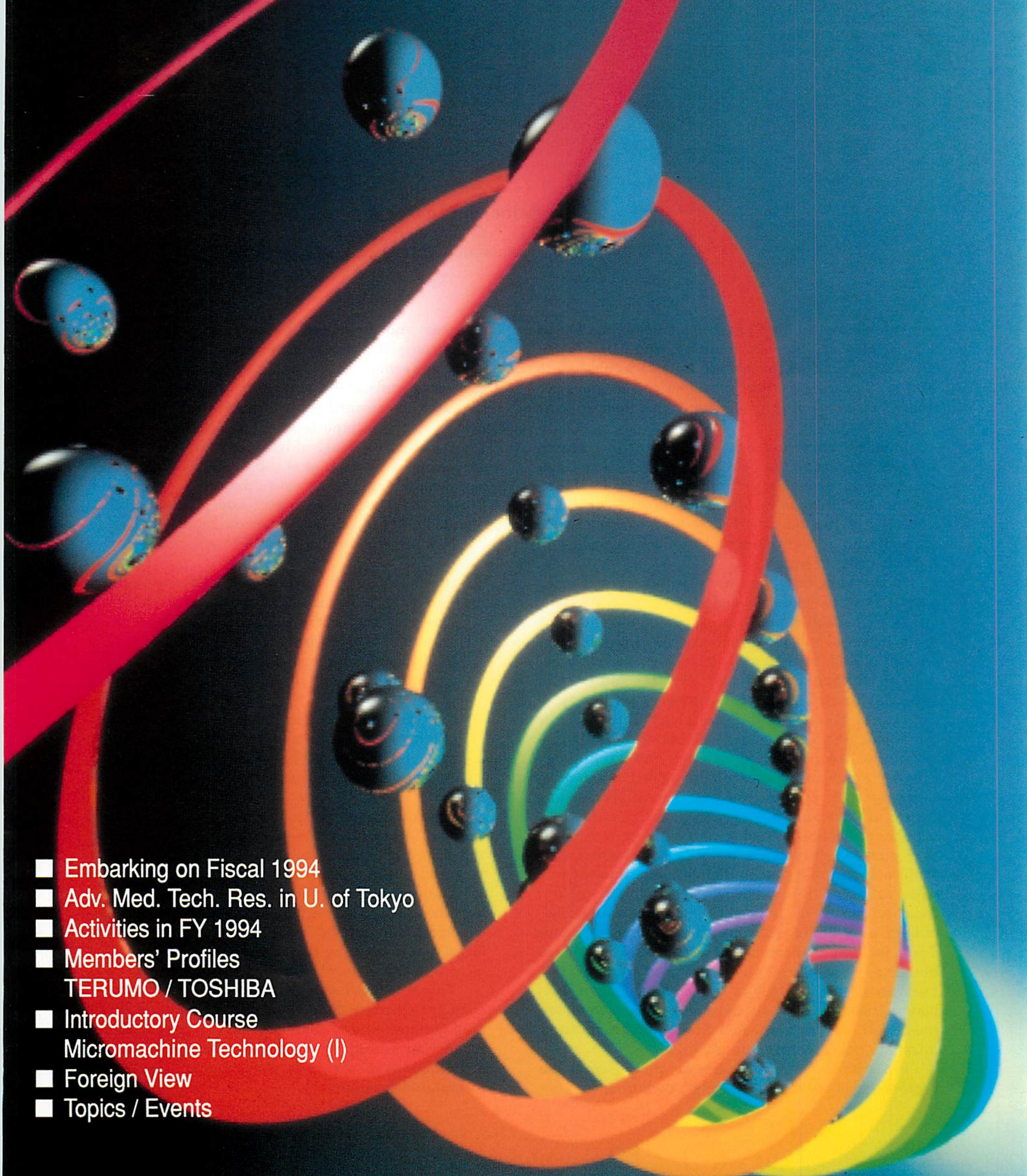
MMC MICROMACHINE

May 1994 No.7



Micromachine Center

Embarking on Fiscal 1994

Seiuemon Inaba
Chairman
Micromachine Center

The Micromachine Center has entered the fourth new fiscal year since its founding, and *MICROMACHINE* has reached its seventh issue. I would like to offer my sincere gratitude to related people who have enabled us to reach this milestone with their support and guidance.

Immense expectation is being placed in research and development in the field of micromachine technology, since this technology, through the microminiaturization and advanced integration of functional components, can be expected to lead to spectacular developments in industrial and medical technology in the twenty-first century.

At the same time, because this technology breaks a lot of new ground and includes many innovative elements, the establishment of a system of micromachine technology will involve a high degree of risk, a large amount of R&D investment, and a long period of time.

For this reason, in fiscal 1991 the Ministry of International Trade and Industry's Agency of Industrial Science and Technology launched the "Micromachine Technology," a large-scale R&D project under its Industrial Science and Technology Frontier Program. At present the agency is pursuing this project in cooperation with the Micromachine Center as the main R&D body on the private side.

Micromachine technology, an extreme technology that pursues microminiaturization, is expected to achieve applicability as an innovative technology in a wide range of fields in the twenty-first century. Needless to say, micromachines occupy an interdisciplinary area linking various scientific and academic fields, including machine engineering, electronic engineering, biology, physics, and chemistry. Furthermore, since R&D in this area has only a short history, research strongly requires cooperation among industrial, government, and academia. In addition, international cooperation is essential.

Since its founding the Micromachine Center has been engaged in various projects, including surveys, research, and the dissemination of information, with the purpose of promoting the development of micromachine technology. In addition to these activities, the center in fiscal 1994 will take a particularly positive attitude toward international exchange in the field of micromachine technology, which internationally is still at the stage of infancy, and emphasize the deepening of international cooperation by, for example, dispatching and accepting missions to and from Europe and the United States and publishing R&D reports in its English-language newsletter.

New projects during fiscal 1994 will include:

(1) the holding in Japan of a "Micromachine Technology Summit" for representatives from countries that are active in the development of micromachine technology with the purpose of building an international environment for the continuation of long-term R&D;

(2) the holding of lectures overseas with the purpose of relaying the results of R&D in Japan to a wide range of researchers in other countries and deepening exchange and understanding.

In addition, as an educational project, as well as lectures to announce the results of R&D, the center will hold a micromachine contest, mainly for elementary and junior high school students, and organize seminars with the purpose of spreading understanding among people in various walks of life and of various ages, planting the seeds for the birth of original ideas, and implanting familiarity with micromachines more widely and deeply into society.

Through the development of these new projects during the current fiscal year we hope to promote the systematization and dissemination of micromachine technology in Japan and in turn contribute to the development of the Japanese economy and to the international community.

