



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

Research Information Database

Technology Information Department Research Database Office Yoichi HAMAZAKI

The databases have been constructed based on study results by AIST

In the promotion of research and development projects, substantial data are often accumulated unknowingly while collecting various data and conducting experiments and measurements systematically and cyclopaedically. Although discoveries and new findings derived from these data are disclosed in research papers in the form of study results, the accumulated data themselves have little chance of being widely utilized. The Research Information Database (RIO-DB) is the name of the project to input the valuable data and study results accumulated in these research procsses into databases and to disclose them via the Internet to be used widely as an intellectual foundation for the sake of promulgation. The aggregate of numerous databases constructed based on research results by the RIO-DB project is called RIO-DB also.

Feature

The RIO-DB project was started in 1995. Study results and factual data owned by research laboratories controlled by the Agency of Industrial Science and Technology were presented as databases to be used widely by the public and eventually to contribute to promoting industrial development and technological advancement. In fiscal 2001, this project was taken over by the National Institute of Advanced Industrial Science and Technology(AIST), and we are currently promoting database construction and fulfill-

RIO-DB covering wide research field

Recently, thanks to the development and promulgation of the Internet, it is possible to use vast amounts of data without time and place constraints. Enhanced by the remarkable promulgation of the personal computer, the importance of the data available on the network and their competitive edge over printed matter has been increasing. At the same time, due to the increased number of accesses, the importance of presenting study results in database form has been increasing year by year. With this in mind, since 2001, we have been working to generate a valuable database for use as an intellectual database. In selecting the category of the database, more importance is assigned to large-scale databases to be constructed over time, geology-related databases, and characteristics databases that can be presented by AIST only and are frequently requested by industry and academic sectors. The databases thus constructed are successively being made public, while old databases no longer being updated are being disclosed as archives.

An exciting challenge in the construction of the RIO-DB is to lead the database world while the number of ac-



Fig. 1 Yearly change of the number of disclosed databases and the total access count of RIO-DB

ment of the data.

In fiscal 1996, when data disclosure was launched, the overall total accesses (page views) was 310,000, and the number of databases disclosed was 22. In fiscal 2003, the overall total access exceeding 30 million and 77 databases are disclosed.

cesses to the RIO-DB worldwide has been increasing.

The RIO-DB contains databases of various fields, and its contents are diverse. Table 1 shows the number of databases by section. A total of 77 databases are currently available, while 13 archives are listed.

Table 1 The numbers of databases by section

Research fields	# of DBs	In archive
Life Science & Technology	8	0
Information Technology	5	0
Nanotechnology, Materials and Manufacturing	16	2
Environment and Energy Science & Technology	19	6
Geological Survey & Geoscience, Manne Science & Technology	16	1
Standards and Measurement Technology	10	2
others (public relations related)	3	2
total	77	13



RIO-DB users

Figure 2 is a graph showing RIO-DB users by domain. It can be seen from this that the RIO-DB is utilized worldwide (in about 100 nations). Users from the United States (total of edu, com and net) account for 30%, and Europe and Japan, 20% each. The rest are those whose domain name cannot be resolved from their IP address by the DNS. Of these accesses, a little over 80% of the whole is for one database called the 'spectral database for organic compounds' (SDBS). Thus, the distribution of all users



Fig. 2 Ratio of accesses worldwide

almost agrees entirely with that of SDBS.

As for accesses from Japan (.jp domain), academic institutes such as universities (ac.jp) account for 45%, while general households (ne.jp supposed to be primarily ISP) and companies (co.jp) account for 20% each. (Figure 3)

(Statistical data such as the number of accesses referred to here are based on the analysis of access logs for 11 months from April 2003 to February 2004.)



Fig. 3 Ratio of accesses from japan (.jp)

Introducing databases for categories with which you may be familiar:

Typical databases selected from the RIO-DB from science, technology, and social viewpoints are introduced hereafter. (See explanations given by the persons in charge on the following pages.)

1. Spectral database for organic compounds

Of the databases in the RIO-DB, this database is the most frequently accessed, and the majority of users are from academic institutes such as universities. Specialists throughout the world utilize this database that provides standard and highly reliable data evaluated by AIST researchers.

2. Cyclopedia of strata, rock units and volcanoes (Stratigraphic name database)

Of the databases in the RIO-DB, the majority of accesses to this database are from domestic service providers. In other words, this database is most frequently accessed by the general public. This site is very popular and is ranked 2nd place in the number of accesses. Quaternary volcanoes in Japan are introduced here together with beautiful photographs that attract the attention of the general public even if they are not geologists..

3. Brain image database

With this database, one can see the appearance and various sections of the human and the monkey brains. The contents of this database are one of best suited for school education.

4. Ceramic color database

The study results of ceramic ware accumulated over a long period by research laboratories (predecessors of AIST) are compiled into a database. Of the RIO-DB databases, this is the most historical.

5. Network database system for thermophysical property data

The policy of constructing this database is unique. Data presented by researchers throughout the world as well as those measured and collected by AIST are scrutinized and verified before registration to this database.

6. Relational Information System for Chemical Accident Database (RISCAD)

In this database, not only records of accidents but also their causes are verified for effective use for the prevention of problems related to chemical accidents.

As introduced above, in addition to specialty data, those with educational contents, those related to social safety such as earthquakes, literature databases for specialized fields, and energy and environment-related databases are made available. Anyone can access any database at no cost if a computer environment that allows Internet utilization and browsing are available. (User registration is required for certain databases from a management viewpoint.)

URL is http://www.aist.go.jp/RIODB/

Whenever you have a subject requiring investigation, business, hobbies or homework, access RIO-DB for immediate assistance.

Inqiry

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Spectrum database for organic compounds (SDBS) Metrology Institute of Japan http://www.aist.go.jp/RIODB/SDBS/menu-e.html

Outline of the database

This is a comprehensive spectrum database containing approximately 32,200 organic compounds. A total of six kinds of spectrum are covered – the ¹H magnetic nuclear resonance (NMR) spectrum, ¹³C NMR spectrum, Fourier transform infrared spectrum (FT-IR), mass (MS) spectrum, Raman spectrum, and electronic spin resonance (ESR) spectrum. A total of 103,600 items are stored. The



An example of FT-IR spectrum of SDBS

study of database construction commenced in the 1970s, and this database was introduced in 1982 as a substantial spectrum database. As one of the activities of the RIO-DB, since 1997, this database has been opened to the public at no cost via the Internet. Thanks to the abundant data and the ease of search, people throughout the world are showing considerable interest in this site. SDBS is a symbol of the activities of many research staff promoted for over 30 years, and to refine this valuable resource, we are currently collecting and disclosing new data.

