emissions. There is accordingly an urgent need to develop a highly reliable method for performing detailed analyses of different isomers so that accurate risk assessments may be performed on toxic ingredients.

In recognition of these factors, we are now working to develop advanced nonylphenol separation and measuring procedures, working to identify around 20 different isomers and impurities, and working to develop procedures for measuring environmental residues and performing component analyses using relative sensitivity coefficients, and we are also performing the research needed to make revisions to JIS standards (i.e., JIS K 0450-20-10) and provide recommendations to the ISO. Discussions are now underway at the ISO concerning the TC 147/SC 2 standard in the DIS18857-1 committee, and the problems of analyzing nonylphenol as a mixture have been noted by the committee, and it is hoped that by having Japan propose a solution it would be possible to create a new ISO testing method under Japanese leadership.

Now work on the development of advanced methods of separation and measurement is almost completed, and verification testing using environmental samples collected from watersheds from all over the country has been completed. Work is now underway on identifying the chemical structure of the ten types of isomers which have been isolated using analysis instruments which include a high-speed liquid chromatograph, a sample gas chromatograph, and a magnetic nuclear resonance machine.

In work on the creation of international standards, we have been working together in cooperation with the coordinators for the ISO TC147-SC2 standard, and at the ISO TC147 general assembly held in Britain in October 2003 we presented our proposal for a new standard analysis method which was adopted as a resolution by the SC2/WG17 working group on phenols under an agreement where it was stated that the partici-

pants welcomed the new proposal from Japan. In regard to the detailed data including the content of the technical proposal, we are now studying the question of the format in which the proposal ought to be presented in accordance with the comments we have received from the committee.

We plan to present a formal proposal as a new work item at the 2005 general assembly. Some unexpected developments include the fact that as a result of discussions held with related government ministries and agencies, companies, and other organizations concerning the requests made at the general assembly in Britain is that it has now become possible to hold the 2005 TC147 general assembly in Japan and the fact that we have received praise from the TC147 committee, and we have thus been successful in gaining recognition for Japan's contributions to the ISO.

Information on AIST research activities
Databases, software, and web pages

Research Information Database
RIO-DB
http://www.aist.go.jp/RIODB/riohomee.html
RIO-DB is a multimedia one concerning various research information, which are developed and accumulated as AIST R&D projects. Many items are published as RIO-DB (See table below.).

Database for research publications
RRPDB
http://www.aist.go.jp/aist_e/database/rrpdb/index.html
RRPDB (DataBase for Research Result Presentations) is a database, which covers various research publications of AIST. It contains published articles, oral presentations, books, databases, software, measurement standards, geosciences, events and press releases.

Database of intellectual properties (in Japanese)
IDEA
http://www.aist.go.jp/aist-idea/
IDEA (database of Information on DEvelopment of technology in AIST) provides the information of Japanese patents and utility models maintained by AIST.

Software and databases available on the web pages of individual research units
AIST offers the public access to our research activities through the Internet. All research units have the English web pages. On some web pages, you can download software or use databases.

Table : Examples of the databases in RIO-DB concerning environment and energy research

C1-Catalyst Database	It consists of a reaction data about the catalytic synthesis of ethylene glycol, ethanol and acetic acid from C1 compounds (CO, methanol).
Fluorine Compounds Database	It provides the various data (physical properties, toxicity, NMR and IR spectra, etc.) for about 800 fluorine compounds.
Energy Technology Database	It has numerous technological data concerning energy supply, energy transportation and energy demand.

AIST RESEARCH HOT LINE

UPDATES FROM THE CUTTING EDGE

(Apr.—Jun. 2004)

**The abstracts of the recent research information appeared on the Vol.4 No.4-No.6 of "AIST Today" are introduced and classified by research area.
For inquiry about the full article, please contact the author directly.**

Life Science & Technology

Molecularly Imprinted Polymer Membranes with Photoregulated Template Binding

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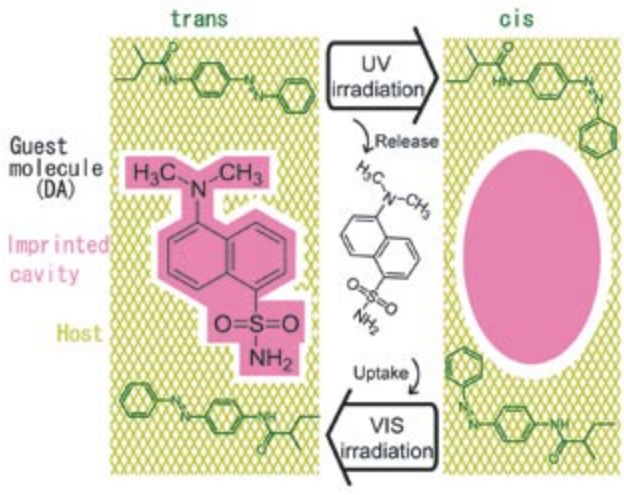
AIST Today Vol. 4, No.4 (2004) 15

Selective, stable, molecularly imprinted polymers having intrinsic photoresponsive properties were synthesized for the purpose of photoregulated binding of a predetermined ligand. For synthesizing molecularly imprinted polymers, p-phenylazoacrylanilide (PhAAAn) was used as a new photoresponsive functional monomer. Highly cross-linked, free-standing, polymer membranes were synthesized. A study of the kinetics of photoisomerization of PhAAAn within the polymer membranes showed the excellent functional stability of the membranes. Polymer membranes synthesized in the presence of the template dansylamide possess selective sites for recognizing dansylamide, and the affinity of these sites can be reversibly changed by illumination with ultraviolet or visible light.



Release/uptake of guest molecule(DA) accompanied by deformation of imprinted cavity upon photo-irradiation

Biotinylated and Enzyme Immobilized Hetero-bifunctional Latex Beads

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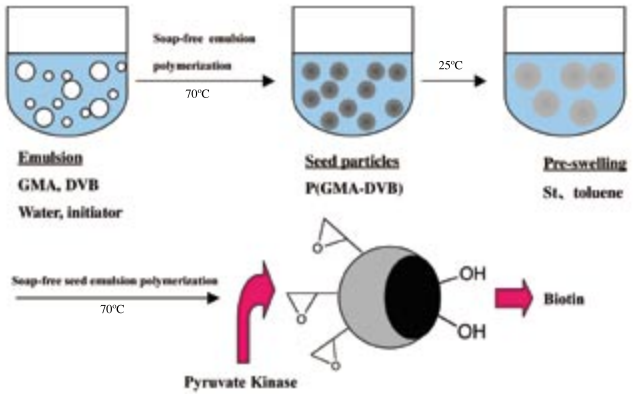
AIST Today Vol. 4, No.4 (2004) 17

A novel biotinylated and enzyme immobilized nano-bio element was first prepared by using hetero-bifunctional poly(glycidyl methacrylate-*co*-divinylbenzene)/polystyrene (P(GMA-DVB)/PSt) composite latex beads (Scheme). 5-(*n*-succinimidyloxycarbonyl) pentyl *d*-biotinamide (Biotin-X-NHS) was firstly reacted with the hydroxyl group on polystyrene domain of latex beads. Pyruvate kinase was then directly immobilized to the biotinylated latex beads through the epoxy groups of latex bead surface. The concentration of pyruvate was monitored spectrophotometrically, to obtain maximum velocity (V_{max}) and Michaelis constant (K_M) of covalently immobilized pyruvate kinase. The enzyme activity was roughly half of the free one when the concentration of substrates was 100 μM, which remained almost unchanged even after stored at 4 ˚C for 48 days.



Scheme. Preparation procedure of biotinylated and enzyme immobilized latex beads

Development of DNA Microarrays for Evaluation of Estrogen Activity

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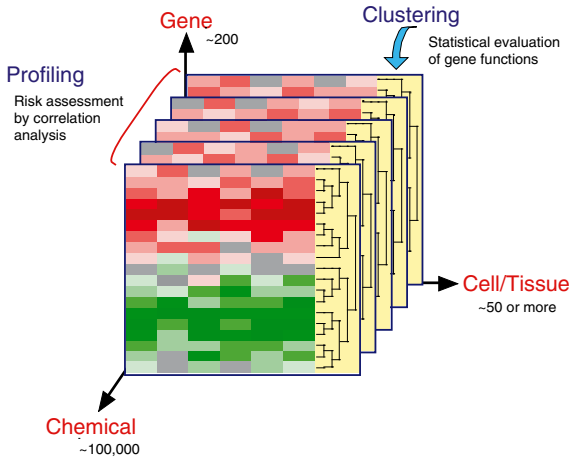
AIST Today Vol. 4, No.5 (2004) 13

We developed DNA microarrays for evaluation of estrogen activity by using human genes which are responsive to estrogen, a female hormone. A total of 203 genes were spotted on a microarray and mRNA from cells of various tissue origins was used for monitoring changes in gene expression before and after treatment of the cells with estrogen or chemicals suspected to have estrogen activity. We will apply this technology for evaluation of endocrine disruptors, screening supplements and medicines, therapeutics and others.



Profiling of gene expression and clustering of estrogen responses after treatment of cells with various chemicals for application of DNA microarray data for risk assessment or gene function analysis. Changes in the expression level of genes are indicated as red (for up-regulation) or green (for down-regulation) tiles.

