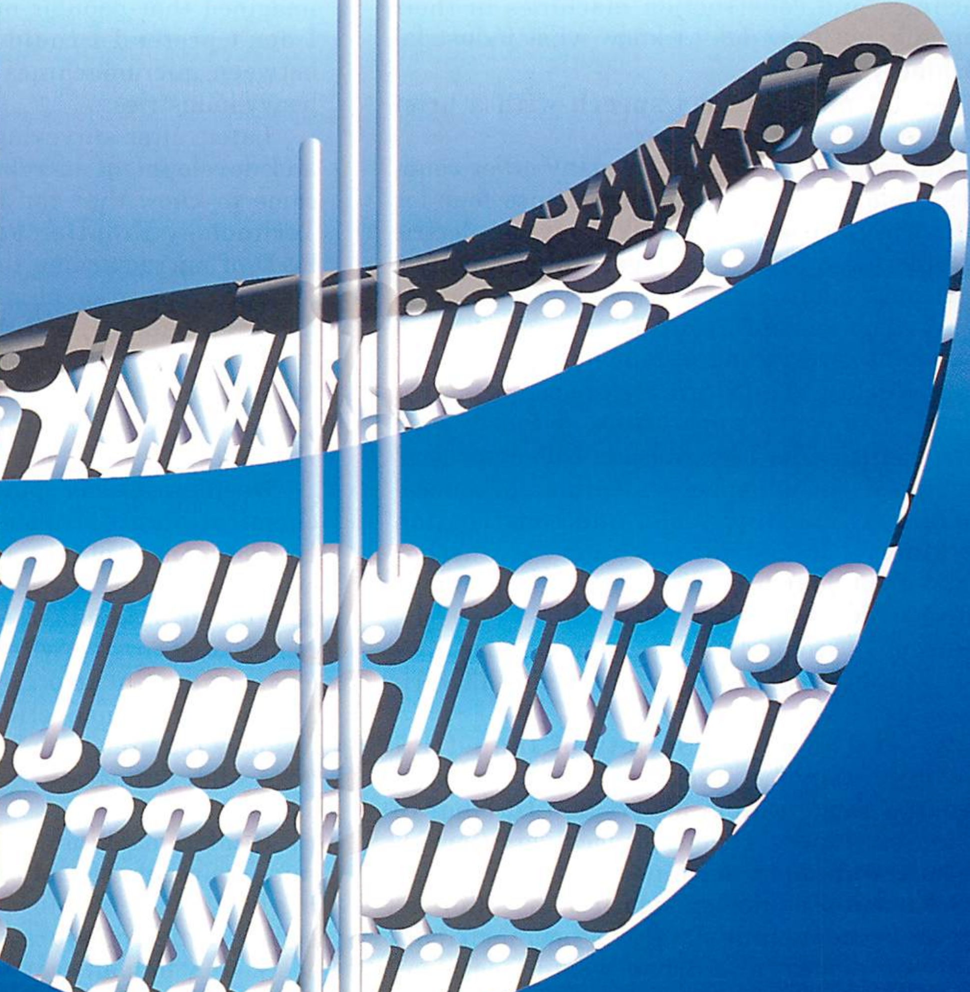
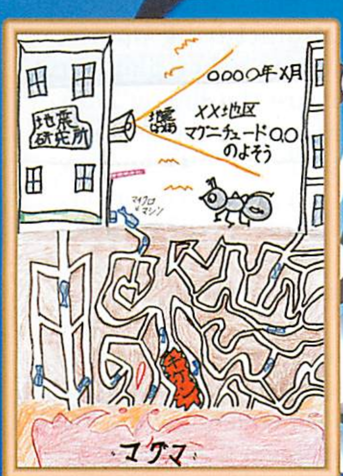
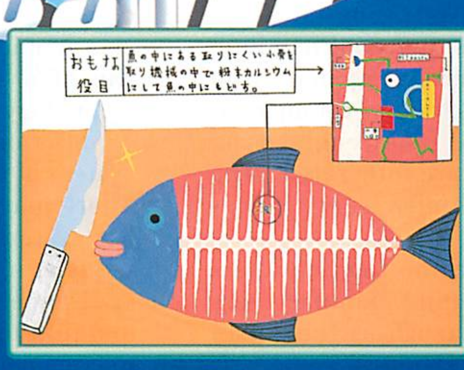
MMC

Micromachine
マイクロマシン

Aug. 1997







No. 20

MICROMACHINE CENTER

Essay

Expectations in Promoting Development of Micromachine Technology

Shigekazu Mino
Chairman of The Japan Society of Industrial Machinery Manufacturers

Many people say they can see milling machines and construction machines in their daily life, but they don' t know what industrial machinery is like.

So, let me begin my speech with a brief sketch of industrial machinery.

Not only in Japan, but in many other countries, "machines" are categorized into four for statistical purpose. The first group is "electric machinery", such as power generators, motors, televisions, and communication-electronic equipment. The second group is "transportation equipment" including automobiles and industrial vehicles. The third is "precision instruments" like optical apparatuses and measuring instruments. The last group is called "general machinery", including boilers, turbines, chemical machinery, machine tools, and construction machinery. Industrial machinery is another name of the fourth group. Although no public body has defined industrial machinery clearly, the term is used as a generic name for machines and apparatuses served for production in various industries.

We at The Japan Society of Industrial Machinery Manufacturers deal with a variety of machines ranging from boilers and turbines to mining machinery, chemical machinery (including pulp and paper machinery), storage tanks, environmental equipment (such as desulfurization equipment, industrial wastewater treatment equipment, and urban waste treatment equipment), plastic processing machinery, pumps, compressors, blowers, material handling machinery, power transmission equipment, iron and steel manufacturing machinery, commercial type laundry machinery and plant engineering in which all these machines are integrated. The association members are chiefly heavy industries.

On the other hand, machine tool manufacturers and construction machine manufacturers have their own associations (such as the Japan Machine Tool Builders' Association).

When I first met the word "micromachine," I imagined that popular movie *Fantastic Voyage.* I don't pretend I could hit upon any contact between micromachines and big machines for heavy industries.

Later, after surveying the trend of research and development in relation with the MITI, I came to know that the Industrial Science and Technology Frontier Program had taken up R&D of micromachine technology in 1991, systematic preparation of micromachine technology had been pursued, and there had been brilliant studies such as *"Development of Advanced Maintenance Technology for Power Plants"* and *"Study on Applications of Micromachine Technology"*.

Needless to say, power generation plants, chemical plants, iron manufacturing plants, environmental plants and any other plant or even unit machines, which are the line of business of our association, are getting increasingly complicated in step with progress of technology and implementation of high functionality. Maintenance, inspection, and repair of such facilities requires labor in narrow, limited space or at high temperatures and under high pressures.

If micromachine technology makes easier, safer maintenance and inspection (such as probing and repair of internal deterioration of hot boilers or high-pressure gas ducts that cannot be checked by human eye), it not only improves the demanding work environment but also saves energy and cost. Heavy machine manufacturers can also expect benefits from micromachine technology in processing and assembly.

Micromachine technology is a totally new system of technology that is yet to be developed. There may be various problems in establishing the system, but it's promising a huge fruits in industries, society, and living.

I hope Micromachine Center will stay active and fulfill its projects to promote development of micromachine technologies.

Principal Research Activities at SAMLAB, Switzerland

Prof. Nicolass de Rooij
Dr. D. J. Strike
University of Neuchâtel

For over ten years the SAMLAB (Sensors, Actuators and Microsystems Laboratory), which is part of the Institute of Microtechnology of the University of Neuchâtel, has been at the forefront of the development of microsensors, microactuators and microsystems. In collaboration with industrial partners, both Swiss and foreign, it has been involved in the development of a variety of commercial products. It has also been highly active in the academic world, producing over 200 papers and patents.

At present the SAMLAB's principal activities are in:

- **Electrochemical Microsystems:**
  Microelectrode array based detectors
  Electronic nose
  Environmental sensor systems
  Systems for in-vitro electrophysiology
- **Micro-Instrumentation for Space Research:**
  Space bioreactor
  Advanced chemical sensor systems for space research
  μTAS (Miniature Total Chemical Analysis Systems)
  Blood-gas analysis
- **Micro Fluidic Systems:**
  Dosing systems for biomedical applications
- **Microsensors and Microactuators:**
  Angular velocity sensors
  Opto-micromechanical components
  Micro-switches
- **Tools for Nanoscience and Nanotechnology:**
  Self-detecting cantilever systems
  Miniaturised SPM's
- **Millimotors:**
  Ultrasonic millimotors
  Electrostatic millimotors

The SAMLAB has a well equipped clean room, used for prototype fabrication and as a 'walk-in' facility where, in addition to the SAMLAB personnel, researchers from other institutions can carry out their technological processes. This facility has proven vital in the development of several innovative processing steps, such as electrochemical etch-stop, surface micromachining and deep dry etching. Over the years it has also been used for technology training courses, principally for industrial participants. These courses include the "Hands on MEMS" course and the FSRM (Swiss Foundation for Research in Microtechnology) course "Introduction to microfabrication technology".

As well as the clean room facilities, the SAMLAB has a chemistry laboratory, and several well equipped measurement laboratories, crucial in the thorough development of new devices and systems.

To illustrate further the activities of the SAMLAB four projects will be highlighted:

Space Bioreactor: This instrument was developed to allow the continuous monitoring of yeast cell cultures under zero gravity conditions (Figure 1). To meet the stringent size requirements of an aerospace application, state of the art microfabricated silicon components were employed. A piezoelectric micropump coupled to

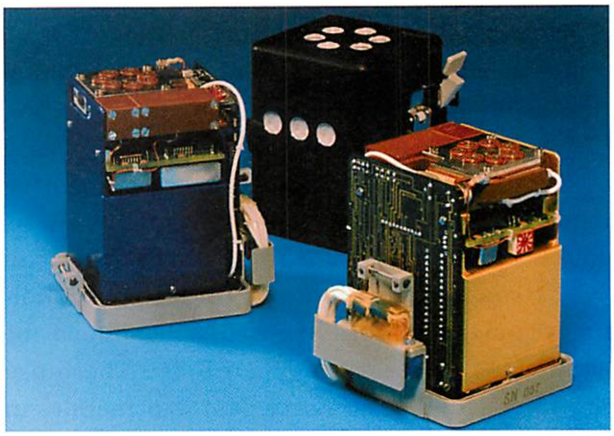


Figure 1. Two flight models of the miniature space bioreactor

a silicon flow sensor was used for the controlled delivery of nutrient solution to the 3 ml reactor chamber, whilst a miniature sensor system was used to monitor pH, redox potential and temperature. To eliminate the requirement for corrosive alkaline solutions, the culture pH was controlled by a unique electrochemical method. This instrument was successfully used in space shuttle missions in 1994 and 1996.

Opto-micromechanical components: The high precession alignment of optical fibres required for telecommunication applications can be achieved using silicon micromachining. This allows whole mechanical systems to be realised, which, due to their much smaller size are faster than bulky conventional mechanical systems. For example, the optical fibre switch developed at the SAMLAB has a switching speed 50 times that of a conventional switch (Figure 2). This device can switch light to either of two output fibres by electrostatically actuating a 75 µm high mirror. Another device produced at SAMLAB is

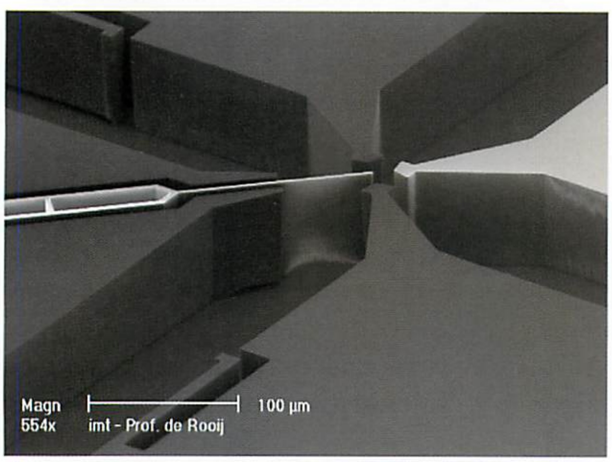


Figure 2. A 2 µm wide plasma etched vertical mirror with fibre aligning grooves

a mechanical light modulator for tomorrow's communication links. Instead of using a separate laser source this device modulates part of the incoming light. This allows the complexity and cost of the communications system to be reduced. The micromechanical modulator allows data transfer rates of 2-3 Mbits/s to be achieved.