Research Group of Advanced Medical Technology, The University of Tokyo

Iwao Fujimasa
Professor, Research Center for Advanced Science and Technology,
The University of Tokyo

Advanced Medical Device Group of The University of Tokyo is comprised of Laboratory of Biological Devices, Research Institute for Advanced Science and Technology and Laboratory of Clinical Medicine, Institute of Medical Electronics, Faculty or Medicine, The University of Tokyo.

These two organizations, which advocate Faculty of Medicine, The University of Tokyo, are pure research laboratories that were organized to conduct developmental research in advanced medical technology. Because they have no need to educate undergraduate and graduate students, they have been conducting studies for an extremely long time, and numerous parallel studies have been going on for scores of years.

Consequently, while their current scope of research is broad and the development of an artificial heart is their primary interest, they also interests in many related and peripheral fields such as medical use of macromolecular material, remote sensing, computer image processing, as well as cellular, thermal, and circulatory physiology, and laser surgery.

The Research Institute for Advanced Science and Technology is near Shibuya, and the Institute of Medical Electronics in Hongo. Both are capable of conducting large or small animal experiments, and they are managed jointly as a group by the staff consisting of two professors (Fujimasa, Imachi), two associate professors (Manbuchi, Baba), three assistants (Chinzei, Abe, Imanishi), and three technicians. Among this research group's 20 members, several are graduate students in doctoral programs and many are collaborating researchers. The staff, assistants and above, consists of six physicians and three engineers, two of which graduated from both medical and engineering faculties. Other than the staff, almost all the other researchers have doctorate degrees. The physical sciences have been represented recently as well.

The most distinctive characteristics of this research group, in terms of medical engineering technology research, are that it is developing the technology of applying machinery to living organisms, which is considered their most important objective. The group can conduct chronic experiments in large animals as a pre-stage to its application in humans, and can fabricate their most important machines in-house. Therefore, most of the engineering graduates learn the techniques of animal surgery and management, whereas the medical personnel receive training in handling various machine tools, electronic circuits, and computers, and as researchers they receive interdisciplinary training in both medical and engineering fields. This means they can immediately apply the technology they develop to living organisms, as well as receive feedback to that development.

Furthermore, because problems with bio-material interface can be expected, and anti-thrombogenicity and host compatibility must be analyzed. Chemical technology such as analysis and reforming of sound macromolecular and protein chemistry are essential. Thus, the development of miniature machinery that is used in the body must proceed from a very broad perspective.

Because the research group was formed with a long term view, it has substantial animal experiment and measuring/analyzing equipment. Enough facilities to conduct chronic animal experiment have been built as it has the know-how to manage animal experiments.

Because only the researchers must maintain and manage all the studies, the automation and information network is remarkable, and the automatic data collection and monitoring systems between the two institutions are connected by a 50 GHz microwave circuit. Some laboratories reduce the amount of labor in terms of management and operation through the use of mutual monitoring in the animal experiments, prearrangement of studies, and television conferences.

This group comprises one of the largest centers in the world for artificial heart research, and is one of the pioneers in micromachine research in Japan. In fact, in order to develop the technology necessary for an artificial heart to be completely enclosed within the body, around 1985 it started conducting studies with aiming towards miniaturizing the components of the artificial heart. There are many other technological developments related to medical technology involved in artificial hearts, and many of the machines used for their production today are micromachines. For example, because the research group focuses on surgery involving the heart, it works on developing laser angioplasty and various catheter sensors. Because these devices have essentially millimeter or less dimensions, they are the foundation for the development of micromachines.

Around 1988 various micromachine projects were started here and there, and this research group also introduced silicon processing equipment that is still in operation today. Since it specialized in macromolecular processing from the beginning, it has the finest macromolecular molding and processing facilities, and a well equipped workshop for fabricating miniature components.

Several of the current research projects will be introduced individually.

Artificial Heart

Research to decrease the size and increase the precision of artificial heart components began initially. Today, the jelly fish artificial valves developed by Professor Imachi are finding wide application throughout the world. In particular, the jelly fish valves used in catheters are miniature valves with a diameter of less than 3mm, and are processed with a small NC bench milling machine. The development of implanted artificial hearts and dispersed ultrasmall hearts requires the miniaturization of components along with the ability to operate continuously over a long period, presenting several technical problems in the development of micromachine component technology. The development and research of supplementary hearts that started from artificial hearts is being jointly carried out by this group, together with Aishin Cosmos Laboratories, and Nippon Zeon Co. Ltd., with the group serving as the core. Their research includes a great deal of investigation on micromachines.

Artificial Muscle

Artificial muscle research begun with the miniaturization of the drive of the artificial heart. This was an unexpected byproduct that started from this research. Based on basic research of vibratory actuators, whose development was promoted to make use of the energy of Brownian particles, trial calculations of the projected conditions of the muscle components, which are biological engines, were performed. The results suggested that organisms in the field of thermal agitation could obtain from the random molecular motions. Research started in this theoretical direction in an attempt to make a unified theory in the case of biological organisms. Although these studies did not result concrete products, theoretically, they were an attempt to obtain interesting results for new engine designs from the principles of biological energy conversion systems, and it presented a new view of mechanical engineering and material science in the mesoscale range.

On the other hand, the development of artificial sarcomere elements such as muscle components started from metal lithography and printing film engraving lithography, and currently an elemental processing method that is in the midst of miniaturization with the possibility of integration is being investigated.

Low-invasive Surgery

This research group has had the ability to develop and utilize laser devices from the beginning. When the Technology Research Association of Medical and Welfare Apparatus, a laboratory under the jurisdiction of the Ministry of International Trade and Industry and the Ministry of Health and Welfare, started a laser coronary angioplasty project, this group also took part as a group. This project, which was started in conjunction with Sumitomo Electric Industries, Ltd. and completed 2 years ago, produced a 1.4mm (OD) laser angioplasty device that was a combination of 0.4mm imaging fibers, 0.4mm quartz laser fibers, manipulators and balloons. The technology that supported the project is connected to the development of various devices for remote operations, and today various techniques of video assisted surgery (VAS) are being developed.

The focus of this technology is a stereoscope and various remote surgical instruments based on 0.4mm diameter image fibers, and the development and clinical application of that technology in such areas as intravascular surgery, and conversion of that technology in vertebral disk evaporation for treating intervertebral hernias, arthroscopic surgery and myeloscopy with these fibers is proceeding with the Department of Orthopedic Surgery of Osaka Medical College. Furthermore, that technology is tied to the development of related devices in general surgery of the chest and abdominal cavities. Because this research group has been able to conduct animal experiments from the earliest stages, practically all of the development in this area has been aimed at products that have a practical use. Because this technology involves virtual reality technology in a minute world, collaborative research is being conducted with Tate's laboratory in Research Institute for Advanced Science and Technology.