Regeneration of Cartilage Tissue using an RWV Bioreactor System

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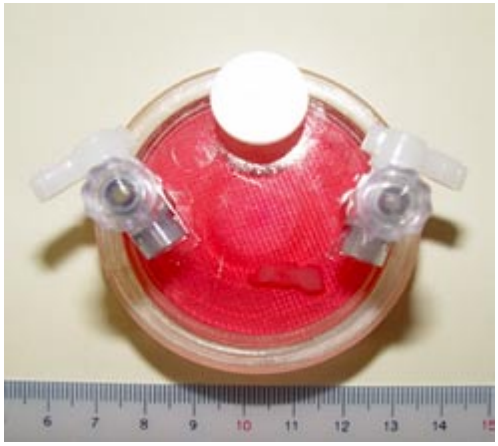
AIST Today Vol. 4, No.6 (2004) 10

Establishment of a cartilage tissue regeneration technique is needed to treat bone diseases such as osteoarthritis. However, problems such as necrosis of cells due to high-density cell culture and shear stress by gravity have not yet been solved. Thus, we examined an RWV bioreactor that simulates a micro-gravity environment. Rabbit bone marrow cells were seeded in the RWV reactor. Large cell aggregate with a longer diameter of about 1.5 cm was formed after 4 weeks. Histochemical and biochemical analysis confirmed that large and homogenous three-dimensional cartilage tissues were successfully generated without necrosis by culture of bone marrow cells in an RWV bioreactor.



Formed cartilage tissue cultured for 4 weeks in the RWV bioreactor

A Small Modulatory dsRNA Specifies the Fate of Adult Neural Stem Cells

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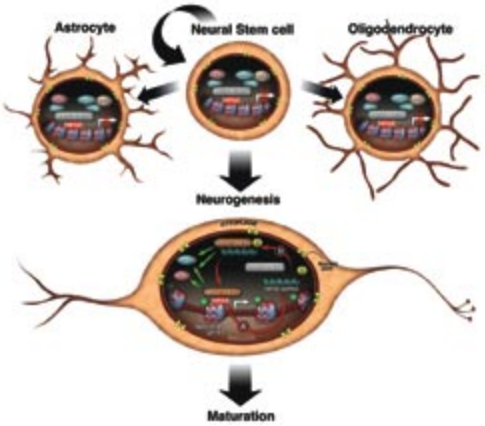
AIST Today Vol. 4, No.4 (2004)10- 12

Discovering the molecular mechanisms that regulate neuron-specific gene expression remains a central challenge for CNS research. Here, we report that small, non-coding double-stranded (ds) RNAs play a critical role in mediating neuronal differentiation. The sequence defined by this dsRNA is NRSE/RE1, which is recognized by NRSF/REST, known primarily as a negative transcriptional regulator that restricts neuronal gene expression to neurons. The NRSE dsRNA can trigger gene expression of neuron-specific genes through interaction with NRSF/REST transcriptional machinery, resulting in the transition from neural stem cells with neuron-specific genes silenced by NRSF/REST into cells with neuronal identity that can express neuronal genes. The mechanism of action appears to be mediated through a dsRNA/protein interaction, rather than through siRNA or miRNA. The discovery of small modulatory dsRNAs (smRNAs) extends the important contribution of non-coding RNAs as key regulators of cell behavior at both transcriptional and post-transcriptional levels.



Schematic representation of activation events by NRSE dsRNA. NRSE dsRNA can trigger gene expression of neuron-specific genes through interaction with NRSF/REST transcriptional machinery. This interaction results in the NRSF/REST complex no longer binding to HDACs, MeCP2, and MBD1.

Symbiotic Bacterium Changes the Plant Specialization of Host Insect

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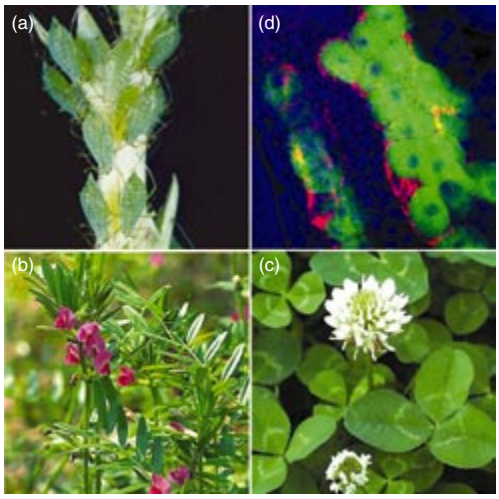
AIST Today Vol. 4, No.6 (2004) 7-9

We discovered that host plant specialization of a herbivorous insect, pea aphid, is substantially affected by a facultative endosymbiotic bacterium.

Thus far, ecological properties of an organism, such as plant specialization and environmental adaptation, have been, needless to say, simply regarded as attributes of the organism encoded by its genome. However, this discovery suggests that, although unseen and therefore unrecognized, endosymbiotic microbial communities might sometimes have a substantial influence on a variety of macroscopic biological phenomena that we observe.

Ref. Tsuchida, T., Koga, R. and Fukatsu, T. (2004) Host plant specialization governed by facultative symbiont. *Science* 303: 1989.



(A) Pea aphid, (B) vetch and (C) white clover. In Japan, the aphid mainly feeds on these plants. (D) Endosymbiotic system of pea aphid. Green, the essential symbiont *Buchnera* harbored in mycetocytes; red, a facultative symbiont called PAUS (pea aphid U-type symbiont) localized in sheath cells; blue, nuclei of host cells. PAUS infection is preferentially found in aphids on white clover, and confers a significant positive effect on the host fitness.

Information and Communication Technology

"Bayesian Network Software BayoNet: Probabilistic Reasoning and Statistical Learning"

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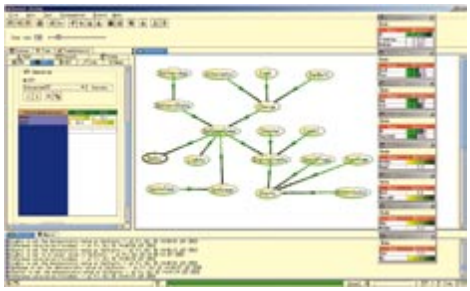
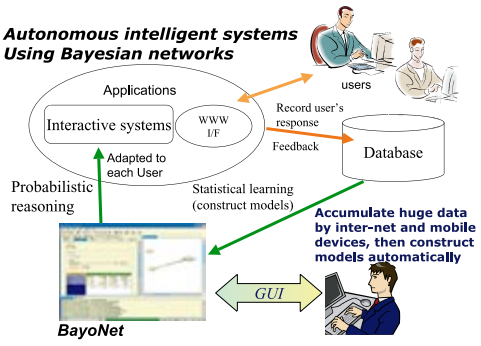
AIST Today Vol. 4, No.4 (2004) 13

Bayesian networks are probabilistic models that can be used for applications like diagnosis, trouble-shooting, prediction under uncertainty, user-modeling customer-modeling, and so on. We need suitable Bayesian network models and probabilistic reasoning methods for practical applications. Our software (BayoNet) can construct Bayesian networks from statistical data in SQL DBs or CSV files. After constructing the model, BayoNet executes probabilistic reasoning via a fast approximate algorithm for practical application systems. BayoNet has been licensed to companies. We apply Bayesian network modeling to marketing, constructing user models that can predict and apply user intentions for interactive systems.



Bayesian network software BayoNet



Application image using BayoNet

GridMPI: MPI Communication Library for the Grid

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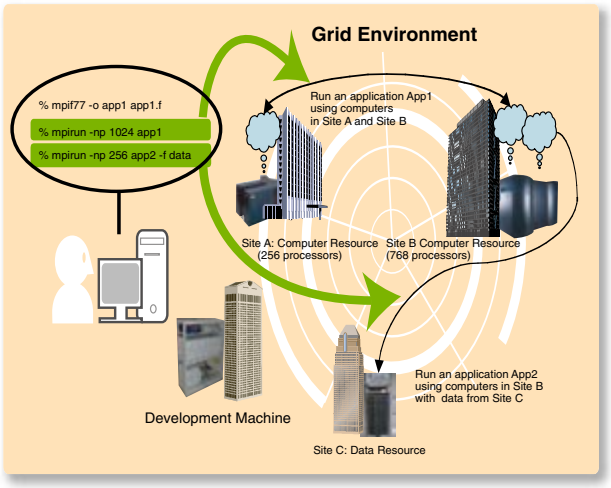
AIST Today Vol. 4, No.4 (2004) 14

The GridMPI is an implementation of the Message Passing Interface Standard (MPI) designed for high performance computing in the Grid environment. It establishes a synthesized single cluster computer environment by gathering multiple cluster computers from distant locations in the Grid. It realizes latency-aware interoperable communication, and employs optimizations in each level of the communication layers. Since it follows the widely-used MPI standard, users are allowed to develop applications using thier usual environment on a local computer, then to seamlessly deploy them to the Grid.



GridMPI Usage Scenario

Service Based Database Integration within the Grid Environment

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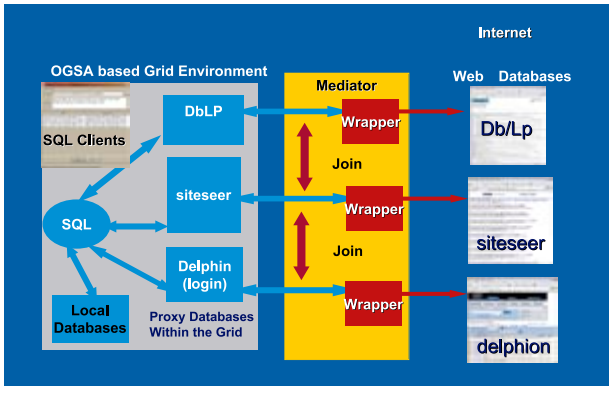
AIST Today Vol. 4, No.5 (2004) 16

Distributed and heterogeneous database integration based on Grid technology is an emerging research topic especially for scientific databases. There is currently an enormous number of databases on the web and the problem is how to interface these existing web databases easily in the Grid. We have developed a system called OGSA-WebDB which brings existing web resources into the Grid without any modifications.



