MMC

MICROMACHINE

2003 10

MMC Activities

Reports on Research Conducted under the 9th Micromachine Technology Research Grants (Part 2)

The research grant program began inviting applications in 1993 as a part of the independent activities of MMC. The purpose of the program is to assist college and university staff engaged in basic research on micromachines, and to promote further development of micromachine technology and communication between academics and people in the industrial world.

Of the 9 themes selected for the 9th (2001) research grants, summaries are provided below of the research results for 2 projects carried over from fiscal 2000 and 3 projects newly selected for fiscal 2001.

NO.	Subjects	Leader and Co-Worker	Affiliations	Period
Carried-Over Projects Granted for Fiscal 2000				
5	Creation of PEGylated Gold Nanoparticles for New Diagnostic System	Prof. Yukio Nagasaki	Professor, Department of Materials Science, Science University of Tokyo	2 Years
6	Surface Micromachining on Three-Dimensional Bulk Si Structures	Dr. Minoru Sasaki	Associate Professor, School of Engineering, Tohoku University	2 Years
Research Projects Newly Selected for Fiscal 2001				
1	Basic Study for Microactuator Controled by Wetting and Driven by Capillary Force between Liquid-Liquid-Gas Interfaces	Prof. Izumi Hirasawa	Professor, Department of Applied Chemistry, Waseda University	1 Year
		Dr. Masato Sakurai	Senior Researcher, Space Technology Research Center, National Aerospace Laboratory of Japan	
2	Study on a Cuff Microelectrode Using MEMS Technology	Dr. Shoji Takeuchi	Associate Professor, Center for International Research on Micromechatronics (CIRMM), Institute of Industrial Science (IIS), The University of Tokyo	1 Year
3	Study on Heart-Emulating Microactuators Using Self-Oscillating Gel	Dr. Ryo Yoshida	Associate Professor, Graduate School of Engineering, The University of Tokyo	1 Year

Affiliations as of May, 2003

Creation of PEGylated Gold Nanoparticles for New Diagnostic System

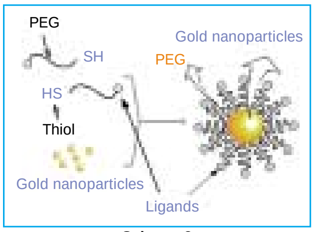
Yukio Nagasaki, Professor, Department of Materials Science, Science University of Tokyo

It is known that small gold particles on the order of several to tens of nanometers can be generated by reducing a chloroauric acid ($HAuCl_3$) using a reducing agent, such as citric acid. Gold nanoparticles obtained in this way disperse stably in an aqueous solution because like particles do not aggregate due to an ion-ion repulsion from the citric acid adsorbed on the surface of the gold nanoparticles. However, under the severe conditions of high ion concentrations or the like, the ionic repulsion of these adsorbed molecules generates an electrostatic shield that remarkably reduces dispersion, facilitating agglutination. In order to improve stability, we performed an experiment to add starch or other water-soluble polymers to form a protective colloid. Murray, et al., succeeded in coordinating a very stable particle dispersion by adding polyethylene glycol having a mercapto group (PEG-SH) to the surfaces of the gold nanoparticles. However, this method suffers from many problems including a drop in stability when investigating functionality, due to the conflicting relationship between stabilizing nanoparticle dispersion and surface functionality.

From the conventional perspective of biomaterial surface treatment, the authors synthesized polyethylene glycol (HeteroPEG) with a different functional group on both ends (Scheme 1). The gold nanoparticles were stabilized using HeteroPEG having a highly configurable mercapto group and polyamine chain on the surface of the gold particles (Scheme 2). Since the PEG was coordinated in a brush formation on the surface layer of the gold nanoparticles and the opposing end possessed a functional group in which a ligand can be introduced, this compound holds promise as a tool for resolving the above problems.

We attempted to functionalize particles using sugar and lectin or biotin and avidin, which are well known for use in specific molecular recognition. Fig. 2 shows photos of a solution of dispersed lactose-conjugated gold nanoparticles when an RCA lectin protein was added to selectively interact with galactose therein. The dispersed nanoparticles agglutinated by the interaction between lactose on the particle surface and lectin, turning the solution a purple color. When free galactose is added to this form, the solution returns to a pink color, indicating that this interaction is reversible. Fig. 3 is a graph showing the relationship between the concentration of RCA_{120} lectin and changes in absorbency for two nanoparticles prepared with lactose and mannose introduced onto the PEG terminals of the respective gold nanoparticles. While the gold nanoparticles modified with mannose, which does not show interaction with the RCA_{120} lectin, do not indicate any changes in absorbency, the lactose-conjugated gold nanoparticles were confirmed to change dependent of concentration. Based on the results of Figs. 2 and 3, this system enables the confirmation of molecular recognition with the naked eye and an accurate assessment of concentration using a simple spectroscope. This novel material will allow us to perform bedside diagnoses of today's extremely serious infectious diseases and highly sensitive diagnoses that were impossible before now.