Features of the database

- Many spectra, primarily common organic compounds, are accumulated.
- Two or more spectra are available for each compound.
- The spectrum retrieval system is simple.
- In addition to the name of the compound, search is possible by the CAS number.
- The spectra are, in principle, of original data measured and evaluated by the researchers.
- In addition to the registration of new data, the contents are always reviewed and corrected, if necessary.

Cyclopedia of strata, rock units and volcanoes (Stratigraphic name database)

Institute of Geology and Geoinformation http://www.aist.go.jp/RIODB/strata/welcomej.html

Outline of the database

This database contains a large number of data (over 10,000 items) for retrieval on the name of the strata, rock units and volcanoes distributed in Japan to obtain definitions and descriptions. This database can be used in proposals of new strata in accordance with the stratigraphic code and in reading geological papers. Reference can be made not only by the names you want to search but also on the location maps of geological units or volcanoes.

Features of the database

In addition to the "database for retrieval of strata and rock units", this data base includes sub-databases such as "Quaternary volcanoes in Japan", "Igneous rocks in Japan, and "Metamorphic rocks in Japan" which individually allows the direct retrieval of specific rocks of volcanoes. Also included is a set of documents on the Cenozoic stratigraphy and geologic history of Japan that has not been distributed to the public so far, even though earnestly desired for years, can now be downloaded from this site at no cost. Originally, these were supposed to be used by experts, but are now accepted more extensively. "Quaternary volcanoes in Japan" is especially noteworthy for ease of retrieval on the map, its beautiful photographs and simple



An output of Chokai volcano from the Quaternary volcanos of Japan

explanations, and has been used for school education. "Igneous rocks in Japan" and "Metamorphic rocks in Japan" will be more familiar by including new photographs of rocks and outcrops. The database is described only in Japanese version at present. An English version will be issued in response to occasional overseas inquiries such as from the Smithsonian Institution.



Brain image database Neuroscience Research Institute http://www.aist.go.jp/RIODB/brain/welcome.html

Outline of the database

This database offers head and brain MRI images of two Japanese monkeys, a rhesus monkey, and a male adult human generated from scans obtained with 3 Tesla appa-



An example of human brain image

ratus at Tsukuba North MRI facility of AIST. As for one Japanese monkey, images at three-months intervals starting from 307 days after birth (still continuing) are shown.

Features of the database

MRI images are a bundle of serial scans at a direction. To obtain section or surface images in different directions, dedicated software is usually necessary. With this database, an image-generating program is incorporated in the server. You can then see arbitrary sections, surface images and their combinations of Japanese monkeys, rhesus monkeys, and human beings with an ordinary Web browser. Determination of viewpoint or cutting plane is quite simple and plain with mouse operation of pointer, buttons and pull-down menues. As for one Japanese monkey, you can select the age at which it was scanned. This function allows you to see changes in the brain with growth. Spatial observation from arbitrary directions is possible, and changes over time are also examined. This is really a four-dimensional image database.

Ceramic color database

Materials Research Institute for Sustainable Development (Chubu center) http://www.aist.go.jp/RIODB/ccdb/index.html

Outline of the database

Several hundred thousand glazed test pieces produced over 80 years of research in ceramic ware, from the establishment of the Imperial Ceramic Experimental Institute (1919), are stored at the Chubu center. From world-famous valuable specimens, those of greater importance are selected for incorporation into the database.

The following data are presented for individual pieces, and information retrieval is possible.

- Name of glaze (Traditional name, names of constituents and raw materials, names of color and properties)
- Firing temperature
- Firing atmosphere
- Color (Munsell)
- Surface condition
- Seger formula (Chemical composition)
- Coloration element
- Recipe
- Images

Features of the database

High-level study results accumulated over a long period of ceramic ware research, which played a vital role in leading the Japanese ceramics industry, are compiled in the database. Glazes with colors or compositions not known so far to the public are included in a huge amount



An example of data sheet (Turquoise blue glaze)

of test pieces. The construction of the database allows retrieval by parameters such as chemical composition or color, and browsing in list form.

This database can be conveniently used by companies, research staff and glaze-associated firms dealing with color development, design, glass and crystallization as well as ceramic ware. It is noteworthy that, recently, this database has been used effectively for the research and development of non-toxic, environment-friendly glazes.

Network Database System for Thermophysical Property Data Material Properties and Metrological Statistics Division, Metrology Institute of Japan http://www.aist.go.jp/RIODB/TPDB/DBGVsupport/English/

Outline of the database

Thermophysical property data such as thermal conductivity, thermal diffusivity, specific heat capacity, thermal expansion coefficient and emissivity of materials are fundamental information in supporting science and technology. We are currently developing a "network database system for thermophysical property data" through which individual thermophysical property databases that are constructed and maintained by individual research laboratories can be referred to in a consolidated fashion.

Basic and functional materials including metals, ceramics, semi-conductors, polymers, carbon materials and fluids are primarily covered. Property data such as thermal conductivity, thermal diffusivity, specific heat capacity, thermal expansion coefficient, emissivity, density, viscosity, surface tension, electrical conductivity, and dielectric constants are stored. Recently, thermophysical property data of thin films and up-to-date data of boundary thermal resistance have been added.

Features of the database

The thermophysical property data are displayed in graph form, so that they can be visually observed. By



Network database system for thermophysical property data

clicking the graph, detailed information such as numerical data and references can be obtained. Two or more plots of data can be displayed on the same graph by drag and drop manipulation. Data-to-data computation is possible for the items displayed in the graph. For example, thermal diffusivity is calculated from the thermal conductivity, specific heat capacity, and density.

Relational Information System for Chemical Accidents Database (RISCAD)

Research Center for Explosion Safety http://www.aist.go.jp/RIODB/RISCAD/PHP_EN/index.php

Outline of the database

Relational Information System for Chemical Accidents Database is based on the accident data such as explosives, high pressure gas, chemical substance and chemical plants of related accident data which have been accumulated in the AIST, and has developed in collaboration by AIST and the Japan Science and Technology Agency (JST) as the Database Development Program of JST. It holds the chemical accident records from 1949 and it has been updated from time to time. The number of the records is 4,164 as of June 2004.

