Micromachine
マイクロマシン

Oct. 1998

- Micromachines addressing 21st Century
- Sato Lab., Nagoya University
- Abstracts of Basic Technol. Res. / Okayama Micromachine Seminar / 4th Internat. Micromachine Symposium
- Members' Profiles
  Hitach, Ltd. / FANUC LTD
- Foreign View
  '98 Mission to Europe
- Topics
  Seminars in Europe
- Introductory Course
  Portable Micromachine Exhibits (III)
- Events

No. 25

MICROMACHINE CENTER

Development and Popularity of Micromachine Technology

Toyo Kato
Chairman, Japan Machine Tool Builders' Association (JMTBA)

For their ability to produce all kinds of machinery and equipment, machine tools are collectively called the "Mother of Machines." As such, machine tool manufacturing has been positioned as a strategic industry in any industrial economy. To be sure, as the machine tool production technology supports the manufacturing industry of a nation and, for that matter, is even used as an indicator of the national production technology standard, each industrial economy of the world has vigorously pursued the development of machine tool technology.

Contemporary machine tool technology can be traced to those innovative machine tools which had driven the Industrial Revolution. Since then, technology to produce machine tools has made spectacular advance through the transmission and accumulation of machine tool-related technologies, skills and expertise, let alone scientific research and development. There is no doubt that Japan has established its foundation as the world's largest machine tool producer through such processes.

That said, we must take heed of a number of problems that have been emerging in recent years as a result of new socio-economic trends. To name a few, we are observing a flight of young people from manufacturing jobs, along with the hollowing of manufacturing industries. These phenomena are, in turn, causing shortages of human resources available for our industry, while also giving rise to other problems associated with human resource nurturing and transmission of technologies. Elsewhere, there are rising concerns about environmental issues, such as global warming, acid rain and so forth.

Out of such awareness, JMTBA put together a report entitled "Outlook for the Machine Tool Industry," last year, in an attempt to grope for a vision of the machine tool industry in the 21st century. Regarding the future orientation of technological development, the report recommends to focus on the development of new concept-based machines and technologies, such as machine tools with parallel-link mechanism, rapid prototyping, environment-conscious machines and high-speed, high-accuracy machining, among other things.

In the meantime, in an attempt to save energy, space and resources, down-sizing of machine tools has been under review. In this connection, a prototype micro-lathe developed by the Mechanical Engineering Laboratory of the Agency of Industrial Science and Technology, Ministry of International Trade and Industry (MITI) is drawing keen attention. The development of this micromachine tool for partial machining has involved the kind of machining accuracy unattainable by any design concept for smaller, lighter machine tools of the conventional type, along with machine rigidity and movement characteristics, as critical factors. Thus, development of new design methods for control technologies, among others, is also apace.

In addition, the Agency of Industrial Science and Technology is also undertaking extensive research and development projects associated with micromachine technologies, focusing on: efficient maintenance and management of complex equipment for power stations; base technologies commonly usable for the inspection, repair, diagnosis and treatment of tight, inner areas of pipings at the plant as well as those of a living body; technology for the upgrading of functional devices; and systemization technology. In keeping with such initiatives, research systems centering around national research institutions, universities and the industry have dramatically expanded to realize the dream technology.

The fact that extensive R&D is actively underway in wide-ranging areas, involving micromachine systems, microfactories and so forth, addressing the 21st century, is giving rise to expectations that the results of such activities will contribute not only to the development of the industry, but also to the international community at large.

In closing, the role being played by Micromachine Center for the development and popularization of micromachine technology is extremely vital. We sincerely wish for lasting success and prosperity of the center.

Sato Laboratory of Nagoya University

Kazuo Sato
Department of Micro System Engineering,
Graduate School of Engineering, Nagoya University

1. Introduction

Our laboratory was established at Nagoya University in 1994 and began as one of six laboratories in the Department of Micro System Engineering at the university's Graduate School of Engineering.

The benefits of research an micromachines are expected in such areas as information devices, industrial equipment, and medical and scientific fields. To implement these technologies the following research is currently underway in the technologies of silicon micromachining, materials measurement and evaluation, and micro-systems.

- Anisotropic chemical etching.
- Tensile, impact, and fatigue testing of micron-scale materials.
- Analysis of micromachining processes and device functions for micromachines.
- Electrostatic micro-actuators and their application in devices.
- Development of ultra-hard materials and ultra-low friction system using ion beam techniques.
- Evaluation of the mechanical properties of thin films using nano-indentation techniques.

2. Recent Topics

(1) Anisotropic Etching Research

This technology has a considerable history. It is based on the fact that the etching rate differs dramatically depending upon the orientation of the silicon crystals, and has been used to fabricate diaphragms and cantilever beams. There are, however, limits to the shapes which used to be produced, and the design of the etching process requires considerable know-how and experience. Our laboratory has analyzed and clarified this etching phenomena, and is currently working towards the fabrication of sophisticated 3D shapes in single crystal silicon wafer.

The hemispherical test piece shown in Fig. 1(a) was machined from a silicon ingot for measuring the etching rate for all crystal directions. The test piece was etched in aqueous solutions of anisotropic etchants such as KOH and TMAH solutions to produce anisotropic etching patterns observable even with the naked eye as in Fig. 1(b). This technique has allowed for the first time precise measurement of the orientation dependence of etching rate on by measuring change in shape in the test piece due to etching.

An example of measurement result is shown in Fig. 2. This picture shows the etching rate contours on the surface of the hemispherical test piece. The results were obtained through accumulated experience in the use of various types, temperatures, and concentration of etchant.

This research is currently being developed in the following industrial and academic applications.

(a) Development of CAD Systems

A CAD system has been developed in cooperation with Fuji Research Institute Corp. for analyzing 3D etching profiles to determine etching conditions. The analysis is performed for any desired shape of mask pattern on a substrate with the desired crystal orientation. The MICROCAD system is a simulation software that permits the analysis of complex 3D etched shapes (e.g. wafer penetrations) such as those shown in Fig. 3. The system is already in use in Japanese industries and institutes.

(b) Research on Etching Mechanisms

Besides a contribution to industry, the results of our research have proved valuable in answering the question of why crystal anisotropy occurs. Further cooperative research in this field is currently under way at the University of Twente and Nijmegen University in the Netherlands, and at

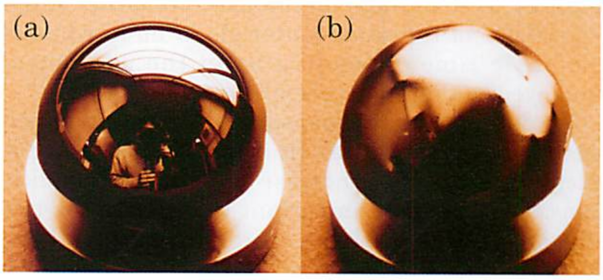


Fig. 1 Silicon test piece before and after etching

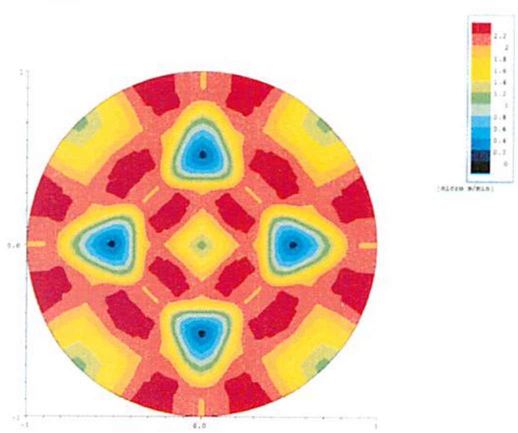


Fig. 2 Etching rate contour lines for all directions

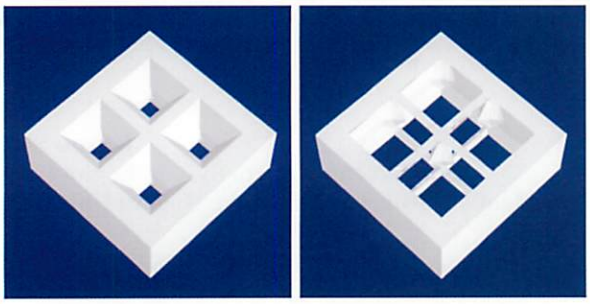


Fig. 3 3D Etching profile analysis example (MICROCAD output)

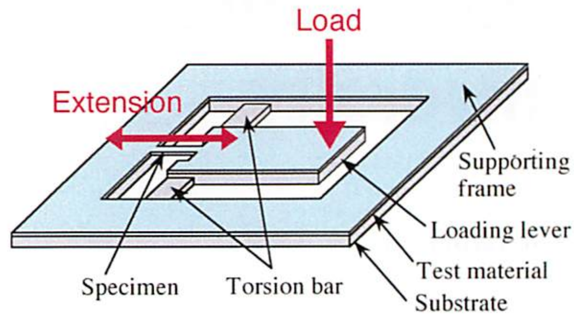


Fig. 4 On-chip tensile testing

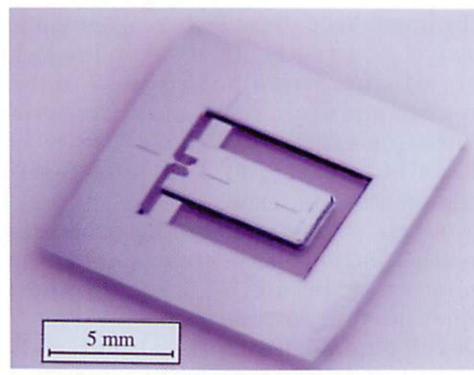


Fig. 5 Silicon chip employed in tensile testing

LAAS/CNRS in France.