Scheme 1



Scheme 2

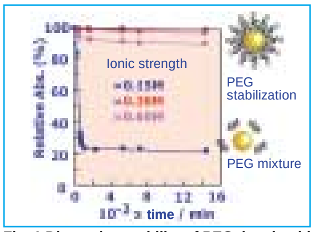


Fig. 1 Dispersion stability of PEGylated gold nanoparticles

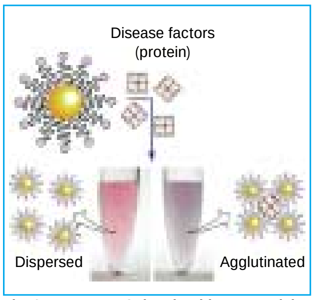


Fig. 2 Lactose PEGylated gold nanoparticles and lactin mixture

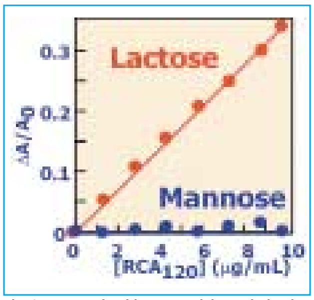


Fig. 3 Degree of gold nanoparticle agglutination in relation to lactose concentration

Surface Micromachining on Three-Dimensional Bulk Si Structures

Minoru Sasaki, Associate Professor, School of Engineering, Tohoku University

1. Introduction

In order to develop devices for micro-optics applications, elements of the device is often required to have 3D structures so as to form a space for the optical path that is decided by the laws of optics, such as the law of reflection. Few optical systems can be integrated on the surface of a single substrate. Strategies for arranging devices three-dimensionally often have problems in assembly that reduce productivity. Such problems can be alleviated by prealigning the microactuator with the micro-optical bench using an alignment guide. We developed an optical device having a thin film construction layer on a three-dimensional bulk Si structure.

2. Optical Scanner

We prepared a micro-mirror on a Si(111) surface obtained by anisotropic etching and fabricated an optical scanner incorporated with a temperature-driven actuator. We applied a 3D photolithography technique capable of forming a SiN mask and forming patterns in the wall surfaces. Figs. 1(a) and 1(b) show the structure of the optical scanner and an actual photo of the fabricated scanner, respectively. The left side of the structure shows a laser diode (LD) chip mounted on a terrace, which serves as a 3D micro-optical bench. The right side of the structure is a V-shaped cantilever microactuator constructed with SiN sandwiched between a doped poly-Si heater layer and Al. When heated by electricity, the structure arches upward as the Al layer on the bottom expands. As the structure bends, the mirror rotates to a position reflecting light emitted from the LD away from the surface of the wafer. A photodiode (PD) provided on the Si substrate makes the structure applicable for barcode readers. The LD, mirror, and PD can be aligned linearly. The ribs are prepared around the periphery of the scanning mirror to strengthen the thin film mirror and make it resistant to warping. The operations of the LD chip were confirmed after mounting the LD chip on the terrace, wherein a laser scanning angle of 30° was obtained at 120 mW. The cutoff frequency was 100 Hz, close to the required value for a barcode reader.

3. Variable Optical Attenuator

For optical communications, we fabricated a bridge-type device shown in Fig. 2(a) that functions on an optical fiber. An optical fiber fixed in a V groove is polished down near its core, and a surface micromachined structure is prepared on the polished surface. When a SiN film having a high refractive index (~ 2) is brought near the optical fiber core, some coupling loss of the propagating light inside the fiber occurs. The transmittance varies according to the position of the bridge. Fig. 2(b) shows one end of the device, wherein the bridge is 0.25 x 3 mm, and the gap between the bridge and the optical fiber is 3μm. The bridge is aligned precisely in relation to the optical fiber core. Since the position of the optical fiber is set by the V groove, the mask can be aligned to achieve an accurate bridge position. The resulting attenuation was about 1 dB. This small variation is attributed not only to a problem of particles, but also the difficulty of positioning the entire long bridge uniformly near the optical fiber.

4. Conclusion

Two types of devices were successfully constructed by combining thin film microactuator and been aligned on the bulk optical base having three-dimensional structures.