Ultrasonic millimotors: In this project millimetre sized motors are being developed for wristwatch applications (Figure 3). These use the so-called Elastic Force Motor principle, in which standing flexure waves of a membrane resonator are converted into the rotation of a

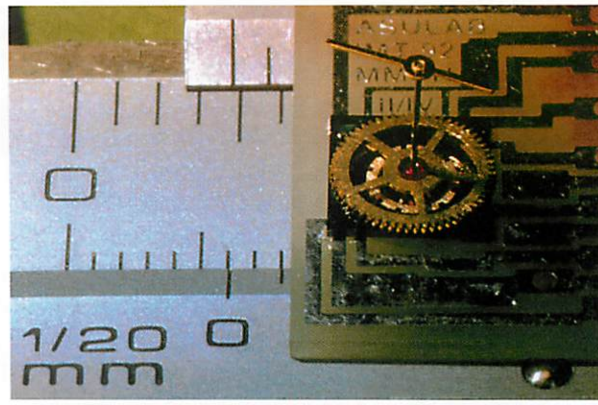


Figure 3. An ultrasonic milli-motor, 6 mm diameter by 2 mm height, with a mounted minute hand

rotor. Ultrasonic millimotors of this type have been operated at excitation voltages of 3 to 30 V, giving mean rotational speeds of 215 rpm with a motor torque of up to 0.1 µNm. Rotors fabricated from metal and polymer are currently under development.

Electronic Nose: This is being developed for the consumer product industry, an area where product quality is still often performed by the subjective appreciation of a group of expert tasters. The system at the SAMLAB is based around an array of conducting polymer sensors. These are electrochemically grown over an array of interdigitated µband electrodes. By varying the deposition conditions, or by changing the starting materials, a family of sensors having different selectivities can be obtained. The sensors are mounted in a computer controlled flow system which allows long term automated measurements to be made. By using suitable pattern recognition techniques various products can be classified.

The SAMLAB is funded by the University of Neuchâtel and by the Swiss Federal Institute of Technology Lausanne; the CTI (Commission of Technology and Innovation); the Swiss Federal Office for Education and Science; the Swiss National Science Foundation; the Swiss Foundation for Microtechnology Research and the MINAST program (Swiss Priority Program in Micro- and Nanosystem Technology). The SAMLAB is a "node" of the NEXUS network (European Network of Excellence in Microsystems).

Activities of the Micromachine Center Conducted in Fiscal 1996

Micromachines are composed of functional elements only a few millimeters in size and are capable of performing complex microscopic tasks. The Micromachine Center (MMC) conducts various activities to establish basic micromachine technology and to disseminate micromachine technology throughout society. It strives to contribute to both development of domestic industry and international community through investigation and research, collecting and providing information on micromachines, and fostering exchanges and cooperation with related organizations in Japan and abroad. In fiscal 1996, MMC conducted the following activities actively disseminating information from Japan, by holding international symposia, for example, as the fundamental policy. Also MMC actively promoted the delegated research by the Industrial Science and Technology Frontier Program of MITI's Agency of Industrial Science and Technology (AIST), and exchanged technical information with researchers in various countries and provided results of investigations and research for those concerned in and outside of Japan.

1. Investigations and research on micromachines

1.1 The AIST's Industrial Science and Technology Frontier Program "Micromachine Technology" (this project has been delegated to MMC by the New Energy and Industrial Technology Development Organization (NEDO).)

The ultimate purpose of this project is to establish technologies applicable to the realization of micromachine systems. These systems are mechanical systems composed of small functional elements that locomote within very narrow spaces in complicated equipment used at power plants and other facilities or inside the human body. They can also perform intricate work autonomously, and produce small industrial products.

This R&D has entered the first year of its second term. To achieve the goal of the basic plan for the R&D (the second phase), the R&D system was further improved and research delegated to MMC was actively promoted.

[Research and development on advanced maintenance technologies for power plants]

(1) R&D of systematization technology (Wireless micromachine for inspection on inner surface of tubes)

R&D of systematization technology has been conducted through production of an experimental system for a wireless micromachine. Inside a metal pipe with a curved section, this micromachine will be able to move forward, backward, horizontally and vertically, stop optionally, and recognize its surroundings as well as detect defects of pipelines. R&D topics promoted were: realization of an experimental system for a wireless micromachine for inspection on inner surface of tubes through developing a locomotion device and a microwave energy-supply/communication device as the main technology; systematization of a micro camera device to detect defects and transmit this image with low power consumption, and an optical energy transmission device for energy-supply and communication using light.

(2) R&D of systematization technology (Chain-type micromachine for inspection on outer surface of tubes)

Systematization technology has been developed through production of an experimental micromachine system composed of a group of single machines capable of combining or separating according to the form of the object to be inspected. R&D promoted the following topics: creation of an experimental chain-type micromachine for inspection on outer surface of tubes through developing a driving device to propel the machine; systematization of reduction and traveling devices that convert the power of a driving device into movement and microconnectors for combining multiple machines.

(3) R&D on systematization technology (Catheter-type micromachine for repair in narrow complex areas)

R&D on systematization technology has been conducted by producing an experimental micromachine system capable of entering the equipment of various structures and performing measurements or repairs of minute internal flaws. R&D topics promoted were: creation of an experimental catheter-type micromachine for repair in narrow complex areas through developing a multi-degrees of freedom flexible pipe structure as the main device and manipulators for repair; and systematization of a position detection device composed of small gyros and a monitoring device using an optical scanner.

(4) R&D of technologies to improve functional devices

R&D has focused on creating the following; an artificial muscle consisting of an actuator with large displacement and output power used for driving and working; a microjoint capable of delivering signals and energy by combining devices with different interfaces; an extremely low-friction suspension device such as magnetic bearings to reduce friction in microdriving parts; a rechargeable microbattery used as an emergency constant-voltage source when energy is not supplied externally; and an optically driven free joint device driven by power generated by photoelectric transfer of a laser that precisely positions work tools.

(5) R&D of common basic technologies

R&D has been conducted on common basic technologies such as technologies for control, measurement, design, and evaluation necessary for realizing micromachine systems. R&D has centered on achieving: pattern forming technology for a group of distributed micromachines in which a number of machines form a pattern suitable for work and at the same time conduct inspections; hierarchical group control technology for realizing a ultra-multidegrees of freedom holonic mechanism to move in a narrow and complicated environment; measuring technology for micromachines that measures minute shapes or dynamic behavior of micromachines and the minute power or torque of actuators; and measurement technology by micromachines that conducts micro optical analysis to detect defects inside a pipe.

(6) Comprehensive investigation and research

Comprehensive investigation and research on micromachine technology have been promoted including investigation and research to conduct the basic design of maintenance micromachines necessary for maintaining future power plants, and leading investigations and research on micromachine systems expected to be used for maintenance.

With the Mechanical Engineering Laboratory of AIST, MMC has also conducted joint research to analyze microdevice characteristics.

[Development of microfactory technology]

(1) R&D of processing and assembling technology

R&D has been conducted on systematization technology by producing an experimental system for processing and assembling capable of manufacturing models of small parts by integrating processing, assembly, conveyance, and inspection machines in a limited narrow space.

R&D topics promoted include: microprocessing technology, microassembling technology, micro fluid operation technology, micro optical driving technology, micro servo actuating technology, micro conveyance technology, and micro inspection technology.

(2) Comprehensive investigation and research

Comprehensive investigation and research on micromachine technology have been promoted including: investigation and research on the influence of microfactories including problems such as electromagnetic interference caused when various devices are integrated or concentrated in a narrow space; leading investigation and research on micromachine systems that will be applied in the production field.

MMC has conducted joint research with the Mechanical Engineering Laboratory of AIST on microfactory technology, including the investigating the downsizing of production systems.

[Research and development of micromachine technology]

(1) Research on micromachine systems

In the medical field, R&D involving the microminiaturization and multi-functionalization of micro laser catheters and microtactile sensor catheters has been conducted. These catheters are the major functional components of a microcatheter for diagnosis and treatment of cerebral blood vessels, an intraluminal diagnostic and therapeutic system. MMC also has set about researching on a ultra small liquid synthesizing system.

(2) Comprehensive investigation and research

Comprehensive investigations and research have been conducted on effectively using micromachine systems for future medical applications.

1.2 R&D of Materials for Micromachines (joint research with the Mechanical Engineering Laboratory of AIST)

MMC has conducted joint research with the Mechanical Engineering Laboratory of AIST on the following research of materials for micromachines.

(1) Research on operating environments for micro functional elements.

(2) Research on materials for micromachine.

(3) Feasibility studies on materials for micromachine.

1.3 Research on Basic Design and Manufacturing Technologies for Micromachines (joint research with the Mechanical Engineering Laboratory of AIST)

To establish basic design and manufacturing technologies for micromachines, MMC has conducted joint research with the Mechanical Engineering Laboratory of AIST.

1.4 Investigation and Research on Fundamental Micromachine Technology (aid activities from Japan Motorcycle Racing Organization: promotion of research with industry and academia)

MMC has conducted joint research with industry and academia, exploring technology seeds of 7 subjects on micro science and technology and micro design technology necessary to construct various micromachine systems.

1.5 Investigation and Research on Effects of the Introduction of Micromachine Technology on Industry and Society (delegated activities by The Japan Machinery Federation)

MMC sampled the major applications and application fields of micromachine technology with possibilities in the 21st Century, studied the impact expected on the changes of existing industrial and social structures, and conducted the investigation and research on micromachine technology to create the new industrial and social structures, focused on changes in industrial and social structures and creation of new industries.

1.6 Investigation on R&D Trends of Micromachine Technology in Japan and Abroad (independent activities)

MMC selected universities, research organizations, and private companies in Japan and abroad concerning micromachine-related research, and investigated researchers, their research subjects, contents, results and organizations, and then analyzed and classified the R&D trends.

1.7 Investigation and Research on Applications of Micromachine Technology (delegated research by Mechanical Social Systems Foundation)

MMC conducted investigation and research on new applications of micromachine technology for agriculture, global environment, urban life, and space.

2. Collection and Provision of Micromachine information

2.1 Collection of Micromachine Information

Information and reference material (such as periodical publications, and books) on micromachines were collected from universities, industries, and public organizations in Japan and overseas, combined with survey results and documents produced by MMC, and stored in the MMC library (the number of books collected in fiscal 1996 is 115: the total 491).

2.2 Provision of Micromachine Information

Technical documents and information collected and stored in MMC library readily available. "Micromachine Index", the excerpts of technical information, was periodically published and distributed. (published seven issues in fiscal 1996)

2.3 Investigation on the Construction of Information Databases of Micromachine Technology

A format to collect data was provided, preparation to construct databases was completed, and it became possible to input the data.

"Micromachine Index" can now be searched for by key word.

3. Exchange and Cooperation with Organizations in Japan and Abroad Involved with Micromachines

To promote affiliation, exchange, and cooperation with related organizations with common interests, MMC provided research grants as part of joint projects with government, industry and academic organizations. MMC also invited or sent researchers and scholars for exchanges with related organizations within and outside Japan, participated in the micromachine summit, and sponsored international symposia and seminars.

3.1 Aid for R&D of Micromachine Technology

MMC assisted university researchers engaged in basic research related to micromachines, and invited subjects for the 4th (FY1996) Micromachine Technology Research Grant to contribute to further progress of micromachine technology and promote cultural exchanges between industrial and academic circles. Many applications were received and after careful selection, seven new projects and six projects carried over for the second year were selected to receive grants.

3.2 Exchange with Organization in and outside Japan and Cooperative Business on Micromachine

(1) Holding the 2nd International Micromachine Symposium

The second International Micromachine Symposium was held at Science Hall in Kitanomaru Park in Tokyo, October 31 - November 1, 1996. The symposium was cosponsored by MMC and Japan Industrial Technology Association. Its theme was: "Micromachine Technology — Foundation of industrial technology in the 21st Century."

In this symposium, results of R&D of micromachine technology and its applications; measures to promote this technology; the plan of R&D of the AIST's Industrial Science and Technology Frontier Program (the first year of the 2nd phase) were introduced. Future applications were displayed and participants exchanged opinions with scholars within and outside Japan.

The number of registrant was 430, including 41 members from 16 countries.

(2) Holding ASIA FORUM

Concerning micromachine technology, Asian countries are behind Europe and the United States. From the point of view of Japanese industrial economy, it is necessary and crucial to establish a close network at an early stage to contribute in this fields. Based on this recognition, seven Asian countries (China, Hong Kong, Korea, Malaysia, Singapore, Taiwan, and Thailand) were invited and the first ASIA FORUM was October 29, 1996.

(3) Holding Seminars for Micromachine Technology Exchange

To promote technology exchange, MMC held seminars in Europe in cooperation with JETRO.

The seminar in Spain was held September 13, 1996.

The seminar in Switzerland was held September 20, 1996.

Also, to exchange micromachine technology and to make network with Asian countries, seminars were held in cooperation with JETRO, in Malaysia, January 14, 1997 and in Singapore January 17, 1997. These were the first to be held in Asia.