Cooperation and technical exchange between these organizations that specialize in atomic-level etching mechanisms, and our research establishments conducting macro-scale experimental research, is proceeding well, and visits of research personnel to Japan are scheduled to begin this year.

(2) Tensile Testing of Micron-scale Materials

Materials hitherto not considered as mechanical elements are being employed in micromachines. These include films grown from the vapor phase, and metals deposited with plating techniques. These materials present particular micro-scale difficulties in that their mechanical properties differ from those of the same materials in bulk, while at the same time depending upon the equipment employed in their deposition.

A database of the measurements of the properties of these films is of vital importance if use of micromachines is to increase in industrial applications. It is therefore important to measure the tensile properties of these thin-film materials as deposited on silicon chips. Since these measurements cannot be obtained using conventional tensile testing techniques, a method for on-chip tensile testing was developed.

Fig. 4 shows the general principle of on-chip tensile testing. The thin-film sample on the chip surface is connected to the silicon substrate at both ends. When one end of the rotating lever is pressed down with a needle, the torsion bar twists and the test piece is tensioned primarily along one axis.

The silicon chips used in these tests were produced by anisotropic etching, and are shown in Fig. 5. Tensile properties were measured under static conditions, as well as under impact, and fatigue. Research is being undertaken to measure the mechanical properties of microscopic materials and determine whether such properties are improved in comparison to materials of conventional size.

3. Conclusion

My research experience began with the machining of metals.

In 1983 I switched to silicon micromachining technology and its application to micromachine systems. Subsequent to the initiation of the Ministry of International Trade and Industry's Industrial Science and Technology Frontier Project in 1991, many research personnel from different fields have participated in micromachine research. I am grateful for such opportunities

I constantly argued that research personnel in mechanical engineering field, the same background of myself, should aware of the importance of silicon micromachining technologies (i.e. the processes based on photolithography), which have great potentialities for expanding their activities.

Micromachines are a technical break-through which fuses disparate technologies, and as such, constantly presents us with new possibilities. My laboratory focuses on machining technology, and is actively involved in exchange with research and technical personnel of other fields.

Visit our website at
http://www.kaz.mech.nagoya-u.ac.jp/index.html.

Research on Basic Micromachine Technology for Fiscal Year 1997 (Part I)

Since 1992, the Micromachine Center has taken up various seeds of technology as themes for joint research by academic, government, and industrial sectors, aiming to reinforce basic technologies by searching for technology seeds, especially in the scientific and technological fields, that are necessary to build various micro systems. In fiscal 1997, research has been carried out on eight themes. The following articles are summary reports on four themes among them.

Investigation into the Energy Use of Living Organisms

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

Organisms decompose the glucose they obtain through photosynthesis, and the energy released in this process is employed to support the activities of the organism.

This glucose metabolism is of two types-glycolysis requiring oxygen, and glycolysis which does not require oxygen. The majority of the energy required is obtained through oxidation in oxygen-dependent glycolysis. As oxygen is not readily stored in the body, oxygen required to sustain the activities of the organism is normally acquired from an external source and supplied to individual cells. Each organism obtains oxygen by a method appropriate to its size and habitat.

Organisms smaller than insects do not require a dedicated respiratory tract. Large organisms employ specialized organs for gas exchange and blood in a circulatory system for the supply of oxygen. Insects employ a system of trachea for respiration. Oxygen is obtained from the atmosphere via spiracles in the body surface and transported to body tissue via these trachea, and then to individual cells to perform gas exchange. The fundamental structure of the respiratory system consists of 12 pairs of spiracles and the associated trachea linking them to the interior of the body. The spiracles are opened and closed by muscular action.

Gas transport within the trachea of insects employs the principle of diffusion. Diffusion occurs as a result of a concentration gradient, as consumption of oxygen in the tissue increases, this gradient automatically results in an increase in the amount of oxygen supplied, and thus provides a simple and effective means of supplying oxygen to the body. As body size increases, however, it becomes impossible to maintain an appropriate concentration gradient that enables their movement power, and insects are therefore limited in size.

The oxygen requirements during movement are at least ten times that at rest, an increase in consumption which may be covered by diffusion alone in smaller insects but requires some method of ventilation for larger insects. For example, the volume of the trachea changes with the contraction of muscle during flight to provide a pumping action.

If we look far enough, we can see that the source of all energy employed by organisms is the sun, and we have therefore investigated photosynthesis and the ATP (adenosine triphosphate) cycle as mechanisms to gather solar energy. A unique feature of organisms is the direct use of ATP chemical energy as an energy source. This involves energy conversion without the temperature gradient as required in, for example, the heat engine.

The miniscale size of micromachines permits only minimal energy storage, and energy supply from external sources is therefore essential. Methods currently under consideration include light, microwave energy, and mechanical vibration as means of obtaining energy from the environment in the same way as organisms. The construction of a battery using the same mechanisms as those employed by organisms to obtain and convert energy is also under consideration. This is referred to as a biological battery, and it employs the chlorophyll present in a chloroplast and a liquid crystal material to form a biological solar cell. Further possibilities are a fermentation cell employing glucose as fuel and modeled on the oxidation-reduction reaction of mitochondria, and a microbial fuelcell using hydrogen-producing bacteria on its electrodes to generate hydrogen from glucose.

The metabolic rate of organisms is proportional to body weight to the power of 0.75. This implies that as dimensions are reduced the energy consumption per unit of body weight increases, and energy efficiency is therefore reduced.

The power available from muscles is generally fixed, irrespective of the type of organism and location of the muscle, and is primarily determined by the structure and cross-sectional area of the muscle tissue. Furthermore, the contraction of muscle is unrelated to body size. As the deformation of the muscle is constant at approximately 0.3, the work produced (force × distance) with each contraction of the muscle is constant per unit volume, and irrespective of the size of the animal in question. The output power of the muscle is therefore proportional to the speed of contraction of the muscle.

As the animal becomes smaller, changes in its structure e.g. skeleton and sensory organs, become simpler and more effective for controlling movement than the use of a brain and transmission of signals via the nervous system to muscles. Investigations have been conducted to determine the structure and effectiveness of use of the energy obtained by small organisms in such representative activities as jumping, flying, and walking.

Mechatronics involves the replacement of traditional mechanical structures such as gears and linkages with computerized components. The use of such computerized components has brought dramatic changes in conventionally sized machinery, however micromachines require a new design approach not found in the generalized textbook descriptions of organisms, but one founded on the investigation of the unique features of the mechanisms of individual species.

Research Study on Characteristic Evaluation of Materials and Components for Micromachines

Kimiyuki Mitsui
Professor, Faculty of Science and Technology, Keio University

For advance of micromachine technology, the establishment of technology to evaluate the properties of various materials, micro-sensors micro actuators and components is required. Research and development on the following items was investigated in support of this requirement.

• Methods of Measuring Shape and Dimensions of Micro-Components

Trends in research on shape measurement of micro-components have been investigated and the fabrication of the micro-probes by means of micro electric discharge machining techniques has been reported. This report covers the manufacture of conical tool electrodes employed in the preparation of dies and the fabrication of L-shaped and X-Z measuring probes. The results of the measurement by the probe have also been shown.

• Methodology for the Evaluation of the Properties of Materials Employed in Micromachines

Material related technology has been described here. Much of the investigations on materials employed in micromachines have focused on silicon-based materials. However it is necessary to establish materials technologies for micromachines that cover metals and other materials to raise the level of sophistication of structure and function. Introduction of the evaluation methods different from conventional methods in case of bulk materials is necessary. One of the important items to be evaluated is the methods and properties of forming fine shapes in these materials. While the machining properties of bulk materials may be superior, they cannot be machined on a micro-scale, and the different properties of bulk materials may make them unsuitable for use in micro-scale applications. This investigative research focused on the evaluation of the properties on the formation of fine shapes in metallic materials as used in micromachines, and the evaluation of machining methods and their properties.

• Methodology for the Design and Evaluation of Moving Components

In addition to proposals for micro active hinges suitable for micro-scale application, trial manufacture of a macro model to clarify properties and the testing of design and evaluation methodology were also undertaken. From the point of view of the need for high precision and minimum use of space, the use of micromanipulators is appropriate. On of the moving components of these manipulators is the hinge. In the serial type of manipulator in particular, these components are primarily active hinges. Because of this, active hinges with the functions of both super-elastic hinges and actuators made of shape memory alloy are selected. Such active hinges made of shape memory alloy and super-elastic alloy are frictionless, and therefore require no lubrication, and are well suited to use in small and silent manipulators. An analysis of the relative joint angles of these hinges, and comparison with experimental results, was also conducted to determine whether or not they are theoretically appropriate, and to consider any potential problems.

• Methodology for Manufacture and Evaluation of Micro-sensors Using Lithographic Technology

Micro-sensors manufactured using photolithography technology come in a considerable variety, and include those designed to measure physical quantities such as pressure, acceleration, and angular velocity, as well as those designed to measure chemical properties such as gas and ion concentration. This investigation covers thermal sensors. The structure of the thermal sensors give influence to sensitivity and resolution, and these are type of sensors for which micro-scale implementation provides the greatest advantage.

• Nano-probes for Micro 3D Coordinate Measuring Machine

We investigated 3D position detection probes with nanometer precision vitally important for nano-scale 3D coordinate measurement. The laser trapping probe employs the radiation pressure of a focused laser beam on the sphere at the tip of the probe to simultaneously resolve the two problems, resolution and contact pressure. As the probe sphere is held in balance mechanically by an extremely low radiation pressure, contact pressure may be generally ignored and it is therefore well-suited for the measurement of the shape of micro-components.