Microscopic Biological Measurements

The group is presently developing devices for photographing the distribution of heat patterns in body cavities utilizing a fiber technology, which is spreading from the visible spectrum to the infrared, and the technology of infrared imaging devices, which are remote infrared ray sensing devices.

Because microprocessing is possible by this group, various minute devices for measurements are manufactured as well. Dr. Matsuda of the Circulatory Disease Center and other macromolecular scientists have joined the research group in developing the plasmon microscope and microfiber sensors, and sophisticated research on modification by microscopic surface processing and surface materials is being conducted.

Recently, associate professors from the field of obstetrics and gynecology have joined in. Besides surgery, internal medicine and orthopedic surgery, research is expanding in the field of obstetrics and gynecology, which could be called reproductive science, as well as in the fields of extracorporeal organ preservation and fetal surgery, in which micro techniques naturally must be used, and the scope of technology development and research is gradually expanding. In addition to remote robot surgery and cellular physiology, this research and these organizations are likely to continue prospering from now on.

Activities of the Micromachine Center in Fiscal 1994

1. Fundamental Policy of the Activities

Micromachines are small machines composed of functional elements only a few millimeters in size and are capable of performing complex microscopic tasks. The Micromachine Center (MMC) plans to conduct various activities with the following objectives: establishing basic micromachine technologies and disseminating micromachines in society, thus contributing both to the development of the domestic industry and to the international community through investigation and research, collecting and providing information on micromachines, fostering exchanges and cooperation with related organizations in Japan and in other parts of the world, and promoting micromachine standardization. In this year, particular emphasis will be placed on international exchange.

2. Details of Main Activities

(1) Investigation and Research on Micromachines

MMC has been aggressively promoting the research on "Micromachine Technology" commissioned by the Industrial Science and Technology Frontier Program of MITI's Agency of Industrial Science and Technology (AIST). MMC also systematizes micromachine technology through joint efforts among industry, government, and university, exchanges technical information with many foreign countries, and transmits the results of its research to other countries and to those involved in Japan.

(1) AIST's Industrial Science and Technology Frontier Program, "Micromachine Technology"
(This project has been delegated to MMC by the New Energy and Technology Development Organization.)

[Development of advanced maintenance technology for power plants]

The ultimate purpose of this project is to establish technologies applicable to the realization of micromachine systems; these systems are composed of small functional elements, locomote in very narrow spaces in complex equipment, and are able to perform intricate work autonomously. R&D is undertaken in the following areas:

(i) Microcapsule
For a cableless floating capsule type of micromachine, researches and developments on magnets, coils and high-speed micro bearings for micro generators, oscillators for signal generators, ultrasonic sensors for flaw detection, micro gyros, and magnetic driving suspension mechanisms are carried out, including trial manufacture and experiment.

(ii) Mother ship
For a micromachine which has functions of transporting inspection and operation modules and relaying to outside controllers, prototypes of optical scanning mechanisms and optical systems, joints for coupling mechanisms, micro batteries, and electrostatic artificial muscles are manufactured and transformation and behavior control techniques are developed.

(iii) Cableless inspection modules
For a cableless micromachine that is mobile inside tubes or pipes and has such functions as environmental recognition, coordination control, energy supply, and communications, researches and developments of actuators for expansion and contraction-type-driving mechanisms, energy supply photovoltaic effect device, CCD micro camera mechanisms for micro vision, wide-band photodetectors for microphoto analysis, functional connection methods, and a communications network are carried out, including trial manufacture and experiment.

(iv) Cabled operation modules
For a cabled micromachine with operation units, prototypes of tubular manipulator mechanisms and their mechano-chemical actuators are manufactured and an efficient photoelectric converter and a step-up transformer are developed.

(v) Total system research
The requirements for a micromachine total system are clarified, and the research trends of the technology necessary for system construction and the course of micromachine system development based on user needs are investigated.

[Intra-luminal diagnostic and therapeutic systems]

To develop the element technology necessary for intra-luminal diagnostic and therapeutic systems, including that for use in cerebral blood vessels, the following technologies are focused on:

(i) a laser-applied diagnostic and therapeutic technology

(ii) microtactile sensing technology

(iii) blood pressure and flow sensing technology.

[Micro factory technology]

From this fiscal year, the following researches and developments are started as necessary technologies (micro factory technology) for constructing micromachines and systems which are used in the manufacturing process to make compact factories for small industrial products.

(i) Micro operation mechanism
Manufacturing technologies for clamping mechanisms to be used in fine positioning adjustment, optically driven operation mechanisms, environmental recognition mechanisms, and functional connection are developed with regard to various micro operation devices which is used to hold, move small parts, and recognize their locations and dimensions rapidly and accurately.

(ii) Micro driving mechanism
Manufacturing technologies for locomoting and manipulating mechanisms, driving mechanisms, steering mechanisms and high output power sources are developed with regard to various micro driving elements which handle and transport small parts with high response speed.

(iii) Total system research
A conceptual design and feasibility study of the total system of micro factory are conducted to clarify the scope of application and the most effective methods of introduction. Power supply systems in such a factory are also studied.

(2) R&D on micromachine materials

The following joint researches on micromachine material with the Mechanical Engineering Laboratory of AIST has been continued since last year:

(i) Operating environments for micro functional elements

(ii) Micromachine materials in general

(iii) Feasibility study on micromachine materials

(3) Research on basic design and manufacturing technologies

The following basic research is carried out with the Mechanical Engineering Laboratory of AIST:

(i) Processing methods using FIB, RIE, CVD, and others

(ii) Mechanical device technology to optimize kinetic functions and tribology

(iii) Micro assembly technology using teleoperation

(4) Investigations on basic micromachine technology

The following joint studies on basic micromachine technologies such as micro science and engineering, material engineering, and design engineering between industries and universities are carried out to explore basic technical "seeds", to evaluate them in details by experiments and other means, to educe the promising ones, and to clarify foster methods:

(i) Exploration of technical "seeds" on micro science and engineering

(ii) Exploration of technical "seeds" on design engineering

(5) Investigations on the technical prediction (economic effects) of micromachine technology

For long-term predictions on the micromachine technology behind the minute functioning parts to be used in advanced mechanical systems, MMC will sight the R&D direction to be taken by assessing the expected effect in industrial fields and will contribute to its effective establishment, dissemination and promotion. This will require the following:

(i) Prediction of development of micromachine technology (to fiscal 2005 and 2010)

(ii) Evaluation of economic effects expected from micromachine systems in various industries

(6) Investigations on R&D trends of micromachine technology in Japan and in other countries

To promote R&D of micromachine technology effectively and assure its early dissemination in society, MMC will seize the latest overseas developments and conduct the following surveys:

(i) Review of R&D trends of micromachines

(ii) Analysis of technical trends of micromachines

(7) Construction and maintenance of a micromachine database

MMC will construct a micromachine database and put it out in the form of annual reports to aid other researchers in the field.