Features of the database

The feature of RISCAD is that the accident data is linked relationally with the additional information such as the accident progress flowcharts, hazard information of related chemical substances and the chemical progress flowcharts which are organized in chronological order. To be more serviceable for prevention of the accidents, it is available to search by date, time, place of the accident occurrence like the common accident database. It also has the keyword search function from the final event, activity, equipment, probable causes, and damage conditions classified by experts in the chemical accident analysis.



Relational Information System for Chemical Accidents Database

Furthermore, searching by human damage such as number of fatalities, injuries, the classification of related chemical substances and explosives is available. The search results can be displayed as a list, then the details of the accidents, the additional information, and the hazard information of related substances can be displayed as well. Additionally, the search results can be shown dynamically as a graph on the Web browser. And the search function to get the hazard information from the name of the chemical substance has been newly added.

AIST RESEARCH HOT LINE

UPDATES FROM THE CUTTING EDGE (Jul.—Sep. 2004)

The abstracts of the recent research information appeared on the Vol.4 No.7-No.9 of "AIST Today" are introduced and classified by research area. For inquiry about the full article, please contact the author directly.

Life Science & Technology

Application of the Biosensor for a Diagnosis of Soil Disease - Plant disease is predicted by a biosensor -

A sick problem which has arisen in human society has arisen also in the agricultural fields. Soil disease is caused by soil microbe which is infected with crops. However soil microbes are not only pathogenic microbe, but are also good microbe (antagonist). Many good microbes live in healthy soil.

We invented the new instrument which predicts occurrence of the soil disease, cooperated with Sakata-Seed Corporation.

The principle of this instrument is based on the diagnosis for the reduction of the oxygen concentration that depends on the amount of respiration of each microbe, antagonist and pathogen.



Chlamydospore of Genus Fusarium isolated from carrot

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Innate Immunity and Aging

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Age Dimension Reseach Center e-mail: t.tanabe@aist.go.jp AIST Today Vol. 4, No.7 (2004) 15 The innate immune system, that mediates the first line of defense against microbial pathogens, is essential for the activation of acquired immune system.

Mutations in Nod2, one of the innate immune factors, have been associated with Crohn's disease, the inflammatory bowel disease, and Blau syndrome, characterized by systemic granuloma. Our analysis revealed that the Nod2 variants carried by CD patients demonstrated impaired MDP-dependent response, and Nod2 alleles associated with Blau's syndrome promoted MDPindependent activation. We also identified precise ligand recognition mechanism through the analysis of 500 Nod2 mutants.



Mechanism of FEN-1 with DNA Substrate to Form the Complex

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Biological Information Research Center e-mail: junko.abe@aist.go.jp AIST Today Vol. 4, No.8 (2004) 7 Flap endonuclease-1 (FEN-1) play important roles in DNA replication and

repair. In this study, the kinetics parameters of mutants at highly conserved aromatic residues, Tyr³³, Phe⁷⁹, and Phe²⁷⁸Phe²⁷⁹, in the vicinity of the catalytic centers of the FEN-1's molecules were examined. According to the kinetic parameters of the mutants and other results, DNA binding model of the phFEN-1 with the nick substrate was proposed as shown in the figure. The stacking interactions of Tyr³³ and Phe⁷⁹ might play important roles to fix the template strand and the downstream strand, in close proximately to the active center to form the productive transient state leading to the hydrolysis.



The proposed model showing the interactions between the aromatic residues of phFEN-1 and the nick substrate. The main chain structure of phFEN-1 is shown in green. Magnesium ions 1 and 2 are colored in red and orange, respectively. The template strand of nick substrate is colored yellow. The downstream and upstream strands are in orange and brown, respectively.

Development of An Integrated Database for Human Transcriptome

We developed an integrated database of human genes, called H-Invitational Database (H-InvDB), based on comprehensive annotation of human fulllength cDNA sequences. This database is open to the public and accessible at http://www.h-invitational.jp/ (or hinv.jp). This is a product of an international col-

laborative project by more than 150 researchers in 44 countries, organized by AIST, Japan Biological Informatics Consortium and National Institute of Genetics. H-InvDB contains functional and structural annotation of 21,037 human genes, and will be indispensable for human transcriptome studies in various fields of basic research, education and industry.

References

- H-Invitational Database, http://www.h-invitational.jp/
- T.Imanishi, T.Itoh, Y.Suzuki, C.O'Donovan, S.Fukuchi, et al.: PLoS Biology Vol.2, No.6, 856-875 (2004).
- D.Cyranoski: Nature, Vol.419, 3-4 (2002)



Official homepage of H-Invitational Database (A) and its main page (B).

Brain Activity to Speech Offsets

Speech offsets, i.e. sudden transitions from continuous speech sound to silence, activated both hemispheres differently. In addition to peak activities in the bilateral temporal cortices at about 120 ms after the offsets, the right parietal cortex was activated later irrespective of the stimulated ear. The result was discussed in the context of auditory attention.





Positions of the dipole in the right parietal cortex

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Circadian rhythm is regulated by phosphorylation of clock protein PER:Its phosphorylation and Degradation System

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Serum stimulation caused daily oscillations of human PER1 protein (hPER1) and the apparent molecular mass of hPER1 changed. Inhibitor studies indicated that the casein kinase I family. phosphorylated hPER1 and increased the apparent molecular mass of hPER1. The inhibition of hPER1 Phosphorylation by CKI-7, a casein kinase I inhibitor, disturbed hPER1 degradation, delayed the nuclear entry of hPER1 and allowed it to persist for longer in the nucleus. Furthermore, proteasome inhibitors specifically blocked hPER1 degradation, while leptomycin B, an inhibitor of nuclear export, did not alter the degradation state of hPER1 protein. These findings indicate that circadian hPER1 degradation through a proteasomal pathway can be regulated

through phosphorylation by casein kinase I, but not by subcellular localization.



Phosphorylation of PER1 controls its degradation. CKI phosphorylates PER1 (1) and then degraded through ubiquitin-proteasome pathway (2,3). CKI-7 inhibits hPER1 phosphorylation and its degradation (4).