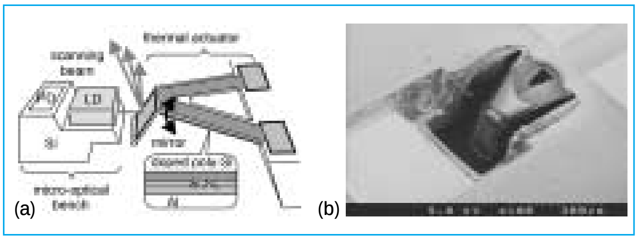


Fig. 1 Optical scanner formed on a 3D micro-optical bench

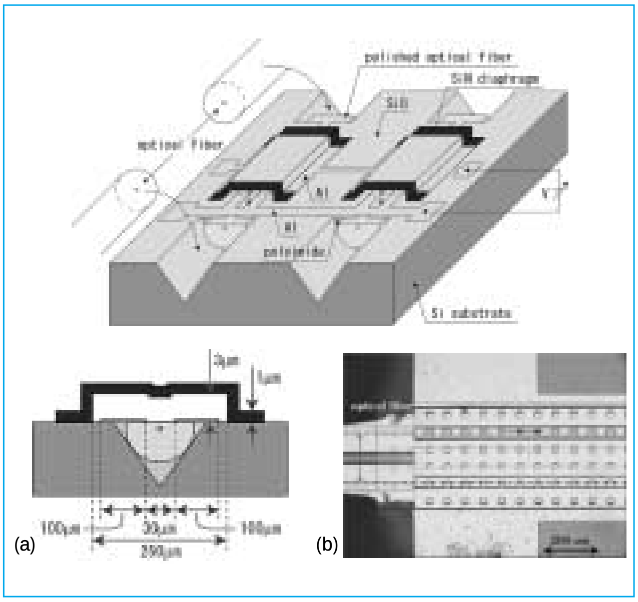


Fig. 2 Movable bridge-type variable attenuator prepared on the polished surface of an optical fiber

Basic Study for Microactuators Controled by Wetting and Driven by Capilary Force between Liquid-Liquid-Gas Interface

Izumi Hirasawa, Professor, Department of Applied Chemistry, Waseda University
Masato Sakurai, Senior Researcher, National Aerospace Laboratory of Japan

1. Introduction

In fluid phenomena, the effects of wettability and surface tension become dominant as the scale becomes smaller. Since these forces become dominant in a microgravitational field, this study was focused on the similarities between microscale systems and a microgravitational field. We attempted to control a fluid by actively controlling the wettability and surface tension.

2. Fluid Handling by Wettability

Next, we will give an example of fluid handling through wettability distribution. A metal plate in the shape of a letter was placed on top of a Peltier element for cooling, and a culture dish coated with the temperature-responsive polymer IPAAm was placed over the letter-shaped plate. Since the bottom surface of the dish had been coated with the IPAAm, only the cooled parts showed good wettability. Hence, water droplets only adhered to areas with good wettability, forming a path in the shape of the letter on the coated dish, as shown in Fig. 1.

3. Liquid-Liquid-Gas Marangoni Convection

It was discovered that a spontaneous flow occurs when a drop of silicon oil is placed on a layer of fluorinert, as shown in Fig. 2. This flow is attributed to evaporation, since the flow stops when the system is accommodated in a hermetically sealed vessel. The thickness of the silicon oil drop is thought to be about 1 mm. As can be seen from the velocity distribution in Fig. 3, the driving force of this flow appears to originate at the point of intersection between a gas and two liquids. An experimental device that applies this driving force was manufactured in order to produce rotational force. The impeller of this device distributes wettability. When the impeller was floated on the fluorinert and when a silicon droplet dyed red with a syringe was adhered only to one blade of the impeller, as shown in Fig. 4, the impeller began to rotate spontaneously.

4. Conclusion

Developing a microscale system for handling fluids is easy, since fluids are treated without mechanical structures in this study. Future studies will attempt to elucidate the mechanisms of the spontaneous flow and produce linear motion, while developing driving forces that work effectively on a microscale.

Fig. 1 The path of flow is formed by wettability distribution

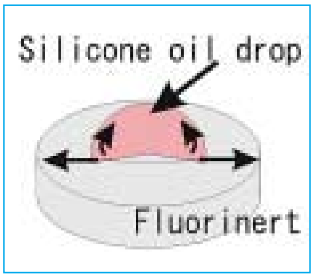


Fig. 2 Liquid-liquid-gas Marangoni convection

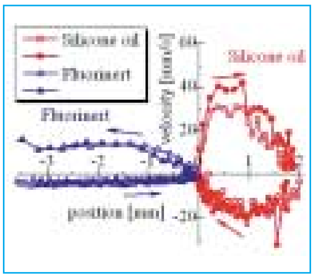


Fig. 3 Velocity distribution in liquid-liquid-gas Marangoni convection

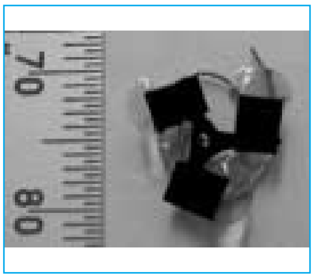


Fig. 4 Impeller employing liquid-liquid-gas Marangoni convection

Study on a Cuff Microelectrode using MEMS Technology

Shoji Takeuchi, Associate Professor, Institute of Industrial Science, The University of Tokyo

1. Introduction

This study aims at developing a cuff microelectrode capable of easily being fixed to nerve cords having micro-sized diameters. While nerve regeneration type and insertion type microelectrodes have been proposed, minimally invasive electrodes that do not cut or pierce the nerve are needed for measuring electric potentials during activity. Therefore, in this study, we incorporated a shape memory alloy (SMA) thin film microactuator in an electrode and attempted to attach the electrode to a nerve by electrically controlling the fixing operations. We proposed a 3D shape memory technique required at this time to develop a microcuff structure.