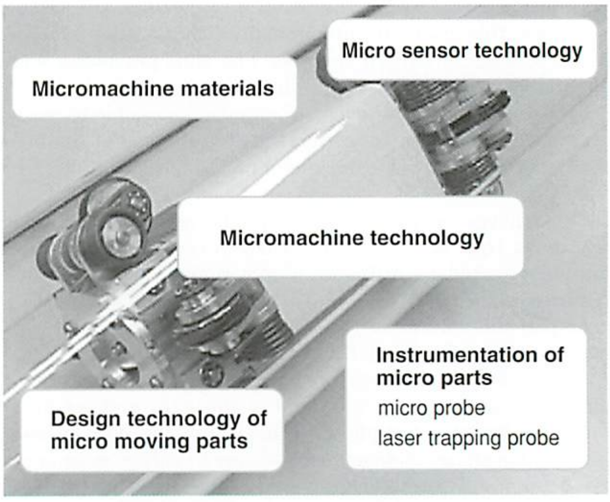


Fig. 1 Conceptual figure of the research study

Research on the Fusion of Micromachines and Optical Technologies

Hiroyuki Fujita and **Hiroshi Toshiyoshi**
Professor and Lecturer, Institute of Industrial Science, The University of Tokyo

While the Internet and multimedia communications are currently used in a wide range of applications, the speed of communications through conventional telephone circuits still leaves much to be desired. To resolve this problem a program is currently being implemented which will provide high-speed and high-volume communications to individual residences over optical fiber networks by 2010. The transmission of optical signals requires that the route for transmission be selected carefully to ensure that they reach the desired location. Optical signals are conventionally converted to electrical signals, switched, and then converted back to optical signals for further transmission, a process which is obviously time-consuming. The use of micromachines able to physically move the optical fiber, or to insert and remove small mirrors from the path of the light beam, would allow transmission of optical signals without intervention, and would considerably simplify the route over which they are transmitted.

The application of micromachines to optical communications technology is further facilitated by the fact that, as light has no weight, large forces are not required to move the mirrors, and the micromachines involved can be mounted in a transparent package so that they could manipulate light from an external source without contact. Optical micromachines are indispensable not only in communications networks, but in a variety of computer-related equipment such as data recording, printers, and sensing, and their effect on society is therefore expected to be considerable.

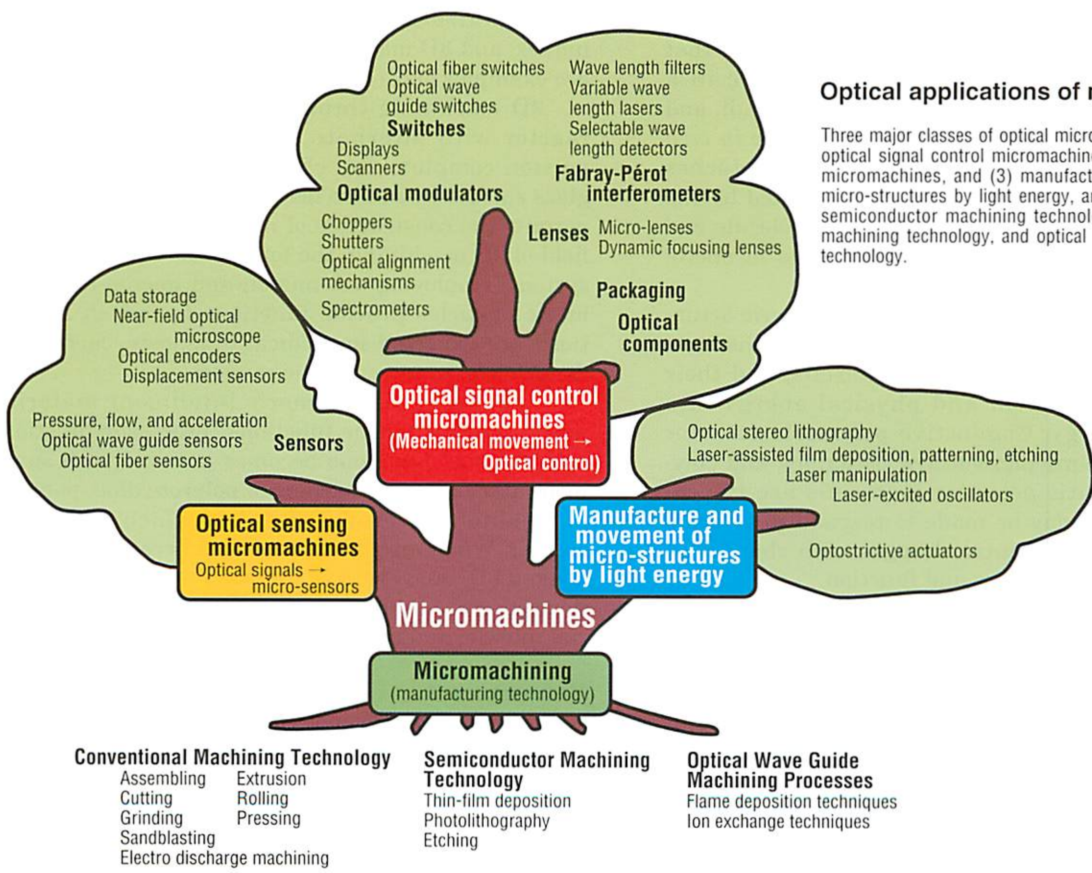
The history of optical micromachines may be traced back to the 1970s, however it is only recently that integrated optical micromachines have become possible, i.e. the ability to integrate such components as optical wave guides, optical fiber connectors, semiconductor lasers, micro-lenses, and movable mirrors into micromachines.

Such optical micromachines have the following advantages.

(1) Overall reduction in system size.
(2) Multiple devices may be used together to implement high performance through parallel processing.
(3) Alignment of optical axes, and assembly are unnecessary.

The application of such optical micromachines is shown in the diagram. Broadly speaking these applications may be classified as (a) those in which micromachines are employed for control of optical signals, (b) those in which micromachines are employed for sensing light, and (c) those in which light is employed to move and create micromachines.

Of the applications shown in the diagram, the optical network devices such as fiber aligners, optical switches, and variable wavelength lasers and filters, hold the most promise. Applications in computer-related equipment such as displays, data recorders, and various sensors are also prospective.



Optical applications of micromachines

Three major classes of optical micromachines, such as (1) optical signal control micromachines, (2) optical sensing micromachines, and (3) manufacture and movement of micro-structures by light energy, are developed based on semiconductor machining technology, machinery-based machining technology, and optical wave guide machining technology.

Research on Feasibility of Polymeric Intelligent Materials for Micromachines

Nobuyuki Yui
Professor, School of Materials Science,
Japan Advanced Institute of Science and Technology

The concept of intelligent materials which possess sensor functions, processor functions, and actuator functions presents the possibility of a radical departure from the separately designed, independent systems with which we are currently familiar.

The ease of forming, diversity of structure and function, and low manufacturing cost of polymeric intelligent materials ensure great potential in a variety of applications. This investigation focused on the ease of application of polymeric intelligent materials to micromachines.

Considerable progress has been made in recent years in the field of polymeric intelligent materials, and this research covered the ease of application of polymeric intelligent materials to micromachines, and focused on (1) the application of supermolecular materials to micromachines, (2) the application of polymeric actuator materials to micromachines, and (3) the application of polymeric soft materials to micromachines, and the micromachining of these materials in (4) 2D and (5) 3D.

An example of the application of polymeric materials to micromachines (1) is a polyrotaxane supermolecule consisting of a clathrate complex, a linear molecule passed through multiple cyclic molecules, with both ends capped by a massive substituent group. An investigation of the reciprocating function of the polyrotaxane supermolecule has revealed that the cyclic molecules can be made to move in a reversible motion in response to external stimuli, and thus have applications in micromachines. The *in vivo* decomposition of the polyrotaxane which detaches from the supermolecule structure is regulated by the decomposition of the polyrotaxane supermolecule end groups, and as such presents opportunities in micromachines for medical applications.

An example of the application of polymeric actuator materials to micromachines (2) is the transducer function of polymeric actuator materials, and their conversion of chemical and physical energy into mechanical energy. Conductive polymeric actuator materials, polymeric piezoelectric actuators, and polymeric electrostatic actuator materials are typical examples, which may be made to respond to external stimuli and environmental changes with changes in their size, shape, structure and function.

When these materials are used at micro-scale they form powerful actuators and thus have the potential for application in intelligent devices in the μm range.

An example of the application of polymeric soft materials to micromachines (3) is the use of polymeric gel in actuator systems which mimic the functions of muscle in organisms, or in other words, the construction of bio-chemomechanical systems for energy conversion and which are driven by biochemical reactions (enzyme reactions).

Bio-chemomechanical systems using poly N-isopropylacrylamide (PNIPAAm) gel and enzymes employ enzyme reactions to generate expansion and contraction which is then converted into mechanical energy. This expansion and contraction is affected by the net-like structure of the gel, and control of the rate of expansion and contraction of the gel is possible by varying its composition.

The production of a uniform net-like structure in the gel ensures that the rate of contraction is considerably greater than that possible with gels of a non-uniform structure. In terms of the design of a polymeric gel with an autonomous oscillation function, the construction of a drive system employing a framework of PNIPAAm gel in conjunction with the Belousov-Zhabotinski reaction (BZ reaction) permits an oscillation system which does not require external stimuli.

