MMC
MICROMACHINE
2005 5

MMC Activities

Overview of MMC's Activities in Fiscal 2005

I. Basic Objectives of Activities

The basic objectives of MMC activities are, firstly, to establish basic micromachine technologies and increase utilization of micromachines through promoting research and investigation of micromachines (MEMS and other minute machines and systems), collection and provision of micromachine information, and exchange and cooperation with worldwide organizations; and secondly, to contribute to the further development of Japan's industrial economy and to international society.

MMC's basic objectives in Fiscal 2005 are, as in the previous fiscal year, to promote the industrialization of micromachines/MEMS and to strive for the establishment of next generation basic micromachine and NEMS technologies in accordance with trends in cutting-edge technological fields such as biotechnology, nanotechnology, and IT.

II. Description of Primary Activities

1. Research and Investigation of Micromachines

Planned activities in the field of micromachine/MEMS technology, which is becoming a key technology for the manufacturing industry, are aimed towards gaining a clear understanding of the trends in micromachine technologies and industries and conducting investigations of and research on new technological issues regarding the fusion of micro- and nano-technologies. The MMC also proposes national and NEDO projects in fields in which new research and development is deemed necessary.

(National/NEDO Project-related Activities)

(1) MEMS-ONE: MEMS Open Network Engineering System of Design Tools Project (NEDO-commissioned project)

Now entering its second year, the objective of the MEMS-ONE Project is to develop an open network engineering system of design tools for MEMS. This is starting to be made possible for the first time by bringing together the intellectual data of universities, corporate researchers and technicians that have a track record in cutting-edge MEMS research and development, the leading numerical analysis researchers and software development companies, and foundry-operating businesses and public institutions, the latter two of which both have substantial knowledge about the problems that occur in the MEMS manufacturing process. In particular, the MMC plays a management role in cooperation with universities and the AIST in overseeing the creation of a knowledge/materials database, as well as the promotion and progress of the project overall.

(2) Studies on MEMS-ONE Propagation Activities (NEDO-commissioned project)

In parallel with the MEMS-ONE project, studies will be conducted on activities that promote MEMS-ONE as part of research on the propagation effect of and propagation activities related to the project. In Fiscal 2004, studies were conducted on the attitudes and needs of Japan-based businesses, universities, and public institutions that were potential users. In Fiscal 2005, however, studies will be conducted mainly on effective propagation methods, including the role of support centers.

(3) Next Generation Project Investigation Committee

With a view nationalizing the Next Generation Project from Fiscal 2006 in accordance with Fiscal 2004 proposals, policies concerning the project's research system and development base, refinement of the research topics undertaken and the consequent results, and elaboration of common elements for integration will be considered.

(4) Micro-chemical Chip DB System (Contract agreement with The Research Association of Micro Chemical Process Technology)

As part of the Microanalysis/Production System Project, in which The Research Association of Micro Chemical Process Technology plays a central role, the MMC is creating a database of documentary information useful in the research and development of microchip devices and systems as well as carrying out activities, such as information gathering and data provision, that aid the creation of this database.

(Research and Investigation-related Activities)

(5) Studies on R & D trends for micromachine technology in Japan and abroad

These studies aim to identify and analyze the latest trends in the field of micromachine technology, which is progressing at a remarkable pace, and micromachine R&D in Japan and abroad; and to develop basic technological data to aid in developing micromachine technologies.

(6) Joint Survey Research Activities Concerning the Industrialization of MEMS

Opportunities for the industrial application of MEMS have been opening up rapidly in recent years; in order to further accelerate the industrialization of MEMS, this research will comprehensively tackle such challenges as advancing foundry services and coordinating MEMS devices and materials fields. Joint research with businesses that provide foundry services will also be conducted, as in the previous fiscal year, on specific issues such as overseas foundry fact-finding missions, process standardization, creation of a materials database, and coordination between foundries.

(7) Studies on MEMS Reliability Assessment Technology (application submitted to the Japan Machinery Federation as a commissioned project)

This research project involves the investigation and consideration of current status, issues, and policies relevant to the improvement of MEMS reliability.