System Architecture of OGSA-WebDB

Do You Know How You Drive a Car?

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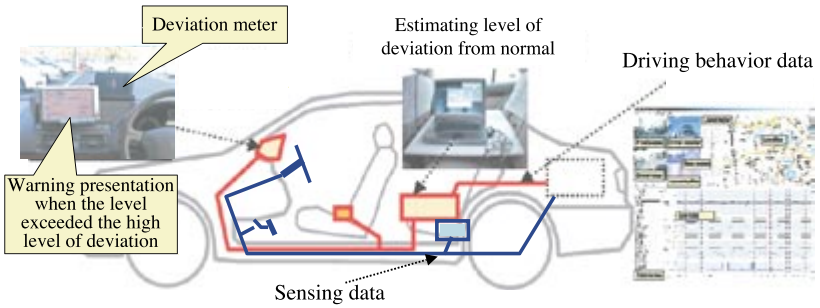
AIST Today Vol. 4, No.6 (2004) 11

In order to understand how people drive a car in a real road environment, quantitative behavioral data of a hundred drivers were collected using equipped vehicles. The collected data were stored to establish a driving behavior database for convenient use in industry. We also have applied the database to develop a driving assistance system based on the driver's behavior. Focusing on deceleration maneuver when approaching to an intersection with a stop sign, we identified range of the normal driving behavior. Based on a concept that the driving risk increases when a driving situation is out of the range of the normal driving, an on-board driving assistance system has been developed that gives a caution information to the driver when the driver behaves differently from the normal driving.



The on-board system evaluates the level of deviation from the normal driving behavior when approaching to an intersection. A large number of the braking maneuver data is stored in the on-board computer and it is compared with the sensed braking maneuver. When the maneuver at the moment is out of range of normal driving, the alerting signal is given to the driver to inform that the driving risk is increasing.

Development of the Desk-Top Type Crystal Growth Furnace

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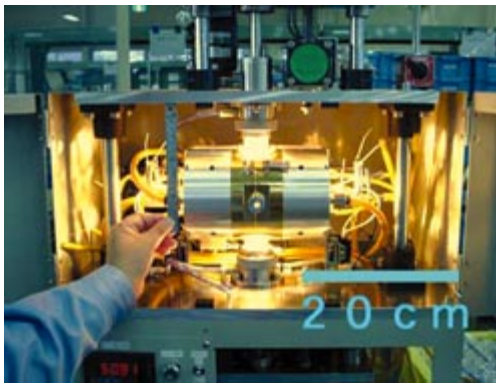
AIST Today Vol. 4, No.6 (2004) 18

We have successfully developed a desk-top type image furnace for crystal growth, smallest in the world, enabling to grow synthetic single crystals quickly for the exploration of inorganic materials and the creation of artificial jewel, such as ruby, in collaboration with NEC Machinery Corporation. The equipment can be driven by a household power outlet (100 V, 15A AC in the case of Japan) to heat up raw materials to 2,000 °C in 5 min at the fastest. In this way, you will be able to make a single crystal or artificial jewel wherever and whenever you want. The equipment will be commercialized by NEC Machinery Corporation soon.



The developed furnace which consists of double elliptical mirrors with halogen lamps

A Driver-Adaptive Driver Assistance System for Better Acceptance

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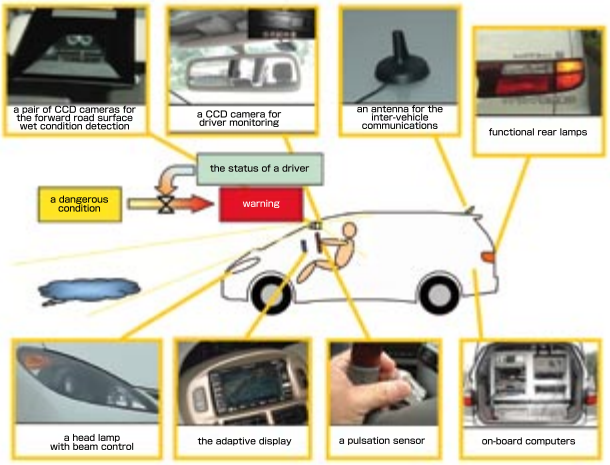
AIST Today Vol. 4, No.6 (2004) 12

A driver assistance system that helps a driver with safe driving must have better driver acceptance in order that the system may be effective. The system, "Human-centered ITS View Aid System," introduced here provides kind but not annoying assistance on a driver adaptive display. The output timing of the warning and the degree of the contents to be displayed are controlled by the status of a driver and the conditions of the forward road surface and traffic to make the display driver-adaptive. A CCD camera embedded in the rear view mirror captures the driver face to monitor the drowsy and eye casting conditions. A pair of CCD cameras detects the forward road surface wet condition, and a lidar measures the inter-vehicle distance. The conditions can be transmitted to the following vehicles over the inter-vehicle communications, and vehicles without the communication unit receive the information with the functional rear lamps, which show an emergency. In addition, a pulsation sensor for a driver, and head lamps with beam control are also included in the system. The comprehensive experiments were conducted to show the feasibility of the assistance system.



The configuration and functions of the Human-centered ITS View Aid System

Development of Grid PSE (Problem Solving Environment) Builder

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AIST Today Vol. 4, No.6 (2004) 20

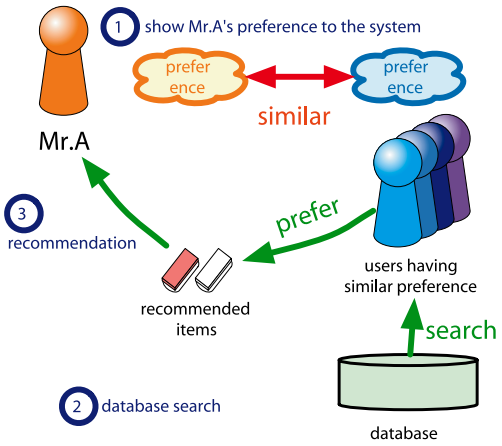
We have developed the "Grid PSE (Problem Solving Environment) Builder", a software toolkit that enables users to easily construct a portal system as an interface to the Grid ASP (Application Service Providers). The Grid PSE Builder consists of several distinct components, including single sign-on, file transfer, and job submission. Using the Grid PSE Builder, we have constructed grid portals for several commercially available software packages including Gaussian, a standard software package for quantum chemistry, and Phoenics, a computational fluid dynamics package.

An example of portal system using Grid PSE Builder

Nantonac Collaborative Filtering Methods

- Recommendation Based on Order Responses -

A recommender system suggests the items expected to be preferred by the users. Recommender systems use collaborative filtering (CF) to recommend items by summarizing the preferences of people who have tendencies similar to the user preference (see Figure). Traditional CF algorithms adopted the Semantic Differential (SD) method, in which preferences are measured using an n-point-scale on which extremes are represented by antonyms. We propose some CF algorithms adopting the ranking method. In the ranking method, the preferences are represented by orders, which are sorted item sequences according to the users' preferences. Our methods could recommend more preferable items to the users.



Collaborative filtering

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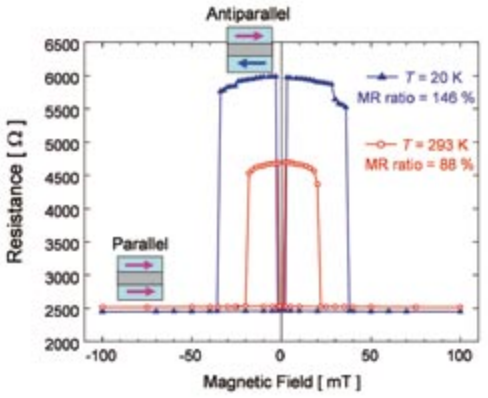
AIST Today Vol. 4, No.6 (2004) 21

The Highest Magnetoresistance Achieved in Single-Crystal Magnetic Tunnel Junctions

- Key technology for ultrahigh-density MRAM -

We fabricated single-crystal Fe/MgO/Fe magnetic tunnel junctions (MTJs) and achieved a magnetoresistance (MR) ratio of 88% at T = 293K (146% at T = 20K), the highest value yet reported. This MR ratio exceeds the theoretical limit for the conventional MTJs with an aluminum-oxide tunnel barrier. The bias-voltage dependence of the MR was very small, resulting in a high output voltage of 380 mV. This high voltage will help overcome problems in the development of next-generation ultrahigh-density MRAM.



Magnetoresistance curves of Fe/MgO/Fe tunnel junction at T = 293 K and 20 K

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AIST Today Vol. 4, No.5 (2004) 4-6

Novel Metal Membranes Permeable only to Hydrogen

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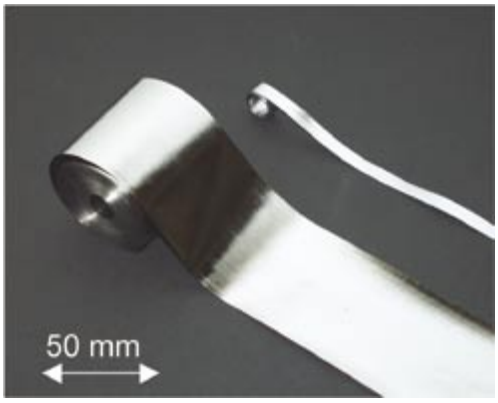
AIST Today Vol. 4, No.5 (2004) 9

Palladium membranes are permeable only to hydrogen. Producing high purity hydrogen by means of such membranes and feeding it to fuel cells as fuel, the energy efficiency of fuel cells can be improved. However, palladium is extremely expansive. We have, therefore, looked for new membrane materials to find that amorphous $Zr_{36}Ni_{64}$ alloy membranes have a practical level of hydrogen permeability and good mechanical properties even in a hydrogen atmosphere. Moreover, we have developed various amorphous alloy membranes including amorphous $Zr_{60}Ni_8Al_{15}Cu_{15}Co_2$ with a high permeability comparable to palladium. Since 2003, we have been developing a prototype of hydrogen production system using amorphous alloy membranes in METI's regional consortium project. We have already succeeded to produce amorphous alloy membranes as wide as 50 mm, using which we have successfully demonstrated hydrogen separation from gas mixture containing carbon monoxide and carbon dioxide.