Techniques for the machining of polymeric intelligent materials are an essential part of the building of micromachines. The synthesis of 2D machining and functional nanospheres (polymeric particles) using mononuclear and Langmuir-Blodgett film (LB film) self-organization, and surface modification techniques, and 3D machining of deposited thin films, etc. are examples of (3) and (4).

2D machining through the production of a bioreactor with alternate absorption employing the polyion complex, and chemical modification of the glass surface by *in vivo* decomposition of polyrotaxane permits the construction of intelligent systems. In the field of 3D machining, the formation of self-organizing systems employing sub-micron and micron-level polymeric particles provide functions for which applications are expected in medical diagnosis, carriers for drug delivery, and catalytic carriers.

The design of polymeric intelligent materials which possess sensor functions, processor functions, and actuator functions becomes possible with supermolecular materials such as of polyrotaxane, polymeric actuator materials, and gels which respond to stimuli. When intelligent functions become possible in 2D and 3D, much is to be expected in terms of applications in such fields as medical micromachines, artificial muscle, and micro-devices.

References

1. N. Okata, M. Terano, N. Yui (editor) - Functional Design and Future Prospects of Functional Supermolecules, CMC Tokyo, 1998

Okayama Micromachine Seminar

The Okayama Micromachine Seminar began in the afternoon of Friday, September 11, 1998 at Okayama Techno Support in Okayama City. The seminar was sponsored by the Micromachine Center (MMC), Industrial Technology Center of Okayama Prefecture, Technopolis Foundation of Okayama Prefecture, Okayama Prefectural Precision Manufacturing Technology Research Association, and Okayama Prefectural Laser Machining Technology Research Association.

The seminar began with an introductory speech on micromachine technology, which was followed by reports on four specific examples from the Industrial Science and Technology Frontier Program's development of Micromachine Technology, led by the Micromachine Center.

During an intermission, portable micromachine technology exhibits "a piezoelectric micro-motor" made by Seiko Instruments Inc., and "micro fluid operation devices" made by Hitachi, Ltd. were exhibited. These devices were explained by Mr. Kazuyoshi Yoshida (Seiko Instruments Inc.) and Dr. Yuichi Ishikawa (General Manager of MMC's Research Department). It was a good opportunity for the participants to understand the outline of the micromachine technology.

Mr. Naoyosi Ekawa, Industrial Technology Center of Okayama Prefecture's System Technology Manager acted as moderator for the first half of the seminar, with Mr. Masahiro Katayama, CEO of Kibi NC Skills Development Center Ltd., serving this role in the second half. The seminar began with greetings from Mr. Yoshihiro Nakamura, Director General of the Industrial Technology Center of Okayama Prefecture, followed by lectures on "MMC Activities", "Features of Micromachines", and "An Outline of the Second Phase of the Micromachines Project" by MMC's Executive Director Takayuki Hirano, Professor Tokio Kitahara of the Shonan Institute of Technology, and MMC's general manager Yuichi Ishikawa, respectively.

The results obtained in the Industrial Science and Technology Frontier Program were introduced in the following lectures.

"Current State and Future Prospects Microfactories" by Mr. Kazuyoshi Yoshida (Seiko Instruments Inc.)

"A 2D Transport Unit" by Mr. Haruo Nakazawa (Fuji Electric Corporate Research and Development, Ltd.)

"Ultra Precise Micromachining With Nanomachines" by Mr. Hideaki Oku (Basic Research Laboratory, FANUC LTD)

"Force Measurement of Micromachines" by Mr. Yasushi Onoe (Development Projects Center, Yokogawa Electric Corp.)

The seminar was closed by Mr. Shigeji Yoshida, Executive Director of the Technopolis Foundation of Okayama Prefecture.

The sponsors of this seminar form the primary membership of a central technology support organization in Okayama, and are engaged in cutting-edge technical development in the fields of mining, textiles, and brewing, and joint research by industrial sectors, academic, and government.

They also provide technical consultation services for business needs, and conduct research and testing, and provide a system of support for industry within the prefecture. They also provide access to private facilities for research and technical personnel from public, private, and academic organizations as part of a program of support for research and development and technical exchange within the region.

In Okayama Prefecture, there are many companies that have the technology to apply to micromachines and micromechanisms such as micromachining technology, precision die technology, and various aspects of biotechnology.

This provides an excellent opportunity to use effectively the fusion of a number of diverse fields of technology such as micro-engineering and the technology of fine functional elements in both industry and more general activities within society. The seminar therefore attracted considerable interest. Of the 70 participants in the seminar, 46 were drawn from the laser machining, the precision machining and electronics industries in Okayama Prefecture and the surrounding region, and 24 from universities, technological colleges and schools, and research institutes. The lectures promoted lively question-and-answer sessions, and the result was a very meaningful and informative seminar for all involved.

Scene from the seminar at Okayama Techno Support


Display of the portable micromachine technology exhibits

The Forthcoming Fourth International Micromachine Symposium

The International Micromachine Symposium has become an annual event and attracts considerable interest both within Japan and overseas. This year's symposium will be the fourth of its kind, and will be held on the 29th and 30th of October in Tokyo in the Science Hall of the Science Museum at Kitanomaru Park in Tokyo.

The UK International Technology Service (ITS) Mission to Japan participated in last year's symposium. Members of the mission hold leading positions in UK industry, and Professor Howard Dorey of Imperial College, leader of the mission, was also an invited speaker at the symposium. The mission visited 14 universities, research organizations, and private companies, 11 of which are supporting members of MMC.

The conference of the International Advanced Robotics Programme (IARP) is coincidentally being held in Japan at the same time as this year's symposium, and conference participants will also participate in the latter. IARP was established under an agreement at the 1982 Versailles Summit for the purpose of contributing to the development of high-technology robotic systems to replace human workers in the difficult industrial environment prevailing at that time, and to contribute to activation of the international economy. Over subsequent years, micromachines have become one of the themes of the program.

The organizing committee of this year's symposium is headed by Dr. Naomasa Nakajima, dean of the School of Engineering at The University of Tokyo. Lecturers have been selected by the program committee headed by Professor Tomomasa Sato of The University of Tokyo. An advisory board consisting of nine Chief Delegates at the 4th Micromachine Summit in Melbourne, Australia, has also been established.

Activities on the first day of the symposium will consist of lectures by invited guests. The opening session will include greetings from the Ministry of International Trade and Industry, the Agency of Industrial Science and Technology, and the New Energy and Industrial Technology Development Organization, followed by a special speech on "The World of Micromechanisms" by Professor Teru Hayashi, Dean of the Faculty of Engineering at Toin University of Yokohama. Professor Hayashi is the pioneer in the development of micromachines in Japan, and his speech is expected to be of great interest not only to personnel involved with micromachine technology, but to those in a wide variety of other fields as well.

Seven lecturers have been invited from six overseas organizations this year. Mr. Gaetan Menozzi, the Chairman of NEXUS (Network for Excellence in Multifunctional Microsystems), who lectured last year, will also give a lecture in conjunction with Mr. Jean-Christophe Eloy this year on NEXUS's annual market analysis.

Other lectures will give descriptions of the US foundry industry, with its recent successes in product development, an implant type bionic ear already in use in Australia, MEMS research conducted at Case Western Reserve University in the US, and lab-on-a-chip-based devices for acquisition of chemical and biological information.

Lecturers from abroad and their lecture titles follow.

Mr. Gaetan MENOZZI (NEXUS, EC/France) and Mr. Jean-Christophe ELOY (YOLE Development/France): "NEXUS - Results of the Market Analysis"

Mr. John HUIGEN (Bionic Ear Institute/Australia): "Application of MEMS to Cochlear Implants"

Ms. Karen W. MARKUS (MCNC/USA): "MEMS Infrastructure and Manufacturing Support: Prototype-to-Products"

Prof. Wen H. KO (Case Western Reserve University/USA): "MEMS Research/Development at Case Western Reserve University, USA"

Dr. Jean-Jacques GAGNEPAIN (CNRS/France): "Microsystems Technology R and D at CNRS"

Dr. J. Michael RAMSEY (Oak Ridge National Laboratory/USA): "Lab-on-a-Chip Devices for Acquisition of Chemical and Biological Information"

In addition to Professor Hayashi, eight other Japanese lecturers will present papers on topics in the field of micromachine research and development such as the role of machining foundries in micromachine research and development. Other unique topics were encounters of micromachines with school children, living organisms, and origami.

Lecturers from Japan and their lecture titles follow.

Associate Prof. Tetsuo KIDOKORO (The University of Tokyo/Japan): "Micromachine and Lifestyle in the 21st Century"
Prof. Susumu SUGIYAMA (Ritsumeikan University/Japan): "Role of Microfabrication Foundry in MEMS R&D"
Prof. Naomasa NAKAJIMA (The University of Tokyo/Japan): "Schoolchildren and Micromachines"
Assistant Prof. Ryohei KANZAKI (University of Tsukuba/Japan): " Insect and Micromachine"
Prof. Yoshihide MOMOTANI (Kyoto International University/Japan): "Origami may Reveal Idea of Micromachine Structure"
Dr. Naoe HOSODA (The University of Tokyo/Japan): "Reversible Micro-bonding"
Prof. Takashi MIYOSHI (Osaka University/Japan): "Optical Radiation Pressure Micro-machining Using Diamond Grain"
Prof. Hiroyuki FUJITA (The University of Tokyo/Japan): "Micromachined Optical Bench"

Activities scheduled for the second day of the symposium consist of presentations on the progress of AIST's Industrial Science and Technology Frontier (ISTF) Program "Micromachine Technology". This will be delivered in the form of a lecture on the overall situation by Mr. Makoto Okazaki, Director for Machining and Aerospace R&D, MITI's AIST, an introduction to research in micromachine technology and its future by department and section heads of three national research laboratories (Mechanical Engineering Laboratory, Electrotechnical Laboratory and National Research Laboratory of Metrology), an outline and investigation of technical trends in Phase II research and development under the ISTF Program by the research committee chairman of MMC, and members of four a study group. Each supporting member company will give a presentation of the latest results of the ISTF Program.