2. Collection and Provision of Micromachine Information

Information and documents on micromachine use in universities, industries, and public organizations in Japan and overseas will be collected, combined with survey results and MMC-produced documents, and made freely available in the MMC library. At the same time, information will be disseminated widely, both domestically and internationally, through the MMC website.

(1) Improved Dissemination and Exchange of Information through the MMC Website

Utilizing the MMC website, efforts to exchange and disseminate information will be made proactively. Website content aimed at supporting members will be enhanced.

(2) Publication of a Micromachine Periodical

"Micromachine Index," containing abstracts of technical documents and information on materials, is issued on a regular basis and provided to supporting members and organizations concerned with micromachines.

(3) Publication of a Newsletter

Information concerning research and governmental trends related to micromachines is distributed monthly to supporting members and other interested individual and organizations.

(4) Maintaining and Upgrading the MMC Library

Technical documents and materials are collected and stored in the MMC library and listed in a database together with other relevant information.

3. Exchange and Cooperation with Organizations Worldwide

To promote affiliation, exchange and cooperation with related organizations in and outside Japan, MMC will involve itself in such activities as participating in the micromachine summits, holding international symposiums, inviting to Japan and sending overseas researchers and experts in the field, and building foundry services.

(1) Participation in the 11th Micromachine Summit

MMC will participate in the 11th Micromachine Summit in Dallas, USA, taking part in discussions of a wide range of topics, including worldwide trends in micromachine technology and its fields of application.

(2) Holding the 11th International Micromachine/Nanotech Symposium (partially subsidized by activities promoting the Japan Motorcycle Racing Organization)

This year MMC will hold the 11th International Micromachine/Nanotech Symposium focusing on technological issues pertaining to and the future prospects for the fusion of micromachine/MEMS and nanotechnology.

(3) International Exchange and Dispatch of Researchers

A group will be dispatched overseas to promote the exchange of information and opinions with micromachine-related research institutes in universities and similar institutions. This group will also participate in international symposiums and academic meetings held overseas. MMC will further promote exchange by inviting experts in the field from America and Europe and by sending our experts and researchers overseas.

(4) Building a foundry network system

Foundries are vital to the industrialization of MEMS. In order to improve these facilities, we will undertake the establishment of a system to improve services through a network comprising members of the Foundry Service Industry Committee, who represent businesses either involved in or related to the provision of foundry services.

(5) Establishing a forum for the exchange of cutting-edge micro/nano technology

In order to accelerate the development of cutting-edge micro/nano technology – a basic technology expected to have a diversity of applications in various fields – MMC will hold a meeting for the exchange of cutting-edge micro/nano technologies as an exploratory opportunity for the exchange of information and joint research as in the previous fiscal year.

4. Standardization of Micromachines

In cutting-edge technological fields such as micromachine/MEMS, standardization is being promoted as international initiatives are being taken.

(1) Standardization of Fatigue Testing Methods for Micro-nano Materials (NEDO-commissioned project)

Continuing from last year, research on standard fatigue testing methods that enable evaluation of the properties of various thin film materials measuring less than 10μm wide and 100μm long, with the aim of international standardization. Fatigue tests using conventional 1/1000 sized specimens will be conducted in order to clarify the limits of application for fatigue testing methods that use the current standard mm order specimens, and proposals for international standards will be made in Fiscal 2005, the 3-year project's final year.

(2) Standardization of Tensile Testing Methods for Thin Film Materials

The results of MMC research conducted between Fiscal 1999 and Fiscal 2001 as part of the NEDO project "standardization of evaluation method of properties for micromachine material" have been included in international standardization proposals submitted to IEC in Fiscal 2003; the CD (Committee Draft) was approved in Fiscal 2004 and the CDV (Committee Draft for Vote) will be submitted in Fiscal 2005. This year MMC will continue its activities towards international standardization.

(3) Standardization of Micromachine Terminology

Having passed the NP (New Project) stage, the international specifications proposal "Technical Terms in Micromachine Technology" submitted to IEC in Fiscal 2002 was approved at the CDV (Committee Draft for Vote) stage in Fiscal 2004, and the FDIS (Final Draft International Standard) will be drawn up in Fiscal 2005. This year MMC will again continue its activities towards international standardization.