3D Structure of Inositol 1,4,5-Trisphosphate Receptor Channel

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Neuroscience Research Institute and Biological Information Research Center e-mail: ti-sato@aist.go.jp AIST Today Vol. 4, No.9 (2004) 18 The inositol 1,4,5-trisphosphate receptor channel in the endoplasmic reticulum is involved in neuronal transmission

via Ca2+ signaling and for many other functions that relate to morphological and physiological processes in living organisms. We analysed the three-dimensional structure of the ligand-free form of the receptor based on single particle technique using an automatic particle picking system. We propose a model which explains the complex mechanism for the regulation of Ca²⁺ release by co-agonists, Ca²⁺, inositol 1,4,5-trisphosphate based on the structure of multiple internal cavities and a porous balloonshaped cytoplasmic domain.

1) C. Sato, K. Hamada, T. Ogura, A. Miyazawa, K. Iwasaki, Y. Hiroaki, K. Tani, A. Terauchi, Y. Fujiyoshi, K. Mikoshiba : J. Mol. Biol., Vol. 336, 155-164 (2004).



Predicted membrane topology, Sections and surface-rendered representations with loops and terminal extensions for the IP_3R1 (upper) and the voltage-dependent Na+ channel (lower)

Topology Representing Network Enables Highly-Accurate Classification of Protein Images Taken by Cryo Electron-Microscope

In single-particle analysis, a threedimensional (3-D) structure of a protein is constructed using electron microscopy (EM). The primary process of this 3-D reconstruction is the classification of images according to their Euler angles, the images in each classified group then being averaged to reduce the noise level. In our newly developed strategy of classification, we introduce a topology representing network (TRN) method. It is a modified method of a growing neural gas network (GNG). In this system, a network structure is automatically determined in response to the images input through a growing process. The GNG creates clear averages of the inputs as unit coordinates in multi-dimensional space,

which are then utilized for classification¹⁾. 1) T. Ogura, K. Iwasaki & C. Sato, J. Struct. Biol., Vol. 143, 185-200 (2003).



Accuracy of the GNG, the SOM and the MSA to classify a mixed library composed of sodium channel taken by cryo-EM.

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Direct Observation of Kinesin's Hand-over-Hand Motion

A conventional kinesin molecule travels continuously along a microtubule, in discrete steps of 8 nm. This processive movement is generally explained by models in which the two heads of a kinesin move in a hand-over-hand fashion. In order to prove this model, we have con-

structed a heterodimeric kinesin in which the mechanochemical cycle rate of one of the heads is considerably slower than the other's. Optical trapping nanometry experiments showed that a single heterodimeric kinesin exhibits fast and slow, 8 nmsteps alternately. Our results provide the first, direct evidence for the hand-over-hand model. Co-authors : K. Kaseda (Gene Function Research Center, AIST), H. Higuchi (Tohoku University)

K. Kaseda, H. Higuchi, and K. Hirose : Proc. Natl. Acad. Sci., USA. 99 (25), 16058-16063 (2002).

K. Kaseda, H. Higuchi, and K. Hirose : Nature Cell Biology, 5(12), 1079-1082 (2003).



Alternate fast and slow steps of a heterodimer kinesin

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What You Touch is What You Get!

- An approach for direct manipulation by tactile modality for blind computer users -

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The Institute for Human Science and Biomedical Engineering developed a basic device combining tactile display function and force sensing function in collaboration with the University of Electro-Communications and the KGS Corporation. The device consists of two major components, a tactile graphic display and a 6-axis force/torque sensor. The force sensor measures six dynamical values generated by touch action on the display surface and PC estimates the point based on the data and a simple dynamical principle. Preliminary investigation indicated the validity of this device and promising capability for HCI using tactile modality.





A shematic illustration of the principle for estimating a touch position

Information and Communication Technology

World-First Manufacture of Photosensor Based on Bio-conjugated Material

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An innovative photosensor using bioactivity unit as ultimate parts was developed. The use of photosynthetic protein, extracted from cyanobacteria living in a hot spring and characterized by 100% quantum yield of photo-electric conversion for red light, as a photoreceptor is promising way to achieve highperformance, no-heating and stable bionic-photosensor. The key-process for construction was as below; (1) extraction of protein with keeping their bioactivity, (2) direct connection of conductive molecular wire to electron relay system in photosynthetic protein (just like plugging) and (3) integration on semiconductor devices (FET). The work will be extended in future to the development of a bio-electronic imaging device with higher degree of integration, leading to the establishment of bio-electronic industrial technology and innovative materials science.



A schematic drawing of bio-photosensor. A photoreceptor illuminated by light emits electrons, which are led through integrated molecular wirings to gold flow gate of FET and given out as electrical signals.

Development of Molecular Orbital Calculation System for a Large System on Grid

In order to study electronic state of protein-biomolecular system, we started to develop a Molecular Orbital(MO) calculation system on Grid environment.

This system realizes MO calculation for large scale biosystem such as Estrogen receptor and DNA. (Figure 1) Analysis of electronic state gives a lot of basic information to not only drugs and materials design but also guidelines for medical treatment. For the Estrogen dimer and DNA system, the role of the dimer and waters became clear. Dimer fixs coordinate position and direction. Waters shield Coulomb force and play as glue connecting DNA and Estrogen dimer.

Grid technology is indispensable to large scale MO calculation.



Estrogen recepter dimer binding to DNA

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Maximization of the EUV Radiation Efficiency from a Laser-Produced Plasma for EUV Lithography

Increase of the conversion efficiency of radiation at 13-14nm is the most important issue for making EUVL affordable. An analytical formula for maximizing the radiation efficiency from a laserproduced plasma has been derived. The maximum efficiency is achieved when the plasma expansion distance during laser heating is equal to the laser absorption length. Theoretically predicted dependence of the radiation efficiency on the plasma density was confirmed in a experiment using a particle-cluster target. By creating a relatively uniform density plasma with a 0.3 mm diameter by dispersing SnO₂ particles coated on a Si wafer, the conversion efficiency at 14-nm as high as 4 times of that for a solid density SnO₂ target was observed.



Expansion of particles observed by the scatter of a back-illuminating laser light. The image was taken at 150 microsecond after a laser-induced shock to disperse SnO_2 particles coated on a Si wafer.

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Digital Human that Errs for Usability Test

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Virtual user model that operates machine spontaneously and makes errors is now developing as a novel usability test method. Conventional estimation methods of usability of artifacts have difficulties on practicability. Experiment with real-human subjects takes money and time. Also, most of conventional 'user model' do not simulate process of error emergence and recovery form error. Our Digital Human That Errs (DHTE) model makes error like humans and tries recovering, so that plausible user behavior can be obtained. Since characteristic of DHTE is controllable, weak points of machine can be detected with fewer simulations by reducing abilities of DHTE.