(4) Receiving the mission

Mission from the total of fourteen countries (5 countries from Asia, 9 from Europe and the United States) visited Japan. Views were exchanged on R&D of micromachine technology of Japan and MMC's activities.

(5) Dispatching the mission

MMC dispatched the mission to Europe from April 21 to May 5, 1996 (13 members). Universities and research organizations were visited in Switzerland, Italy, and Germany, and The Second Micromachine Summit held in Montreux, Switzerland, was observed.

(6) Holding workshops

In November 1996 discussions with researchers of micromachine technology, micromachine users, and experts in the global environment were held in Oxford, England, and investigations on micromachine technology trends and new applications were conducted.

(7) Participating International Congress and Seminars

1) Participating in the 2nd Micromachine Summit

MMC participated in The 2nd Micromachine Summit held in Montreux, Switzerland, April 24 - 26, 1996. During the summit, the state of micromachine technology was reported by the chief delegate of each country, and the experts had presentations on 7 subjects. Discussion followed.

In addition, the following subjects were agreed upon:

• Cooperation in standardization of micromachine technology

• Opening the next summit in British Columbia, Canada, in April 1997 (plan)

• Summit will be held by the host country, but make MMC the permanent secretariat

2) Participating MST 96

We participated in MST 96 held in Postdate, Germany, September 17 - 19, 1996, and Mr. Takayuki Hirano, Executive Director of MMC, gave the keynote speech, "R&D in Japan — now & future."

3) Cooperation and Participating in AITC 1997 (Asian International Technology Congress 1997)

MMC cooperated AITC 1997 held in Hong Kong, January 6 - 8, 1997, and recommended four lecturers.

4) Cooperation MEMS '96

MMC cooperated MEMS '96, held in Nagoya, January 26 - 30, 1997. MMC exhibited promotion posters and 4 items of ISTF Project.

4. Promotion of Standardization of Micromachine Technology (partly delegated research by The Japan Machinery Federation)

MMC conducted the following activities:

• Translated 103 micromachine-related technical terms into English. This was necessary for standardization.

• Studied the essential features of standardization of "shape; size," "power; torque," "fluid related" in micromachine technology field.

• Started investigations on a measurement and evaluation method for "characteristics quality of material."

• Strove for cooperation with overseas standardization activities.

5. Dissemination and Education about Micromachines

5.1 Publishing and Distributing Public Relations Magazines

In fiscal 1996, the 15, 16, 17, 18 issues were published in Japanese and English.

5.2 Presentation of R&D Results of Micromachine Technology in Fiscal 1996

In November 1, 1996, at Science Museum in Kitanomaru Park in Tokyo, results were on "The 2nd phase R&D of systematization technology" and "R&D results", concerning the national R&D project "Micromachine Technology" delegated by NEDO.

5.3 Producing Videos for MMC's Public Relations and for Dissemination and Education about Micromachines

A revised edition of video for MMC's PR and video for popular use, "What is Micromachine?" were completed and distributed to supporting members.

5.4 Micromachine Drawings Contests

Following the previous fiscal year, the 3rd Drawing contest was held in cooperation with supporting member companies. Applications were received from six primary and junior high schools in Narashino City, Chiba, Nagaokakyo City, Kyoto, and Nakai-machi, Kanagawa.

The total applications: 335

Winning works: 20

5.5 The 7th Micromachine Exhibition

The 7th Micromachine Exhibition was held in Kitanomaru Park Science Museum in Tokyo, October 30 - November 1, 1996. Exhibitors were 22 MMC supporting members who exhibited the results of the 2nd phase of the Industrial Science and Technology Frontier Program, and other 40 organizations (private companies and universities), totaling 62. The number of visitors in three days was 3169.

5.6 Evening Seminar

As our purpose in the beginning was achieved, the 28th Seminar in September 1996 was the last and considered the alternative.

5.7 Dispatch Information with Internet

Internet WWW home page was used to dispatch information on micromachine and since fiscal 1995, public relations magazines in English and information for micromachine technology related events were sent through Internet.

Home page directory: http://www.iijnet.or.jp/MMC/

5.8 Micromachine Seminar in Japan

Micromachine Seminars for people interested in R&D of micromachine technology, were held in :

Sapporo City, Hokkaido, Sept. 5, 1996

Okaya City, Nagano, Oct. 1, 1996

Takamatsu City, Kagawa, Jan. 16, 1997

Summary of the Research Supported by the Third Micromachine Technology Research Grant

Micromachine Center (MMC) is promoting the research and development of national project "Micromachine Technologies," one of the Industrial Science and Technology Frontier Program of Agency of Industrial Science and Technology, Ministry of International Trade and Industry (MITI), entrusted by New Energy and Industrial Technology Development Organization (NEDO). At the same time, MMC is conducting an independent activities to promote R&D and its diffusion of micromachine technology.

The titled research grant program started invitation in 1993 as a part of the independent activities of MMC, intended to assist college and university staff engaged in basic research on micromachines, as well as to promote further development of micromachine technology and communication between academics and people in the industrial world.

Among themes selected for the third (1995) research grant, one 1-year research and five 2-year researches carried over from fiscal 1994 have completed. Turn the page for the summary of the research results.

• Carried-Over Projects Selected for Fiscal 1994

Subjects	Leader & Co-Worker	Positions	Period
Molecule-assisted molecular systems driven by external stimuli	Kunihiro Ichimura	Professor Research Laboratory of Resources Utilization, Tokyo Institute of Technology	2 Years
Microrobot control using reflex actions of insect	Takashi Yasuda	Research Associate Faculty of Engineering, The University of Tokyo	2 Years
The thermal ratchet and its application for the actin myosin systems	Hiroyuki Matsuura Iwao Fujimasa Masahiro Nakano	Research Associate, Research Center for Advanced Science and Technology, The University of Tokyo Professor, Graduate School of Saitama University University of Occupational and Environmental Health	2 Years
Studies on micro-pump employing liquid stream by ion drag force	Nuio Tsuchida Jun Ohsawa	Professor Associate Professor Department of Information and Control Engineering, Toyota Technological Institute	2 Years
Multi-SOI structures for new micromachine-material with single-crystalline insulator Al_2O_3 and Si films	Makoto Ishida	Professor Electric and Electronic Engineering, Toyohashi University of Technology	2 Years

• Research Project Selected for Fiscal 1995

Subjects	Leader & Co-Worker	Positions	Period
Basic research on target orientation control of medicine delivery micromachines	Takao Aoyagi	Assistant Professor Institute of Biomedical Engineering, Tokyo Women's Medical College	1 Year

An Application Guidelines for the 5th (Fiscal 1997) Research Grant Theme on Micromachine Technology

1. Object of the research grant
   Basic research on basic technology, functional element technology and systematization technology of micromachines.
2. Research period
   Theme A: Late in March, 1998 - March 31, 1999, or
   Theme B: Late in March, 1998 - March 31, 2000
3. Application period, theme decision and fund grant date
   Application period: July 1 - October 31, 1997
   Theme decision: Early in March, 1998
   Fund grant date: Late in March, 1998
4. How to apply
   Send a fax request for the application form to Micromachine Center, with your fax number specified.
   Fax: +81-3-5294-7137
5. Qualification
   College or university faculties (professors, associate professors, lecturers and research associates) who belong to the academic societies which are affiliated with Federation of Micromachine Technology
6. Others

(1) Total fund granted: about 15 million yen
(The limit for a single research is 2 million yen for theme A and 3 million yen for theme B.)

(2) We may ask the grant receivers to carry out the researches in cooperation with supporting member enterprises of the Micromachine Center after the grant is decided, since one of the objectives of this project is to encourage communication between enterprises and academies.

(3) Reference: Research Department, Micromachine Center (persons in charge: Murakami/Namise)

Molecule-assisted Molecular Systems Driven by External Stimuli

Kunihiro Ichimura
Research Laboratory of Resources Utilization, Tokyo Institute of Technology

1. Introduction

The function of muscles is based on the slide motion of myofilaments of skeletal muscles. Although little is known about the behavior of filament interfaces in molecular levels, several models of the motion have been proposed. In the concept presented by M. Suzuki, crucial involvement of changes of hydrophilic and hydrophobic natures at the interfaces, leading to surface energy changes, is suggested. The major objective of the present research is to control surface energies using light as one of external stimuli to manipulate water drops. Success in manipulating water drops by light would guarantee feasibility of various devices driven by light.

2. Monomolecular Films of Calix[4]resorcinarenes and Their Photoresponsiveness

We had already found that calix[4]resorcinarene (CRA) derivatives, cyclic amphiphilic molecules having hydrophilic groups on one rim of the cylindrical structure, is readily adsorbed onto a surface of silica glasses from solution to form self-organized monomolecular films displaying a closely packed structure. We also found that CRA substituted with photoisomerizable azobenzene groups exhibits reversible changes in the area of monomolecular films in a range of several tens percent upon exposure to light (See Figure 1). In this system, light energy is transduced into mechanical energy.

Then we proceeded to devise a system to produce a macroscopic phenomenon by the photoresponse of the CRA with the azobenzene units, where the dispersion and coagulation of colloidal silica was controlled by light. The azobenzene-CRA was adsorbed on a surface of silica particles of a 160 nm diameter from a solution to give a homogeneous dispersion in organic solvents. After the irradiation with ultraviolet light, the colloidal silica started coagulation and sedimentation. This phenomenon is explained as follows: Photoisomerization increases a surface energy of the adsorbed monomolecular film and makes the dispersion of colloidal particles unstable, consequently to make them coagulate and settle. This means the macroscopic control of molecular solution properties by irradiation with light.

Based on these results, we tried to control a contact angle of a water droplet placed on a plate surface-modified with a monolayer of the azobenzene-CRA by irradiation with light. However, the contact angle was unstable because the CRA molecules adsorbed through hydrogen bonds were easily released. To achieve tighter bonds, we chemically modified phenolic hydroxyl groups of the CRA to synthesize a new compound that has eight carboxyl groups, and formed a monolayered film by adsorption onto a glass substrate covered with aluminum by vacuum evaporation. This new absorbed monomolecular film is stable in water, and contact angles for water were measurable. The angle was 85° and 78° before and after exposure to ultraviolet light, respectively. Encouraged by the relatively greater change of the angle compared to those reported to date, we tried to move a water drop as shown in Figure 2. One half of a water drop was irradiated with ultraviolet light, and the other with blue light, to narrow the angle of contact for the former and widen for the latter. However, actual move of a water drop has not yet been observed.

3. Conclusion

At present, we are not successful to move water drops by guiding with light, which was the initial purpose of the study. We will continue this study though, because the difference between contact angles before and after irradiation can probably be increased by modification of the molecular structure of azobenzene-CRA and the shape of a substrate surface.

CRA and its derivatives easily form monomolecular films. Taking into consideration that interfacial dynamic phenomena like lubrication and friction can be controlled by monomolecular films, this sort of compounds are likely to be useful for surface treatment of moving parts of micromachine devices. Our future research will also investigate in this probability.

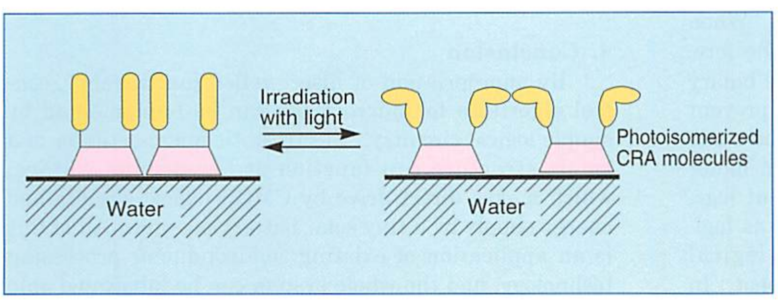


Figure 1 Illustrative presentation of photo-induced areal alteration of a CRA monomolecular film on a water surface.

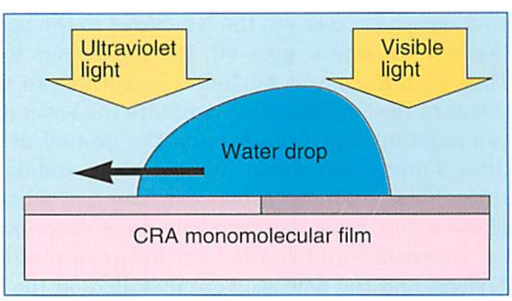


Figure 2 Conceptual illustration of moving water drop by irradiation with light

Microrobot Control Using Reflex Actions of Insect

Takashi Yasuda
Faculty of Engineering, The University of Tokyo

1. Introduction

To control motion of an autonomous microrobot that incorporates micro-actuators, sensors, electronic circuits, and battery in a limited space, control algorithm must be simplified to reduce size of the controller circuit. Insects are managing with an extremely small number of nerve cells. (While a human has more than 10 billion nerve cells, an inset has only about 100,000.) In order to make fit and quick motion in changing surroundings, insects process terminal sensory inputs by lower order nerve systems to switch standing and moving of a leg and adjust stepping timing by reflex action. Such reflex motion algorithms can be described by logical circuitry, hence applicable to control of microrobots. In this study, we created an algorithm that combined reflex actions to generate a walking pattern for a six-legged robot. We also developed a electrostatic micro-actuator that can be controlled by logical circuits, and demonstrated a real microrobot in which the micro-actuator and the reflex algorithm are integrated.