Other lecturers and their lecture titles follow.

Dr. Yuji ENOMOTO (Mechanical Engineering Laboratory, AIST, MITI/Japan): "R&D on Micromachine at Mechanical Engineering Laboratory — today and tomorrow —"
Dr. Hideo TSUKUNE (Electrotechnical Laboratory, AIST, MITI/Japan): "Research on Micromachine Technology at ETL"
Dr. Akira UMEDA (National Research Laboratory of Metrology, AIST, MITI/Japan): "Results of Research on Micromachine and Prospects for Future Subjects in NRLM"
Mr. Kazuhisa YANAGISAWA (Research Committee, Micromachine Center/Japan): "Overview — Present Status of 2nd Phase 'Micromachine Project' —"
Mr. Takanari SASAYA (DENSO CORPORATION/Japan): "Microwave Energy Supply for In-pipe Micromachine"
Dr. Hisaki TARUI (SANYO Electric Co., Ltd./Japan): "Integration of Photon Transmission System by Laser CVD Wiring"
Mr. Munehisa TAKEDA (MITSUBISHI ELECTRIC CORPORATION/Japan): "Motion Performance Simulator for Micromachine"
Mr. Norisato SHIMIZU (Matsushita Research Institute Tokyo, Inc./Japan): "Mechanical Planetary Gears for a Micro-reducer"
Mr. Hideto NAKADA (OLYMPUS OPTICAL CO., LTD./Japan): "Micro Welding Device for Experimental Catheter-type Micromachine"
Mr. Yasuyuki MITSUOKA (Seiko Instruments Inc./Japan): "Microfabrication Technology using Scanning Near-field Optical Microscopy"
Mr. Takeshi HARADA (Hitachi Ltd./Japan): "Microfluid Operation Device using a Surface Treatment Technology"
Mr. Takeshi KUDOH (TERUMO Corporation/Japan): "Application of Micromachine Technologies for Catheters"
Mr. Hideaki YAMAGISHI (Research Committee, Micromachine Center/Japan): "The R&D Trend of Measuring Technologies for Micromachines"
Dr. Hiroshi GOTO (Research Committee, Micromachine Center/Japan): "The R&D Trend of Design and Simulation Procedure for Micromachines"
Mr. Haruo NAKAZAWA (Research Committee, Micromachine Center/Japan): "The R&D Trend of Micro-Actuator Technology"

The 9th Micromachine Exhibition "Micromachine '98" is to be held on the first floor of the Science Museum from October 28th. Exhibits have been accepted from a total of 76 businesses, universities, and other organizations, including supporting members of MMC. Practical examples of micromachine technology from the ISTF Program will be exhibited by supporting companies and the three national research laboratories.

Activities on the second day will be completed by 3:50 p.m., to provide an opportunity to leisurely peruse all the exhibits. All participants in the symposium will receive free admission to the Micromachine '98.

Registration for the symposium must be completed by October 15th, however admission on the day will be possible provided seats are available.

Hitachi, Ltd.

Sueo Kawai
Director General of the Mechanical Engineering Research Laboratory

1. The Challenge of Micromachine Technology

Hitachi, Ltd. is making a considerable effort to create and strengthen new fundamental mechanical technologies in order to support the development of a wide range of products. In addition to developing fundamental mechanical technologies, it is also involved in research which touches on a number of other fields such as physics, chemistry, biology, electronics, and micromachine technology. The company believes that micromachines are a revolutionary fundamental technology with applications in a range of areas, such as information and communications equipment, medical and analytical equipment, and motor vehicles, and as such is an active participant in the Ministry of International Trade and Industr's Industrial Science and Technology Frontier (ISTF) Program.

2. Development of Micromachining Technology

As part of its research and development on implementing microfactory systems in the ISTF Program, Hitachi, Ltd. is currently developing microfluidic operating devices (fluidic transport and holding devices). The fluidic transport devices the company has developed include high-output microtrochoid pumps, valves, and flow channels for transporting corrosive fluids such as etching and plating fluids. A holding device consisting of a vacuum adhesion micropump is currently under development. It consists of fixed and revolving involute curved scrolls and promises high volumetric efficiency with low vibration. It is designed to be attached to the tip of a micromanipulator used in component assembly (see Fig. 1).

Hitachi, Ltd. has developed 3D micromachining, surface treatment, and bonding and assembly technologies required for implementing these devices.

- **3D Micromachining Technology**

This technology has been developed for anisotropic etching of single-crystal silicon. Etching rates in all crystal directions were measured, and the measurements were used to create a database which was then employed to develop software for analyzing anisotropic etching profiles. This work has enabled the manufacture of 3D microcomponents such as that shown in Fig. 2.

- **Surface Treatment Technology**

As a means of improving the fluid seals of fluidic transport devices, Hitachi, Ltd. has developed a surface treatment which completely repels fluids. This ensures that sealing is possible, and pump performance is not degraded, despite small gaps due to machining errors. Durability of the pump is also improved.

Fig. 2 3D winged rotor

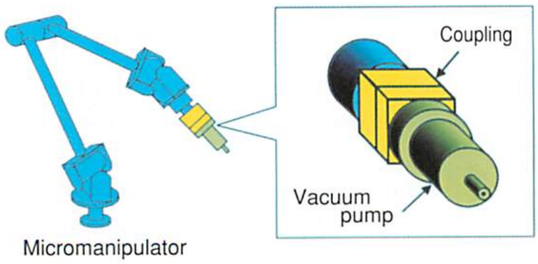


Fig. 1 Microholding device

- **Bonding Technology**

Hitachi, Ltd. has developed low-temperature bonding technology and related equipment for assembling wafer-sized microstructures. This technology employs irradiation with argon ions and atoms to clean and activate the surfaces to be bonded, and the low temperatures involved avoid the problems of distortion when bonding multiple layers of wafers simultaneously. Technologies for bonding materials other than silicon and for selective bonding at specific locations are also under development.

3. Future Challenges

With the increasing sophistication of micromachining and the continuing improvement of the technology for producing systems on a single chip, it is expected that the focus of research and development will change from single-element microdevices to microsystems. The μ-TAS (Total Analysis System), which integrates analysis and control circuits, is a good example of this trend.

Hitachi's approach to its research and development is to emphasize market requirements and fulfill its mission to contribute to society.

FANUC LTD

Seiuemon Inaba
Chairman and CEO

1. The Challenge of Micromachine Technology

The recent difficult economic situation in Japan has not altered the fact that the manufacturing industry is the foundation of Japan's economy. FANUC LTD has incorporated research and development into its management policy, and continues to pursue robotization, ultra-high precision, and artificial intelligence in its product development to contribute to the automation of the manufacturing industry.

Research and development in micromachine technology is also a component of this policy. The company is engaged in research and development on high-precision machining technology employing ultra-high precision machine tool, and the development of a micro-arm for use in automation of micro-assembly operations.

2. Development of Micromachine Technology

Micromachining technology as an application of semiconductor manufacturing technology has made great progress in recent years. The score of micromachine technology could be greatly expanded if a machining technology could be developed that is relatively unrestricted by the shape of the object to be machined. The precision of micromachining is obviously of great importance in these operations. Dimensional precision and surface precision are generally dependent upon the size of the component, and much greater precision is required as components become smaller. Ultra-high precision micromachining technology is therefore particularly suited to the manufacture of micro-components. FANUC LTD has developed ultra-high precision machine tool which uses static air pressure to support moving components such as bearings, guides, feed screws and nuts. This equipment employs ultra-high precision servo mechanism which provide an accuracy of approximately 1 nm over a stroke of 100 mm.

This equipment makes use of a high-speed air turbine spindle rotating at speeds of tens of thousands of rpm's on which is mounted a single-crystal diamond cutting tool for micromachining. The diamond cutting tips are in a variety of shapes to machine flat surfaces, curved surfaces, V grooves, and rounded grooves, etc. at extremely high accuracy. Fig. 1 shows a *Noh* mask machined in 3D within an overall diameter of 1 mm, and the surface is mirror-finished to nano-meter tolerances.

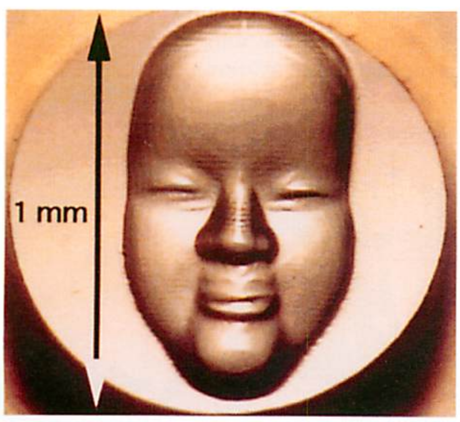


Fig. 1 A Micro-scale *Noh* mask

FANUC LTD is also engaged in the development of a micro-arm for assembly tasks. The arm is designed to handle components of less than a few millimeters in size, and is a vertical articulated type robot. The key to the implementation of the arm was the development of the ultrasonic micro-servo motor used to drive the joint. It uses a direct drive, i.e. without a reduction gearbox, for most effective implementation at micro-scale. The servo motor provides high torque, with good holding torque when power is off.