(4) Research and Investigation of Micromachine Standardization

Further to the international standardization proposals mentioned above, to enable formulation of new strategic proposals for international standardization, issues for inclusion in standardization proposals will be narrowed down through cooperation between the MEMS-ONE project and the MEMS Reliability Assessment Committee and a roadmap for future international standardization formulated.

5. Dissemination of Information and Education about Micromachines

By issuing and distributing quarterly magazines and by holding exhibitions, we hope to disseminate information on micromachines extensively in order to educate as many people as possible.

(1) The quarterly magazine "MICROMACHINE" will be published periodically and distributed to those in or connected with the field. The quarterly magazine will also be made available on the Internet through the Center's home page.

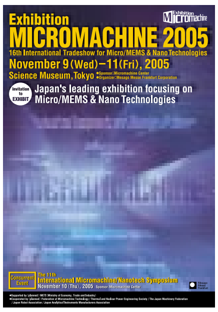
(2) The 16th Micromachine Exhibition and other events will be held to present the latest research achievements, as well as the latest cutting-edge micromachine/MEMS industry-related products and product materials.

(3) We will serve as the Federation of Micromachine Technology Secretariat to work with and strengthen micromachine-related organizations.

Upcoming Event Announcement
The 2005 International Micromachine / Nanotech Symposium and Micromachine Exhibition

The 11th International Micromachine / Nanotech Symposium
November 10 (Thurs.), 2005
Science Hall
Science Museum, Tokyo (Kitanomaru Park)

The 16th Micromachine Exhibition
November 9 (Wed.) – 11 (Fri.), 2005
Science Museum, Tokyo (Kitanomaru Park)



Special Guest Speech: New Progress of Integration and Fusion in MEMS –Expectations for New Industry Creation–

Susumu Sugiyama
Professor, Ritsumeikan University

I would like to talk about some of the MEMS research we have been doing and consider together the future outlook for MEMS. MEMS are integrated devices much like integrated circuits, but while the in/out signals for LSI chips are electric signals, MEMS can support numerous types of quantities, including such physical quantities as electrical, mechanical, optical, and magnetic quantities; chemical quantities; and biological quantities. The characteristics of MEMS can be further exploited in the form of living (or motional) devices in which moving mechanisms have been introduced. At the International Conference on Solid-State Sensors and Actuators in 1987, a U.S. presentation introduced living devices in which gears and linkage were formed on silicon using the same method for fabricating LSIs. This triggered a boom in the research and development of MEMS throughout the world.

Now in the 21st century, we have entered an age of industrialization that no longer asks "how" to make something, but "what" to make. There is much anticipation for a fundamental device to succeed the integrated circuit and be useful in our everyday lives. With advanced integration and the introduction of nanotechnology in systems, micro and nano systems have become the standard. Microtechnology employing a top-down approach to investigate the limits of fine processing and nanotechnology employing a bottom-up approach to develop new functions by designing materials from the atomic and molecular level come together on a MEMS substrate. Hence, MEMS provides the bridge for putting nanotechnology to use for us.

MEMS devices are expected to be vital in such industrial fields as information and communications, automobiles, precision machines and biotechnology. While the market for MEMS in 2002 was about 430 billion yen, it is estimated that this value will rise to 1.3 trillion yen by 2010. The NEDO project was initiated to respond to this market demand. The MEMS project (2003–2005) has included R&D on optical MEMS with such themes as mirror flatness, angular control, and rotational life; RF-MEMS with such topics as low loss at 10 GHz, high-processing precision, and the life of RF-switch contacts; and sensor MEMS with the goal of achieving chip size packaging at a low cost. In the MEMS-ONE project (2004-2006), we have conducted research on MEMS designing tools, with which we hope to facilitate manufacturing that combines creating technologies with design technologies.

Next, I will talk about the integration of MEMS and the fusion of MEMS with other technologies based on our research.

(1) Multicellular integration: many cellular elements are assembled to produce various functions, such as ① thermopile generators capable of generating several volts with a low temperature difference by arranging hundreds or thousands of thermocouples in series, ② painless micro needles in a drug delivery system that includes 1,000 needles arranged in $1cm^2$, and ③ pneumatic balloon actuator that uses the air pressure in an array of balloons to produce cell-like movement similar to cilia.