2. Fabricating Microelectrodes

A TiNi-based shape memory alloy was formed in a thin film to serve as the electrode structure. We fabricated a clipping mechanism (Fig. 1) that actively grips the nerve when driven by an electric current. Conventional TiNi thin films have lower responsiveness than other actuators due to the difficulty in raising their Martensite transformation temperatures because they are severely deformed at room temperature. By modifying the composition of the thin film and conditions of thermal treatment, we were able to raise the transformation temperatures to obtain a thin film that was Martensite at room temperature. Therefore, rather than allowing the clipping mechanism to be used repeatedly, we gave the mechanism unidirectionality, so that once clipped it could not be removed. This enabled us to manufacture a SMA thin film clipping mechanism that avoids the problem of responsiveness, normally a shortcoming in SMA actuators, has great elasticity at room temperature, and takes full advantage of its strength in high output.

3. Evaluating Electrode Properties

We recorded neural activity using the fabricated electrode. The 3D clipping mechanism was fixed to the ventral nerve cord of an insect without causing injury. It was also determined that heating had no effect on the nerve. Based on the measurements, no problems-and particularly no noise-were observed in the waveform of activity compared to those of normal electrodes (Fig. 2). Since the structure is highly elastic, the body tissue of the insect incurred no damage even when the mechanism collided with the tissue. It was also seen that neural activity could be measured while the insect was active, without the electrode coming loose.

4. Conclusion

The smaller the nerve to be treated, the more difficult it is to position the electrode near to or in contact with the nerve. It is impossible to record clear signals when an electrode has poor contact with the nerve. Electrodes using SMA thin films can easily perform this operation and remain fixed to the nerve even when the insect is active.

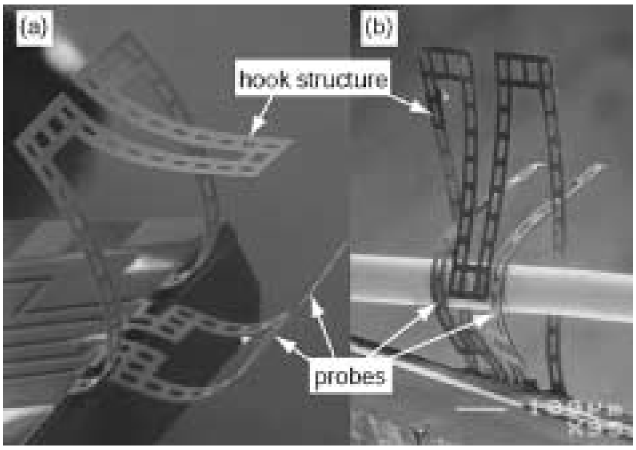


Fig. 1 (a) The fabricated SMA thin film microelectrode
(b) the electrode clipped to a 100-μm wire

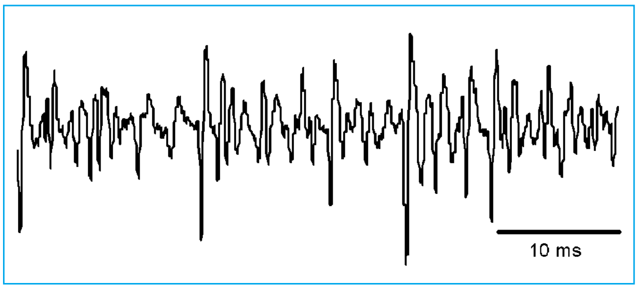


Fig. 2 Neural activity measured from the ventral nerve cord of an insect using the fabricated electrode

Study on Heart-Emulating Microactuators Using Self-Oscillating Gel

Ryo Yoshida, Associate Professor, Graduate School of Engineering, The University of Tokyo

1. Introduction

We developed a novel self-oscillating gel that, under fixed conditions, is capable of oscillating autonomously in a spontaneous rhythm like a heartbeat, as opposed to the conventional stimuli-responsive gels. Through a molecular design that converts chemical energy into mechanical energy by inducing the Belousov-Zhabotinsky reaction (BZ reaction) with a cyclic reaction circuit in the gel, also found in a chemical model of a metabolic response (TCA cycle), we demonstrated that the gel is made to periodically swell and deswell. This self-oscillating gel can conceivably enable the design of new materials capable of imitating biological functions, such as microactuators capable of autonomous periodic motion, self-beating (peristaltic) micropumps, molecular pacemakers, and information transfer elements. With the aim of developing new micromachines equipped with these functions, we established a technology for developing micro-size self-oscillating gel, analyzed the behavior of the oscillations, and conducted a basic study on constructing a material system.