(i) For R&D data: MMC will make a survey of current research emphasis, future plans and published papers on micromachine researchers in Japan and elsewhere in the world through a questionnaire; will investigate the trend of presentations made in study sessions and details of related projects; and will draw maps of its findings categorized by technical item.

(ii) For application data: MMC will investigate the applications and practical uses of micromachines in industries in Japan and elsewhere through its questionnaire surveys, patents, technical magazines, and newspapers, will draw maps categorized by field and technical item, and will store them.

(iii) For technical data: MMC will prepare and store lists of technical information available from the literature and learned from its research activities.

(2) Collection and Provision of Micromachine Information

Information and data on micromachines will be obtained from universities, industry and public organizations within and outside Japan. These materials will then be catalogued along with MMC's own research data, made available in the Center's planned documentation room, and broadly disseminated to interested researchers worldwide.

(i) Publication of a newsletter on micromachines

(ii) Maintenance of a documentation room

(iii) Construction of an information network and establishment of an information retrieval system as part of the micromachine database

(3) Exchange and Cooperation with Worldwide Organizations related to Micromachine

MMC will make research grants as one of the activities of joint projects with government, industry, and university, invite researchers and scholars to Japan, sponsor a micromachine summit and seminars, and arrange technical exchanges to further affiliation and cooperation with related organizations with common interests.

(i) Grants for R&D projects relevant to micromachine technology
To promote studies on micromachines smoothly and effectively, MMC will make grants for fundamental and basic researches to universities as part of promotion of this joint project with government, industry, and university.

(ii) International exchange among researchers on micromachine technology
MMC will invite scholars from the U.S.A., Europe, and Australia to Japan and will send Japanese researchers to other countries as a mission for international exchanges.

(iii) Participation in and planning and sponsorship of symposia on micromachine technology
MMC will cosponsor the 5th International Symposium scheduled for October 2-4, 1994 in Nagoya. The Center will also begin preparing for the 6th symposium to be held in Tokyo in 1995.

(iv) Micromachine summit (a new project in 1994)
MMC plans a micromachine summit in Japan among the U.S.A., Europe, Australia, and Japan. This summit will provide a place for discussion of a broad range of related issues applicable in the future development of international activities.

(v) Micromachine seminars (a new project in 1994)
To supplement the international exchange of specialists and assure the most extensive awareness of results of Japanese research, MMC will hold seminars in those countries actively developing micromachine technology.

(vi) Dispatch of missions to other countries
Research missions will be sent to Europe and the U.S.A. to exchange information and promote international cooperation with universities and other micromachine-related organizations. The missions will also participate in international symposia held abroad.

(vii) Evening seminars
MMC will hold evening seminars on the third Wednesday of each month to encourage closer exchange among government, industry and university.

(4) Promotion of Micromachine Standardization

Based on the micromachine standardization program established in the last fiscal year, MMC will conduct the following activities:

(i) Detailed surveys of the meaning of related technical terms

(ii) Identification of technical problems in standardization through individual detailed surveys of the instrumentation/evaluation method

(iii) Closer cooperation with standardization activities in other countries to foster early establishment of international standards.

(5) Dissemination and Enlightenment of Micromachine

MMC will disseminate and enlighten micromachine through publication and distribution of micromachine magazine, and through seminar, and exhibitions.

(i) Periodically publish and distribute a public relations organ Micromachine (in Japanese and English), as well as a newsletter to relevant bodies

(ii) Hold contests on micromachines and issue introductory booklets (a new project in 1994)

(iii) Cosponsor a symposium (in May 1995) and sponsor a meeting at which research results of "Micromachine Technology" under the AIST's Industrial Science and Technology Frontier Program will be presented.

(iv) Cosponsor a Micromachine Exhibition (in May 1995)

(v) As the secretariat of the Federation of Micromachine Technology, which was organized in April 1993, strive for closer affiliation among micromachine-related organizations.

TERUMO Corporation

1. Introduction

TERUMO Corporation was established in 1921 as Japan's first manufacturer/supplier of quality clinical thermometers, and for the past 70 years it has devoted itself to the research and development of medical products to achieve its corporate philosophy, which is to contribute to society through medical technology. Terumo is now recognized internationally as a global medical industry manufacturing pharmaceuticals, medical devices, artificial organs and so on.

Today we visited the Terumo Research and Development Center in Nakai-machi in the western Shonan area, Kanagawa Prefecture, 70 kilometers southwest of Tokyo. The center stands on a hill and commands a fine view of Sagami Bay to the south, the Tanzawa mountain range to the north, and Mt. Fuji to the west. It was built in 1989 to integrate Terumo's R&D facilities which until then were dispersed in Tokyo and Shizuoka. The Information and Corporate Strategy Center was built on the same site the following year to facilitate strategic R&D activities. The Institute of Biomedical Science was also founded here and is engaged in basic research in many areas of medical science and technology.

R&D Center (Left) / Information and Corporate Strategy Center

Pharmaceuticals, medical devices and artificial organs must be tested in living things, and for this purpose Terumo has established the Biological Evaluation Center. Here, the effectiveness of pharmaceuticals, and the performance, safety and metabolism of medical devices and artificial organs can be thoroughly checked and evaluated . The Center thus plays an invaluable role in assuring that Terumo's products meet the highest standards.

2. Terumo's Policy for Research and Development

Terumo seeks to perform R&D pharmaceuticals, medical devices and artificial organs at the highest levels as regards both safety and utility. The company's R&D principle is thus to apply the best materials for its medical devices, artificial organs and containers for pharmaceuticals. The development of materials requires broad and in-depth study. This emphasis on material development has continued uninterruptedly since Terumo's introduction of the first disposable syringe in Japan. It has contributed to the evolution of blood bags that prolong the life of blood cells, parenteral solutions in transparent and drug-resistant plastic bags, and renal dialysis equipment consisting of own-make efficient hollow fibers. The world's first hollow fiber oxygenator, developed by Terumo, which is displayed at the Cleveland Museum in the U.S., has gained worldwide recognition.