(2) Multiaxis integration: integrating one axis to three axes of rotation in multiple dimensions to produce ① 6-DOF (six-Degree of Freedom) force-moment sensor ② 6-DOF accelerometer for precisely measuring the movement of humans and other moving objects.

(3) Mechanical integration: combining mechanical elements in a single system to produce ① micro reciprocating engine for power generation in which a cylinder and piston are integrally processed by dry-etching silicon, ② electrostatic controlled linear inchworm actuator (ECLIA) capable of high-precision work that includes an array of piezoelectric actuators and electrostatic actuators, ③ micro/nano materials testing system employing 1,000 electrostatic actuators to create a motor, load mechanism, and measuring mechanism capable of performing tensile tests in nano-level fields such as nanotubes and nanowires, and ④ micro conveyer systems that employs electrostatic actuators for capturing, transporting, measuring, and selecting nanoparticles and cells under a microscope.

(4) Fusion with information technology: the fusion of MEMS with information technology is important. By incorporating a communication function in MEMS, leads would become unnecessary. The objective is to create MEMS as small as 0.5 x 0.5 mm that cost just a few pennies. These particle-like MEMS called "smart MEMS" would be used for sensing and measurements. By incorporating the Internet, points of data detected by this smart dust are expanded to linear data by a communication device and further expanded to planar data when transferred to the Internet. These sensors are widely anticipated for use in simultaneous measurements in agriculture, transportation, distribution, and health care.

Finally, MEMS devices are important for industry, since manufacturing technology and equipment are essential for innovation. MEMS is a platform for making nanotechnology useful in our daily lives. Thus a union with nanotechnology for producing new functions can be considered an important role for MEMS. To achieve this, an R&D center for incorporating nanotechnology in MEMS must be linked with businesses and universities in order to produce a high benefit-cost ratio. However, rather than distributing research activities among many locations, a certain degree of concentration may be necessary since distribution requires a large investment. Furthermore, improvements in the infrastructure will be necessary to provide a foundation for international competitiveness.

MEMS Foundry Service at the National Institute of Advanced Industrial Science and Technology

Ryutaro Maeda

MEMS and Packaging Group, Advanced Manufacturing Research Institute
National Institute of Advanced Industrial Science and Technology

Outline

As part of the "Focus 21 Project" under the Ministry of Economy, Trade and Industry, the National Institute of Advanced Industrial Science and Technology (AIST) completed construction of the "MEMS Business Building" that makes available MEMS production facilities to promote the industrialization of MEMS. Operations at the building began in March 2004.

As MEMS foundry services have become more popular, the private sector has enhanced the services available for producing device prototypes with some potential for mass-production. At present, however, the private sector cannot immediately handle prototypes required in research and development or prototypes of diverse devices with limited production that are the niche of small and medium venture businesses. For this reason, AIST is serving as a collaborative research base for providing a prototype service for devices that are essential in research and development but a high risk for private businesses.

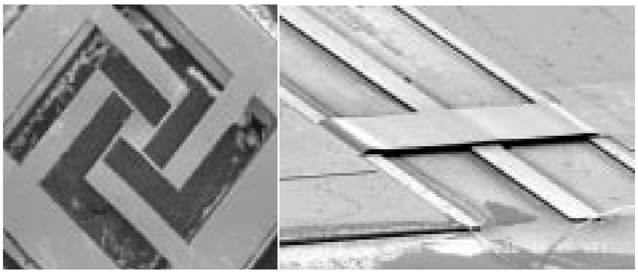
These facilities coordinate the research potential and technological seeds in MEMS possessed by AIST with the technology and needs of industry. It is hoped that these facilities will bring together the intellectual minds of industry, academia, and government in the field of MEMS, strengthen cooperation, and nurture creative personnel. The facilities are now actively operating as a control base for MEMS R&D.