2. Manufacturing microactuators (artificial cilia) through gel micromachining

We attempted two methods of micromachining self-oscillating gel. In the first method, shown in Fig. 1, we introduced a photocrosslinked section (phenyl azide group) into a polymer chain and micromachined the gel to a desired shape through photolithography using a photomask. The other method was performed according to a cutting-edge 3D micromachining technique (LIGA, moving mask X-ray lithography) using synchrotron radiation. In the latter method, we produced artificial cilia in the gel surface. The cilia comprised hundreds of protrusions of several ten to several hundred microns in size that were arranged in an array (Fig. 2). When effecting a chemical reaction wave in the gel, we observed periodic changes in the surface protrusions accompanying the wave propagation. This technique can conceivably be applied to a micro-transport system, for example, for transporting minute particles, cells, and the like added to the surface.

3. Conclusion

We designed and constructed a gel with a novel functionality for oscillating in a spontaneous rhythm like a heart muscle. This gel is of great interest for use as a microdevice element because of its ability to produce a rhythmical periodic motion and to transmit this rhythm as data. This may lead to the development of a novel material system having such functions as rhythmical motion, mass transport, and data conversion and transfer.

Fig. 1 Gel micromachining through photolithography

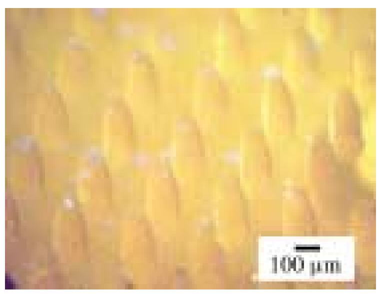


Fig. 2 Ciliary motion actuator formed of gel through LIGA

Invitation to The 9th International Micromachine / Nanotech Symposium

Micromachine Center Organizes The 9th International Micromachine/Nanotech Symposium. It will be held on November 13 (Thursday) 2003, at the Science Museum in Kitanomaru Park Tokyo, under the supporting of METI and NEDO, and with the sub-theme of "Micromachine technology that integrates nanotechnology in it makes the foundation of industrial technology in the 21st Century".

Micromachine technology has been expecting to realize novel functions in the nono domain with fusing both micro and nano technologies. To meet this expectation, the program of the symposium puts emphasis particularly on MEMS that is recently developing the ways for application.

As you see the speakers and the lecture titles on the program, thirteen speakers including six foreigners are invited. Lectures by experts who are studying at the forefront of cutting edge technologies interweave invaluable case examples in their lectures for the participants. Micromachine Center hopes that your inspiration catches quickly something, which is needed to solve the problem or remove obstacle in your research or in your business development.

In session 1, "Opening" we provide two special lectures by MEMS pioneers in Europe and U.S.A. One is "MEMS and Opportunities for University/Industry Technology Transfer" by Professor Nico F. de Rooij of University of Neuchatel, Switzerland. The other one is "Turning MEMS Ideas Into MEMS Products" by Professor Stephen D. Senturia of Massachusetts Institute of Technology, U.S.A.

In session 2, "The Path to New Industries in the 21st Century," will discuss on the following three themes.

1. "The Evolution of Relay to RF-MEMS for High-speed and Large-scale Transmission"
2. "Evolution of the MEMS business models : Status of the MEMS industry"
3. "Reliability of the Digital Micromirror Device (DMD)"

The first lecture will talk on the R&D of OMRON Corporation's hit products. The second lecture will discuss on the "Evolution of the MEMS business models: Status of the MEMS industry" based on data of global survey by Yole Development (France) and the talks will attract you as Japanese government is going to promote MEMS industrialization in "Focus 21 project". The third lecture will talk the quality insurance of Texas Instruments Inc.'s Digital Micromirror Device (DMD), as an excellent "role model" on reliability of MEMS products.

In session 3, "Innovative R&D", will discuss the following four lectures.

1. The Fabrication of a 100gm Co-Orbiting Satellite Assistant (COSA)
2. Bio-Hybrid Nanomachine
3. Micro Power Generation
4. Nano Channel

The first lecture will talk the development of a remote-control mini-satellite, measuring 5 x 5 x 5 (cm) and weighting 100g, which is developing by Aerospace Corporation in U.S.A. Launched from a space satellite (called "mother ship"), this mini-satellite is to be used in maintenance support of sight-checks, such as the condition of solar cells or extending the antenna of the mother ship. And it is controlled by wireless transmission from the mother ship. In the development of this satellite, MEMS technology such as laser technology and 3D fabrication are being used.

The second lecture will talk on the system that integrates biomoleculars and micro/nano structure. Biomolecular motor is a protein measuring approximately 10 nm that is highly involved as substance for transportation, protoplasmic flow, cell division, and other processes within the body. The lecture will focus on research involving the patterning of these mobile proteins in microfluidic devices and the handling of nano-sized substances.

The third lecture will talk on the portable fuel cells that are studying for application in near future and expecting for large market.

The fourth lecture will talk on sensors for biomedical and environmental monitoring and on transducers that change the chemical and physical signals into electronic signals. The fruits of recent study in this field will much attract you.