Terumo's blood-compatible bio-materials, which can be used in the living human body, and sensor technology have entered a completely new medical field, which combines the best of technology, functions and materials. For example, artificial blood vessels and artificial skin composed of a special polymer employing tissue cultivation technology can be adapted to the living human body in a natural state to substitute for lost function.

3. Development of Micromachine Technology

With the continued advancement in medical treatment, there is a growing demand for Micromachine Technology for new methods that cannot be achieved by existing medical devices. A catheter, for instance, must be refined enough to pass through a tiny blood vessel and yet perform multiple functions such as diagnosis, treatment, and drug delivery; this requires remarkable downsizing and efficiency greater than ever before.

Terumo, recognizing the importance of Micromachine Technology for future medical care, is taking active steps towards its maturation. Using semiconductor technology, Terumo has developed and made practically applicable Medical Electronic products and sensors that play a key role in monitoring vital signs. To advance further miniaturization and to achieve even higher performance, the company is researching photoelectric generation and booster system, and is working on microactuators. These technologies are anticipated to contribute to the realization of extremely efficient, active catheters and implantable artificial organs for better health care.

TOSHIBA CORPORATION

Introduction

TOSHIBA CORPORATION will soon celebrate its 120th anniversary. We recently visited Energy & Mechanical Research Laboratories belonging to the Research and Development Center which is responsible for Toshiba's basic and future technology. A variety of state-of-the-art techniques and new products were on display: home electrical appliances, OA equipment, medical apparatus and nuclear equipment. We were impressed with the historical impact of Toshiba's development over the years.

Energy & Mechanical Research Laboratories

Devotion to research and development

Toshiba's research and development organizations have those layered structures to support its widespread operations and to assure the efficient transfer of its innovative technology. The organizations include Corporate Laboratories, Development Laboratories, and Engineering Departments of Business Groups. The Research and Development Center heads Laboratories delving into the fields of materials/devices, communication/information systems, machinery/energy, VLSI, and environmental technology. They well befit what might be expected of a electrical company with the reputation that Toshiba has.

Manufacturing Engineering Research Center is also affiliated with the Head Office, and is responsible for developing new production technology and devices to support advances in the in-house production divisions. Eight development laboratories are involved in devising product-oriented technologies.

Energy & Mechanical Research Laboratories

The headquarters of the Research and Development Center are located off National Highway No.1 to the right shortly after crossing the *Tamagawa Ohashi* Bridge going toward Yokohama. The Energy & Mechanical Research Laboratories is situated at the mouth of the *Tama* River, and the new Haneda Airport terminal is located on the opposite side of the river. We found the roar of jet planes continuously landing and departing somewhat annoying, but researchers at the laboratory say that one soon becomes accustomed to the noise and ceases to notice it. The Nuclear Engineering Laboratory is housed on the same site as the Energy & Mechanical Research Laboratories. It was originally engaged in heavy electrical apparatus research but mechatronics research has increased recently and now emphasis is placed on the development of special robots for nuclear energy and space deployment.

Micromachine Applications

Actuators and sensors are important components in mechatronics. There is a group presently studying these mechanical elements at the laboratory. We were shown a strange-looking gear reducer which is used as a space manipulator and is of great benefit in micromachines. In a micro-reducer prototype each gear was so small that, to the naked eye, it looked like the lead in a mechanical pencil. A micro-servoactuator was being manufactured on an experimental basis which employed these gears as well as a newly conceived super miniature encoder and a micromotor recently developed by the Manufacturing Engineering Research Center.

The Nuclear Energy division requested a small inspection robot and researchers are participating in the project. First, they wish to develop a microcamera to be used for inspection. Toshiba can claim credit for the original technology behind miniature cameras and is responsible for the commercialization of cameras roughly the size of a thumb. The micro robot project involves technical experts from all of the laboratories: the micro catadioptric system is being studied by the Manufacturing Engineering Research Center, the 3D mounting technology of CCD and processing circuits are being handled by the Multimedia Engineering Laboratories and Materials and Devices Research Laboratory, and the Energy & Mechanical Research Laboratories are working on the universal head mechanism.

Strange-looking gear reducer (4.25mm in diam.)

Conclusion

Kawasaki Daishi Temple is situated near the Energy & Mechanical Research Laboratories; Known for protecting people from evil, it is often visited by employees of the laboratory. Its location on the bank of the *Tama* River, opposite a gateway to the sky somehow seems most appropriate for this laboratory. We left feeling that it was a setting in which technologies will first see the light which will enrich our lives in the future.

Micromachine Technology (I)

1. Introduction

To attract attention to "Micromachine Technology" from as many people as possible, the Micromachine Center (MMC) will provide introductory technical commentaries on a serial basis within this *MICROMACINE*. However, since this technology has only a short history, a common concept has not yet been established among the researchers and engineers who are interested in this technology. We wish to proceed with this description incorporating any opinions about this course that may be received from our readers.

(1) What is micromachine technology?

No common recognition has yet been established regarding the image of "micromachine", however, classification of functional parts (for instance, actuator, mechanism, and sensor) by size as shown in Figure 1[1] by Professor Iwao Fujimasa (The University of Tokyo) is accepted as the likely common denominator. Any device produced by assembling extremely small functional parts of around 1mm to 1μm is called a micromachine. However, some sections of technical boundaries between a micromachine and millimachine or nanomachine cannot be determined only by size. As well since the interrelationship is also important for application systems, the MMC defines a micromachine in a wide sense, including these other sizes.

Table 1 Technological system of micromachine

Item	Element technology
Fundamental technology	Machining technology Assembling technology Material technology Design technology Measurement technology Micro science and engineering
Functional device technology	Micro functional element technology Energy supply technology Electronic circuit technology
Systematization technology	Control technology Hybridization technology

The technology required to put a micromachine into practice is called "Micromachine Technology". Although the common concept of this technology has not yet been established, with the MMC the system of technology formed by many element technologies as shown in Table 1 is defined as micromachine technology. As similar concepts, the terms of "Micro Electro Mechanical Systems (MEMS)" and "Micro System Technologies (MST)" are also in use.