Amorphous alloy membranes quenched from the melt by courtesy of MITSUBISHI MATERIALS CO.

Time series measurement of CO_2 in the Western North Pacific

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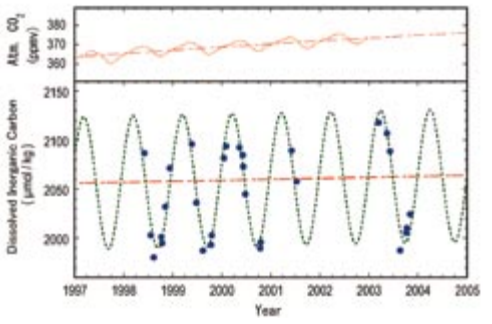
AIST Today Vol. 4, No.5 (2004) 12

Carbon dioxide concentrations in the surface seawater have been determined in the Japanese ocean time series program at station KNOT (155°E, 44°N). The seasonal amplitude of dissolved inorganic carbon was more than 100 μmol/kg (Figure), mainly due to biological uptake in summer and strong vertical mixing in winter. As a result of these large changes, surface fugacity of carbon dioxide was lower than the atmospheric value in summer and autumn, and oceanic absorption of carbon dioxide was largest in autumn when the wind velocity started to increase. The increase rate of carbon dioxide in the surface seawater was estimated at about 1 μmol/kg/year.



Time series of CO_2 in concentration in the atmosphere at Hawaii Maunaloa and in the surface seawater at station KNOT

Development of High-Speed CVD Process on SiC Homoepitaxial Growth

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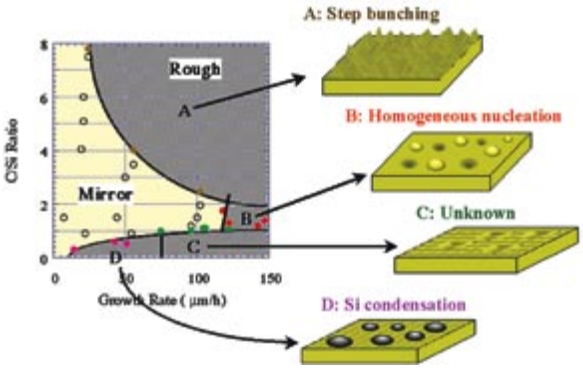
AIST Today Vol. 4, No.6 (2004) 15

We have carried out the epitaxial growth of 4H-SiC by CVD method with the various growth conditions. We found that the C/Si ratio influences strongly on the surface morphology of epilayers, and that the window of the C/Si ratio bringing about mirror-like surfaces becomes narrow with the increase of growth rate. We also found that the change from mirror to rough with the growth conditions is abrupt, and that it is important to introduce the process gases in the early growth stage. Based on these results, we have achieved two orders in magnitude higher than usual growth rates.



The relationship between the C/Si ratio and the growth rate

Development of Alternative Cleaning Agent

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AIST Today Vol. 4, No.6 (2004) 19

The development of environmental friendly alternatives to prevent the depletion of the ozone layer and global warming is necessary for a sustainable society. In this research, 6 HFEs (Hydrofluoroethers) have been developed as new alternative cleaning agents. These HFEs were selected out of 88 compounds by various evaluations such as physical properties, toxicity and atmospheric life time. Also, we developed an efficient synthetic process of HFEs using water as a solvent in the addition reaction of alcohol to fluorinated olefin.

HFE-347pc-f ($CHF_2CF_2OCH_2CF_3$) has been already commercialized, and its use will be extended further.

Evaluation of 12 fluorinated ethers for alternative cleaning agent

#	Structure RITE name	Bp (℃)	Properties	Flammability	Stability	Toxicities	Life time (year)	Selection
1	$CF_3CF_2CH_2OCHF_2$ HFE-347pc-f	45.9	○	○	○	○	5.7	○
2	$CF_2CHFCF_2OCH_3$ HFE-356pcf3	54.3	○	○	○	○	2.1	○
3	$CHF_2CF_2OCH_2CF_3$ HFE-347pc-f	56.2	○	○	○	○	6.0	○
4	$CF_3CH_2OCF_2CHF_2$ HFE-356mf2-s	65.0	○	○	○	○	-	-
5	$(CF_3)_2CHCF_2OCH_3$ HFE-458mmz	69.9	○	○	×	×	-	×
6	$CF_3CF_2CH_2OCF_2CHF_2$ HFE-449pc-f2	70.3	○	○	○	△	-	×
7	$CF_3CHFCF_2OCH_2CF_3$ HFE-449pc-f	72.7	○	○	○	○	7.0	○
8	$CHF_2CF_2CH_2OCHF_2$ HFE-356pcf	76.5	○	○	×	×	4.0	×
9	$CF_3CHFCF_2OCH_2CF_2CF_3$ HFE-54-11mec-f	87.5	○	○	○	○	6.7	○
10	$CF_3CHFCF_2CH_2OCHF_2$ HFE-458pcf	88.4	○	○	○	○	-	-
11	$CHF_2CF_2CH_2OCF_2CHF_2$ HFE-458pc-s	93.2	○	○	○	×	-	×
12	$CF_3CHFCF_2OCH_2CF_2OHF_2$ HFE-55-10mec-fc	105.9	○	○	○	○	4.8	○

Systems Analysis of PV R&D and Market Deployment

- Research on methods for supporting energy technology development planning -

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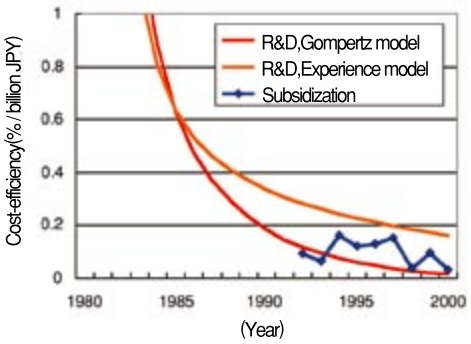
AIST Today Vol. 4, No.4 (2004) 20

To support planning of effective and efficient energy technology development, research on methods based on energy systems analysis and cost-effectiveness analysis is conducted especially focusing on photovoltaics (PV). Based on the cost-effectiveness analysis of PV R&D and subsidization, subsidy to PV capital cost is appropriately planned because subsidization is done when cost-efficiency of PV R&D is decreased well as shown in Figure. On the other hand, by using energy system model of Japan, buy-back subsidy to photovoltaics, which makes target for PV capacity attainable by achieving goal of PV system sales price, is analyzed and the results show that it becomes unnecessary if PV can be attained 170 JPY/w by 2030.



Cost-efficiency of PVR&D and subsidization to photovoltaics in Japan.

SiC Epitaxial Wafer for Ppower Devices in next Generation

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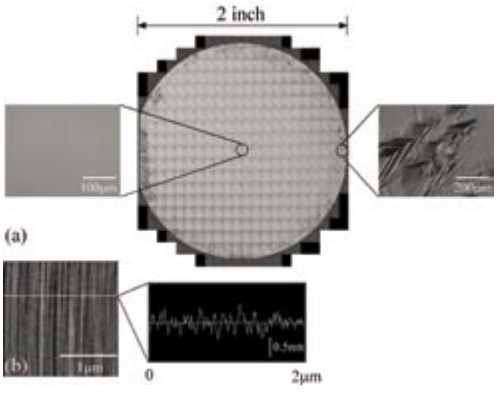
AIST Today Vol. 4, No.5 (2004)7

4H-SiC homoepitaxial growth was carried out on low off angled 4H-SiC substrate. By using (000$\bar{1}$) substrate, homoepitaxial layer was successfully grown on 2-inch 4H-SiC substrate with 0.5° off angle. The grown homoepitaxal layer showed an atomically flat surface morphology and crystal homogeneity without near wafer edge. This result solves problems on SiC power devices due to a large off angle of the epitaxial wafer.



The surface morphology of a epitaxial layer grown on a 2-inch substrate. (a) Nomarski image of whole 2-inch wafer. The surface morphology of the center and edge of the wafer is enlarged in this Figure. (b) AFM image of the epitaxial layer surface obtained at the center of the wafer.

Synthesis of Self-ordered Nanoporous Crystalline Metal Oxide Materials

- Utilization of crystalline phase opens the way to upgrading energy devices, photocatalyst devices, etc -

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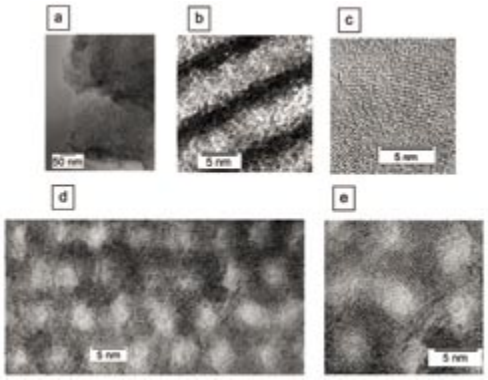
AIST Today Vol. 4, No.4 (2004) 16

Energy Electronics Institute (EEI) of National Institute of Advanced Industrial Science and Technology (AIST), succeeded first in the world to synthesize crystalline metal oxide (MO) composite porous materials, that is, composite self-ordered nanoporous materials with a framework of crystalline MO with tailored 3-dimensional structures having regularly arranged nanopores and forming a porous framework. The newly developed material is expected to be applicable to catalyst carrier, adsorbent, photocatalyst, dye-sensitized solar cell, sensor, energy storage device, and so on through the utilization of its electronic and chemical properties as well as molecular sieve features of nanopores.