Features of the Foundry Service

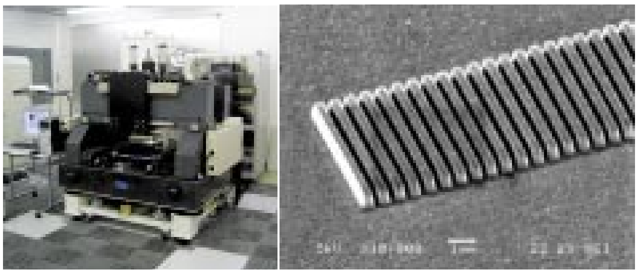
To date, MEMS technology has been commercialized in the forms of medical and automotive sensors, inkjet print heads, and mirrored reflection projectors. Soon sensors and actuators developed with MEMS technology are expected to have applications in optical communications and mobile equipment, computer peripherals, portable power supplies, and biotech analysis. MEMS has reached the status of a next-generation technology that can revitalize Japan's industry.

We have identified the need to improve our developing speed and to reinforce proprietor technologies that cannot be immediately imitated, particularly material technologies that require lengthy research and development. At AIST we are rapidly developing next-generation devices through close collaboration with industry, making use of sophisticated thin film material technology used in sensors and actuators and 3D micromachine technology for silicon, as well as our own cultivated glass and carbon. Some of our primary areas of development include RF-MEMS for use in next-generation high-frequency communications, optical MEMS for use in optical communications and elements of information presentation, and fluid MEMS used in biotech analysis. These technologies have attracted much attention for their ability to make Japan's industrial goods sophisticated and differentiated. With the aim of applying MEMS to other fields, which has not been possible due to the scarcity of technical experts, our facilities have also contributed to training advanced and creative experts. In collaboration with the nonprofit organization Precision Engineering and Science Network, we have launched a hands-on MEMS course that is not merely a classroom lecture but focuses on design simulations and the practice of actual process measurements. The course has drawn praise from experts in many fields of the private sector.

Our facilities comprise primarily a high-accelerating voltage electron beam lithography device as a machining tool for use in nanoregions, a deep-focus stepper for MEMS designed to print patterns on multilevel structures with high precision, a high-aspect ratio ICP etcher having numerous uses in MEMS, and a nanoimprinter for low-cost industrial manufacturing of nanostructures. In addition to these specialized devices, the facilities include machining and measuring equipment commonly used for MEMS to provide everything necessary in one environment to support the rapid development of prototypes. We are also working to prevent reductions in service features due to the limited number of available government workers.



An optical scanner using ferroelectric material (left) and an RF switch driven by a low voltage



A nanoimprinter (left) and a nanoimprinted glass structure

Expectations For The MEMS-ONE Project

Hiroyuki Fujita, Project Leader and Professor at The Institute of Industrial Science, the University of Tokyo

As a variety of MEMS products led by automotive sensors are now entering the market, it is a safe bet that the applications for MEMS will continue to expand into other fields. Some areas that look particularly promising for MEMS are optical applications such as optical communication devices and optical sensors; information systems such as printers, displays, and data storage devices; micro/nano chemical systems and nano-biotechnology applications; and nano-technology applications such as scanning probe microscopes.

In order to accelerate MEMS commercialization in these diverse fields of application, it is important to develop not only individual products, but also a more complete infrastructure consisting of manufacturing equipment to serve as a foundation for micromachine-related industries, foundry services that undertake production, and design and analysis software. Since the development of such an infrastructure can reduce development and manufacturing costs for individual products, there is an increased likelihood that the degree of added value from MEMS can be used effectively toward the successfully marketing of MEMS products, for which the market scale is not always great.

The provision of a computer-aided design system is particularly effective in reducing the costs of trial production since the actual desired MEMS are produced after freely designing and analyzing the shapes of mechanical parts on a computer. This environment consists of a simulator for analyzing processes and electrical and mechanical properties suited to MEMS characteristics, and a database used by this simulator. Since the content of a database for manufacturing processes is heavily dependent on the device and its operating parameters, cooperation between a foundry company and companies involved in manufacturing the device is indispensable for constructing an effective database. By standardizing the manufacturing process and dividing the process into design, analysis, processing, and evaluation steps, a mechanical engineer will be able to apply a design and analysis simulator effectively to obtain design results approaching the desired final product, without being conscious of the actual details in each process step.