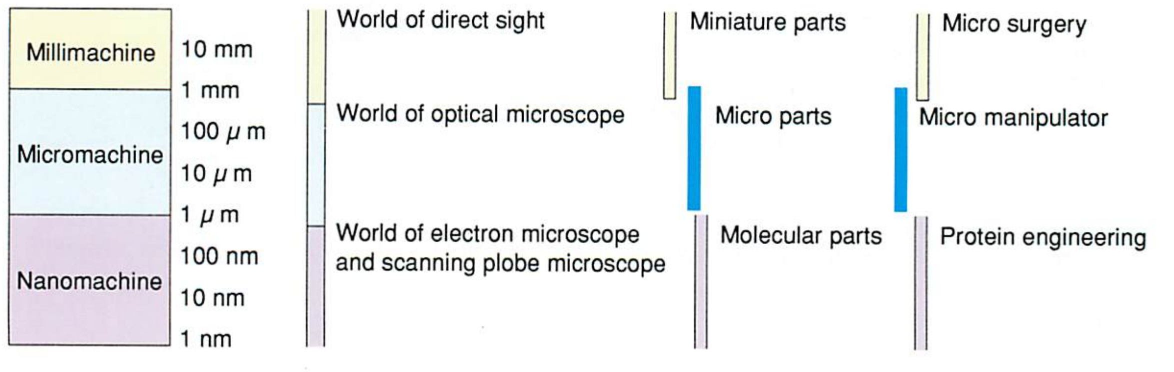


Figure 1 Size of micromachine

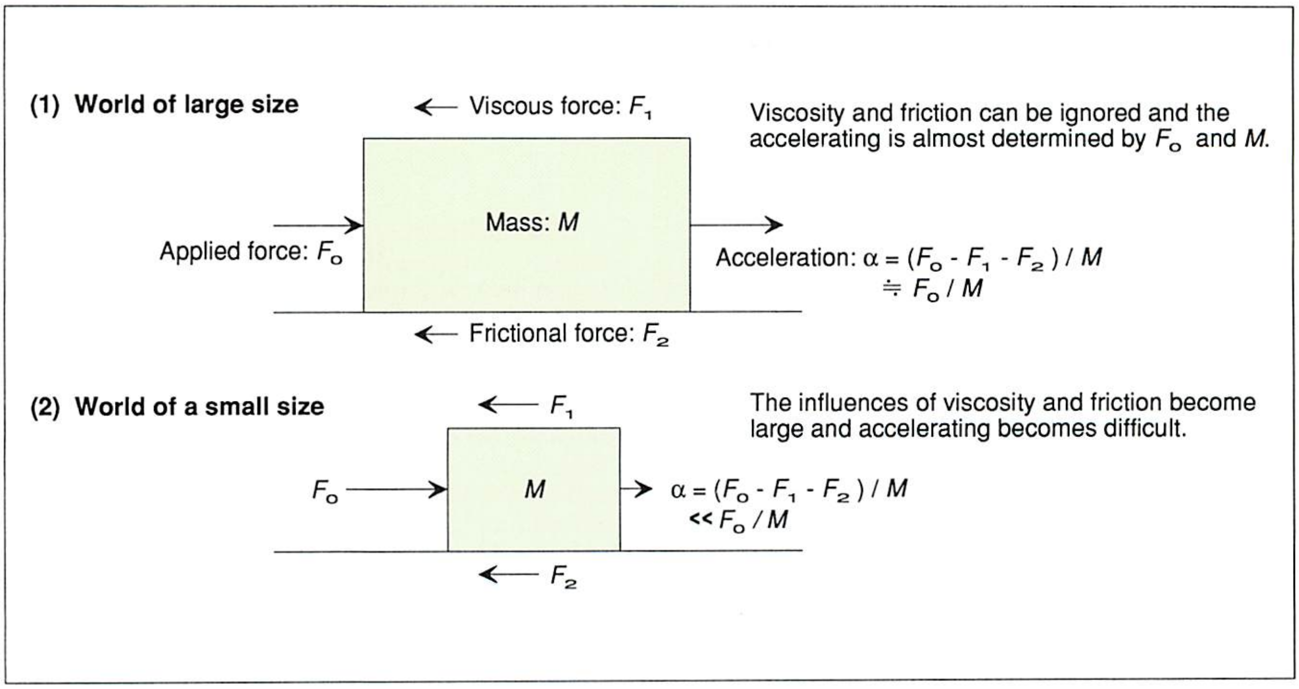


Figure 2 Features of the world of micromachine

(2) Features as a technology

In the world of less than 1mm, effects of viscosity and surface tension on the microscopic body become extremely large and on the contrary, the effect of inertial force becomes relatively small (Figure 2). Consequently, if the sizes of functional elements such as mechanism and actuator are simply micronized, the working efficiency deteriorates and the functional elements cannot be operated. Therefore, a micromachine requires various elements suitable for the micro environment. In the field of micromachine, machining, assembling, materials, energy supply, and system configuration also require new methods suitable for micronization. In other words, a micromachine technology is composed of a group of technologies used to fit the machine into a micro environment.

This micromachine technology can be assumed to be one of ultimate technologies used to achieve micronization of machines. The application ranges of many ultimate technologies are considerably restricted, however, a micromachine technology is regarded as a technology that provides a new base in the industry because the utilization of the technology is anticipated in various industrial fields. A part of the technology has already been utilized in the information, communication and automobile fields in the form of functional elements such as microsensors.

The diversity of current research and development is also one of the features of this technology. This technology appears to have attracted the attention of many researchers and engineers since the production of a micromotor and a micro link mechanism of less than 1mm by the IC process. However, research and development are currently carried out in various technical and engineering fields such as mechanical, electronic, and medical fields, and a interdisciplinary technological field is being formed.

In this issue, the concept and features of micromachine technology have been introduced as the prologue. From the next issue, the background of this technology and individual commentary of the details of the technology will be provided.

Reference

1) Ed. by Hiroyuki Yoshikawa, et. al; Product Downsizing by Micromachine Technology, Intelligence Cyclopedia, *Sangyō Chōsakai* (1992) p.544

A Visit to the U.S. and Canada

As part of the international exchanges which are one of the activities of the Micromachine Center (MMC), in March of this year a four-member team headed by Executive Director T. Hirano visited the U.S. and Canadian universities and businesses listed below where micromachine-related research and development is being carried out.