In Session 4, a panel discussion will be held to discuss on exploring of new MEMS development as a strategy for Micro/Nano technology with seven panelists including four guest speakers from overseas. Prof. Fujita, The University of Tokyo will serve the chairman. Before this panel discussion Prof. Hiroyuki Fujita, Professor Koji Ikuta, Nagoya University, Prof. Isao Shimoyama, The University of Tokyo and Dr. Atsushi Yusa, Olympus Corporation will give short lectures on recent MEMS developments.

This symposium was planned by the International / Exchange Committee, and then Organizing Committee (Chairman: Professor Naomasa Nakajima, The University of the Air) and the Program Committee (Chairman: Professor Hiroyuki Fujita, The University of Tokyo) composed the program and nominated speakers. Moreover this symposium has an international advisory board organized by ten chief delegates of the 8th World Micromachine Summit (2002).

This symposium aims to contribute to the promotion of our Micromachine technology through exchange of opinions among the experts in this field and by providing the direction of technological movement of the world.

The 14th Micromachine Exhibition will be held on the ground floor of the Science Museum from November 12 (Wednesday) to November 14 (Friday), 2003. The participants of the symposium will be allowed free admission to the Micromachine exhibition. We look forward to welcoming a good many attendees from throughout the world (a tentative program for the symposium is on the last page).

The Japan Motorcycle Racing Organization has been offering fund to this symposium.

Overseas Trends

Transducers '03

Transducers '03(The 12th International Conference on Solid-State Sensors, Actuators and Microsystems)was held from June 9 (Mon.) to 12 (Thurs.), 2003 at Boston Marriott Copley Place in Boston, Massachusetts, USA. With approximately 1,100 participants, attendance was slightly less than the 1,200 participants at Transducers '01 two years ago; nevertheless, with attendance exceeding 1,000, the conference was an overall success. The SARS scare, which broke just prior to the conference, is believed to have been one of the factors behind the drop in attendance.

A total of 486 papers were presented: 4 plenary presentations, 12 invited presentations, 199 oral presentations, and 271 poster presentations. Altogether 960 papers were submitted, making the selection rate 48%. At Transducers '01, a total of 401 papers from 856 submissions were presented, with a selection rate of 47%. Thus, as the number of papers submitted for Transducers '03 increased over those for Transducers '01, the number of presentations also increased. Moreover, the number of papers submitted for Transducers conferences has consistently increased (1997: 641, 1999: 826, 2001: 854), a trend that is indicative of the growing intensification of research in the MEMS field. Except for the plenary session held on the first day, the conference consisted of parallel sessions (four sessions conducted simultaneously), each of which was filled almost to capacity. Sessions on technologies close to commercial application were particularly popular, with standing room only for sessions on packaging and RF-MEMS.

By country, American speakers made the largest number of presentations (192), followed by Japanese (89), then German (32). The number of Korean presentations was the next highest, and the increased number of presentations by speakers from China, Taiwan, and other Asian countries and regions reflected the widespread expansion of MEMS research worldwide. By field, a large proportion of presentations concerned fluid technology. Many of the presentations on medical treatment, biotechnology, and chemistry subjects also overlapped into fluid technology, indicating the remarkable progress being made in this field. Throughout the conference overall, there was also an extremely large number of presentations concerning product development, a trend that has manifested in recent years. This trend was advanced even further at Transducers '03, with a noticeable increase in the number of presentations addressing problems, and measures for resolving these, faced in the practical application of MEMS technology to commercial production.

The conference venue, Boston, was also host to the first Transducers conference in 1981; in coming full circle over these 22 years, it feels as though we have reached a landmark. During this period, research focus has shifted from element research to product development-related research, and the number of papers presented by businesses has also increased. This conference clearly demonstrated how the industrial world and the world at large are moving significantly towards the industrialization of MEMS.

European Foundries

Between July 7 and 11, 2003, a study tour of leading foundry services in Europe was conducted in order to promote the development and expansion of a foundry service network in Japan.

The study tour consisted of visits and discussions in order to obtain information and hear workers opinions directly. While focusing on foundries, the tour also visited research institutions, design houses, and marketing consultants, taking a multidimensional approach that revealed through these various perspectives the true workings of European network services.

The study tour found that several overseas foundries have been established as spin-offs of public research institutions and have continuing strong partnerships with their parent institutions. We also discovered that the places we visited had several features in common. For example, with superior IP, the enterprises tended to choose business strategies that involved using their high added value in pursuing small to medium niche markets, and they actively welcomed investment from a variety of sources, with business already being begun along innovative themes. For tour participants, the freshness of and enthusiasm for new industries were palpable.

Furthermore, those whom we spoke to showed a high degree of interest in foundry services in Japan, expressing great expectations for the concept of a network service for the future.