DHTE virtual user in action

Operation of AIST Super Cluster Started

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Grid Technology Research Center e-mail: t.kudoh@aist.go.jp AIST Today Vol. 4, No.9 (2004) 21 "AIST Super Cluster" with the top aggregate computing performance among clusters in Japan, 14.6 TFLOPS, put into operation. It has more than 3000 processors, 9.6 TB main memory capacity and 803TB storage, and is based on a Linux operating system. It consists of three cluster subsystems, "P-32", "M-64" and "F-32", as well as 20 TB storage subsystem. These subsystems are interconnected through 10giga-bit Ethernet.

The AIST Super Cluster will be used in nano-technology, bioinformatics and other research fields. It serves as the core system for inter-field and international research promotion and cooperation between industries, academy and government based on Grid technology.



AIST Super Cluster

Development of Buffer Method in Parallelized Molecular Orbital Calculation

The modified direct SCF-MO method (buffer method) was developed to improve the parallelization efficiency in Fock matrix generation by using a PC cluster that does not have secondary storage on each processor. In this method, in the first SCF cycle, part of the electron repulsion integrals is stored in a buffer (unused memory) and the stored integrals are reused in subsequent SCF cycles. This simple method achieved super-linear scalability.



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Parallelization efficiencies of buffer method with various buffer sizes

*Test data: target molecule was Crambin (46 amino-acid residues, 642 atoms), basis set was STO-3G (1974 basis functions)

World's Fastest Fiber-Optic Quantum Key Distribution at 1550 nm

- Toward practical use of quantum cryptographic technology for ultimate security -

The Photonics Research Institute (PRI) of the National Institute of Advanced Industrial Science and Technology (AIST), one of independent administrative institutions, has developed a thermoelectrically cooled single-photon detector boasting of its fastest operational speed in the world in the wavelength band for optical fiber communication, 1550 nm, based on the AIST-developed epoch-making single-photon detecting technique, discharge pulse counting, and succeeded in demonstrating the world's fastest quantum key distribution at 1550 nm. The repetition rate of single-photon detection was 10 MHz. The key rate was 45 kbit/s when using a 10.5 km long optical fiber as a quantum channel.



Topology of unbreakable cryptography

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Environmental Science & Technology

Moisture Changes Drastically the Catalysis of Gold Nanoparticles

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Research Institute for Innovation in Sustainable Chemistry e-mail: m-date@aist.go.jp AIST Today Vol. 4, No.7 (2004)11 It was originally found in the late '80s in AIST that 'noble' gold exhibits high catalytic activities when its size is reduced to less than 5 nm. Among a variety of the reactions catalysed by gold nanoparticles, low-temperature CO oxidation has been most intensively studied. We have investigated moisture effect on this reaction for Au/TiO₂, Au/Al₂O₃ and Au/SiO₂ over a wide range of concentrations, ~0.1 to 6,000 ppm, and found that the activity is enhanced no less than two orders of magnitude. The effect of moisture strongly depends on the type of support oxide.



Reaction rates of CO oxidation (represented by turnover frequencies, number of CO molecules converted by a surface Au atom per second) over Au/ TiO₂, Au/Al₂O₃ and Au/SiO₂ as a function of moisture concentration in the reactant gas.

Mechanism of Peculiar Chemical Reactions in Supercritical Water Clarified

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We have successfully opened the way to understanding the mechanism of peculiar reactions taking place in supercritical water. One of reactions in question refers to the Beckmann rearrangement where ε -caprolactam is produced from cyclohexanone oxime in supercritical water without using concentrated sulfuric acid, which was experimentally demonstrated by the SFRC-AIST. It has been successfully demonstrated, first in the world by the computer simulation based on the first principle molecular dynamics, that the rearrangement is made through incomplete hydrogen bond network created owing to peculiar density property of supercritical water, neither liquid nor gas, but an intermediate state between them.



: hydrogen ion, : oxygen atom, : nitrogen atom, : carbon-to-carbon bonding, ••• : hydrogen bond.

Computer simulation of chemical reaction with a hydrogen ion added.

Energy Science & Technology

High Rate Plasma Process for High Efficiency Microcrystalline Silicon Solar Cells

grain boundaries.

High-rate deposition technique of hydrogenated microcrystalline silicon $(\mu c-Si:H)$ light absorber is essentially required for low cost manufacturing of silicon-based thin film solar cells. We have developed a high-rate plasma process based on SiH₄-H₂ glow discharge for highly efficient μ c-Si:H *p-i-n* junction solar cells. In high-deposition-rate regime (2-3 nm/s), we observed a remarkable improvement in visible-infrared responses upon increasing deposition pressure (up to 7-9 Torr) under SiH₄-depletion plasma condition, yielding high short circuit current. As a result, a maximum efficiency of 9.13% has been achieved at a deposition rate of 2.3 nm/s. We attribute the improved photovoltaic performance of high-pressure-grown μ c-Si:H to the structural evolution toward denser grain arrangement that prevents atmospheric impurity diffusion and post-oxidation of

ZnO n µc-Si:H ~30 nm *i* µc-Si :H 2.2-2.4 µm *y* µc-Si:H ~25 nm *y* µc-Si:H *z* nO Substrate(glass) *y i* µc-Si !H

Schematic illustration of µc-Si:H single junction *p-i-n* solar cell

Direct Power Generation from Waste Heat - Development of lead-free high performance segmented thermoelements -

High performance lead-free p- and n-type segmented thermoelements which are designed to produce electric power at 10% conversion efficiency were developed. The p-type element consists of newly developed zinc-antimony compound (Zn_4Sb_3) and bismuth-antimonytelluride ((Bi,Sb_2Te_3) while the n-type consists of Skutterudite compound ($CoSb_3$) and bismuth telluride (Bi_2Te_3) based material. Zn_4Sb_3 exhibits superior performance over PbTe based material, which has been regarded as the best material for power generation.

A simulation software for thermoelectric power generation has also been developed to accelerate the development of the segmented thermoelements. The software has proven to be a powerful tool for designing thermoelectric modules.