- University of Wisconsin-Madison
- Massachusetts Institute of Technology (MIT)
- IS Robotics, Inc.
- University of Michigan
- Ford Microelectronics Inc.
- Simon Fraser University (SFU)

In the U.S. emphasis on micromachine R&D (termed MEMS R&D) is clearly on industrial applications. Professor H. Guckel of the WI Center for Applied Microelectronics at the University of Wisconsin-Madison said: *"This is due to a governmental policy which has overall jurisdiction over science and technology. Major R&D funding sources in this area are the Advanced Research Project Agency (ARPA) of the Department of Defense, whose portion is comparatively large, the National Science Foundation and private businesses."*

Professor S. D. Senturia of Microsystems Technology Laboratories at MIT stated: *"After the termination of the Cold War, even funds from ARPA were shifted to non-military areas, particularly industrial applications, in an increasing amount."*

The facilities required for micromachine research are expensive, making it difficult for a university to manage on its own budget alone. The University of Michigan established the Center for Integrated Sensors and Circuits using a government grant and is conducting joint research with related departments. This Center has good facilities centered around photo fabrication and beam technologies. Professor K. D. Wise of the Solid State Electronics Laboratory of the University explained: *"Practical R&D activities are carried out by the Center under contract with the government. Research is funded largely by the government, though industry also funds some portion."*

Conducting research by establishing a research center on a university campus with government funds is also done in Canada. SFU has a laboratory called the Institute of Micromachine and Microfabrication Research. The Director, Dr. A. M. Leung, said: *"Five universities including SFU and UBC (University of British Columbia) conduct joint micromachine-related research here."* Their work covers a wide range of areas including techniques for manufacturing sensors and other devices, biotechnology, modeling, and physical and dynamical analysis. SFU also has MTC Micromachining Technology Center Ltd. Mr. Gordon N. D. Guild, who is president of this company and also managing director of the Institute, said: *"We undertake joint research projects with private businesses and foster collaboration among government, industry and academic individuals and groups."* SFU's Assistant Professor M. Parameswaran stated: *"Last year I was with Mechanical Engineering Laboratory, the Agency of Industrial Science and Technology and this year I invited researchers from that lab here."* They carry on an active exchange with Japan.

In the meantime, private businesses are also pursuing research in the micromachine area. Just like ants that are weak individually but carry out a single large job if they work as a group, the manner and degree of control are important research factors when minute robots are involved collectively in carrying out one job. Relevant to this, the Chairman of IS Robotics, Inc., a supporting member of MMC, is Prof. R. A. Brooks of the Artificial Intelligence Laboratory of MIT, who established the theory of behavior based control, and this firm is conducting research on group control by experimentally manufacturing various sized robots.

Ford Microelectronics Inc. located in Colorado is a subsidiary of Ford Motor Co. (a supporting member of MMC); it is also involved in microelectronics-related research and work on the development of sensors and actuators.

At each of these universities and businesses the team described MMC's activities and research results and was able to learn of their host's activities, thus promoting an international exchange of information in a very personal manner.

Listening to Dr. W. Klose from Germany

The following interview on micromachine technology was made on January 26, 1994, with Professor Dr. Wolfgang Klose, Managing Director of Karlsruhe Atomic Energy Research Institute, Kernforschungszentrum Karlsruhe GmbH (KfK). He participated in the MEMS-94.

Q: *"We know that micromachine research is intensively done in Germany. What, do you think, is prominent progress made in your country or in KfK in these days?"*

A: We think that with the modern technics we are able to make small parts, but those parts alone are not very useful. They have to be integrated into some machine or some device and they have to operate for a purpose. We think this is the first step towards learning ways to produce it cheaply, increase reliability and finding problems which prevent mass production. Therefore, I think this is not so much progress in developing the individual parts but progress in our thinking. So if you ask me, prominent progress is the spirit and the way we have started the process of integration. The first one I should mention is the Meintz Institute of Professor Erfeld, the IMM. Erfeld is one of the co-inventors of LIGA technic. His career started with KfK. He is not very well advanced in his new institute it's the moment with LIGA technic, although he was inventor. He has many things outside of LIGA technic which are very good, such as mechanical micromachining of special glass, of special plastics and of special measuring devices. Second I should mention some institute of Fraunhofer organization. The Fraunhofer organization also deals with small devices mainly with silicon technology.

Q: *"What will be the application and impact of micromachine technology in the near future?"*

A: That's a difficult question, but I can give you one example. We think it is feasible now and are preparing for that. More and more people are concerned with pollution, so more and more people like to have some sort of constant monitoring of environment. *"Do you mean the pollution of water, air, and so on?"* Yes. Water and air and soil and such. People like to be sure that everything is OK. So they like to have monitoring. But they will not be happy if the monitoring is done once a year or the stations of monitoring are set at intervals of 10 kilometers. They like to locate monitoring. They like to know what's going on. Therefore you have to look for automatic devices which can do on-line monitoring and which can be put everywhere. They must be verbose, and they must be cheap. They can be building it in water, in the soil and so on. We think this is the first real application. Even if such a device went wrong, it wouldn't matter too much, because it is one order or not. So it is not the same as having something put into a human body. When you put something into a human body it must be perfect, because otherwise you will harm people. So that is not the first step. It may be a long term going, but not first application.

Q: *"What are the principal barriers to the success of the micromachine research?"*

A: There're too many researchers, and not enough engineers. Real research, to my understanding, is necessary, but we have enough of it. We need engineers using things which are already in existence. So I think the principal barriers are that people are too research minded. They should be engineering minded. They should focus more on engineering. People don't like it, I know. But it's my honest feeling.

Q: *"What field, do you think, will the micromachine technology mostly affect?"*

A: I think ... I have three answers. Packaging, switching and measuring.

Q: *"Do you have any dream about micromachine technology? Please tell us."*

A: Well, it's difficult to dream. In my ... being responsible for work done in the field. Of course I want to like to have success. You see, I always like to use 0.5 millimeter pencils. And I do not care if it breaks. And micromachining is in a position such that you don't care. And it is natural to use it. If you use such a pencil then micromachine technology is successful. And we dream that that comes true. This is a very cheap object. Everyone can use it. And I don't think about how much I need it, I just take it. If it breaks, I take another one. I would like to see micromachine technology in such a state of development where people could use it naturally.

MEMS-94 Held

A four-day workshop on Micro Electro Mechanical Systems (MEMS-94) was held from January 25-28 at the Oiso Prince Hotel in Kanagawa Prefecture.

While in past meetings many reports have focused on devices made using thin film fabrication technology in silicon processing, there were a greater number of papers at this meeting on mechanical elements and systems employing other technologies. For example, details were given of a miniature wobble motor, micro forceps made by photofabricating, and an electrostatic motor with a reduction unit, a heavy duty electrostatic linear actuator, and medical instruments with snake-like flexibility.

MEMS-94 Workshop

The Micromachine Center (MMC), a cooperator of the workshop, promotes research and development work under the Industrial Science and Technology Frontier Program "Micromachine Technology" begun in 1991 delegated by the Ministry of International Trade and Industry's Agency of Industrial Science and Technology.

MMC provided an exhibition booth to display its activities and recent research work. The following eight items from the "Micromachine Technology" project were presented by panels and prototypes.

(1) *Micromotor*
This micro wobble motor presented at the workshop has a diameter of 1 mm and a stator length of 2 mm. At an applied voltage of 350 V and a pulse rate of 10 kpps, a rotating speed of 100 rpm is obtained.