2. Generation of Six-Leg Walking Pattern with Reflex Action

Figure 1 shows the six-legged robot we fabricated. It measures 312 mm × 210 mm × 160 mm and weighs 1.8 kg including the battery. Each leg has one motor for moving the leg fore and back, another motor for moving up and down, a front sensor (for detecting that the leg is in the foremost position possible), and a landing sensor (for detecting that the leg is in contact with the ground). If the front sensor goes on, the leg moves down. If the landing sensor goes on, the leg moves to the back. When the landing sensor goes off, the leg swings to the fore. Thus each leg moves by "reflex" according to the binary status of the sensors. To coordinate the legs and prevent two adjacent legs from leaving the ground at the same time, suppression signal (to control up-and-down motor status) was exchanged between any two adjacent legs. These algorithmic requirements were described as logical formulas and loaded on programmable logical devices, and the devices were installed on the robot. In walking experiments, the robot automatically generated tripod gait pattern and waving gait pattern, which are walking patterns just as natural insects, at different walking speeds. Walking experiments on uneven ground proved that the robot automatically generates more stable gait pattern than it uses on flat ground.

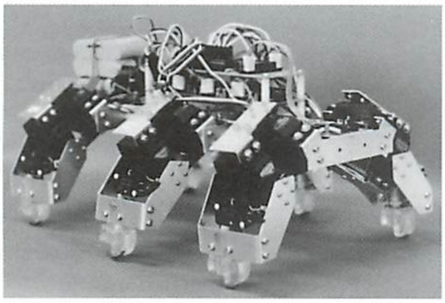


Figure 1 Six-legged robot walking by reflex action

3. Electrostatic Micro-actuator Driven by Logical Circuits

What is needed to miniaturize the six-legged robot is a micro-actuator that can be driven by a logical circuit. We devised a electrostatic micro-actuator that shows noteworthy deformation at low voltages. Figure 2 shows a SEM image of the actuator. This actuator gains a good deformation as a whole by a series connection of cantilevers that deform a little at low voltage. Necessary driving voltage was 11.8 V, and a maximum deformation at the tip was 245 μm. Materials were aluminum and chromium thin film. We connected the output of the CMOS device directly to the actuator and succeeded in turning on and off the actuator by changing the input level to the logical device. Conventional electromagnetic motors and electrostatic micro-actuators need amplifiers to boost output currents and voltages from the logical circuits. Such amplifying circuits are not necessary for the actuator we developed in this study, which means very simple and small system as a whole. Low driving voltage is also a great advantage in view of energy supply. We verified that the actuator functioned on power supplied by a commercial solar battery, and calculated that sufficient power was obtainable from a solar battery as large as 2 mm × 3 mm.

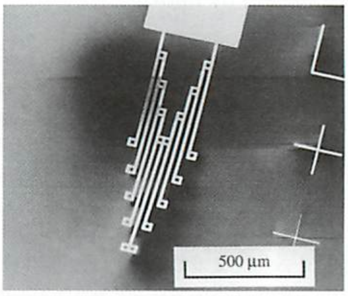


Figure 2 Electrostatic micro-actuator

4. Conclusion

By appropriation of insect reflex functionality, control algorithm for microrobots can be implemented by simple logical circuitry. Electrostatic micro-actuator of a smart structure can function at low driving voltage, which makes direct drive by CMOS logical circuits and energy supply by a tiny solar battery possible. All of this is an application of existing semiconductor processing technology, and the whole system can be integrated onto a silicon chip. This makes autonomous functioning microrobots possible.

The Thermal Ratchet and its Application for the Actin Myosin Systems

Hiroyuki Matsuura
Research Center for Advanced Science and Technology, The University of Tokyo
Iwao Fujimasa
Graduate School of Saitama University
Masahiro Nakano
University of Occupational and Environmental Health

1. Introduction

The ultimate goal of this study is to create an energy transformation device (micro-actuator) that functions in living bodies. Aiming this, we built a micro-actuator and analyzed its underwater behavioral characteristics, energy transformation mechanism, and mechanical system elements. To develop studies on conventional vibrating artificial muscles (micromachines that works opposing to thermal motion of the medium molecular), we thought of a muscle (actin-myosin system) as a micro-nanomachine. One fundamental problem with micromachines is that miniaturization of machines deteriorates their energy efficiency and S/N ratio badly. On the other hand, bio-mechanical systems function efficiently with input energy at a noise level. We thought there must be a common principle for micromachines in the intermediate region, and came up with the concept of Feynmans' ratchet model that rotate clockwise by one step to the next sprocket.

2. Thermal Ratchets Model for Micromachine

Thermal ratchets is shaped like a saw with asymmetric teeth. One face of each tooth is oriented perpendicular to the circumference and the other is inclined at a shallower angle. A wheel wound with string with a weight at its end (load) is attached to the ratchet, and the ratchet and wheel are in turn connected by rod to a vane. If the paw/ratchet and the vane are placed in chambers that enable them to be isolated at same temperature, this micro-actuator dose not rotate. If this system are placed in the chamber at different T_1 temperature, kinetic energy is imparted to the ratchet by water molecules of temperature that collide with the vane. For the ratchet rotate to the one direction by one step to the next sprocket, we need give sufficient energy to withdraw the pawl and lift the load. Then the ratio of one direction of rotation (clockwise) is determined by Boltzmann factor of temperature T_1. On the other hand, we estimate the probability of counterclockwise, which is expressed in Boltzmann factor T_2. In order to derive the moving force from the thermal ratchet, at first we need the different temperature between the vane and saw. The net power of micromachine is proportional to relative probabilities of the ratchet going forward versus backward motion. In absence of a load and different of temperature, net production of power is equal to zero. It means the ratchet moves randomly clockwise and counterclockwise. Moreover, even if two temperature(vane and saw) are equal, it is quite different forward with probability from backward with probability as long as the micromachine has a kind of load. We find that it makes a great difference whether load is positive or not. If load increases in the positive range, backward velocity approaches a constant. As load becomes negative, angular velocity takes off forward. The angular velocity that was obtained from different forces is thus very unsymmetrical. Thus, Going one way it is easy and we get a lot of angular velocity of little force.

3. Application for Micromachine

We adopt a certain hypothetical scheme; micro or nanomachine can operate like Feynman ratchet. In this scheme, the asymmetric subunits of micromachine corresponds to the teeth of the saw-toothed Feynman ratchet. And ATPase functions as spring loaded pawl do. Without the input of chemical or any other supplements of energy, thermal energy would displace the nanomachine to adjacent asymmetric teeth in either direction with equal probability. Some kinds of energy is used to direct the thermally induced displacement of nanomachine in one direction. Thus, the thermodynamic drive to elicit one directional motion is bias of load (ATP hydrolysis).

4. Summary

In the absence of thermal noise, this system behaves the way we expect a ratchet to behave. If we attempt to advance the ratchet, there will be minimum force necessary to overcome the barriers. We considered, however, the thermal model, which utilize the thermal noise and random fluctuation as Huxley proposed that an actin-binding protein of myosin is attached to a spring which is subject to thermal fluctuation. Based on the principle of fluctuation and bias(load), micro-thermal ratchet moves forward to one direction. When we apply micromachine for the explanation of the energy conversion of actin myosin system, we can find that micro-system can get the sufficient energy as myosin drives the actin filaments by thermal noise.

Studies on Micro-pump Employing Liquid Stream by Ion Drag Force

Nuio Tsuchida, Jun Ohsawa

Department of Information and Control Engineering, Toyota Technological Institute

1. Introduction

In order to move micromachines, high performance micro-actuators are crucial. To date, various micro-actuators working on different principles have been studied. In this study, we developed a micro-pump actuator employing a unique ion drag drive principle. The direct current drive pump is quite unique in a way: it needs no piston, impeller, or cam rotor.

2. Pressurizing Principle

Figure 1 shows the basic structure and pressurizing principle of the pump. As seen in the figure, in the pressurized liquid: silicone oil with several tens percent of butyl alcohol blended, pairs of a cathode and an anode are placed in a row. One side of each electrode is covered with insulating barrier. When an ampholytic butyl alcohol molecule (BA) falls into contact with anode 1, the molecule is deprived of an electron and turns into a cation. Then the cation is accelerated to the right of the diagram, attracted by the cathode 2, the nearest electrode of the opposite polarity, which is standing to the right of anode 1. Similar cations, dragging liquid around them and generating flow, proceed until they get to the left half of cathode 2, which is covered by the barrier layer. The ions cannot exchange electrons on the barrier, so they are washed as they are by liquid flow and reach to the exposed part of cathode 2, where the positive electric charges of the ions are neutralized and then negative charges are added. The ions have now turned into anions and attracted by anode 3, which is the nearest electrode of the opposite polarity, to the further right. The same process repeats as the ions proceed always from left to right changing their polarity by giving and taking electrons at each electrode, and the acceleration of the ions to the right generates flow of the liquid.

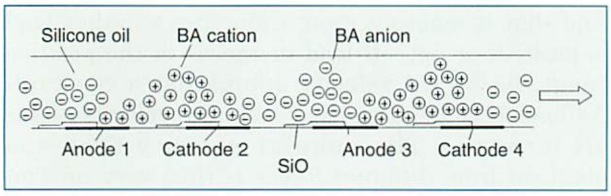


Figure 1 Pressurizing principle

3. Structure of the Pump

To demonstrate the working principle and measure flow rate and pressurizing force in this study, we fabricated a pump having ion accelerators which are metal meshes with one side covered with insulating coating. See Figure 2. The figure shows a six-metal mesh configuration which accelerates ions on five stages. We changed the number of the stages in the series of experiments. These electrodes were installed in a small rectangular vessel with two holes as the entrance and exit for the liquid. At each hole, a thin pipe was stood up to measure liquid levels and obtain pressurizing force from the difference of the levels. To measure flow velocity, alumina particles of 0.06 μm were dispersed in the flow path and their behavior was observed on a microscope with a CCD camera.

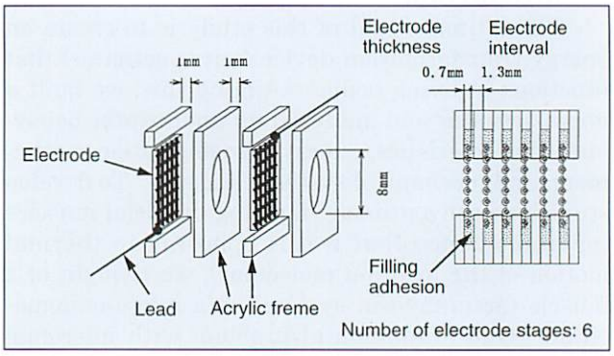


Figure 2 Assembly and configuration of pump

4. Results of Experiments

Figure 3 shows the dependency of the pressurizing force and electrode current of the pump with six electrode stages upon field intensity applied. As seen from the figure, the pressuring force of the pump is approximately proportional to the applied electric field intensity to the power 2.5, and the conductive current for the electrode is approximately proportional to the field intensity to the power 1.2. This means that the pump is functioning in a region near to the ohmic conduction range.

As a result of experiments with different numbers of ion accelerators, it was known that the pressurizing force of the pump is proportional to the number of ion accelerators, which agreed to our expectations.

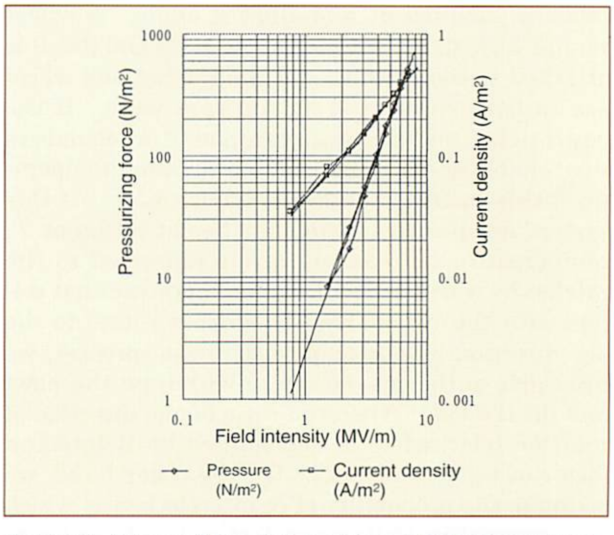


Figure 3 Pressurizing force of ion drag micro-pump

Multi-SOI Structures for New Micromachine-material with Single-crystalline Insulator Al_2O_3 and Si Films

Makoto Ishida
Electric and Electronic Engineering, Toyohashi University of Technology

1. Introduction

The silicon-on-insulator (SOI) structure is a basic structure important not only for making an integrated circuit faster, dense, and power saving, but also stacking circuit layers. The objective of this study is to form a multi-layer thin film SOI structure consisting of Al_2O_3 single-crystalline insulating thin film and Si single-crystalline film (see Figure 1), formed by epitaxial growth, which we have studied to date, to study and present as a new material for micromachines. So far, we have evaluated the Al_2O_3 layer as the etching stopper, and applied to pressure sensors. With our method, it is easy to stack any number of thin films or to control films to a desired thickness. By use of substrates of different crystallizing orientations like Si(111), films of various orientations can also be used. Another advantage of this system is that it is well compatible and can be joined with Si IC process.