A Schematic drawing of thermoelectric power generation module and a segmented thermoelement



A picture of two stage segmented thermoelements prepared by not pressing

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Nanotechnology and Materials Science & Technology

Preparation of Si Fluorescent Material by Micro-Reactor System using Supercritical Fluid

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Micro-Space Chemistry Laboratory e-mail: inoue-kozo@aist.go.jp AIST Today Vol. 4, No.7 (2004) 12 Fluorescent material containing Si was prepared from organosilane such as diphenylsilane by micro-reactor under the condition of supercritical fluid. Generally, supercritical fluid is obtained under high pressure and high temperature condition using high pressure reactor which is usually big and heavy apparatus. But, supercritical fluid condition was easily and safely obtained using micro-reactor system. The product was dark yellow discus material. PL spectral of the product was similar to that of porous silicon which was known to be composed of Q-dot silicon nano particle.



Photoluminescence of Si fluorescent material prepared by micro-reactor using supercritical fluid

Roof Box Made from Noncombustible Magnesium Alloys - New application of frictional stir welding -

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Material Reserch Institute for Sustainable Development e-mail: naobumi-saito@aist.go.jp AIST Today Vol. 4, No.7 (2004) 14 We developed in collaboration with Hyogo Prefectural Institute of Technology and Sakurai Industries Co., Ltd. technology for manufacturing large-sized products from the extruded noncombustible magnesium alloys through frictional stir welding (FSW) or laser welding without degrading merits of the materials. In this way, it has been made possible to build an automobile roof box, 2,000 (L) × 670 (W) \times 270 (H) mm, from noncombustible magnesium alloys. The new technology allows reducing weight of a structure by about 25 % from that of comparable size made from fiber-reinforced plastics (FRP). It is expected that the technology is applied to the development of products with complicated 3D geometry from extruded or wrought magnesium alloy materials, taking advantages of superior properties.



The bottom part of the roof box (a), the exterior of the roof box (b) and the roof box on the car (c).

Novel Synthesis of Sol-Gel Silica in Organic Solution

Silica solid is prepared by a novel sol-gel type method using silane alkoxide and acid anhydride instead of water. This synthetic procedure is performed in organic solution media, which is advantageous to make homogeneous systems of the precursors of silica and organic compounds. This procedure readily produced an epoxy resin/silica nanocomposite material, which had no Tg point under 300 °C. On the other hand, when silica was prepared in the presence of dissolving cholesterol, silica obtained adsorbed steroid hormones such as progesterone more predominantly than other analogous compounds, probably due to the molecular imprinting effect of cholesterol.



Conceptual schemes of (A) common and (B) developed sol-gel methods

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Micro/Nano Hot Embossing Pyrex Glass with Glassy Carbon Mold fabricated by Focused-Ion –Beam Etching

Micro/Nano imprinting or hot embossing is a target of interest for industrial production of micro devices. In Fluidic MEMS (Micro Electro Mechanical Systems) applications, polymer materials have been employed for their low cost fabricate the economical products . However glasses are much more suitable for the higher temperature applications or under strong chemical environments. In Optical MEMS as well, glasses are good candidate materials for better optical properties. In this study, Micro/Nano hot embossing was employed for Pyrex glass molding and the test structures were successfully fabricated with good fidelity of $0.3\mu m$ line and space and $0.4\mu m$ height.



SEM images of hot embossed Pyrex micro structures 1µm, 0.5µm,300nm line and spaces (Temp.:590 °C, Press.:0.22MPa, Keeping time:60sec).

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An Innovative Ceramics Compaction Technology using Nano-Fracture of Fine Particles at Room Temperature

-Ultimate ceramics processing, toward super ceramics-

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Advanced Manufacturing Reserch Institute e-mail: akedo-j@aist.go.jp AIST Today Vol. 4, No.8 (2004) 4-6 The Advanced Manufacturing Research Institute (AMRI) of the National Institute of Advanced Industrial Science and Technology(AIST) successfully consolidate α -Al₂O₃ fine powder on the metal substrate at room temperature without binder and firing, for forming the ceramic thick layer, using Aerosol Deposition(AD) method.

It was discovered that the materials particles were fractured and deformed into 10 to 30 nm nano-crystallite size particles during the impact with the substrate. As the result of fracture,

substrate. As the result of fracture, the activation of newly formed particles surfaces was occurred stimulating the inter-particle bonding and resulting the formation of very dense nano- crystal structure. Uniform deposition on metal substrate over a 200 mm square area was achieved. α -Al₂O₃ thick layer has fine mechanical and electrical properties as same as that of the bulk sintered material.

This process represents a technological breakthrough, in as much as wide ranging applications are anticipated, such as the use of moderately priced raw material particles, currently used for ceramic processing, to form nano-structured ceramic films, although the conventional sintering process of over 1000°C is not required while achieving the hardness and density equal to ceramics sintered in bulk at high temperatures.



 $\alpha\text{-}\mathsf{Al}_2\mathsf{O}_3$ layer and its microstructure formed at room temperature by AD method

Mechanical Engineering and Manufacturing Technology

RT Middleware - Robot Technology for the Made-to-Order Business Model

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Intelligent Systems Institute e-mail: t.kotoku@aist.go.jp AIST Today Vol. 4, No.9 (2004) 23 As a potential application of RT middleware technology, we developed a robot system for supporting daily life activities (RT space) and demonstrated various made-to-order robot services.

In the project, we have carried out research and development regarding the software, which helps the efficient development of robot systems. We studied the standard specifications of the robot middleware, which promotes modularization. We also developed a prototype middleware. Finally, we proved the effectiveness of middleware technology on typical robot system construction examples.

We would like to disseminate the use

of this open robot system architecture and make a contribution to industrial technology and the economy.



Living room incorporating robot technologies for supporting daily life activities (RT-space)

Standards and Measurement Technology

Flatness Measurement with the World's Best Measurement Uncertainty

Flatness is an important parameter for various industrial products particularly silicon wafer, hard disk substrate, flat panel display, and other products. The large aperture flatness interferometer was developed by the AIST with the collaboration of FUJINON Company. The flatness of a specimen is compared with a precisely polished reference optical flat whose flatness has been calibrated with respect to the mathematical absolute flatness. The interferometer is capable of measuring flatness over a 300 mm diameter area with an uncertainty as low as 10 nm, which is the smallest uncertainty in the world.