NB: The result of this study was published in a British science journal, *Nature Materials*, January 2004.



The TEM images of Self-ordered Nanoporous Crystalline Metal Oxide Materials, (a), (b) and (c) for TiO_2-P_2O_5; (d) and (e) for TiO_2-P_2O_5-MnO_2

A New Route to Carbon Nanotubes

- Via the scrolling process of graphene sheets -

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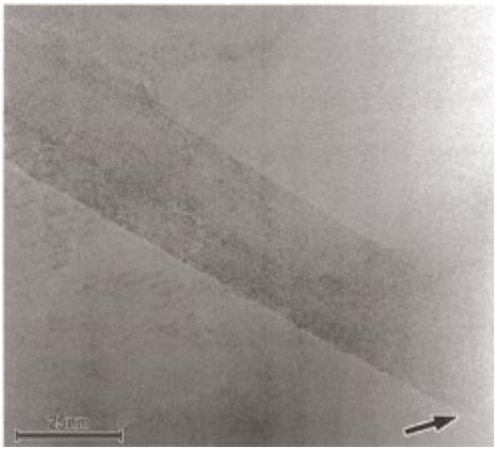
AIST Today Vol. 4, No.4 (2004) 18

Potassium-graphite intercalation compound (K-GIC), a kind of donor-acceptor complex of host graphite with potassium was allowed to react with unsaturated hydrocarbons such as stylene. Several tens of minutes after contact with the vapour of monomer, K-GIC was found to have expanded along the c-axis direction. Molecules of unsaturated hydrocarbons are considered to be introduced into the interlayer of K-GIC and polymerized progressively. This suggests that the stacked graphene layers are drawn apart. When polymer was dissolved with an appropriate solvent, a graphene sheet would be isolated. In such a case, graphene sheet will be rolled up to decrease the surface energy. In the scroll between the faced sides of the graphene sheet, van der Waals interaction is expected. The structure is quite different from that of carbon nanotubes prepared by the conventional arc-discharge or laser vaporization method.



High-resolution TEM micrograph of the scrolled-type carbon nanotube

On Demand Material Processing using Microplasma

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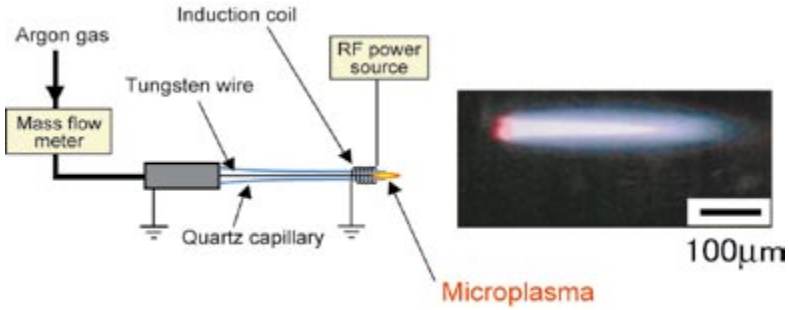
AIST Today Vol. 4, No.5 (2004)8

Miniaturization of the plasma results in the generation of a high density plasma even at atmospheric pressure with a low input energy. The novel microplasma CVD technology uses a miniaturized inductively coupled plasma generator for low temperature and ambient pressure nanomaterial processing. As examples, carbon nanotubes can be prepared without a heater; metallic nanoparticles can be deposited directly on polymer substrates. In addition, microplasma CVD can also be applied to advanced manufacturing applications for MEMS devices such as the inner wall coating of micro tubes and capillaries, and mask-less direct patterning on the micrometer scale.



Inductively coupled microplasma generator

Diamond-Like Carbon Films for Water Hydraulic Machinery

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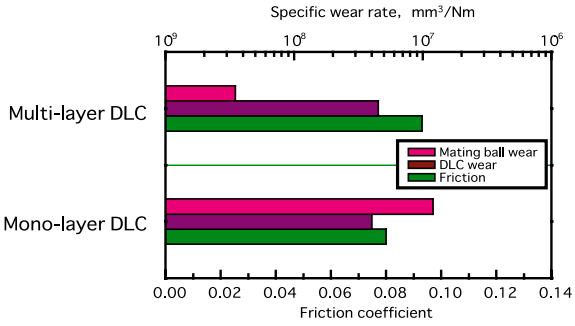
AIST Today Vol. 4, No.5 (2004) 10

To prevent the environmental pollution, water hydraulic systems are replacing oil systems. However, the systems have some technical problems, including tribology and corrosion. Many researches have demonstrated that diamond-like carbon (DLC) films have excellent tribological properties under unlubricated conditions. We have developed DLC films covered with Si-doping DLC layer using a plasma-enhanced CVD technique and evaluated their tribological properties in water environment. They had a low friction coefficient of less than 0.1 and a very small wear rate of 5×10^{-8} mm^3/Nm. Moreover, they showed good adhesion to the substrate.



Friction and wear of DLC films in water

Towards Ultimate Vibrational Spectroscopy with Single Molecule Sensitivity and Spatial Resolution

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AIST Today Vol. 4, No.6 (2004) 13

We have studied to establish an ultimate vibrational spectroscopy relevant for *in situ* characterization of single molecules at solid/liquid interfaces. The blinking of SERS (Surface Enhanced Raman Scattering) arises from thermal diffusion of adsorbed molecule between junction and other ordinary sites as evidenced from correlation between Raman and elastic scattering spectra in addition to temperature dependence and local field evaluation. Exploiting SERS of underlaid silver films, Raman images with ca. 50 nm in spatial resolution were obtained simultaneously with topography using chemically etched optical fibers under an attenuated total reflection configuration.

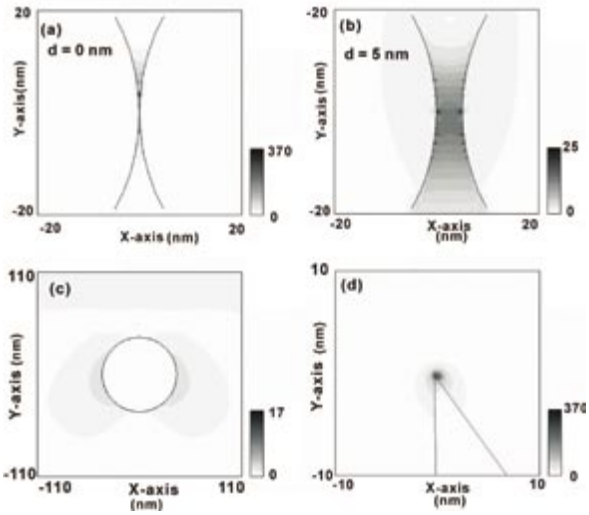

Figure electric field distribution (amplitude) for various Ag nanostructures: adjacent circular tubes (r = 40 nm) with the gap size of (a) 0 nm, (b) 5 nm, (c) isolated tube (r = 40 nm), and (d) triangular edge. Excited at the resonance wavelengths of 480 nm (a, b), 380 nm (c) and 430 nm (d). The enhancement > 330 yields single molecule sensitivity in Raman scattering.

Polytype Control of SiC Heteroepitaxial Films by Pulsed-Laser Deposition

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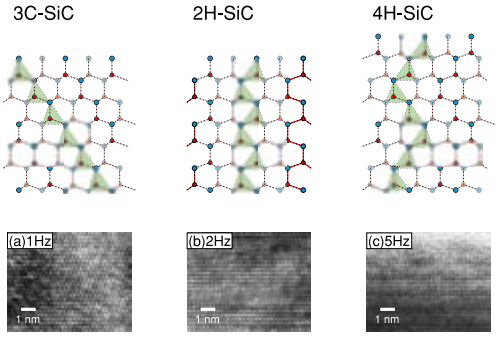
AIST Today Vol. 4, No.6 (2004) 14

Polytype formation of SiC heteroepitaxial films is controlled using pulsed-laser deposition (PLD) technique. The 3C, 2H, and 4H-SiC films are fabricated on sapphire substrates at a low temperature of 1100°C. Transmission electron microscope images clearly show that each film consists of a single polytype. The SiC polytype of the films can be changed by varying only a single parameter: the laser pulse frequency. The result suggests that precise control of the growth conditions, which is essential for polytypic materials, is possible using the PLD method. Our technique allows new application of SiC electronics such as high-temperature, high-power, and high-speed heterostructure devices.



Crystal structure of 3C, 2H, and 4H-SiC polytypes (upper) and high resolution images of SiC films fabricated at different laser pulse frequencies (lower)

Selective Purification of Semiconducting Single Wall Carbon Nanotubes

- STM revealed the effect of hydrogen plasma treatment -

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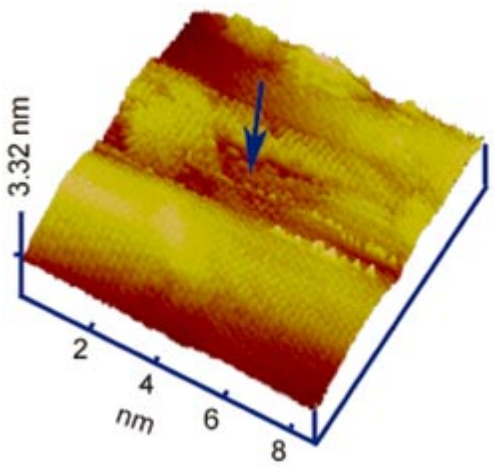
AIST Today Vol. 4, No.6 (2004) 16

Selective purification of semiconducting single wall carbon nanotubes has been long-awaited key technology. The effect of hydrogen plasma treatment was studied through direct observation using scanning tunneling microscope. We discovered that hydrogen plasma causes serious damages to the metallic carbon nanotubes while leaving semiconducting ones intact. This finding may lead us to a new technology for preferential preparation of semiconudcting single wall carbon nanotubes.