Now that MEMS technology has already made significant progress, manufacturing equipment and processes, as well as micromachines, actuators, and other devices developed for specific applications can be used intact in other fields after only slight changes. However, few businesses have the know-how for accumulating knowledge acquired through development processes in a form that can be used in other situations. Further, each business has limited specializations and may not have the capacity to appropriate this knowledge to diverse fields of application. Databases for accumulating intellectual property on MEMS design and production in a reusable form and simulators for applying this database to MEMS applied systems of various fields to demonstrate the functions of these systems are expected to play a large role in overcoming such limitations.

In response to these demands, NEDO has undertaken the MEMS Open Network Engineering System of Design Tools (abbreviated as MEMS-ONE) project as a consignment project for a three-year period beginning in 2004 with the aim of constructing a database and simulation software conforming to Japan's manufacturing environment and integrating research findings to date. The activities of MEMS-ONE involve conducting earnest research and development through collaboration with companies that develop design and analysis software, companies involved in manufacturing MEMS products, and The National Institute of Advanced Industrial Science and Technology through coordination by the Micromachine Center. Databases for materials and processes have also been constructed with the cooperation of MEMS foundry companies and universities specializing in MEMS or numerical analysis.

Upon completion, we plan to distribute a MEMS design and analysis support system and database to everyone at a very low price. The system is provided with sufficient functionality for use by scientists and students studying MEMS for the first time, enabling these users to simulate basic manufacturing processes and to analyze the structural properties of manufactured devices. To meet more advanced demands, various functions may be used to enhance the performance of the system, including an interface for connecting the system to existing or new development software programs and a function allowing users to expand the database.

It is my hope that this MEMS design and analysis support system will be used at various levels, from venture companies to large firms and from beginners to experts, to assist in the implementation of MEMS and industrial construction based on MEMS. I would be pleased if our project helps to promote new businesses by developing special analysis software and constructing special databases on a common platform.

MEMS 2005, Miami (Jan. 30 – Feb. 3, 2005)

The 18th International Conference on Micro Electro Mechanical Systems (MEMS 2005) was held in Miami Beach, Florida at the Fontainebleau Hilton Resort from January 30 to February 3, 2005. The conference, which began in 1987 as the Micro Robots and Teleoperators Workshop, has continued to grow in scale, exceeding the previous year's numbers of submissions and participants.

The number of abstracts submitted for this year's conference was 750, of which 216 were accepted, a considerable increase over last year's 629 submissions, of which 217 were selected. Since the accepted number changed very little, the percentage of accepted abstracts dropped to 29% from 34% last year. Countries who gave the largest number of presentations this year were the United States with 107, Japan with 47, South Korea with 16, and Germany with 9, followed by Denmark, Holland, Switzerland, and Taiwan. By region, 50% of the presentations were given by North America, 21% by Japan, 16% by Europe, and 13% by Asian countries other than Japan. Among research institutes, 21 presentations were given by the University of Tokyo, 20 by the University of Michigan, 9 by the Georgia Institute of Technology, and 9 by the University of California, Berkeley. The final tally of participants was estimated at about 702, with 376 participants from North America, 162 from Asia, and 104 from Europe, based on advance enrollment.

Sessions of the conference featuring oral presentations were divided into the categories Self Assembly and Packaging, RF-MEMS, Pneumatic/Jet Systems, Optical Microsystems, Power MEMS, Physical Microsystems, Polymer MEMS, Bioanalytical Systems, and Nano Systems. Polymer MEMS was a new category established this year.

The presentations covered a wide range from basic research on materials, processing technologies, and element technologies for actuation to applied research envisioning specific applications. However, few companies gave presentations detailing actually commercialized devices and systems. Overall, the conference seemed to serve as an opportunity for speculating about what systems will be produced over the long term. This impression is supported by the fact that 86% of all presentations were given by universities.

The three invited speakers at this year's conference introduced the principles of microfabricated atomic clocks, liquid lens technology, and direct methanol fuel cells, and reported on the recent trends and future outlook of these technologies. These fields are expected to have future applications and, consequently, seemed to attract much interest.

One of the general trends in many presentations appeared to be developing practical applications for RF-MEMS and Physical Microsystems based on CMOS. Presentations on Polymer MEMS talked about on-chip processing of the polymers themselves, and the use of polymers for flexible movement. Devices manufactured by combining nanoprocessed polymers (plastics) and silicon substrates that are capable of controlling the functions and performance expressed through nanoprocessing by extending and pulling the polymer with the silicon actuator likely indicate a future trend toward devices that are capable of integrating dissimilar materials.