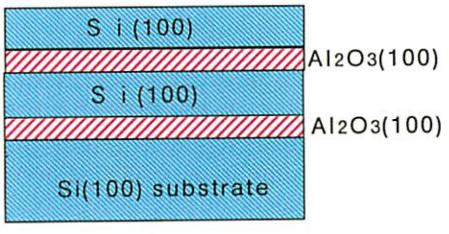


Figure 1 Multi-layer SOI structure

2. Research Results

We formed SOI structures by ultra high vacuum chemical vapor deposition (UHV-CVD) and molecular beam epitaxial growth methods. As we expected, on a Si(100) or Si(111) wafer, Al_2O_3(100) or Al_2O_3(111) film was formed respectively. This brought us that multi-layer thin film structures having five or more arbitrary number of similar layers based on the Si(100)/Al_2O_3(100)/Si(100) or Si(111)/Al_2O_3(111)/Si(111) basic structure can be formed.

To apply etching to this single-crystalline Al_2O_3 film and sapphire substrate, we implanted Si ions to γ-Al_2O_3 film deposited on Si substrate and sapphire substrate, consequently proving the feasibility and mechanism of HF + H_2O chemical etching.

In the experiment, we used single-crystalline γ-Al_2O_3 film on Si(100) substrate and sapphire substrate. Si ions were implanted at a dose of 1×10^{14} cm^{-2} to 1×10^{17} cm^{-2} and an accelerating voltage of 30 kV to 120 kV. Then chemical etching was applied to the single-crystalline Al_2O_3 film with aqueous solution of HF, at an etching rate of 100 Å/min. Characteristics of ion implantation to the Al_2O_3 film were checked by secondary-ion mass spectroscopy (SIMS). The result was a projection range of 450Å at an accelerating voltage of 80 kV, which was much shallow than our simulation. Possible hindrance of implantation was positive charges on the substrate caused by a sufficient amount of positive holes and the energy level created by damage by implanted ions. We tried the same experiment by the multilayer resist (photoresist/Al) method, which succeeded in deep implantation and improved implantation characteristics. Status of chemical etching by Si ion implantation on single-crystalline γ-Al_2O_3 film and sapphire substrate was observed by step checker and electron scanning microscope (Figure 2). Transformation of the Al_2O_3 film into aluminosilicate ($Al_2O_3 \cdot SiO_2$) by the implanted Si ion was observed by X-ray photoelectron spectroscopy (XPS). We expected the mechanism of the etching as follows. First, the Al_2O_3 film implanted with Si ions contains many defects and composition change. Then the changed part (aluminosilicate) and the defective part are etched by HF. We formed a spiral pattern with line and space, both of 5 μm thick, which is shown in Figure 3.

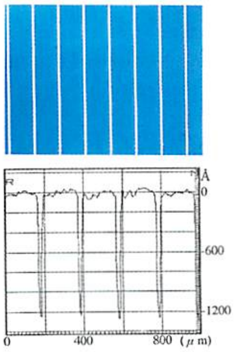


Figure 2 Etching of Al_2O_3 film (20 μm/120 μm)

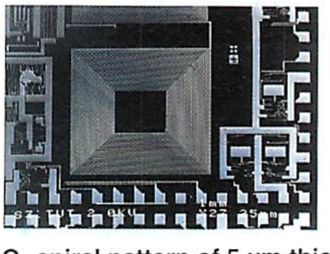


Figure 3 Al_2O_3 spiral pattern of 5 μm thickness and interval created by etching.

3. Conclusion

Many applications are expected of the multi-layer thin film SOI structure consisting of Al_2O_3 single-crystalline insulating thin film and Si single-crystalline film formed by epitaxial growth, for the chemical stability of Al_2O_3 equivalent to sapphire, which makes the film useful as both the Si etching stopper and electrical insulator. Development of easy etching method for this stable Al_2O_3 has created new prospect application of the film as a material for micromachines.

Basic Research on Target Orientation Control of Medicine Delivery Micromachines

Takao Aoyagi
Institute of Biomedical Engineering, Tokyo Women's Medical College

1. Introduction

For application of micromachines in the medical field, the machines have to be securely delivered to the site where they are to work. In this study we examined molecular design of a target orientation drug delivery micromachine that delivers and accumulates drugs to specific target sites or organs. Knowledge acquired through this study will be useful not only for creating drug delivery system but also as a basic motion control technology for in vivo micromachines.

2. Results of Study

In this study, we created a block copolymer consisting of poly-isopropyl acrylamide (PIPAAm), a thermal responsive polymer that repeats dissolution and precipitation at the phase transition point, and hydrophobic poly-DL-lactide (PDLLA), aiming to form thermal responsive associated molecule. PIPAAm, which shows hydrophilic characteristic only at the phase transition point or lower, was expected to form hydrophilic-hydrophobic micelle-like associated molecule at lower temperatures, but to become entirely hydrophobic as a molecule and form coagulated insoluble molecules at higher temperatures. If a specific site is heated when such associated polymer is stable in the body, the polymer coagulates and accumulates on that site. We expected this system to enable drug delivery target control using external thermal changes as the signal. (See Figure 1.)

We began with synthesis of PIPAAm having a hydroxyl group on one end. Then, using that hydroxyl group as the initiation point, we carried out ring opening polymerization of lactide to synthesize the PIPAAm-PDLLA block copolymer. The polymer was dissolved in dimethyl acetamide and dialyzed against water to prepare associated molecules.

Then we observed the changes in size and homogeneity of associated molecules in response to thermal changes of the PIPAAm chain, by dynamic light scattering (DLS) method, starting from 5°C at an interval of 5°C. Formation of associated molecules of a mean diameter of about 120 nm was suggested as the temperature went up. The size scarcely increased while the temperature went up until it reaches to about 30°C. Then, suddenly at 35°C, drastic size reduction was observed, resulting associated molecules of a size about 65 nm. At that moment, the degree of polydispersion was about 0.1. The DLS measurement principle suggests formation of roughly spherical associated molecules at 0.1 or lower degrees of polydispersion. When the temperature climbed higher, the associated molecules started to coagulate and formed precipitate.

Thus, the associated molecules made of the PIPAAm-PDLLA block copolymers formed roughly spherical polymer micelles as little as 65 nm at about human body temperature. It was proved that polymer micelles form associated molecules and precipitate when the temperature goes up.

3. Conclusion

One possible application of this study is a treatment system that delivers anti-cancer drugs only to the tumor site. This system is expected to reduce side effects of the anti-cancer drugs because the drugs are selectively delivered to the organ with the tumor, making a chemical treatment of an excellent efficacy. The study results would be also useful to establish fundamental technology to deliver micromachines to targeted site.

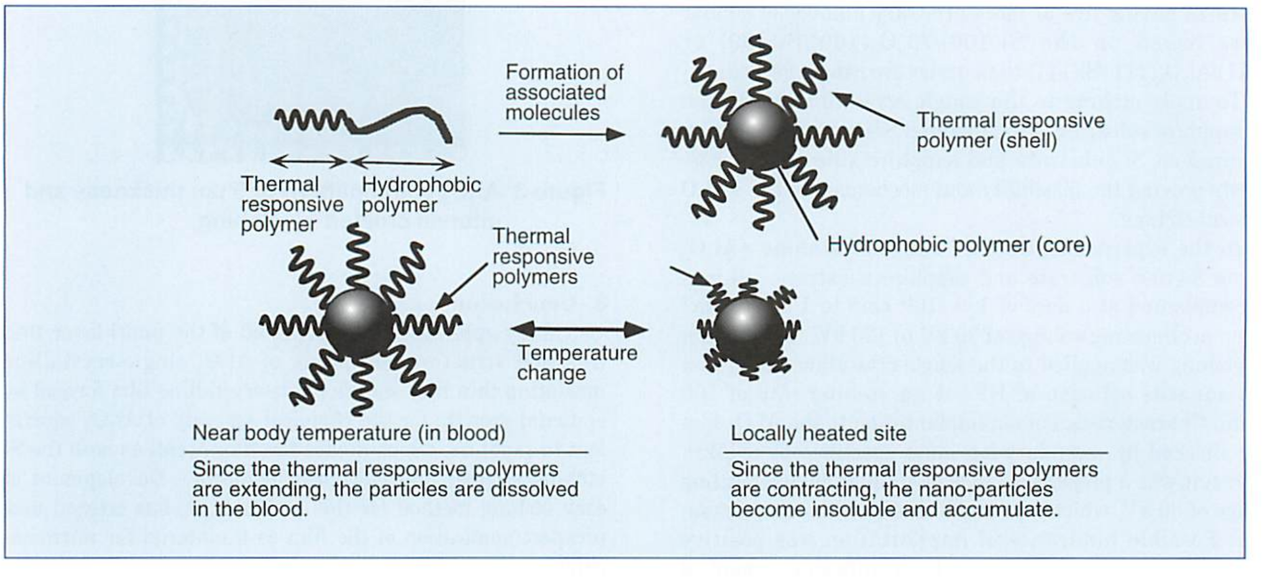


Figure 1 Conceptual diagram of thermal responsive nano-scale associated molecules

Sanyo Electric Co., Ltd.

Dr. Yukinori Kuwano, Managing Director, and Director of R&D Headquarters, Sanyo Electric Co., Ltd.

1. Work on Micromachine Technology

Toward the 21st Century, global environment problems and energy problems are highlighted on worldwide. And through the changes in means of communication, such as Internet, and digital revolution in multimedia, globalization is rapidly progressing. In big change on these issues, there is a need to create more advanced lifestyle in order to pass on a better global environment to the next generation.

Progression of semiconductor processing technology created small, highly functional electronic equipment, and then wireless portable equipment. It made our lives rich. Semiconductor technology also created the clean, new energy source as a solar cell.

Micromachine technology will also create new machinery forms and bring about new patterns of life. The development of new-generation fundamental technology and element technology, especially micromachine technology, will lead the 21st Century and the future of human life and the earth.

2. Development of Micromachine Technology

When thinking of realization of micromachines, the wireless "self-propelled micromachine" would be one form. However, technology to supply energy to the machine without wire is much more difficult than that of electronic equipments. Therefore, under a national project "Industrial Science and Technology Frontier Program," we are working on the development of photon energy transmission technology as an effective measure.

In photon energy supply technology for micromachines, it is necessary to supply high voltage of some 10 to hundreds volts in a small area for driving micro actuator such as electrostatic actuator and piezoelectric actuator. Although energy required for driving micromachine drops in proportion to its volume, the power consumption of electronic circuit, such as IC, is the same and, therefore, it is also necessary to supply larger output power. Figure 1 shows a high voltage micro photovoltaic device we developed. Micro photovoltaic elements (0.5 mm by 2 mm) are highly integrated, realized three dimensional interconnection of 285 elements. It is one square centimeter in size, and generated voltage of 207 V by the sunshine which is the world highest. It achieved much higher output power than before. This high voltage is realized through laser microprocessing technology which precisely removes selected area of multilayer thin film structure composed of several materials, such as a laminated structure of a-Si, metal and TCO. in thickness direction. We also developed a flexible micro photovoltaic device to supply energy using the surface of micromachine effectively. This device is possible to be mounted on a curved surface in a minimum 2 mm radius. As shown in Figure 2, mounted on the insect-shaped micro actuator (size: 1 cm by 1.5 cm, driving electric power: 2 mW), the device proved that supplying enough energy to drive the actuator on the vertical plane was possible with light.

Fig. 1 High voltage micro photovoltaic device

Fig. 2 Photon energy supply to the insect-shaped actuator

3. Plan for the Future

Almost every machine and equipment around us is now controlled by electricity, and photovoltaic energy is widely used for electronic calculators, watches and clocks, and power plants for domestic use. Through a development on new micromachine technology, photovoltaic device technology, or systematization technology, photon energy will be still more widely used. Photon energy will be for "energy saving" and for realizing a new devices "friendly for human and global environment" . We will conduct research and development on micromachine technology, highly functionalize and systematize, for realization of future technology for a better human life.