STM image of the surface of metallic carbon nanotubes after hydrogen plasma treatment.
An arrow indicates defects caused by selective etching.

The Fabrication of Microarrays on Fused Silica Plates using the LIBWE Method

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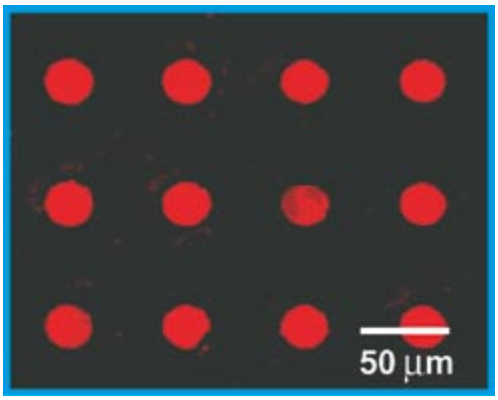
AIST Today Vol. 4, No.6 (2004) 17

Using laser-induced backside wet etching (LIBWE) technique, microstructures were fabricated onto the surface of fused silica plates, which were pre-coated with self-assembled monolayers (SAMs). Dye molecules, proteins, and polystyrene microbeads were alternately deposited onto the laser-irradiated or nonirradiated areas by either chemical bonding or physical adsorption.

1) J. Wang, H. Niino, A. Yabe, Appl. Phys. A, vol.68, pp.111–113 (1999); JP-Patent: No.3012926.
2) X.Ding, Y.Kawaguchi, T.Sato, A.Narazaki, H.Niino, *Chem. Commun.*, No.17, pp.2168-2169 (2003).



Fluorescence images of a protein layer on the surface of fused silica plates. The inside of the cycles corresponds to the LIBWE-etched cavities.

Development of Magnetic Force Microscope with World Finest Resolution

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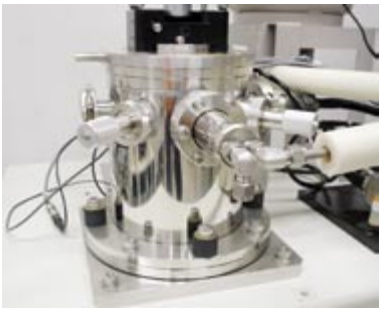
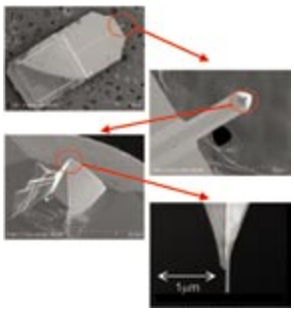
AIST Today Vol. 4, No.6 (2004) 4-6

While the development of new generation magnetic storage medium requires an instrument to characterize magnetic nanostructures finer than 20 nm, none of standard apparatus with such performance was available. New magnetic force microscope (MFM) and the MFM probe have been successfully developed. The probe was fabricated by use of carbon nanotube and technology for vapor depositing magnetic materials, leading to characterization of magnetic storage medium with 10 nm resolution. The newly developed MFM is expected to become a powerful research tool in areas of magnetic storage and spin electronics. This work was performed in AIST in collaboration with SII Nanotechnology and Fujitsu Ltd. under Nanotechnology program, NEDO.

(a) 

(b) 

(a) A newly developed magnetic force microscope. (b) SEM images of the new MFM probe. Red arrows mean the expansion of the image. The thin segment represents the carbon nanotube coated with a magnetic film. The diameter is about 40nm

Mechanical Engineering and Manufacturing Technology

MZ Platform: Design and Manufacturing Software Development System

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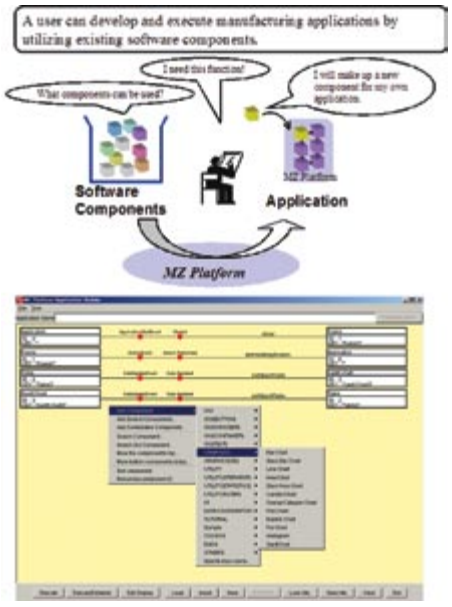
AIST Today Vol. 4, No.4 (2004) 23

Systematization and digitization of manufacturing processes by introducing information technology (IT) tools is regarded as a key approach for increasing manufacturing companies' competitiveness. In order to support them to build manufacturing software applications for their own use, we have developed a component-based software development framework, named "MZ Platform". It provides manufacturers with a set of software components that carry out unit functions. Users can develop an IT tool by integrating those small software components into a large software system. Its advantage of reducing the time and the cost of building manufacturing software system has been proven through several case studies.



Outline of MZ-Platform

Development of Vacuum Ultraviolet Circular Dichroic Technology

- A breakthrough technique using AC modulated polarizing undulator -

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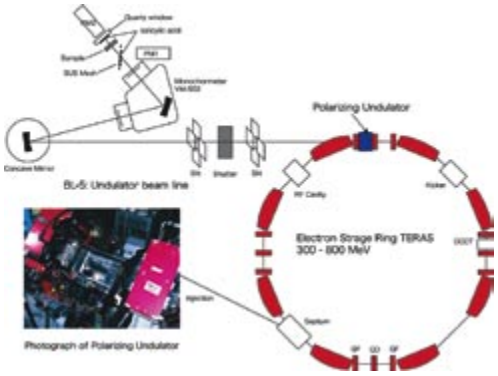
AIST Today Vol. 4, No.4 (2004) 21

Circular dichroism (CD) is an optical measuring technique based on difference in polarization responses among different bio-polymer species. CD is caused by difference in response to left- and right-handed circular polarization depending on molecular structures, and exhibits spectra highly sensitive to 3D structure of bio-polymers. The AIST developed modulated polarizing undulator (SOR device) by using an electron storage ring, TERAS based on an original concept. With this SOR device, the AIST developed CD technique for identifying 3D structure of amino acids. Since the TERAS can produce AC-modulated polarized radiation of wavelength as short as 40 nm, it is expected to have CD measurement extended to 40 nm. The new technique has made it possible to measure CD in the VUV region, and is expected to contribute to determination of 3D structures of bio-polymers and acceleration of the development of chiral medical drug to eliminate drug-induced suffering.



AIST electron storage ring TERAS and polarizing undulator

Monochromatic X-ray Excitation X-ray Fluorescence Spectrometry as a new SI Traceable Method

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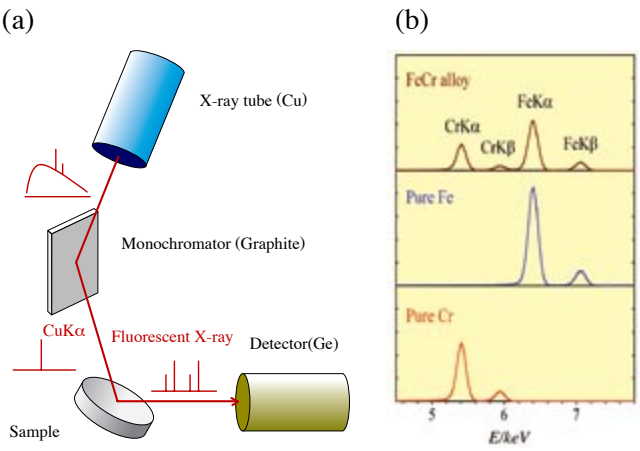
AIST Today Vol. 4, No.4 (2004) 22

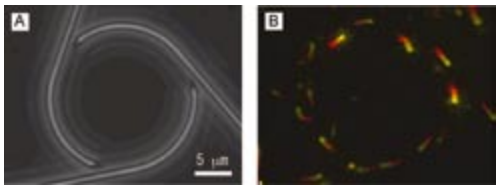
Monochromatic X-ray excitation X-ray fluorescence spectrometry was developed as a new SI traceable method (primary method of measurement). For the validation of the method, the certified reference materials such as FeCr alloys and sediments were analyzed. The evaluation of the uncertainties was carried out. The analytical results were in good agreement with the certified values within the uncertainties. Schematic drawing of the system and typical spectra are shown in Fig. (a) and (b) respectively. This method is non-destructive, and is used for various reliable measurements.



Schematic drawing of the system(a) and typical spectra(b)

Controlling the Direction of Movements by Protein Molecular Motors

The kinesin molecular motor moves unidierctinally along microtubules that serve as filamentous tracks. By fabricating micrometer-scaled troughs on glass surfaces and by adding arrowhead-shaped patterns to the troughs, we were able to realize unidirectional, one dimensional movements of microtubules. The gliding bacterium *Mycoplasma mobile* is another attactive material of nanoactuators. By taking advantage of these cells to move along walls of lithographic patterns, we have succeeded to make them move unidirectionally along lithographic tracks. These unidirectional movement systems should be foundation of a micro-belt coveyer system to be used in, for example, miniature chemical plants.