There was also a sense of heightened anticipation for future applications of bio and nanomaterials in reports on cell patterning in the Bioanalytical Systems session, particularly with regard to imagers for patterning and mapping bacteriorhodopsin and property measurements of nanomaterials in the Nano Systems session.

Next year, MEMS 2006 is scheduled to be held in Istanbul, Turkey on January 22-26, 2006.

Conference room for oral presentations

Conference room for poster presentations

Mizuho Information & Research Institute

Participating company in the MEMS-ONE project

Endeavors in MEMS

While the U.S. and European nations are currently at the forefront of the MEMS industry, momentum has been building recently in Asian countries such as Taiwan and Singapore toward establishing MEMS as a new pillar of their industry with national backing. An increasing number of people in Japan as well are hoping that MEMS technology in the form of accelerometers, pressure sensors, and inkjet print heads will revive Japan's manufacturing industry. In light of this, and with the heightened anticipation for the future market expansion of MEMS, we are applying our past achievements to integrate four of our strengths given below in order to provide solutions for MEMS development.

- **Research:** fact-finding studies through collaboration with a group of experts in economics, policy, and technology
- **Consulting:** drawing on our experience in simulation techniques and research
- **Simulation:** techniques based on our extensive achievements in scientific analysis
- **Software:** development, sales, and customization

Future Endeavors

Our objective is to develop advanced simulators for semiconductor process analysis, electrostatic-magnetic field analysis, optical, electronic, and plasma analysis, thermal fluid analysis, chemical reaction analysis, and structural analysis to develop advanced simulators for MEMS devices that can help developing this field. It is our goal to lead Japan in performance simulations for MEMS technology.

This year, a research consortium was formed through cooperation among industry and academia. Initiated by the Ministry of Economy, Trade and Industry and the New Energy and Industrial Technology Development Organization (NEDO), the MEMS Open Network Engineering System of Design Tools (MEMS-ONE) project will last for three years until 2006. Our company is participating in MEMS-ONE as a core business for developing a mechanism analysis simulator, process analyzing tools, function-enhanced software (bouding and packaging functions), and a database system.

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Primary Achievements

Research

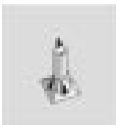
- Micromachining Process Consortium (representative: Prof. Kazuo Sato of Nagoya University)
- Study on lithography
- Study on microchemical processes
- Survey on machining precision and product precision in manufacturing technology

Consulting & Simulation

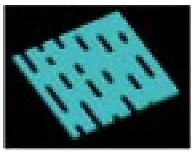
- Capacitance analysis for MEMS devices
- Stress and structural analysis of microstructures, including accelerometers and pressure sensors
- Microfluid analysis
- Polymer structure analysis of resist materials
- Wet/dry etching analysis of microstructures

Software

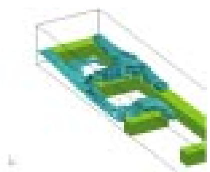
- Designing Microstructures
  - Anisotropic etching simulator
  - Plasma etching simulator
- Lithography
  - Optical, electron beam, and X-ray lithography simulators
- Microfluid analysis
  - 3D fluid analysis system
- Electronic device analysis
  - Process device simulator



A microneedle manufactured by anisotropic etching (MICROCAD)



Pit pattern in an optical disc formed by direct electron beam writing



Free surface analysis

Worldwide R&D

Biomaterials System Engineering Laboratory, Department of Materials Engineering, Graduate School of Engineering, The University of Tokyo

Ryo Yoshida, Associate Professor
http://www.bmw.t.u-tokyo.ac.jp/yoshida/

The Biomaterials System Engineering Laboratory is entering its fifth year since its launch in April 2001. The laboratory is currently staffed by three doctoral students (one working adult), four master's students, three undergraduate students, and one technical assistant.

Living organisms are perhaps the ultimate material system capable of transmitting data, transporting materials, and creating motion and force through cooperation at the molecular level. Using such organisms as a model, we are attempting to artificially design and construct materials and systems with polymer gels that can replace or imitate the functions of these living organisms.