(Dr. Hisaki Tarui, R&D Headquarters, Sanyo Electric Co., Ltd.)

DENSO CORPORATION

1. Work on Micromachine Technology

Some major problems such as shortage of energy, exhaust of resources, and deterioration of the environment will come to the surface in the 21st Century. We, enterprises, are required to wisdom intelligence and develop technologies to solve those problems now. Micromachine technology is expected to be the fundamental technology to solve problems in the 21st Century. Micromachine technology which includes many different fields is not an easy technology to be followed. However, the key words, energy-saving, space-saving, and resource-saving, tell us that micromachine technology is a correct trend and it will be used for various new products in the future.

2. Development of Micromachine Technology

We participate in Industrial Science and Technology Frontier Program (ISTF), and develop on in-pipe inspection systems. Figure 1 shows micro inspection machine produced in the first phase of the project to identify the subject of micromachine systems. Two eddy current sensors with a diameter of 2 mm are attached on its head in order to inspect cracks in a metal pipe. By expansion/contraction movement of stack-type piezoelectric actuator inside a package, sensors can move forward and backward with 6 mm/s of speed inside a pipe of 8 mm-internal diameter. This is the simplest in-pipe inspection system with mobile and recognition function. The following technologies are used in this micro inspection machine:

Fig. 1 Micro inspection machine

Shellbody formation technology to form a package of three dimensional ultra thin film structure (thickness: 60 μm, weight: 0.084 g)

Direct bonding technology to transmit heat from actuator to radiation fin with little heat of resistance.

Through development of this micro inspection machine, subjects were presented which were characteristic of the micro system. The most important subject is wireless energy supply. Whether using power supply from batteries or by optical/microwave transmission, energy to be supplied is quite limited. Therefore, the device for this system requires low power consumption. We are now conducting research on actuators which control displacement and output power by the number of laminates with low power consumption, and a microwave energy-supply/communication device. Figure 2 shows wireless moving mechanism produced with those technologies. By transforming microwave of 14 GHz into sawtooth wave of 15 V, 600 Hz, it can move in a pipe of 15 mm with the speed of 1 mm/s. This wireless moving mechanism includes an antenna which effectively receives microwave inside a pipe, microwave rectifying device with high breakdown voltage, and a layered actuator with large displacement and high output power used for driving with low power consumption.

Norio Omori, Executive Managing Director, and President of Research Laboratories, DENSO CORPORATION

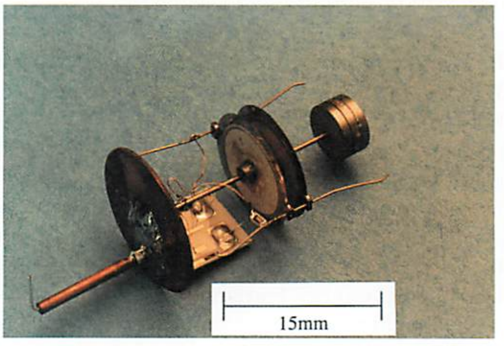


Fig. 2 Wireless moving mechanism

3. Plan for the Future

Micromachines will be applied in various fields for its wide range of technology. We will apply micromachine technology, provide production for the 21st Century, and contribute to the society.

(Mr. Norio Omori, Executive Managing Director, and President of Research Laboratories, DENSO CORPORATION)

The Third Micromachine Summit Held

The third micromachine summit was held from April 28 to 30, Vancouver, Canada. Adding to the 10 participant countries of the last year (Japan, the U.S., the U.K., Italy, Australia, the Netherlands, Canada, Switzerland, Germany, and France), Scandinavia, China, and Taiwan joined this year, and the representatives added up to 81 from 13 countries/regions.

From Japan, led by the chief representative Professor Naomasa Nakajima from The University of Tokyo, Chairman Tsuneo Ishimaru of Denso Corporation, Chairman Toshiro Shimoyama of Olympus Optical Co., Ltd., Vice President Sadao Moritomo of Seiko Instruments Inc., and Executive Director Takayuki Hirano of Micromachine Center (MMC) attended as 5 representatives, with 14 observers from MMC and supporting members of MMC.

Since Canada hosted this time, President Gordon Guild of Micromachining Technology Center, Simon Fraser University, Canada, chaired the meeting. State of local micromachine-related activities were reported in the country/region review section. Then discussion was held on micromachine technologies on topics such as standardization, health care, environment, new horizons and new materials, transportation, and information technology.

Major points of the meeting are shown below.

(1) Country/region review

Situations of Asian economies other than Japan were reported for the first time by China and Taiwan, which attracted much attention. Other countries and regions also reported names of major R&D organizations and other information like they did in the last year's meeting. No drastic changes were reported; researches and developments were continued mainly on government-supported projects. Professor Nakajima from Japan reported the outline of the phase II Industrial Science and Technology Frontier Project.

(2) Standardization

Dr. Wolfgang Menz, Director of Albert-Ludwigs Universität Freiburg, Germany, and Mr. Takayuki Hirano, Executive Director of MMC, reasoned necessity of early standardization. Mr. Hirano proposed to hold a workshop for international standardization of micromachines, which was followed by both pro and con statements, casting light on different views on the matter.

(3) Health care

Dr. Toshiro Shimoyama, Chairman of Olympus Optical Co., Ltd., and Mr. Chris Lumb, President of Alberta Microelectronic Center, made announcements, both of which confirmed the importance of micromachine technology in minimum invasive medical treatment. Mr. Lumb observed that analytical system and medical devices would be

Table 1 Chief Delegates (Country/region review presenters)

Country	Chief Delegate	Affiliation
Australia	Ian Bates	Professor, Royal Melbourne Institute of Technology
Benelux	Albert van den Berg	Doctor, University of Twente, The Netherlands
Canada	Gordon Guild (Dan Gale)	President, Simon Fraser University (Vice-President, Canadian Microelectronics Corporation)
China	Zhaoying Zhou	Chairman, Tsinghua University
France	Daniel Hauden	Director, LPMO-CNRS
Germany	Wolfgang Menz	Director, Albert-Ludwigs Universität Freiburg
Italy	Paolo Dario	Professor, Scuola Superiore Sant' Anna
Japan	Naomasa Nakajima	Professor, The University of Tokyo
Scandinavia	Ingemar Lundstrom	Doctor, Linkopings Universitet, Sweden
Switzerland	Nicolaas F. de Rooij	Professor, University of Neuchâtel
Taiwan	Min-Shyong Lin	Vice-President, Industrial Technology Research Institute
U.K.	Howard Dorey	Professor, Imperial College of Science
U.S.A.	Richard Muller	Professor, University of California, Berkeley

promising applications of micromachine technology, and market needs would be more important than technology in commercializing.

(4) Environments

Dr. Tsuneo Ishimaru, Chairman of Denso Corporation, Dr. Benjamin Hocker at Honeywell Technology Center, the U.S., and Prof. Howard Dorey of Imperial College of Science, the U.K., made announcements. According to them, to conserve the global environment, status of pollution and environmental changes must be monitored on a global scale, which calls for environment monitoring using low cost sensors enabled by micromachine technology. Some praised Japan's energy saving efforts such as microfactory schemes.

(5) New holizons and new materials

New holizons reported are the method of processing three dimensional fine structure using laser pulse ablation by Dr. Erol Harvery of Exitech Ltd. from U.K., and μTAS (micro fluidic analysis system) by Professor D. Jed Harrison of University of Alberta, Canada. As for new materials, importance of non-silicon materials such as piezoelectric materials, polymers, and metals was stated.

(6) Transportation

Prof. Wendong Zhang from North China Institute of Technology, China, Dr. Richard Payne from Analog Devices Inc., the U.S., and Mr. Michael Ward from Defence Research Agency, U.K., explained commercialization of automobile acceleration sensors and low cost micro sensors was brisk. It was stressed that in this field, unnecessary high functions are not preferred because of the high cost, but inexpensive sensors of modest performance are in demand. Japan provided one feasibility of micromachine technology by showing videotaped demonstration of automatic highway driving system (AHS), which attracted attention and evoked brisk discussion.

(7) Information technology

Dr. Sadao Moritomo, the Vice-President of Seiko Instruments Inc. and Dr. Gunnar Edwall from Ericsson Components AB, Scandinavia showed possible applications of micromachine technology to information and communication network. Prediction of market scale presented by Dr. Moritomo attracted high attention and evoked heated discussion on the validity of the prediction.

In general, presentation made by Japanese representatives showed prospects of micromachine technology from high viewpoint, and won high evaluation from the chairman and participants.

It was determined to hold the next meeting of Micromachine Summit in Melbourne, Australia, at the end of April next year.

Table 2 Presenters at the Third Micromachine Summit

Topics	Presenter	Affiliation
Standardization	Wolfgang Menz	Director, Albert-Ludwigs Universität Freiburg, Germany
	Takayuki Hirano	Executive Director, MMC, Japan
Health Care	Chris Lumb	President, Alberta Microelectronic Center, Canada
	Toshiro Shimoyama	Chairman, Olympus Optical Co., Ltd., Japan
Environments	Howard Dorey	Professor, Imperial College of Science, U.K.
	Benjamin Hocker	Doctor, Honeywell Technology Center, U.S.A.
	Tsuneo Ishimaru	Chairman, Denso Corporation, Japan
New Holizons and	Erol Harvey	Doctor, Exitech Ltd., U.K.
New Materials	D. Jed Harrison	Professor, University of Alberta, Canada
Transportation	Wendong Zhang	Professor, North China Institute of Technology, China
	Richard Payne	Doctor, Analog Devices Inc., U.S.A.
	Michael Ward	Business Manager, Defence Research Agency, U.K.
Information Technology	Sadao Moritomo	Vice-President, Seiko Instruments Inc., Japan
	Gunnar Edwall	Doctor, Ericsson Components AB, Scandinavia

97 Micromachine Seminars in Europe

MMC cosponsored seminars, as part of the international exchange activities, to exchange micromachine technology with related research organizations abroad. Details of seminars are as follows:

June 23 (Monday)
[Micromachine Seminar]
Place: Marina Congress Center, Helsinki, Finland
Sponsors: Micromachine Center and TEKES (Technology Development Center Finland)
Participants: 50 people
Lecturers and Topics:

- Future Prospect of Micromachine
  Takayuki Hirano, Executive Director, Micromachine Center
- Current Status of Micromachine Technology R & D
  Kazuhisa Yanagisawa, Chairman of MMC's Research Committee, and General Manager, Olympus Optical Co., Ltd.
- Development of Inspection Micromachine
  Nobuaki Kawahara, Project Manager, Denso Corporation
- Development of Microgyroscope
  Kuniki Owada, General Manager, Murata Mfg. Co., Ltd.
- Micromachine Research in Finland
  Oiva Knuuttila, TEKES
- Microtelemanipulation System
  Heikki Koivo, Helsinki University of Technology
- Micromechanics Research at VTT
  Ari Lehto, Technical Research Center of Finland
- Microactuators at Oulu University
  Seppo Leppavuri, Oulu University
- Micromechanics for capacitive accelaration sensors
  Risto Mutikainen, VTI Hamlin oy

Technical information of micromachine and results of its research were presented by both countries, followed by questions and answers. They showed deep interest in the results of R&D of the first phase of industrial technology project, and the commitment and efforts to the project as a total system were highly appreciated.

It was the first seminar held in Finland, with very little previous technical exchange. This successful seminar would be the first step to establish a partnership in R&D of micromachine technology.

June 26 (Thursday)
[MMC/MIC Seminar on Micromachines]
Place: Technical University of Denmark, Copenhagen, Denmark
Sponsors: Micromachine Center and Mikroelektronik Centret, Technical University of Denmark
Participants: 70 people
Lecturers and Topics: Japanese lecturers and topics are the same as those of seminars in Finland.

- Strategy within Technology Development at Microtronic
  P. Schell, Microtronic A/S
- Microsystems Research at NKT
  T. Freltoft, NKT research A/S
- Microsensors & Microprobes
  S. Bouwstra, Mikroelektronik Centret
- Artificial Muscles
  P. S. Larsen, Riso National Laboratory
- Microdevices by Metal Plating
  O. Hansen, Mikroelektronik Centret
- Design of Microactuators using Topology Optimlization
  O. Sigmud, Technical University of Denmark
- Microelectrodes for Biological Applications
  T. Sinkjaer, University of Aalborg.

Most of the participants were students, but there were also some from local companies. Micromachine technology in Japan and research results in the Technical University of Denmark were the topic of the seminar, with presentations in various fields. Students, particularly, were taking interest in research results of Japan, and the seminar was very lively with many questions and answers. We provided our Micromachine technology to researchers and engineers who would lead prospective industries in Denmark.