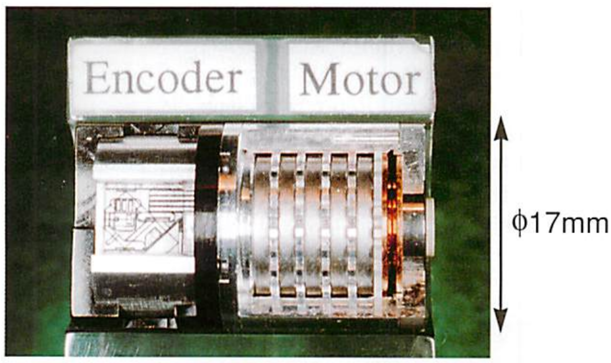


Fig. 2 Ultrasonic micro-servo motor (Cutaway)

3. Future Challenges

A question associated with the development of ultra-high precision machining technology is how the technology may be best used. Its application in such areas as the machining of micro-dies and the production of micro-components in injection molded plastic is considered one possibility for the future.

Micro-assembly using micro-components is a field in which automation is particularly difficult, and the development of the micro-arm is expected to enable great progress in this area of industry.

1998 Micromachine Mission to Europe

Local research organizations in Europe were visited in conjunction with the holding of a joint seminar. Details are as follows.

Visited organization: LAAS/CNRS (Toulouse, France)
Date: June 8th (Monday)
Conferred with: Dr. Augustin Martinez
Outline of visit:

LAAS/CNRS is a French national research laboratory founded in 1967 which deals primarily with aircraft and motor vehicle-related research. During this visit the emphasis was on micro-systems, and we therefore visited the labs of the Microstructure and Integrated Microsystems Group.

Discussions were held after a field trip to the clean-room.

Visited organization: SINTEF (Oslo, Norway)
Date: June 11th (Thursday)
Conferred with: Dr. Ralph W. Bernstein
Outline of visit:

SINTEF is Scandinavia's largest research organization, and operates as a non-profit foundation. The location is close to the North Sea oilfields, and many of the research topics reflect the national emphasis on the environment. Micromachine research is conducted within the Electronics and Cybernetics Microsystems Division. During the visit we were shown an automated rubbish classifier which is currently under research as a means of resolving various environmental problems.

Visited organization: Royal Institute of Technology (Stockholm, Sweden)
Date: June 15th (Tuesday)
Conferred with: Prof. Peter Enoksson
Outline of visit:

KTH is located in Stockholm, and was established in 1827. It is the largest engineering university in Sweden bestowed with a royal charter. A variety of research is underway, covering everything from micromachine materials to systems. The sensor engineering department's instrumentation laboratory headed by Professor Stemme has a considerable track record of development and research in the fields of blood pressure sensors and gas analysis systems for anesthetic and ventilation equipment as products for industry. They are currently engaged in research on micro-pumps and 3D silicon actuators using silicon technology.

Visited organization: Linköping University (Linköping, Sweden)
Date: June 16th (Wednesday)
Conferred with: Prof. Ingemar Lundstrom
Outline of visit:

Linköping University is located 200 km southeast of Stockholm, and is a national university established in 1968 that conducts considerable research in the fields of sensor technology, chemistry, and biotechnology. The university works in conjunction with industry, particularly in the case of sensor-related technology, to ensure direct contact with the market. One of the features of the system employed in the laboratories is the unfettered fusion of electrical, mechanical, high-polymer science, and biotechnology across faculty lines. Research topics reflect this fusion in a new approach to micromachines, for example, high-polymer actuators, nano-scale chemical LEDs, and a bionic nose.

Visited organization: Uppsala University (Uppsala, Sweden)
Date: June 17th (Thursday)
Conferred with: Prof. Jan-Åke Schweitz
Outline of visit:

Uppsala University is located approximately 70 km north of Stockholm, and is a university holding an important position in the Swedish academic world. In 1997 the Angstrom Laboratory, with a 2,400 m^2 dedicated laboratory area, was completed. The facility has a staff of 300, with 1,100 students, and is operated by the materials chemistry, chemistry, and physics faculties, and seven external organizations. Research focuses on fundamental technologies, and covers fine structure technology, functional surfaces, and thin-film processing, with the long-term objective of application in sophisticated systems.

At Linköping University

At LAAS/CNRS

Micromachine European Seminars

In June 1998 as a part of the business exchange mission of the Japan External Trade Organization (JETRO), joint seminars with Micromachine Center (MMC) and local research organizations were held in France, Norway and Sweden for the purpose of technical exchange with researchers engaged in research on micromachines. In the past, European seminars were based on exchange of fundamental technologies with researchers in universities and laboratories. However, the latest seminars were based on commercial applications for micromachines, with a focusing on venture companies. Micromachines are developing towards commercial use and the ideal world that we used to expect is becoming more realistic. Details of the seminars follow.

1. MMC-LAAS Joint Seminar

Date: June 9, 1998 (Tuesday)
Venue: LAAS/CNRS (Toulouse, France)
Participants: 42
Titles and lecturers:

"Seminar Opening" by J. C. LAPRIE (Director, LAAS-CNRS)
"Future Prospects of Micromachines" by Takayuki HIRANO (Executive Director, Micromachine Center)
"R&D Issues and Present Status of National Micromachine Project" by Kazuhisa YANAGISAWA (Research Committee, Micromachine Center)
"3D Electronic Systems for Space" by M. COELLO VERA (Alcatel Espace)
"Development of Inspection Micromachine" by Nobuaki KAWAHARA (DENSO CORP.)
"Sensors Technologies for Analytical Sensory System" by Tsung TAN (Alpha MOS)
"Multi Functional Micro Scanner" by Tsuneji YADA (OMRON Corp.)
"Development of Microgyroscope" by Kuniki OHWADA (MURATA MFG. CO., LTD.)
"BICMOS Surface Silicon Micromachine Sensors" by M. GENOT (Siemens Automotive)
"Microtechnology for MIS (Minimal Invasive Surgery) Devices" by Shigeru OHMORI (TERUMO Corp.)
"Molecular Electronic: Transistor and Nanotechnologies" by Ch. JOACHIM (CEMES)

Industries in Toulouse, where the seminar was held, are active in the transportation field, mainly automobiles and aircraft. Consequently, there was some micromachine R&D for application in that field. Through the seminar, we could exchange our opinions regarding future research tasks in addition to the products that have been marketed. This may enhance the research and cooperation relationship between Japan and France.

2. MMC/SINTEF Joint Seminar on Micromachines

Date: June 11, 1998 (Thursday)
Venue: SINTEF Electronics and Cybernetics Microsystems (Oslo, Norway)
Participants: 20
Titles and lecturers:

"Introduction" by Ralph W. BERNSTEIN (SINTEF Electronics and Cybernetics Microsystems)
"Future Prospects of Micromachines" by Takayuki HIRANO (Executive Director, Micromachine Center)
"R&D Issues and Present Status of National Micromachine Project" by Kazuhisa YANAGISAWA (Research Committee, Micromachine Center)
"Development of Inspection Micromachine" by Nobuaki KAWAHARA (DENSO CORP.)
"Multi Functional Micro Scanner" by Tsuneji YADA (OMRON Corp.)
"Development of Microgyroscope" by Kuniki OHWADA (MURATA MFG. CO., LTD.)
"Microtechnology for MIS (Minimal Invasive Surgery) Devices" by Shigeru OHMORI (TERUMO Corp.)
"Sensor Development at SensorNor" by Henrik JAKOBSEN (SensorNor ASA)
"The New Norwegian Micro-Technology Centre: μ-Tech" by Anders HANNEBORG (SINTEF Electronics and Cybernetics Microsystems)

SINTEF is the largest research organization in Scandinavia and is actively conducting research in Europe mainly on sensor technologies in the Electronics Cybernetics Research Center. However, over the past few years, technological exchange with Japan has not been very active. In this seminar, we could exchange our opinions regarding the status of latest developments in both countries and the methods for tackling problems. This established the basis of the cooperation structure for micromachine technologies.

3. MMC-KTH Joint Seminar

Date: June 15, 1998 (Monday)
Venue: Royal Institute of Technology (Stockholm, Sweden)
Participants: 60
Titles and lecturers:

"Opening Address" by Tomas ARONSSON (Swedish National Board for Industrial and

Technical Development)
"Future Prospects of Micromachines" by Takayuki HIRANO (Executive Director, Micromachine Center)
"R&D Issues and Present Status of National Micromachine Project" by Kazuhisa YANAGISAWA (Research Committee, Micromachine Center)
"Inertial Sensors: Gyros and Accelerometers" by Gert ANDERSSON (Chalmers University of Technology)
"Development of Microgyroscope" by Kuniki OHWADA (MURATA MFG. CO., LTD.)
"Applied Microelectromechanical Systems Research at KTH" by Göran STEMME (Royal Institute of Technology)
"Gas Analysis in Anesthesia and Ventilator Equipment" by Pekka MERILÄINEN (Instrumentarium Corp.)
"Microtechnology for MIS (Minimal Invasive Surgery) Devices" by Shigeru OHMORI (TERUMO Corp.)
"A Commercialized Ultra-Miniaturized Pressure Sensor for Blood Pressure Measurements" by Edward KÄLVESTEN (Royal Institute of Technology)
"Chemical Sensor for Combustion Engines" by Peter TOBIAS (Linköping University)
"Multi Functional Micro Scanner" by Tsuneji YADA (OMRON Corp.)
"Microsatellites for Space Applications" by Lars STENMARK (Uppsala University)
"Closing Remarks" by Peter ENOKSSON (Royal Institute of Technology)

There were many participants from mainly businesses and universities. In the seminar, results of research done in both countries were announced and ranged from details on comprehensive micromachines to applications. Opportunities were provided for questions and answers regarding common problems and schedules for commercial availability.