(Places Visited)

- Colibrys (Foundry)
- Institute of Microtechnology, Neuchatel University (R&D)
- Yole Development (Marketing)
- CEA-LETI (R&D)
- Tronics (Foundry)
- MST-Design (Design House)

Visiting CEA-LETI (Grenoble, France)

Nano Device and System Research, Inc.orporation

Yoshikazu Tobinaga
COO

1. The Challenge of Micro- and Nanomachine Technology

Nano Device and System Research, Inc.orporation (NanodeS) is a venture company established on April 2, 2001. A primary activity of Nanodes is to cultivate applications based on the development of practical micromachine (MEMS) technologies. NanodeS also plans to pursue nanodevices, which are anticipated to be a key technology of the 21st century. Susumu Sugiyama, the CEO of NanodeS who serves concurrently as a professor at Ritsumeikan University and is a specialist in MEMS, has been working closely with the university on nanodevice research. Professor Sugiyama has achieved nanolithography using the university's synchrotron for irradiating soft X-rays. By making good use of this technology, it will be possible to develop devices capable of functioning at nano level.

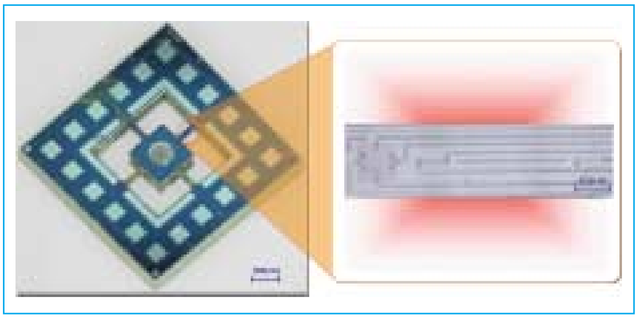
The synchrotron at Ritsumeikan University, having a peak wavelength of 1.5 nm

2. Micro- and Nanomachine Technology

MEMS can be broadly categorized as sensors incorporating signals from the environment and the like and actuators for driving something. Because current sensors can achieve functionality through a more simple construction than actuators, there have been more advances in the development of sensors. Our company has also focused on the development of sensors. Specifically, sensors include accelerometers, biosensors, and pressure sensors.

(1) Developing Applications for Existing MEMS

NanodeS is primarily focusing on MEMS devices researched at Ritsumeikan University and their application development. At present, we have nearly completed the development of a six-axis accelerometer and are now searching for partners to conduct joint research aimed at the commercialization of these sensors. Due to its ability to sense rotational movement in particular, this accelerometer is most suitable for use in robotic arms performing complex movements, or in fluid sensors. Capturing subtle human movements may also be feasible.



Six-axis accelerometer developed at Ritsumeikan University

(2) Developing Nanodevices

Although fine machining at nano has been achieved through X-ray lithography using a synchrotron, NanodeS is attempting to develop a nanogap biosensor. A biochip sensor grips a single strand of DNA within a nanogap and evaluates the electrical characteristics of the strand by applying an electrical bias.

3. Future Challenges

Products are employed in closer proximity to our bodies as the functional dimensions of the products grow smaller, as in the progression of buildings on the order of meters, automobiles on the order of centimeters, home appliances on the order of millimeters, and computers and cell phones on the order of micrometers. So what will happen when we make the next step to nanometers? Perhaps products on this order will cross the periphery of our bodies and be used therein, as in the field of drug delivery systems, for example. Certainly sensors capable of monitoring activity in living bodies like this will flourish in the next generation. While current techniques focus on extracting biological tissue and materials for measurements, future sensors will be capable of performing direct and noninvasive measurements of living body tissue. It is for this that we are preparing.

Seko Epson Corporation

Mituro Atobe
General Manager, Production Engineering and Development Div.

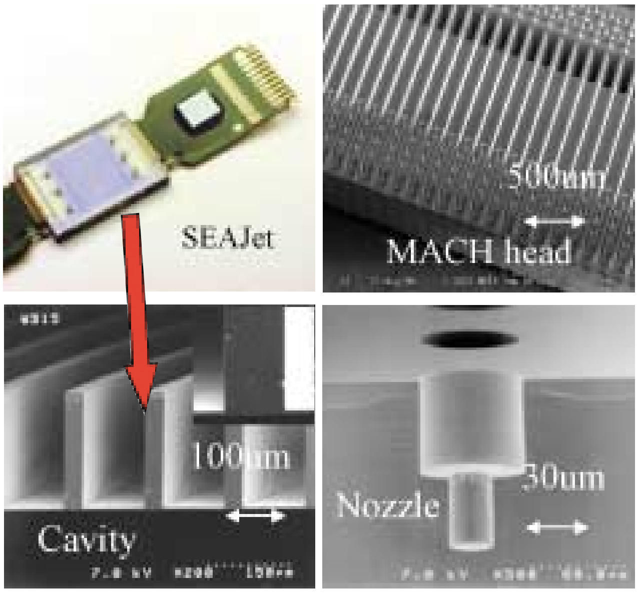
1. The Challenge of Micromachine Technology

Through the world's most advanced technologies, Seiko Epson is providing products that bring us a high quality of life based on harmony with the environment in such fields as information systems, device production, and micro-mechatronics. Our primary products deal with information-related equipment, including personal computers and such peripherals as printers and scanners, and such imaging equipment as liquid crystal projectors; electronic devices, such as semiconductors, displays, and crystal devices; precision instruments, such as watches, glass lenses, and factory automation; and other developments, productions, and services.