MMC visited the Technical University of Denmark several times in the past and conducted technical exchanges. The "clean" room was under construction at those times, but now is completed and interesting efforts are being made.

June 30 (Monday)
[Joint Seminar on Micromachine / MST in Besancon]
Place: Central Nationale de la Recherche Scientifique (CNRS), Besancon, France
Sponsors: Micromachine Center and Central Nationale de la Recherche Scientifique (CNRS)
Participants: 32 people
Lecturers and Topics: Japanese lecturers and topics are the same as those of seminars in Finland.

- Outline of the three calls for proposal in Microsystems and ANVAR Role
  N. DELORME, ANVAR
- Ultrasonics and Electromagnetic Micromotors
  M. FROELICHER, CETEHOR
- Local LIGA technology and applications
  S. BASROUR, CNRS
- Design and control of cooperative microrobots
  N. CHAILLET, CNRS
- French Research Microsystem Programme 1997-2000
  D. HAUDEN, CNRS

Besancon is located near the border of Switzerland and France. There are many laboratories related to electric machine based on clock technology, and R&D is conducted jointly by government, industry, and academia. Therefore, many researchers participated in the seminar, and very specialized discussions on technology was held. Results of those discussions would be quite helpful for future technical exchanges.

97 Micromachine Mission in North America

MMC is striving for the promotion and dissemination of micromachines in various fields, and its activities are highly evaluated in Japan and abroad. The mission to foreign countries, of which objective is to collect and exchange the information on micromachine-related R&D by visiting universities and research institutes, is being carried as a part of the international exchanges which are the important activities at MMC and has brought about good results.

The "97 Micromachine Mission in North America" was dispatched from April 26 until May 10, participated in the 3rd Micromachine Summit in Vancouver, Canada, which was held from April 28 until April 30. The group was composed of 12 members from MMC and other supporting companies, and led by Prof. Naomasa Nakajima, The University of Tokyo (the first half of the mission) and Mr. Tatsuaki Ataka, Seiko Instruments Inc. (the last half of the mission). Five universities in Canada and in the united States were visited and the R&D of micromachines were investigated. We presented our state of R&D, and promoted a better understanding of our activities.

The five universities and outline are as follows:

(1) Simon Fraser University / Canada

Date: April 28

Host: Prof. John Stubbs, president, Prof. Ronald G. Marteniuk, Dean, and Mr. Gordon Guild, and others

Harbor Center Campus located in the center of Vancouver was visited. It has only class rooms and conference rooms, and no laboratories. Instead, they arranged the staff from related departments. Their R&D of micromachines in the micromachine & microprocessing research center in the Department of Applied Science was introduced by video.

Main results of R&D: tactile sensor for endoscope surgery, fluid device for DNA analysis, and acceleration sensor with heater.

The devices are mainly applied for medical and bio-related fields. The processing system is based on semiconductor processing technology by etching, mainly thin-film bridge structure and groove formation technology, and equipment for semiconductor processing of 4-inch wafer are fully equipped.

(2) Louisiana State University / USA

Date: May 2

Host: Dr. Volker Saile, the head, and others

The research organization called CAMD (Center for Advanced Microstructures and Devices) in Baton Rouge, Louisiana was visited. This organization is financed by the State Government of Louisiana and operated and managed by Louisiana State University. They have a SR device (1.3 - 1.5 GeV ring diameter 16.3 m) and are conducting R&D high-aspect structure processing technology using X-ray lithography.

Main results of R&D: spindle motor for hard disc drive by LIGA process (joint research with IBM), and implanted drag delivery system with silicon bulk machining and LIGA process.

CAMD is the base of R&D of microprocessing technology using X-ray lithography, in Research Cooperation Network of universities and enterprises in the United States, with MCNC as leader.

(3) Louisiana Tech University / USA

Date: May 5

Host: Prof. Barry A. Benedict, Dean, Mr. Philip Coane, and others

The Institute for Micromanufacturing (IfM) in Ruston, Louisiana was visited. This institute was completed in 1995, composed of laboratories for ion beam processing, micromachining, laser processing, transfer technologies, and a clean room.

Main subjects of research: laser processing technology (excimer laser ablation), ion beam processing technology, micromachining technology (drilling, milling, electric discharge machining), and LIGA.

These processing technologies will be applied mainly for micro fluid devices, optical devices (such as fiber connector), and bio medical devices. Although R&D of MEMS, which is on the line of semiconductor processing technology, is generally conducted in the United States, this institute aims for realization of micro systems with various micromachining technologies as in Japan.

(4) Case Western Reserve University / USA

Date: May 7

Host: Dr. Wen H. Ko, professor emeritus, and others

We visited departments of electrical engineering/ applied physics in Cleveland. R&D of MEMS, including semiconductor processing technology (specially various sensors of pressure, power, displacement, flow, and chemical amount) research. They have a series of semiconductor processing lines to produce 4-inch CMOS IC and bonding devices for silicon chips, and SiC epitaxial devices. It is being remodeled to a 6-inch line.

The main subjects of research include gas sensor, flow sensor, and temperature sensor; array those sensors, and make it one-chip (smart) with control IC. Also, being researched are fluid device, optical device, actuators for fuel jet nozzle, SMA, and polymer materials.

(5) Massachusetts Institute of Technology / USA

Date: May 8

Host: Prof. Ian W. Hunter, Dr. John Madden, and others

At MIT in Cambridge, there is a wide range of R&D, such as micro actuator, micro optical system, micro sensor, simulation, and micro robot, using conducted in several departments. We visited Hunter Laboratory in the Department of Mechanical Engineering, where research on conductive polymer application, and MTL (Microsystems Technology Laboratories), where R&D on MEMS device process is conducted. In Prof. Hunter's laboratory, robot technology based on fundamental technology (optics, electrotechnology, mechanical engineering, chemistry, and molecular biology), is being developed to solve biological problems. Researchers are striving to develop sensors, actuators, and systems for an autonomous robot, and to realize various functional devices with conductive polymers. MTL has a series of semiconductor processing lines to produce various semiconductor devices with 4-inch wafer (will be remodeled to 6-inch line). It is the center of R&D of MEMS devices in MIT, and plays an important role in joint research with industry and academia.

Federation of Micromachine Technology Operation Council Held

The sixth meeting of Federation of Micromachine Technology Operation Council was held on May 30 (Fri.) in the meeting room, Micromachine Center. Those present were Dr. Tomomasa Satoh, Executive Director of the Federation and Professor at The University Tokyo, and other committee members representative of 11 organizations. At the meeting, activities of Federation of Micromachine Technology in fiscal year 1996 were reported, action plans for fiscal 1997 were discussed, the Executive Director was selected, and applications for membership were examined.

Major activities of the federation in fiscal 1996 were cosponsoring four events listed below and information providing to members from web site. Prof. Iwao Fujimasa at Saitama University was selected for the Executive Director for fiscal 1997. As the Sensor and Micromachine Division of the Institute of Electrical Engineers of Japan joined the Federation as a new member, constitution of the Federation is now 29 members, 1 semi-member, and 1 support member. According to the action plans for fiscal 1997, the Federation will sponsor and cosponsor events based on the project plans determined by the Federation rules, and provides information on events and topics of federation members, micromachine related books and magazine on federation's web site to encourage information exchange between members. The federation will also review the first edition of its member list issued in April 1995, and publish a revised version in 1997.

Events cosponsored by the Federation of Micromachine Technology in 1996

Name	Host	Date	Place
7th Micromachine Symposium	Nagoya-shi municipal government, etc.	'96.10.2 ~10.4	Nagoya Municipal Industrial Research Institute
7th Micromachine Exhibition	Micromachine Center, etc.	'96.10.30 ~11.1	Science Museum
2nd International Micromachine Symposium	Micromachine Center, etc.	'96.10.31 ~11.1	Science Hall, Science Museum
10th MEMS Workshop	Institute of Electrical and Electronic Engineers, etc.	'97.1.26 ~1.30	Hotel Nagoya Castle

Home Page Address of the Federation of Micromachine Technology:

http://biomed.poli-sci.saitama-u.ac.jp

Living Organisms and Micromachines (I)

Scaling, Hints for Mechanisms

Isao Shimoyama
Associate Professor, Department of Mechano-informatics, Graduate School of Engineering, The University of Tokyo

Many have tried to make technical implementation of functions and structures of living organisms. And the outcomes, like the airplane, frequently showed excellence in performance to the model organisms.

Micromachines are machines of microscopic dimensions that used to be out of the range of human manipulation until recently. Extrapolation of conventional machine designs to micromachines would never achieve expected performance. One reason for this is that size reduction changes dominant forces. For example, viscous force has more dominance than inertial force over phenomena of smaller scales. It is accepted that to move things by the fluid dynamic force, use of viscous force is more effective. One phenomenon generally known is that relative importance of surface tension increases as the size of objects involved reduces. Hence, fine components often adheres to a silicon substrate. Since frictional force also increases its relative importance in microscopic world, turning rotary axes there requires relatively greater force.

Let's turn our eyes to the nature. Living organisms are thought to have acquired body structures and functions fit for their size in the process of evolution through natural selection. Insects, among all, are most surprising for their small size and all kinds of motions such as flying, jumping, and escaping. Insects are perfect models for micromachines because they are about the same size to micromachines we are making.

Let's take a close look at insects and check biological data in with the eye of a micromachinist. Figure 1 shows the metabolic rate by various animals of different dimensions. The figures are calculated from measured amounts of oxygen consumed by the animals in unit time, converting 1 liter of oxygen to 20.1 kJ. As seen in the graph, metabolic rate, P_{met}, is proportional to body mass m to the power 0.75.

$$P_{met} \propto m^{0.75}$$

This means that as the body size reduces, metabolic rate per unit body mass consumed by the animal

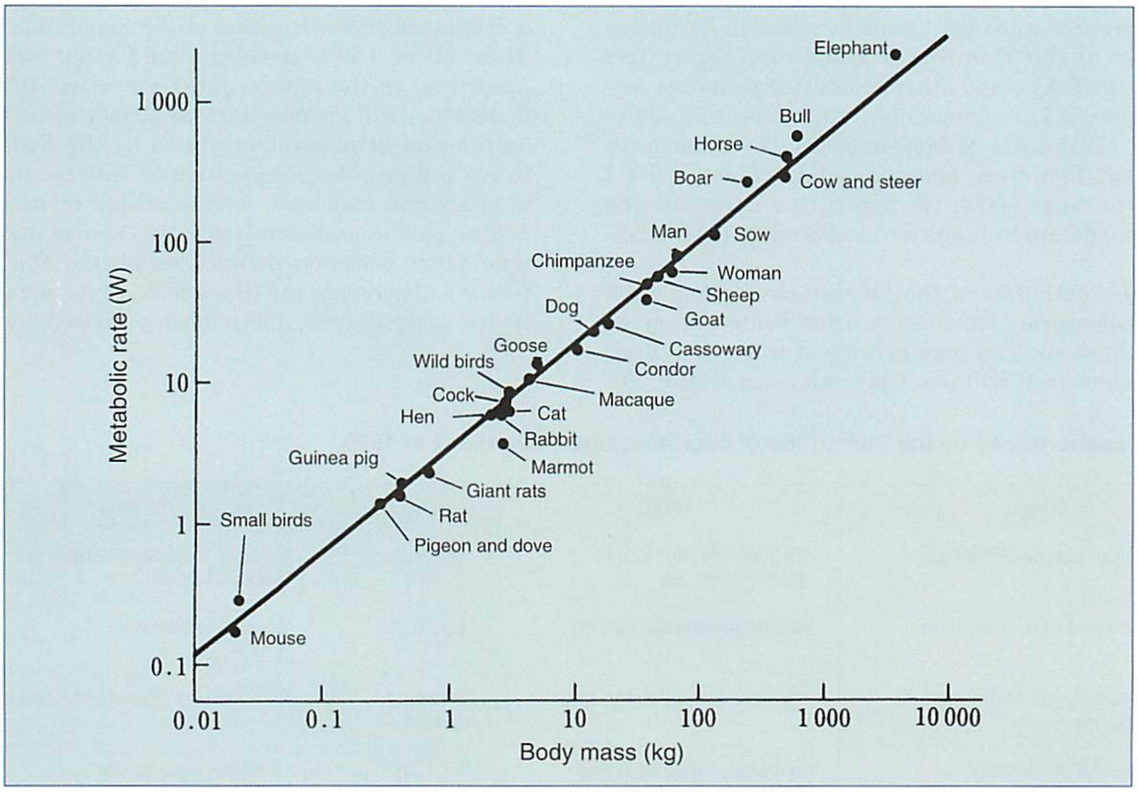


Figure 1 Metabolic rate to weight of mammals and birds, both on logarithmic scales (by Benedict). The plot shows linear relationship. Reproduced from "Scaling: Why is animal size so important?" by Schmidt-Nielsen (Translated by Shimozawa, Oohara, and Urano, Corona Publishers).