Flatness interferometer (measuring size: 300 mm diameter, uncertainty: 10 nm)

Development of Small-angle Measurement and Calibration Method

An angle generator equipped with a self-calibration mechanism has been developed. Its angular span is more than 30°. The angular displacement of the axis of rotation is measured by an angle interferometer, which observes the displacement of two retro-reflectors attached to the rotation axis. The angle is calculated from the function of the observed interference order parameterized by the separation of the retro-reflectors and wavelength of the laser. To avoid the effects of long-term drift of the separation and wavelength due to a meteorological change, a self-calibration method is introduced. The self-calibration is realized by a 24-sided optical polygon attached to the axis through an indexing face gear with a 1° resolution. The autocollimator is calibrated by comparing its readings against

angles set by the angle generator. Last year, a single-axis autocollimator calibration service was commenced using this system with an uncertainty of 0.1" and angular span of +-1000".



Photograph of the autocollimator calibration system consisting of the angle generator and angle interferometer.

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Wide-Range Optical Attenuation Standard by Incremental Attenuation Method

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Metrology Institute of Japan e-mail: s.mukai@aist.go.jp AIST Today Vol. 4, No.8 (2004) 16 We have developed a system for measuring the linearity of fiber-optic power meters over a dynamic range of about 100 dB on the basis of the incremental attenuation method. The measurement system and uncertainty of calibration by this method are reported.



Setup for calibrating wide-dynamic range optical power meters

A New Protective Garment System Against Radioactive Substance without Causing Secondary Waste

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Research Institute of Instrumentation Frontier e-mail: nagai-h@aist.go.jp AIST Today Vol. 4, No.8 (2004) 17 In order to prevent generating secondary radioactive waste during works in a closed environment contaminated with radioactive substances, we developed a new protective garment system in collaboration with Chiyoda Maintenance Co., Ltd. It is realized by developing a new put-on/take-off mechanism based on reversible shape-changing structures composed of shape memory alloy and elastic materials. Isolation with pollution environment and clean environment is always maintained and anti-contamination smocks, which turn into secondary waste after works, are not necessary any longer.

The system is applicable to works in an environment handling hazardous substances as well as in a clean room.



Developed protective garment system against radioactive substance

The New Fabrication Method of a Surface Source

A standard surface source is a planar radioactive source material. It is used as a surface source for the calibration of hand-foot cloth monitors and survey meters. We have developed a new method for the fabrication of standard surface sources. Uniform printing density, a broad range of radioactive intensity, high positional resolution and arbitrary shapes could be also realized by the method. The printed sources will be applied for a radioactive logarithmic scale for imaging plate and a radioactive surface source for calibration of radiation measurement instruments.



A printed radioactivity log scale.

A broad range of radioactive concentrations can be obtained by setting inks, with different radioactive concentrations, in an inkjet printer and using the adjustment function of printing concentrations for each ink color.

Superconducting Energy-Dispersive Spectroscopy

Energy-dispersive x-ray spectroscopy is one of the indispensable methods for elemental analysis. Superconducting detectors can outperform the conventional semiconducting detectors in energy resolution and a coverage of x-ray photon energies. However, the smallness of superconducting detectors limits their applications to real analyzing tools. We have found by using spatially-resolved measurement with synchrotron radiation that the detector size can be increased by changing the structure of superconducting electrodes. The finding resulted in the superiority of the superconducting detector to the semiconducting detector as shown in the figure, and thus opens the possibility of real analyzing tools.



Comparison of energy resolution between a Si detector and a superconducting detector for energydispersive spectroscopy.

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Geological Survey and Geoscience

Geophysical Exploration using Proton Nuclear Magnetic Resonance

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I am developing a portable proton nuclear magnetic resonance (NMR) surface scanner for geotechnical engineering. The proton NMR refers to a spectroscopy to observe the precession of the proton or nucleus of hydrogen. Because there are many hydrogen atoms in the underground as water molecules, NMR enables us to obtain useful information of subsurface water. The prototype of the portable NMR scanner being developed is shown in Fig. 1. I will apply the scanner to detect the water-saturated hidden fractures in tunnels, shafts, and galleries and to estimate the fracture aperture in terms of the safe maintenance.



Photo of the portable NMR surface scanner



Thai Sci-Tech Minister Visits AIST to Promote Cooperation

On June 5, 2004, a delegation of 20 science and technology officials from the Kingdom of Thailand visited AIST Tsukuba to further promote cooperative ties with the Institute. The group included Science and Technology Minister Korn Thapparansi and Permanent Secretary Sunthad Somchevita, as well as National Science and Technology Development Agency (NSTDA) President Pairash Thajchayapong.

The visit began with remarks from Minister Korn explaining the current Thai administration' s strategy for promoting science and technology and actively importing personnel and technology to strengthen Thai industry. Thailand is also working to advance the development of human resources at the policy and organizational level. Conscious that Thailand lags behind Malaysia, Singapore, South Korea, and Taiwan in science and technology, it has established NSTDA and four subsidiary research centers (BIOTEC for biotechnology, MTEC for materials, NECTEC for information technology, and NANOTEC for nanotechnology) to work on closing the gap. Listeners were particularly impressed by NSTDA's organizational structure, which has enabled and facilitates prompt action and rapid progress, without rule-binding procedures..

Participants from AIST included Senior Vice President Dr. Kisaburo Kodama, as well as two Vice Presidents, Dr. Kazunobu Tanaka and Dr.



Tatsuo Katsura. After the welcoming remarks, Dr. Hiroshi Yokoyama, director of the Nanotechnology Research Institute, provided an overview of research activities in nanotechnology, and Dr. Kenji Yokoyama, deputy-director of the Research Center of Advanced Bionics, described his organization' s work. In addition, Dr. Michio Kondo, director of the Research Center for Photovoltaics, gave a presentation on the center's activities and conducted a tour of its solar panel installation.

The participants were divided into individual research fields at separate tables, and spirited discussions were held on ways to promote both comprehensive cooperation and collaboration in specific fields.

President Yoshikawa Gives Zuckerman Lecture

On June 16, 2004, AIST President Hiroyuki Yoshikawa gave the Eleventh Annual Zuckerman Lecture in London. Speaking at the invitation of Lord David Sainsbury of Turville, Britain's Parliamentary Under-Secretary of State for Science and Innovation, Dr. Yoshikawa became the first Japanese to be selected for this honor since the series was inaugurated in 1994.

Named after Solly Zuckerman, the first Chief Scientific Adviser to the UK Government, the Zuckerman Lecture is given by important figures in the field of science policy at the invitation of Britain's Minister for Science and Innovation. Past lecturers include top science officials and scientists from various Western countries.