Unidirectional movement of *M.* mobile cells along circular tracks. **A**, Scanning electron micrograph of a part of the repetitive broken circular patterns. **B**, Overlay of five consecutive fluorescence micrographs taken at 0.33 s intervals. The color gradient shows the counter-clockwise rotation of all 13 cells along the circular track (time sequence: yellow to orange to red).

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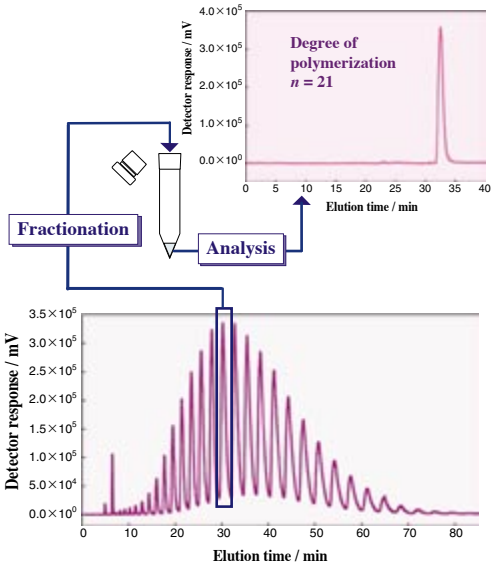
AIST Today Vol. 4, No.5 (2004) 14

Precise Quantitative Analysis using Uniform Oligomers

Uniform oligomers are special polymers with no molecular weight distribution. We separated uniform oligomers from commercial monodisperse samples by preparative super-critical fluid chromatography. Using equimolar mixtures of uniform oligomers, we showed it possible to evaluate the quantitativeness of matrix-assisted laser desorption/ionization time-of-flight mass spectrometry for analysis of molecular weight distribution of a monodisperse polymer sample. Uniform oligomers are also useful to know exact values of physical properties of polymers. We measured their diffusion coefficients and radii of gyration in dilute aqueous solutions and have shown clear molecular weight dependence of these properties.



Preparative super-critical fluid chromatograpy (SFC) chromatogram for poly(ethylene glycol) 1000 (bottom) and analytical SFC chromatogram for a separated uniform oligomer with the degree of polymerization $n = 21$ (top)

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AIST Today Vol. 4, No.5 (2004) 15

NMIJ/AIST Succeeded in Increasing the Accuracy of the Avogadro Constant

- Contribution to the fundamental physical constants and opening a way for replacing the kilogram -

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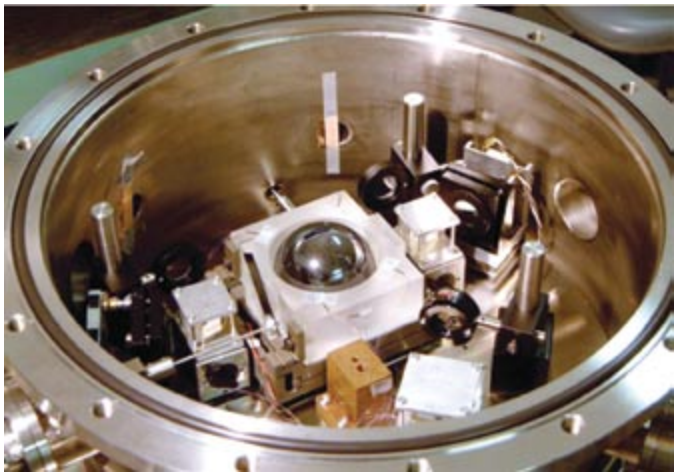
(2004) 7-9

A more accurate value of the Avogadro constant is of primary importance because fundamental physical constants, such as the Planck constant, Boltzman constant, elementary charge, and Josephson constant, are so closely related to the Avogadro constant that its accurate value is indispensable for determining the fundamental physical constants used in physics and chemistry. In the field of metrology, the kilogram is the only SI base unit still defined by a material artifact made of a platinum/iridium alloy. For replacing the present definition of the kilogram by defining the number of atoms, a more accurate value of the Avogadro constant is needed. A determination of the Avogadro constant by the x-ray crystal density (XRCD) method has therefore been conducted at the National Metrology Institute of Japan (NMIJ), AIST, where the lattice constant, density, and molar mass of a silicon crystal are measured in conformity with the definition of the SI units. The photograph shows an optical interferometer used to measure the diameter of a single-crystal silicon sphere. This interferometer determines the volume of the 1 kg silicon sphere with an uncertainty of better than 0.1 ppm. From the known value of the lattice constant, it determines the number of atoms in this sphere. By combining this number with the mass data for the silicon sphere, it leads to an accurate value of the mass of a single Si atom. Recently, a research group led by K. Fujii succeeded in increasing the accuracy of the Avogadro constant; NMIJ measured the density and lattice spacing, and an European Joint Research Center, the Institute for Reference Materials and Measurement (IRMM), measured the molar mass of the silicon crystal. The Aogadro constant was thus determined to be $6.022\ 1375 \times 10^{23}$ mol^{-1} with a standard uncertainty of 0.2 ppm, the best accuracy ever achieved by the XRCD method (see *IEEE Trans. Instrum. Meas.*, 52-2, 2003, 646-651). The data was reported to the CODATA Task Group on Fundamental Constants as one of input data for finding a best set of the fundamental physical constants, and the new set of the constants was issued in December 2003. This research is now organized as an international project with the PTB (Germany), IMGC (Italy), IRMM (EU), CSIRO (Australia), NPL (UK), NIST (USA), and BIPM (France) for replacing the kilogram. This project, scheduled to continue till 2010, uses an isotopically enriched silicon crystal ^{28}Si to further increase the accuracy of the Avogadro constant by a factor of ten, and will realize the dream of the Metrologist in the near future.

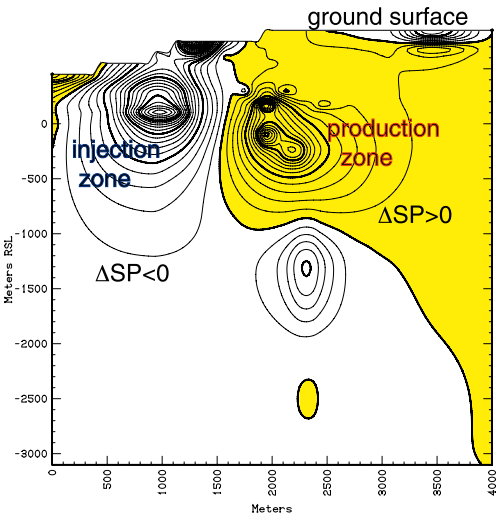


Optical interferometer to measure the diameter of a 1 kg silicon sphere

Reservoir Dynamics Research

- Monitoring and prediction of subsurface fluid flow -

Mathematical postprocessors have been developed in cooperation with NEDO to calculate time-dependent earth-surface distributions of geophysical observables such as microgravity, electrical self-potential, apparent resistivity (from either DC or MT surveys), seismic velocity/attenuation, and geomagnetic force. The temporal changes are caused by changing underground conditions (pressure, temperature, salinity, gas saturation, etc.) as computed by numerical unsteady multidimensional thermohydraulic reservoir/aquifer simulations. Although the initial application was for monitoring geothermal reservoirs during fluid production and reinjection, the postprocessors can be applied to various subsurface phenomena associated with groundwater in addition to management of geothermal resources.



Self-potential cross section calculated by "EKP-postprocessor"

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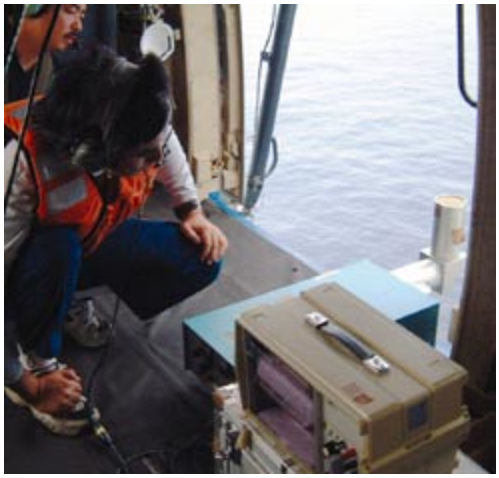
Monitoring of Gigantic SO_2 Emission from Miyakejima Volcano

An extremely large amount of volcanic gas has been released since mid-August 2000 from the volcanic island of Miyakejima, Japan, after formation of a summit. Variation of the SO_2 emission rate was monitored by repeated measurements with airborne COSPEC. In 2000, the SO_2 emission rate averaged at 42 kt/d, which is twice the global SO_2 emission rate from nonerupting volcanoes evaluated before this activity. The SO_2 emission rate gradually decreased to 7 kt/d by the end of 2002 and then remained constant until at least March 2004. The total SO_2 emission amounts to 19 Mt.