MMC-LAAS Joint Seminar

MMC-KTH Joint Seminar

Portable Micromachine Technology Exhibits (III)

Seiko Instruments Inc.
"Micro Piezoelectric Motor"

1. Development of Micromachine Technology

Seiko Instruments Inc. has carried out research on a microfactory that reduces the size of the processing and assembly mechanism for micromachine components to desk-top size. The objective of this research is to reduce the device size while maintaining the basic functions of the existing production line for micro components such as processing, conveyance, and assembly. If this project is implemented an environment-friendly production system that is resource-saving, energy-saving, and space-saving can be constructed. (Fig. 1)

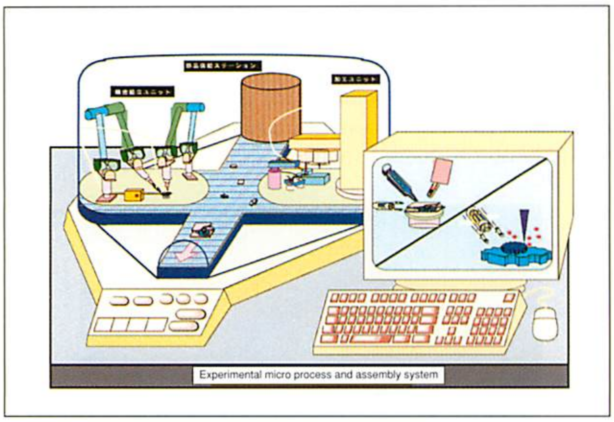


Fig. 1 Image of the microfactory

2. Overview of the Portable Exhibit

[Significance of creating the exhibit]

Besides the micro factory, down-sizing of an actuator is imperative for devices manufactured using micromachine technology. An actuator of large generation power is necessary to enable the devices to function sufficiently. The generation power of the piezoelectric motor that was exhibited (Fig. 2) can be increased to an extent greater than other modes. In this exhibit, a 300 mg prism is attached to the rotor (weight 480 mg) of the motor (size 2 × 2 × 2 mm). By simply applying low voltages (several volts), rotation occurs, proving the features of a piezoelectric motor of small size and high output.

[Explanation of the exhibit]

In this structure, a prism is attached to the rotor of the micro piezoelectric motor and the prism rotates together with the rotor. When a semiconductor laser is irradiated on the prism from the top via a grating, the grid pattern generated by the grating is projected on the screen by the prism. When the motor rotates, the grid pattern moves on the screen with the rotation.

Fig. 2 Portable exhibit

[Key points in the exhibit]

In the micro piezoelectric motor used in this exhibit (Fig. 3), there are three vibrators (0.1 mm thickness) and a piezoelectric device (PZT) is attached to the back of them. When a voltage is applied to the piezoelectric device, the expansion and contraction of the piezoelectric device is converted to up and down movements of the vibrator, and these up and down movements are converted to rotor rotation movements. Very low voltages (several volts) are applied and practical rotations ranging from several tens to several hundreds of rpm's have been achieved.

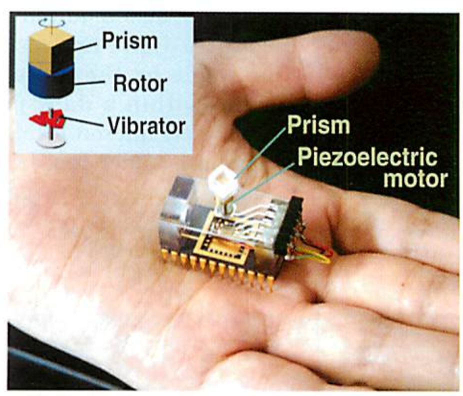


Fig. 3 Micro piezoelectric motor

3. Future Applications

Since this micro piezoelectric motor has superior features including low-voltage operation, high output, and does not require a reduction mechanism, it can be used for various micro devices. In the microfactory also, application of this device in the micro-positioning mechanism is being examined.

Toshiba Corporation
"Advanced CCD Micro Camera"

1. Development of Micromachine Technology

Toshiba Corp. has been researching the Advanced CCD Micro Camera that is to be equipped at the top of the Experimental Wireless Micromachine for Inspection of Inner Tube Surface moving within a 10 mm diameter pipe, assuming a power generation facility. The camera, 9 mm diameter by 15 mm long, consists of a newly developed micro-lens, electrostatic motors, and a three-dimensionally packaged CCD module, to obtain the in-pipe images both forward and sideward, with high-resolution of 20 µm. (Fig. 1)

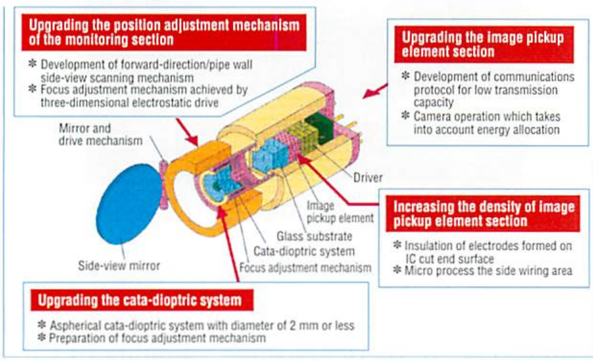


Fig. 1. CCD micro camera

2. Overview of the Portable Exhibit

[Significance of creating the exhibit]

In a mobile inspection micromachine, visual information is very important. The machine must observe, with high resolution, the pipe damages at close distance as well as such images of comparatively far distance as bends and branches of the pipe, necessary for going forward. The technology is also required for correcting the intensive counter-light images of the metallic debris reflection made by the search-light projected from the machine within a dark pipe. In activities of the national project, micron-level operation of all of these functions are under research, and for this exhibit, the research results were partially introduced in slightly larger size. (Fig. 2)

[Explanation of the exhibit]

Fig. 2 Portable exhibit

This exhibit introduces the Advanced CCD Micro Camera built based on Toshiba's finger-size camera. The lens and image signal are adjusted automatically to optimum status according to the position and brightness of the target, that moves forwards and backwards by blinking in front of the camera. The image of several tens of µm that is regenerated clearly in an counter-light condition can be observed on the LCD monitor. An enlarged image of the micro actuator that drives the lens can be observed through an another camera.

[Key points in the exhibit]

The focus of a finger-sized camera is generally adjusted manually, however, in this exhibit, power-driven adjustment is possible since the lens is installed in the linear actuator of 4 × 4 × 8 mm that is propelled by electrostatic force. The feature of this actuator is its larger motion range, and by moving the lens forwards and backwards 3 mm, the camera can take images of a target at a distance of 10 to 100 mm in the highest resolution of 20 µm. One actuator can drive several lenses and the exhibit can be equipped with about 2× zoom function. (Fig. 3)

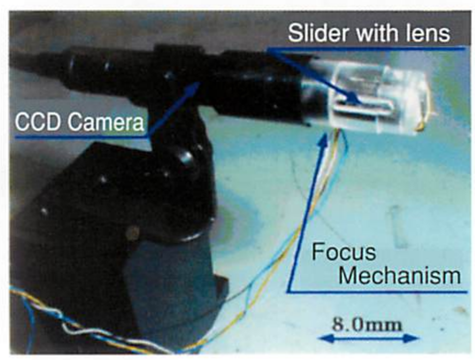


Fig. 3 Camera section of the exhibit

The electric lamp is installed at the rear of the observation target with engraved characters several tens of µm in width. When the brightness of the electric lamp is increased, the characters on the target blend into the light, becoming unreadable. When the aperture is tightened, the entire image becomes dark and the characters also become unreadable.

The exhibited camera has functions for taking images of a bright area and dark area on the target with different sensitivities respectively, to make up an image by compounding these two kinds. Therefore, even for a target that has sections containing largely different brightness levels, clear images can be observed.

3. Future Applications

In the exhibit, other functions are equipped besides the Experimental Wireless Micromachine for Inspection on Inner Tube Surfaces. In the future, we will continue to develop the practical technologies applicable to the Advanced CCD Micro Camera.

Hitachi, Ltd.
"Microfluid Operation Devices"

1. Development of Micromachine Technology

Hitachi, Ltd. is engaged in developing microfluid operation devices (fluidic transport devices and holding devices) as a part of the research and development of system integration technology to produce an experimental microfactory system. A fluidic transport device is an integrated fluid device based on a high-output micro-trochoid pump, which pumps corrosive liquid such as etching liquid or plating liquid used for micromachining. A holding device is a micro-parts chucking tool (Fig. 1) that is attached to the end of the micromanipulator for the micro-parts assembly. It is equipped with a scroll-type micro-vacuum pump for chucking micro-parts.

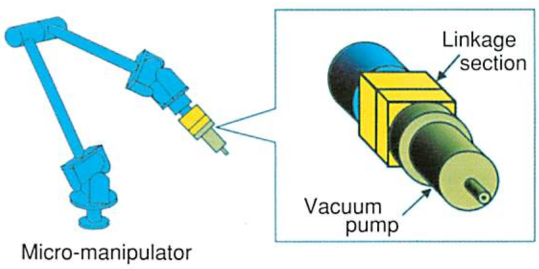


Fig. 1 Concept of micro-parts holding device

2. Overview of the Portable Exhibit

[Significance of creating the exhibit]

To develop these devices, Hitachi, Ltd. has developed a three-dimensional micromachining technology, a surface treatment technology, and a bonding and assembling technology and is engaged in the micronsizing of mechanical devices. This exhibit introduces, in a simple manner, the micro-vacuum pump and one of the forms of a holding device component conveyance mechanism. (Fig. 2).