(2) *Microgenerator*
The generator has a diameter of 6.2 mm and a stator length of 3.8 mm. An output of 2W is attained at 15,000 rpm.

(3) *Optical scanner*
The optical scanner is driven by a piezoelement and is capable of two-dimensional scanning. For use in image recognition it integrates a light-emitting device, a photodetecting device and IC, yet is only 25×26×15mm in size.

(4) *Bonding technology*
Analyzing a hydrogen bond at the bonding surfaces and utilizing its results, Al-Si and Al-PZT can be strongly bonded.

(5) *Three-dimensional micro processing*
As a demonstration of ultra precision diamond mealing, a *Noh* mask 3mm in length, 0.2mm in depth and with 0.1μm of surface roughness was engraved on a surface of oxygen free copper.

(6) *Artificial muscle*
Artificial muscles are made by placing polymeric multilayers between electrodes. A 4% elongation has been attained for the targeted 20%.

(7) *Optical micropump*
This pump is driven by vaporization of working fluid, as an energy source, obtained by converting light energy to heat. A flow rate of 0.5 μl/min can be achieved.

(8) *Microcatheter and laser system for medical use*
The concepts of devices for use in medical diagnostic and treatment instruments for low invasion surgical operations were shown.

MMC's exhibition booth in the hall

Most of the participants at MEMS-94 visited MMC's booth and it was obvious that there was great appreciation of the MMC's participation in the workshop. The results shown of the studies were of real interest to visitors.

MEMS is held annually as one of the IEEE workshops and the site rotates among the U.S., Japan and Europe. This year's workshop in Japan attracted more than 300 participants, 105 of whom were from 15 overseas countries. MEMS-95 will be held in Amsterdam, Holland from January 30 to February 2, 1995.

Presentation Ceremony Held to Award First Micromachine Technology Research Grants

To aid in stimulating micromachine technology and related research by exchanges between industry and academia, MMC in November of last year began inviting applications for its first grants for basic research in this field. Many applications were received and screened, and eight were selected for FY '93. A total of 15 million yen was awarded, one of the grants going to the University of London.

The presentation ceremony was held on March 23 (Wednesday), at 3:30 p.m. at the Kasumigaseki Building in Tokyo, and the many in attendance, all had some relation to MMC or its effort. Under the stewardship of Takayuki Hirano, MMC's Executive Director, the ceremony began with the announcement of the selections by Yoji Umetani, Chairman of the Joint Research among Government, Industry and Academia and Professor of Toyota Technological Institute. This was followed by an address by Seiuemon Inaba, Chairman of MMC, and presentation of the grants. Representatives of the eight recipients then gave a brief overview of their respective research programs, after which a reception was held, and the event ended at 7:30 p.m.

Winners of the grants and their research subjects are as follows:

These research grants are expected to be presented again in fiscal 1994 on a similar scale. Applications will be invited as soon as the details are decided. For inquiry contact:

Micromachine Center
3-F, Sanko Building
3-12-16, Mita, Minato-ku, Tokyo 108
Tel: 03-5443-2971, Fax: 03-5443-2975

1993 Research Grant Recipients

Leader and Co-leader	Positions	Subjects	Period
Shuichi Miyazaki	Associate Professor, University of Tsukuba	Basic research on the development of shape-memory alloy thin film for microactuators	2 years
Kimiyuki Mitsui	Professor, Keio University	Basic research on a method of evaluating the geometrical precision of micro parts	1 year
Shin-ichi Yokota, Kazuhiro Yoshida	Associate Professor, Tokyo Institute of Technology Assistant, Tokyo Institute of Technology	Development of micro control valves using functional fluid	1 year
Hiroaki Misawa	Associate Professor, The University of Tokushima	Development of ultra-precision handling technique using a laser manipulation method	1 year
E. M. Yeatman R. A. Syms	Lecturer of Imperial College, University of London Head of an Imperial College course, University of London	Research on micromolding and microactuation using surface tension	2 years
Kunihiko Manbuchi Iwao Fujimasa	Associate Professor, Research Center for Advanced Science and Technology, The University of Tokyo Professor, Research Center for Advanced Science and Technology, The University of Tokyo	Basic research on application of micromachine technology in the development of remote-controlled microscopic surgery systems	2 years
Nobuhiko Yoshii	Associate Professor, School of Materials Science, Japan Advanced Institute of Science and Technology	Basic research on micromachine materials for medical use having both blood adaptability and internal decomposability	1 year
Yoji Yamada	Associate Professor, Toyota Technological Institute	Development of triaxial force/slip sensors by fine surface processing of PVDF film	1 year

(Note) The period of grant support for this research is as follows:
For one year R&D: March 1994 to March 31, 1995
For two year R&D: March 1994 to March 31, 1996

EVENTS

Evening Seminars Scheduled

Last September the Micromachine Center (MMC) began holding monthly evening seminars on micromachine technology to further understanding, interaction and good relations among industry, the government and universities on this subject. These were well received and we thus plan to continue them this year following the schedule shown below. You are cordially invited to attend.

Date*:
Third Wednesday of each month
2 hours beginning at 15:30
(question-and-answer period included)

Theme*:

- April
  Technology of Energy Transfer
  .... Toshio Fukuda, Professor,
  Faculty of Engineering,
  Nagoya University

- May
  From Robot to Micromachine
  ..... Hirofumi Miura, Professor,
  Faculty of Engineering,
  The University of Tokyo

- June
  Design Technique (Manipulation System)
  .... Tomomasa Sato, Professor,
  Research Center for Advanced Science and Technology,
  The University of Tokyo

- July
  Design Technique (Actuator and Mechanical Systems).
  .... Hiroyuki Fujita, Professor,
  Institute of Industrial Science,
  The University of Tokyo

- August
  No seminar

- September
  Micromachine Technology for Medical Use
  .... Iwao Fujimasa, Professor,
  Research Center for Advanced Science and Technology,
  The University of Tokyo

- October
  Design Technique (SMA Actuator System)
  .... Katsutoshi Kuribayashi, Professor,
  Department of Mechanical Engineering,
  Faculty of Engineering,
  Yamaguchi University

(Others will be announced at a later date.)
*Date, topics and lecturers are subject to change.

Participation Fee (Planned):
Supporting members... ¥3,000 per person
Non-members.............. ¥5,000 per person
(includes buffet and tax)

Application and Other Information:
Evening Seminar Secretariat, Micromachine Center
Floor 3, Sanko Building,
3-12-16, Mita, Minato-ku, Tokyo 108
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MICROMACHINE No.7

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:
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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: May 27, 1994