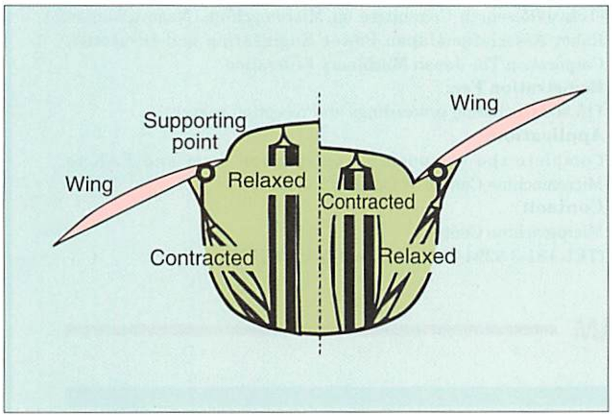


Figure 2 Cross section of insect thorax

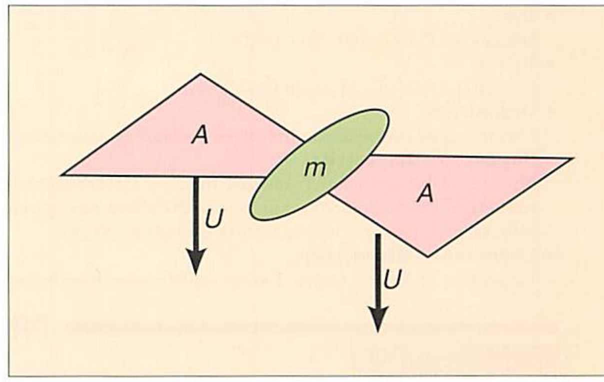


Figure 3 Flight (In a state of fluttering, the aerodynamic force acting on the wings counterbalances gravity.)

increases. If the relation shown in Figure 1 holds true with animals in general, it leads to interesting conclusions. For example, maximum diving time T of an animal that cannot breath underwater is obtained by dividing the amount of oxygen stored in the animal body by the amount of oxygen consumed by the animal in unit time.

Diving time = (internal oxygen storage) / (oxygen consumption per unit time)

Internal oxygen storage is proportional to body mass. Oxygen consumption in unit time is proportional to metabolic rate, which in turn is proportional to body mass to the power 0.75.

(Internal oxygen storage) $\propto m$
(Oxygen consumption in unit time) $\propto m^{0.75}$

Therefore, diving time is in proportion to body mass to the power 0.25, or, in short, larger animals can stay underwater longer.

Since the amount of energy that can be stored in a battery is proportional to the volume of the battery, the relationship between body mass and diving time can hold true with micromachines. As machines are miniaturized, friction and surface tension deteriorate energy efficiency, in the same way as the relative increase of internal loss of metabolic energy shown in Figure 1. Since a constant amount of electric energy can be stored in unit volume of a battery, the smaller the battery is, the shorter it can power a certain load. This suggests that probably a micromachine on its own battery is unable to keep on working for a long time. In general, micromachines that need to stay active for long hours have to be powered from external sources.

A feature of insect body structure is the exoskeleton. Many insects move their wings not directly by the flying muscles in the thorax but indirectly through deformation of exoskeleton of the thorax, as shown in Figure 2. A silkworm moth has about 10 different muscles in the thorax, which contract and extend at different phases to generate complicated wing stroke patterns. Use of the exoskeleton structure enables distributed layout of actuators in the skeleton structure to utilize its limited volume. It is also noteworthy that exoskeleton structures for micromachines can be created by folding thin films on silicon substrate. I think insects have never achieved soft skin made of cells because the skin is too thick and complicated to reduce to small size.

Flight of insects is another interesting model for micromachines. Figure 3 shows a conceptual flight of an insect. If aerodynamic force to the wings f_d is generated by fluctuations of the momentum, it is expressed as follow.

$$f_d \propto AU^2 \propto m$$

Since the aerodynamic force must counterpoises gravity to fly the insect, the force must be in proportion to the weight of the insect. If body mass m is in proportion to the cube of size and wing area A to the square of the size, flow velocity U is proportional to size L to the power 0.5.

$$U \propto L^{0.5}$$

Then, increase in kinetic energy in unit time, or, work P of the wings in unit time is in proportion to the size to the power 3.5.

$$P \propto f_d U \propto L^{3.5} = m^{1.17}$$

In the meanwhile, metabolic rate P_{met} of an animal is proportional to body mass m to the power 0.75. Therefore power P required for flying and metabolic rate P_{met} generated by muscles cross at a specific point of size, meaning that necessary power for flying becomes relatively small compared to usable power as the size of the animal reduces. In other words, smaller animals can fly easier. It may not be a universal truth, however; smaller animals are likely to have poorer efficiency (ratio of effective energy to total metabolic rate).

There are lots of other things we can learn from insects. In the next and the following columns, I will argue what hints micromachine researchers can get from sensor organs and nerve systems of insects.

The Third International Micromachine Symposium

- **Date:**
  October 30 (Thu) and 31 (Fri), 1997
- **Venue:**
  Science Hall (Science Museum B2F), Tokyo
- **Organizers:**
  Micromachine Center/Japan Industrial Technology Association
- **Supporters (Expected):**
  Ministry of International Trade and Industry (MITI)/Agency of Industrial Science and Technology (AIST)/New Energy and Industrial Technology Development Organization (NEDO)
- **Cooperators (Expected):**
  Federation of Micromachine Technology/Micromachine Society (Tokyo)/Research Committee on Micromachine (Nagoya)/Japan Robot Association/Japan Power Engineering and Inspection Corporation/The Japan Machinery Federation
- **Registration Fee:**
  ¥15,000 (Including proceedings and reception party)
- **Application:**
  Complete the symposium registration form and FAX to Micromachine Center by October 15, 1997.
- **Contact:**
  Micromachine Center
  (TEL +81-3-5294-7131, FAX +81-3-5294-7137)

PROGRAM

October 30 (Thursday), 1997

Session 1: Opening

9:30	Opening Declaration	Mr. Takayuki HIRANO, Executive Director, Micromachine Center
9:30- 9:35	Opening Address	Dr. Tsuneo ISHIMARU, Chairman, Micromachine Center
9:35- 9:43	Guest Speech	Guest from MITI
9:43- 9:51	Guest Speech	Guest from AIST
9:51-10:00	Guest Speech	Guest from NEDO
10:00-10:45	Special Guest Speech	Prof. Isao KURABE, The University of Tokyo

Session 2: The Path to New Industries in the 21st Century

10:45-11:15	DNA Chip — Integrated Chemical Circuit for DNA Diagnosis and DNA Computer	Assoc. Prof. Akira SUYAMA, The University of Tokyo/Japan
11:15-11:45	Expectation to Micromachine Technology for Global Environment Protection	Dr. Hiroaki TAO, National Institute for Resources and Environment/Japan
11:45-12:15	Standardization of Metrology in Micromachine Technology	Prof. Kimiyuki MITSUI, Keio University/Japan
12:15-13-15	Lunch	

Session 3: Activities in Europe and USA

13:15-13:45	The NEXUS And Europractice New Organization (tentative)	Mr. Gaëtan MENOZZI, Chairman, NEXUS Executive Board/EU
13:45-14:15	Overview of Microfabrication Research in the U.S. and Current NSF Initiative	Dr. Jay LEE, National Science Foundation/USA
14:15-14:45	Overview on the Micromachine Activities in the UK	Prof. Howard DOREY, Imperial College of Science/UK
14:45-15:00	Break	

Session 4: Innovative R&D

15:00-15:20	Micromachines for Optical Applications	Dr. Hiroshi TOSHIYOSHI, The University of Tokyo/Japan
15:20-15:40	A New HDD by MEMS Technology (tentative)	Prof. Albert PISANO, University of California/USA
15:40-16:00	Microforming and Fabrication of Micromachine with Amorphous Alloys	Assoc. Prof. Yasunori SAOTOME, Gunma University/Japan
16:00-16:20	Design of Blood Compatible Polymeric Surfaces	Assoc. Prof. Nobuhiko YUI, Japan Advanced Institute of Science and Technology/Japan
16:20-16:40	Micro-Insect Robots	Assoc. Prof. Isao SHIMOYAMA, The University of Tokyo/Japan

Session 5: Thinking of Micromachine

16:40-16:55	School Children's Idea of Micromachines	Ms. Ayako MOCHIZUKI, Okubo Municipal Elementary School, Narashino/Japan
16:55-17:15	Japan's Micro Technology	Dr. Masaki UKAI, Kyoto Bunkyo University/Japan
17:15-17:35	Socio-Cultural Implication of Micromachine Technology	Assoc. Prof. Shin-ichi TAKEMURA, Tohoku University of Art and Design/Japan
18:00-20:00	Reception Party at Josui Kaikan	

October 31 (Friday), 1997

Session 6: Current Status of Micromachine Technology Project in ISTF Program

General

9:30- 9:45	Overview of ISTF Program	Mr. Makoto OKAZAKI, Director for Machining and Aerospace R&D, AIST, MITI/Japan

Research in National Research Laboratories

9:45-10:00	Tribology for Micromachine	Dr. Yasuhisa ANDO, Mechanical Engineering Laboratory, AIST, MITI/Japan
10:00-10:15	Research on Micromachine Technology at Electrotechnical Laboratory	Dr. Shigeoki HIRAI, Electrotechnical Laboratory, AIST, MITI/Japan
10:15-10:30	Technique Developed at NRLM for Microdevices and Micromaterials	Dr. Akira UMEDA, National Research Laboratory of Metrology, AIST, MITI/Japan
10:30-10:40	Break	

R&D in Micromacine Center

10:40-11:00	R&D Plan for the Second Phase of the Project "Micromachine Technology"	Mr. Kazuhisa YANAGISAWA, Research Committee, Micromachine Center/Japan

• Systematization Technology

11:00-11:15	Experimental Wireless Micromachine for Inspection on Inner Surface of Tubes	Dr. Nobuaki KAWAHARA, Micromachine Center/Japan
11:15-11:30	Experimental Chain-Type Micromachine for Inspection on Outer Surface of Tubes	Mr. Hiromu NARUMIYA, Micromachine Center/Japan
11:30-11:45	Experimental Catheter-Type Micromachine for Repair in Narrow Complex Areas	Mr. Ryo OHTA, Micromachine Center/Japan
11:45-12:00	Experimental Processing and Assembling System (Microfactory)	Mr. Tatsuaki ATAKA, Micromachine Center/Japan
12:00-13:00	Lunch	

• Functional Device Technology

13:00-13:20	Super Precision Machining of Micro V Shaped Gratings	Mr. Tomohiko KAWAI, FANUC LTD/Japan
13:20-13:40	Application of Block Technology for the Self-Package	Mr. Akinobu SATOH, FUJIKURA LTD./Japan
13:40-14:00	Development of a 2-Dimensional Micro Conveyer	Mr. Haruo NAKAZAWA, Fuji Electric Co., Ltd./Japan
14:00-14:20	Micro Magnetic Bearings and Suspension Mechanisms	Dr. Ronald B. ZMOOD, Royal Melbourne Institute of Technology/Australia
14:20-14:30	Break	

• Common Basic Technology

14:30-14:50	High Speed Shape Measurement Technology for Micromachines	Mr. Takeo TANAAMI, Yokogawa Electric Corporation/Japan
14:50-15:10	A Study for Pattern Generation of Micromachine Group	Mr. Yasuo OHTSUKI, KAWASAKI HEAVY INDUSTRIES, LTD./Japan
15:10-15:30	Formchanging Control and Behavior Control for Holonic Mechanism	Mr. Tomoyoshi IBE, MITSUBISHI HEAVY INDUSTRIES, LTD./Japan

Session 7: Closing

15:30-15:35	Closing Address	Mr. Hikaru HAYASHI, Managing Executive Director, Japan Industrial Technology Association/Japan

MICROMACHINE No.20

MICROMACHINE is published quarterly by Micromachine Center (MMC) to promote the international exchange of information related to micromachines, R&D and other technical topics, and is circulated free of charge. Please send your comments about **MICROMACHINE** to the publisher:

Takayuki Hirano, Executive Director, Micromachine Center (MMC)
5-F, Niikura Building, 2-2, Kanda-tsukasacho, Chiyoda-ku, Tokyo 101, Japan
Tel: +81-3-5294-7131, Fax: +81-3-5294-7137
Internetn Home Page http://www.iijnet.or.jp/MMC/

Change of Address: Please send old address label and new address to the publisher.
Editorial and Production Management: Japan Technical Information Service (JATIS)
Date of Issue: Aug. 31, 1997