Fig. 2 Portable exhibit

[Explanation of the exhibit]

The scroll pump is a compact high-output air pump that is widely used as a compressor in air conditioners and so on. The exhibit includes a model with a flange made of transparent material to allow the actual internal scroll movements to be seen. Fig. 3 shows the scroll-type vacuum pump that was produced as a sample for testing actual vacuum chucking. In the picture, the scroll before assembly of the flange is visible. Using cast iron or aluminum as the material, NC machining was used to make a scroll 0.25 mm wide and 1.5 mm high. The entire size including the driving motor is ϕ 10 × 40 mm and the pump exhaust speed is 70 mL/min (about 10000 rpm). In the demonstration, a component weighing about 1 g is chucked and conveyed by a suction pad of about 10 mm in diameter.

Fig. 3 Scroll-type micro-vacuum pump

[Key points in the exhibit]

The holding devices that have been developed in the research organizations in Japan are either large devices, based on holding a micro-globe of several tens of μm in diameter or less, or ultra-small devices with low holding power. There are no other devices like the device developed by Hitachi, Ltd., which has large holding power with small overall features.

3. Future Applications

For the application fields of microfluid operation devices will be applied to chemical analysis that can handle trace quantities of fluid. In the near future, we expect that small analysis devices for medical and environmental conservation purposes will become widely available for practical use. Fluid device integration technology will be used as the breakthrough technology and, in the societies related to microfluidics, the μ-TAS (Micro Total Analysis System) for integrating analysis systems and control circuits is under research.

THE FOURTH INTERNATIONAL MICROMACHINE SYMPOSIUM

Foundation of Industrial Technology in the 21st Century

Date: October 29 - 30, 1998
Venue: Science Museum, 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 Oct. 15, 1998
Contact: Micromachine Center
(TEL +81-3-5294-7131, FAX +81-3-5294-7137)

PROGRAM

October 29, 1998

9:00 ~

Session 1: Opening		**Chaiman: Mr. T. HIRANO**
9:30	Opening Declaration	Mr. Takayuki HIRANO, Executive Director, Micromachine Center
9:30 ~ 9:35	Opening Remarks	Dr. Tsuneo ISHIMARU, Chairman, Micromachine Center
9:35 ~ 9:43	Guest Speech (Expected)	Mr. Katsusada HIROSE, Director-General, Machinery and Information Industries Bureau, MITI
9:43 ~ 9:51	Guest Speech (Expected	Dr. Takeo SATO, Director-General, AIST, MITI
9:51 ~ 10:00	Guest Speech (Expected)	Mr. Hideyuki MATSUI, Chairman, NEDO
10:00 ~ 10:45	Special Guest Speech : The World of Micromechanisms	Prof. Teru HAYASHI, Dean, Faculty of Engineering, Toin University of Yokohama
Session 2: The Path to New Industries in the 21st Century		**Chairman: Prof. T. SATO**
Exploiting Applications		
10:45 ~ 11:05	Micromachine and Lifestyle in the 21st Century	Associate Prof. Tetsuo KIDOKORO, The University of Tokyo/Japan
Market Forecast		
11:05 ~ 11:25	NEXUS - Results of the Market Analysis	Mr. Gaetan MENOZZI, NEXUS, EC/France Mr. Jean-Christophe ELOY, YOLE Development/France
Application		
11:25 ~ 11:55	Application of MEMS to Cochlear Implants and other Aids to Hearing	Mr. John HUIGEN, The Bionic Ear Institute/Australia
Infrastructure		
11:55 ~	Role of Microfabrication Foundry in MEMS R&D	Prof. Susumu SUGIYAMA, Ritsumeikan University/Japan
~ 12:30	Foundry and Product Development Activities in the USA	Ms. Karen W. MARKUS, MCNC/USA
12:30 ~ 13:30	Lunch	
Session 3 : Thinking of Micromachines		**Chairman : Prof. M. ESASHI**
13:30 ~ 13:50	Schoolchildren and Micromachines	Prof. Naomasa NAKAJIMA, The University of Tokyo/Japan
13:50 ~ 14:10	Insect and Micromachine	Assistant Prof. Ryohei KANZAKI, University of Tsukuba/Japan
14:10 ~ 14:30	Origami may reveal idea of Micromachine structure	Prof. Yoshihide MOMOTANI, Kyoto International University/Japan
Session 4 : Activities in USA and Europe		**Chairman : Prof. H. FUJITA**
14:30 ~ 15:00	MEMS Research/Development at Case Western Reserve University, USA	Prof. Wen H. KO, Case Western Reserve University/USA
15:00 ~ 15:30	MST R and D Programmes at CNRS	Dr. Jean-Jacques GAGNEPAIN, CNRS/France
15:30 ~ 15:50	Break	
Session 5 : Innovative R&D		**Chairman : Prof. K. IKUTA**
15:50 ~ 16:10	Reversible Micro-bonding	Dr. Naoe HOSODA, The University of Tokyo/Japan
16:10 ~ 16:30	Optical Radiation Pressure Micro-machining Using Diamond Grain	Prof. Takashi MIYOSHI, Osaka University/Japan
16:30 ~ 16:50	Micromachined Optical Bench	Prof. Hiroyuki FUJITA, The University of Tokyo/Japan
16:50 ~ 17:10	Lab-on-a-Chip Devices for Acquisition of Chemical and Biological Information	Dr. J. Michael RAMSEY, Oak Ridge National Laboratory/USA
18:00 ~ 20:00	Reception Party at Josui Kaikan	

October 30, 1998

9:00 ~

Session 6 : Current Status of Micromachine Technology Project in ISTF Program		**Chairman : Dr. Y. ISHIKAWA**
9:30 ~ 9:40	Overview of ISTF Program	Mr. Makoto OKAZAKI, Director for Machinery and Aerospace R&D, AIST, MITI/Japan
Researches and Future Prospects on Micromachine Technology in National Research Laboratories		**Chairman : Dr. Y. ISHIKAWA**
9:40 ~ 9:55	R&D on Micromachine at Mechanical Engineering Laboratory - today and tomorrow	Dr. Yuji ENOMOTO, Mechanical Engineering Laboratory, AIST, MITI/Japan
9:55 ~ 10:10	Research on Micromachine Technology at ETL	Dr. Hideo TSUKUNE, Electrotechnical Laboratory, AIST, MITI/Japan
10:10 ~ 10:25	Results of Research on Micromachine and Prospects for Future Subjects in NRLM	Dr. Akira UMEDA, National Research Laboratory of Metrology, AIST, MITI/Japan
R&D in Micromachine Center		**Chairman : Dr. Y. ISHIKAWA**
10:25 ~ 11:10	Overview - Present Status of 2nd Phase "Micromachine Project" -	Mr. Kazuhisa YANAGISAWA, Research Committee, MicromachineCenter/Japan
● R&D (1)		**Chairman : Dr. Y. ISHIKAWA**
11:10 ~ 11:30	Microwave Energy Supply for In-pipe Micromachine	Mr. Takanari SASAYA, DENSO CORPORATION/Japan
11:30 ~ 11:50	Integration of Photon Transmission System by Lasaer CVD Wiring	Dr. Hisaki TARUI, SANYO Electric Co., Ltd./Japan
11:50 ~ 12:10	Motion Performance Simulator for Micromachine	Mr. Munehisa TAKEDA, MITSUBISHI ELECTRIC CORPORATION/Japan
12:10 ~ 12:30	Mechanical Planetary Gears for a Micro-reducer	Mr. Norisato SHIMIZU, Matsushita Research Institute Tokyo, Inc./Japan
12:30 ~ 13:30	Lunch	
● R&D (2)		**Chairman : Mr. K. YANAGISAWA**
13:30 ~ 13:50	Micro Welding Device for Experimental Catheter-type Micromachine	Mr. Hideto NAKADA, OLYMPUS OPTICAL CO., LTD./Japan
13:50 ~ 14:10	Microfabrication Technique using Scanning Near-field Optical Microscopy	Mr. Yasuyuki MITSUOKA, Seiko Instruments Inc./Japan
14:10 ~ 14:30	Microfluid Operation Device using a Surface Treatment Technology	Mr. Takeshi HARADA, Hitachi Ltd./Japan
14:30 ~ 14:50	Application of Micromachine Technologies for Catheters	Mr. Takeshi KUDOH, TERUMO Corporation/Japan
14:50 ~ 15:00	Break	
● Technology Trend		**Chairman : Mr. K. YANAGISAWA**
15:00 ~ 15:15	The R&D Trend of Measuring Technologies for Micromachines	Mr. Hideaki YAMAGISHI, Research Committee, Micromachine Center/Japan
15:15 ~ 15:30	The R&D Trend of Design and Simulation Procedure for Micromachines	Dr. Hiroshi GOTO, Research Committee, Micromachine Center/Japan
15:30 ~ 15:45	The R&D Trend of Micro-Actuator Technology	Mr. Haruo NAKAZAWA, Research Committee, Micromachine Center/Japan
Session 7 : Closing		**Chairman : Mr. T. HIRANO**
15:45 ~ 15:50	Closing Address	Mr. Hikaru HAYASHI, Managing Executive Director, Japan Industrial Technology Association/Japan

MICROMACHINE No.25

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 101-0048, 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: Oct. 26, 1998

MMC