Dr. Yoshikawa spoke about the "Roles of the Scientist in Sustainable Society," covering such subtopics as "The Scientist and the Social Contract," "The Scientist and Discipline," and "Full Research." Professor Yoshikawa also explained the role and function of AIST as an organization

promoting Full Research. After the lecture he fielded numerous questions regarding Japan' s energy policy and other issues. He exchanged ideas on research trends in Japan and the UK and bilateral cooperation, with Lord Sainsbury, Professor Sir David King (the British



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government's current Chief Scientific Advisor), Sir John Browne (BP Amoco CEO), and other eminent British figures in the field of science and technology, as well as Mr. Masaki Orita, Japanese Ambassador to the UK, and Dr. Yasuhisa Kanaguchi, Director of the London Office of the Japan Society for the Promotion of Science.

Second AIST and KOCI Joint Workshop Held in Hokkaido

On June 29, 2004, the Second AIST and KOCI Joint Workshop was held in the city of Sapporo in Hokkaido. KOCI, the Korea Research Council for Industrial Science and Technology, is a government organization directly under the South Korean Prime Minister that comprises seven research centers devoted to various fields of industrial technology (Research Institute of Chemical Technology, Institute of Machinery and Materials, Institute of Industrial Technology, Electronics and Telecommunications Research Institute, Electrotechnology Research Institute, Institute of Oriental Medicine, and Food Research Institute). In February 2002, AIST and KOCI signed a comprehensive cooperation agreement. The first workshop was held in South Korea in November 2002 and dealt primarily with administrative aspects of research collaboration and assessment. It was therefore agreed that the second workshop would focus on specific research topics.

After opening remarks by AIST President Hiroyuki Yoshikawa and his KOCI counterpart President Won-Hoon Park, a total of 21 presentations were given on subjects such as materials, bioscience, and energy. The presentations were followed by lively question-and-answer sessions. The workshop provided a valuable opportunity to advance cooperation in specific areas of research.



A*STAR Visits AIST

From July 13 to July 15 2004, a group of officials from the Agency for Science, Technology, and Research (A*STAR), a core research center in Singapore, visited both AIST Tokyo Waterfront and AIST Tsukuba. They engaged in talks with President Yoshikawa and top AIST administrators and toured AIST's research units.

In addition to formulating the Singapore government's science and technology policy and allocating its science and technology budget, A*STAR oversees 12 research institutes covering a wide range of fields, including bioscience, IT, and materials. Managing Director Boon Swan Foo (at right, photo below), who led the A*STAR delegation, was already well acquainted with the AISTs activities as a member of the AIST Advisory Board. (President Yoshikawa, likewise, is a member of the A*STAR board.) Nonetheless, after touring the facilities, he expressed a respect for the AIST's capacities and indicated his eagerness to conclude a future agreement for comprehensive cooperation. AIST and A*STAR plan to move forward with discussions leading to such an agreement, regarding each other as an important partner in their Asia strategy.



Dr. Ohji of AIST Appointed Fellow of American Ceramic Society

Dr. Tatsuki Ohji, Principal Research Scientist of the Advanced Manufacturing Institute, was granted the title of Fellow by the American Ceramic Society at its 106th Annual Meeting. The title, regarded as one of the highest honors for a specialist in the field of ceramics, is conferred on world-

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class researchers who have made an outstanding contribution to the ceramic arts or sciences. Dr. Ohji became the second AIST researcher to receive this honor, following Dr. Shuzo Kanzaki, Director of the Advanced Manufacturing Institute.

In his work Dr. Ohji has attempted to elucidate the characteristics of ceramics both experimentally and theoretically and to shed light on the mechanisms leading to their formation. He has made a particularly important contribution to confirming the longevity and reliability of such materials through studies into their long-term deformation properties and fracture life at high temperatures. Through his studies on the mechanism of toughness in composite materials, he has established clear guidelines for designing tougher materials. In addi-

tion, his studies on the microstructure of porous materials and their properties have revealed why their dynamic properties often surpass those of nonporous materials. Dr. Ohji' s work has been hailed internationally for its wideranging and important findings.



AIST Exhibits at BIO 2004

The BIO 2004 Annual International Convention is a biotech industry exposition attracting participants from all over the world. This year' s event was held June 6–9 at the Moscone Center in the heart of San Francisco's downtown district. The AIST booth displayed publicity posters for the institute, as well as showing a video, and exhibiting products from InfoGenes Co, Ltd., the first bioventure company of AIST.

The exhibition space was lavishly decorated



and divided into blocs by country and US state. The Japanese pavilion featured exhibits from 57 companies. The AIST booth was very popular with a large number of visitors, including individual visitors from Australia and Canada. It proved a powerful publicity tool, raising public awareness of AIST and its activities.

BIO 2004 attracted considerable attention in the United States, drawing some 17,000 participants. BIO 2005 will be held in Philadelphia.

Industry and Agricultural Science Link up for ASEAN Biomass Meeting

On July 23, 2004, the first ASEAN Biomass Meeting was held at AIST Tsukuba heralding a partnership between industry and agricultural research organizations. The conference falls under the Science and Technology Promotion Program of the Ministry of Education, Sports, Culture, Science, and Technology. It exists to allow Japan and the ASEAN countries to discover ways to cooperate in formulating a strategy and planning a research and development program which will lead to the effective use of biomass, an abundant resource in the ASEAN region.

AIST has been working on an industry-government-academia partnership to pursue the effective use of biomass from an engineering standpoint. By establishing an alliance between businesses on the one hand and research institutions and universities involved in agricultural research on the other, the recent meeting has set the stage for this topic to be tackled on a national basis. Participants were five agriculture research institutes including the Japan International Research Center for Agricultural Sciences (JIRCAS), as well as the Research Institute of Innovative Technology for the Earth (RITE), the University of Tokyo, and various companies in related industries. Remarks by AIST Research Coordinator Masayuki Kamimoto, JIRCAS Vice-President Akinori Noguchi, and Program Officer Dr. Hiroshi Takahashi of the Japan Science and Technology Agency (JST) were followed by an overview by Dr. Yoshiyuki Sasaki, Director of the Biomass Technology Research Laboratory (AIST), and reports from each of the participating institutions.

Future plans call for international workshops and similar events to strengthen partnerships with major ASEAN research institutions. There are also plans to consider the designation of a new category of R&D created through the partnership of engineering and agriculture science.





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