Polymer gels can be broadly defined as a cross-linked polymer network inflated with a solvent such as water. In addition to foodstuffs, there are numerous gels that we use in our daily lives, such as the superabsorbent material in disposable diapers, and soft contact lenses. Polymer gels are used in a variety of fields. Many gel-like tissues can also be found in living organisms, including the cornea of our eye and vitreous bodies.

This type of gel can exhibit a very unusual phenomenon called volume phase transition in which the gel reversibly and discontinuously swells or shrinks in response to environmental changes, such as changes in the solvent composition, temperature, and pH, the application of an electric field, exposure to light, and the addition of specific molecules. Much research is now being conducted on this quality to find applications for these gels as functional materials. So far several "intelligent" gels having organism-like functions have been developed, including gels that function as artificial muscles and gels that release medicine only when heated.

While various stimuli-responsive gels are being created in this way, our laboratory is developing a "life-like" functional gel that produces spontaneous pulses under uniform conditions similar to myocardial cells. By developing a molecular design in the gel for inducing the BZ reaction, an oscillating reaction known as a chemical model of biological metabolic reactions (citric acid cycles), and converting the chemical changes to dynamic changes, we have succeeded in producing a periodic swelling and shrinking oscillation in the gel (Fig. 1). This led to the creation of a new biomimetic gel capable of inducing its own oscillations in a regular rhythm under fixed conditions, much like the pulsations of a cardiac muscle. Unlike conventional stimuli-responsive gels, this is the first gel in the world that produces swelling-shrinking oscillations without an external stimulus being turned on and off and is expected to have applications in molecular pacemakers, pulsating micropumps, and microactuators having peristalsis. New gels that imitate a cardiac muscle have also been developed recently. These gels are capable of self-induced pulsations in the presence of ATP.

Currently we are attempting to apply lithography and other micromachining technologies that have made remarkable advances in recent years to develop micromachines and nanomachines from these functional gels. For example, we are creating microactuators (artificial cilia) by arranging hundreds of microprotrusions on the surface of self-oscillating gel and generating wave propagation through a chemical reaction, spontaneously producing periodic fluctuations in the protrusions (Fig. 2). It is thought that such a microactuator may have applications in a microtransfer system for transporting minute particles and cells added to a surface.

We are also working on applications for medical chips. By providing a medicine storage section in a chip and forming a gel at the exit passage to this section through local photopolymerization, we can produce a drug release system that opens and closes a gate in response to abnormal signals (Fig. 3). We are designing a drug release chip for releasing insulin in response to changes in temperature and pH and glucose concentrations. Further, a pulsating gel embedded in a chip is anticipated to serve as the power source for a pulsating micropump designed to releasing drugs periodically. This chemical engine requires no electrical power and can be used as a completely independent drug release chip having no wires connected to an external power source. By fusing this gel with micromachining technology, we believe that new developments and applications for the gel as a functional material will continue to expand.

For more information on our research activities, please visit our Web site. Although our laboratory is relatively new, the students and I are conducting research round the clock.

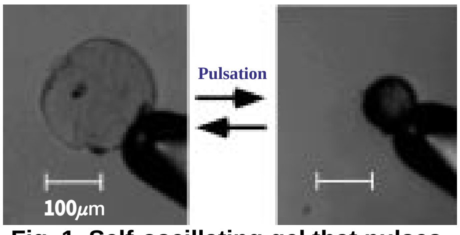


Fig. 1 Self-oscillating gel that pulses spontaneously pulsation

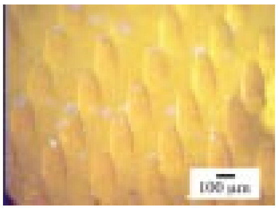


Fig. 2 Gel array created through micromachining (artificial cilia)

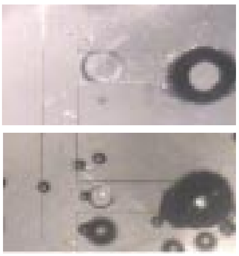


Fig. 3 Microvalve formed of gel in a microchannel for automatically controlling drug release (the valve is closed in the top photo and open in the bottom photo)

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