One manufacturing technology applying our developed micromachine technology is the SEAJet print head used in POS printers.

2. Development of Micromachine Technology

Here, we will introduce some representative products and related technologies that Seiko Epson has worked on thus far.



An enlarged photograph of a MACH head ink channel, the exterior of the SEAJet head, and enlarged photographs of the ink channel and nozzle

(1) Inkjet print head

Our Colorio series of printers are equipped with inkjet heads having micromachined ink channels. We have also applied our own inkjet technology SEAJet to POS printers used in retail operations, for example. The inkjet head provided in these printers is manufactured using micromachine technology and makes full use of the advantages of this technology to achieve small, highly efficient products with low power consumption.

(2) Electronic devices

We have incorporated micromachine technology in electronic devices, particularly in the crystal oscillator industry, to achieve the world's smallest oscillator products. We are also conducting R&D on future high value-added network devices incorporating optical devices or integrated circuits and micromachine devices on a single chip.

3. Future Challenges

We are working to evolve our ultrafine machining technology from micro- to nanotechnology in order to create devices with originality. It is our fervent wish to continue providing advanced products and services that can delight our customers while maintaining harmony with the environment.

THE 9TH INTERNATIONAL MICROMACHINE/NANOTECH SYMPOSIUM

1. Date : Nov. 13, 2003
2. Place : Science hall, Science Museum, in Kitanomaru Park, Tokyo
3. Entrance fee : ¥20,000/person (including proceedings)
4. Acceptance of participants : (till) Oct. 31, 2003
5. Information window : Micromachine Center International Exchange Dept.
Tel : +81-3-5835-1870, Fax : +81-3-5835-1873

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November 13, 2003

9:00 –	Registration	
Session 1 : Opening		**Chairman : Mr. Keiichi Aoyagi**
9:30 – 9:35	Opening Remarks	Mr. Toshiro Shimoyama, Chairman, Micromachine Center
9:35 – 9:40	Guest Speech	Mr. Sakae Takahashi, Executive Director, NEDO
9:40 – 10:20	Special Guest Speech: MEMS and Opportunities for University / Industry Technology Transfer	Prof. Nico F. de Rooij, University of Neuchatel
10:20 – 11:00	Special Guest Speech: Turning MEMS Ideas Into MEMS Products	Prof. Stephen D. Senturia, Massachusetts Institutes of Technology
Session 2 : The Path to New Industries in the 21st Century		**Chairman : Prof. Isao Shimoyama**
11:00 – 11:30	The Evolution of Relay to RF-MEMS for High-speed and Large-scale Signal Transmissin	Dr. Koichi Imanaka, OMRON Corporation
11:30 – 12:00	Evolution of the MEMS business models : status of the MEMS industry	Mr.J.C.Eloy,Yole Development
12:00 – 12:30	Reliability of the Digital Micromirror Device (DMD)	Mr. Andrew B. Sontheimer, Texas Instruments
12:30 – 13:30	✻✻✻✻✻✻✻✻✻ Lunch ✻✻✻✻✻✻✻✻✻	
Session 3 : Innovative R & D		**Chairman : Prof. Koji Ikuta**
13:30 – 14:00	The Fabrication of a100gm Co-Orbiting Satellite Assistant (COSA)	Dr. Henry Helvajian, The Aerospace Corporation
14:00 – 14:30	Bio Hybrid Nanomachine	Assistant Prof. Shoji Takeuchi, The University of Tokyo
14:30 – 15:00	Micro Power Generation	Dr. Ryutaro Maeda, National Institute of AIST
15:00 – 15:30	Nano Channel	Assistant Prof. Wouter Olthuis, University of Twente
15:30 – 16:00	✻✻✻✻✻✻✻✻✻ Break ✻✻✻✻✻✻✻✻✻	
Session 4 : Strategy for Micro/Nano technology (Exploring of new MEMS development)		**Chairman : Prof. Hiroyuki Fujita**
16:00 – 16:10	MEMS and Nanotechnology Industrialization	Prof. Koji Ikuta, Nagoya University
16:10 – 16:20	A Practical Use and Industrialization of MEMS in The Company	Dr. Atsushi Yusa, Olympus Corporation
16:20 – 16:30	Nano on Micro	Prof. Isao Shimoyama, The University of Tokyo
16:30 – 16:40	Two Directions of Development: Commercialization and Nano Frontier	Prof. Hiroyuki Fujita, The University of Tokyo
16:40 – 17:50	Panel Discussion (with seven panelists) Panelists: Prof. Nico F. de Rooij, Prof. Stephen D. Senturia, Mr. J. C. ELOY, Assistant Prof. Wouter Olthuis, Prof. Isao Shimoyama, Prof. Koji Ikuta, Dr. Atsushi Yusa	Chairman: Prof. Hiroyuki Fujita
Session 5 : Closing		
17:50 – 18:00	Closing speech	Mr. Keiichi Aoyagi, Executive Director, Micromachine Center

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