Monitoring of volcanic SO_2 using the COSPEC instrument

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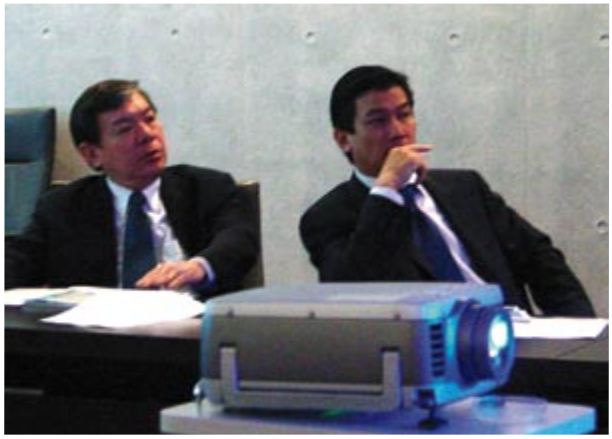
AIST Today Vol. 4, No.5 (2004) 11

Thai Vice-Minister for Commerce Tours AIST Tsukuba

Vice-Minister for Commerce Panpree Bahiddha-Nukara (pictured right) of the Kingdom of Thailand toured AIST's Tsukuba facilities with his staff on May 27, 2004. Following a welcoming speech by Trustee Tatsuo Katsura, Vice-Minister Bahiddha-Nukara delivered an address, noting that his visit to AIST reflected the Thai government's deep interest in Japanese industrial technology. The vice-minister's speech was followed by presentations providing an overview of AIST and explaining research being conducted in the fields of biotechnology, energy, and nanotechnology/materials. The vice-minister's tour of AIST's research sites included the Solar Energy Research site and the Diamond Research Center, where he was shown a diamond membrane.

After the tour of research sites, there was an explanation of AIST's intellectual property management and licensing system, followed by a lively question-and-answer session.



Hanover Messe 2004

The international trade fair Hanover Messe 2004 was held for six days, April 19–24, in Hanover, Germany,

Hanover Messe is one of the world's largest trade shows, bringing industries of all kinds together under one roof. This year the fair had 5,040 exhibitors and drew approximately 180,000 visitors. AIST's exhibit in the Research and Technology Hall took "energy and the environment" as its theme and featured such technologies as photocatalysis, ice thermal storage, exhaust purification, biodegradable plastics, and CO_2 separation, all with the aim of promoting technology transfer. European companies and academic and research institutions showed particular interest in AIST's environmental technology, while the energy-related exhibits attracted the attention of companies in tropical and subtropical countries. In all, the exhibit was successful in fostering technology transfer, leading to talks with several companies on licensing, joint research, and commissioned research, as well as inquiries regarding the products of AIST ventures.

Managing Director of French Atomic Energy Commission (CEA) Visits AIST Tsukuba

On April 20, 2004, Mr. Alain BUGAT, Managing Director of French Atomic Energy Commission (CEA) visited AIST Tsukuba. CEA is the second largest research institute in France. Dr. Kisaburo KODAMA, Senior Vice President of AIST, explained the introduction of AIST and research of the AIST. Mr. BUGAT had a discussion on research and budget and talked amicably about the future collaboration between both countries. Afterwards, he toured the Nanoarchitectonics Research Center, where

he had an overview of the center and introduction of a lipid nanotube by Dr. SHIMIZU, Director of the Nanoarchitectonics Research Center. Moreover, Mr. BUGAT toured the Advanced Semiconductor Research Center, where he had an overview of the Millennium Research for Advanced Information Technology Project (MIRAI Project) by Dr. HIROSE, Director of Advanced Research Center. He visited a super clean room, a world-class clean room for research.

AIST at "nano tech 2004" International Nanotechnology Exhibition & Conference

The "nano tech 2004" International Nanotechnology Exhibition & Conference was held at Tokyo Big Sight (Tokyo International Exhibition Center) from March 17 to 19, 2004. The nanotechnology fair was a major success, boasting the participation of 198 domestic and 62 international business and research organizations and drawing more than 32,000 visitors.

The AIST booth at the fair exhibited 30 products of Institute research in a range of fields, including device technology, environmental technology, materials, nano processing, and assessment technology. Presentations on 14 of those were given on a stage inside the booth over a period of two days. In the general exhibition area, one of the exhibits attracting the most attention was an AIST technology that kept 30 species of ocean and freshwater fish alive for an extended period of time in a sealed tank containing nanobubbles of oxygen; AIST was awarded the biotechnology prize for development of a new technology for manufacturing nanobubbles. The conferences held in conjunction with the exhibition included the First International Symposium on Standard Materials and Metrology for Nanotechnology and the Nano-Biz-Bio 2004: AIST Symposium on Industrial Nanotechnology, both of which drew enthusiastic crowds.

AIST and CAS Conclude a Comprehensive Agreement and Hold a Joint Symposium

Based on the recognition that further development of industrial science and technology is indispensable to realize "sustainable development", AIST is carrying out research activities whose fields range from techno-infrastructure to high technology. Because all fields including the economy are globalized, it is impossible to realize "sustainable development" within one country so international cooperation is essential.

As a part of international cooperation activities, AIST is seeking the collaboration with major research institutes in the East Asian region, which has the highest economic growth rate in the world. AIST signed a comprehen-

sive research collaboration agreement with the Chinese Academy of Sciences (CAS), representing research institutions in the People's Republic of China (P.R.China).

CAS, founded on November 1st, 1949 just after P.R.China was established, is the highest academic institution in China and one of the national organizations equivalent to a ministry. The Academy covers a wide range of research fields including basic science, life science and biotechnology, resources and environment, and high-tech R&D with about 50,000 staffs, 84 affiliated institutes and dozens of technology supporting units all over China. In addition, CAS has invested and set up more than 430 science and technology enterprises.

The signing ceremony was celebrated on May 19, 2004 at AIST Tokyo Waterfront with the presence of Prof. Hiroyuki YOSHIKAWA, President of AIST and Prof. Yongxiang LU, President of CAS.

In commemoration of the agreement conclusion, "AIST/CAS Joint Symposium" was held on the same day at the National Museum of Emerging Science and Innovation, Odaiba, Tokyo. The symposium's main subject was on the collaboration between industry and research. There were about 200 people mainly from enterprises who have an interest in collaboration with China.

At the symposium, Prof. LU and Prof. YOSHIKAWA made keynote lectures titled "Development in Harmony with Man and Nature", "Scientists' Role to Realize Sustainable Development for Mankind", respectively. Both lectures emphasized "Sustainable Development" as a keyword and stated the role of scientists and institutes is to realize "Sustainable Development". The lecture of Prof. Ming TIAN, Deputy Director General, Bureau of Science & Technology Policy, CAS titled "Chinese Academy of Sciences -- Overview, Knowledge Innovation Program, Talent Training" mentioned the historical overview of CAS, Knowledge Innovation Program that started in 1998 aiming at efficiency and improvement of science and technology on a national scale, and CAS's policy to strengthen human resource training. The lecture of Mr. Masanori YOSHIKAI, Vice President of AIST titled "AIST and the Creation of a New Industry" noted the change of the mission from the Agency of Industrial Science and Technology (former AIST) to the National Institute of Advanced Industrial Science and Technology (present AIST), commercialization of research results and philosophy of new industry creation, and meaning and specific plans of collaboration between AIST and CAS. The lecture of Mr. Qin ZHAO, Director, Bureau of High-Tech Industry Development, CAS titled "Promotion of High-Tech Industry Development at CAS" explained that CAS considers commercialization of research results to be important and gave an actual example of "Lenovo Group Limited" which was spun off from CAS to be a representative IT-related company in China. The last special lecture of Mr. Hiroshi KUWAHARA, Chairman of the Board, Hitachi Maxell, Ltd.; Former Member of Council for Science and Technology Policy titled "Expectation for Collaboration between AIST and CAS" mentioned the meaning and expectations of the collaboration by both sides through the specific proposals of cooperation. We think that this symposium was beneficial especially for people from the private sector.

While in Japan, President LU and his party visited several research laboratories at AIST Tsukuba and Tokyo Waterfront, exchanged opinions with AIST executives, and met with political and academic leaders like the Minister of Economy, Trade and Industry, Mr. Shoichi NAKAGAWA.

It is expected that this comprehensive agreement will accelerate specific collaborations between the institutes.

http://www.aist.go.jp/aist_e/event/ev2004/ev20040519/old_ev20040519.html

Deputy Director of Vietnamese Sci-Tech Academy Visits AIST

On March 5, 2004, Nguyen Khoa Son, deputy director general of the Vietnamese Academy of Science and Technology (VAST), visited AIST Tsukuba. VAST, which was called NCST until January this year, is a ministry-level organization directly under the prime minister encompassing 21 research institutes. Deputy Director Nguyen and others visited AIST previously in May 2003, exchanging ideas on a possibility of a research cooperation agreement with AIST Vice-President Kisaburo Kodama and others.

In response to the growing consensus within AIST supporting an Asia-centered international strategy, a group led by Akio Nishijima, deputy director of AIST's International Affairs Department, visited VAST in February this year to hold working-level consultations on a cooperation agreement and explain research topics recommended by the Institute's research coordinators and unit heads as feasible candidates for cooperation. During the most recent visit, VAST's deputy director general, the head of its planning division, and the head of its international division met with AIST supervising researchers to make specific proposals and trade views on research cooperation based on the themes earlier suggested by AIST. Plans for cooperation between AIST and VAST can be expected to begin taking shape in the months ahead.

Asia Nanotech Forum Summit

The Asia Nanotech Forum Summit 2004 (ANFoS2004), jointly sponsored by AIST and Thailand's National Science and Technology Development Agency, was held May 10–11, 2004, in Phuket. The event brought together some 50 researchers and policy makers from Japan, Thailand, Australia, China, Hong Kong, India, South Korea, Malaysia, Singapore, Taiwan, and Vietnam to discuss such topics as research trends in each country, priority areas for research, and international cooperation. Thailand's Minister of Science and Technology Korn Thapparansi delivered an address at the conference.

The summit produced an agreement to maintain a network with AIST as the hub and a decision to hold the next summit in China.

On May 12, the venue shifted to Bangkok for the Thailand Nanotech Business Forum for CEOs. Corporate leaders from Thailand and other countries were invited to participate in and attend lectures and panel discussions on nanotechnology's significance for business.

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