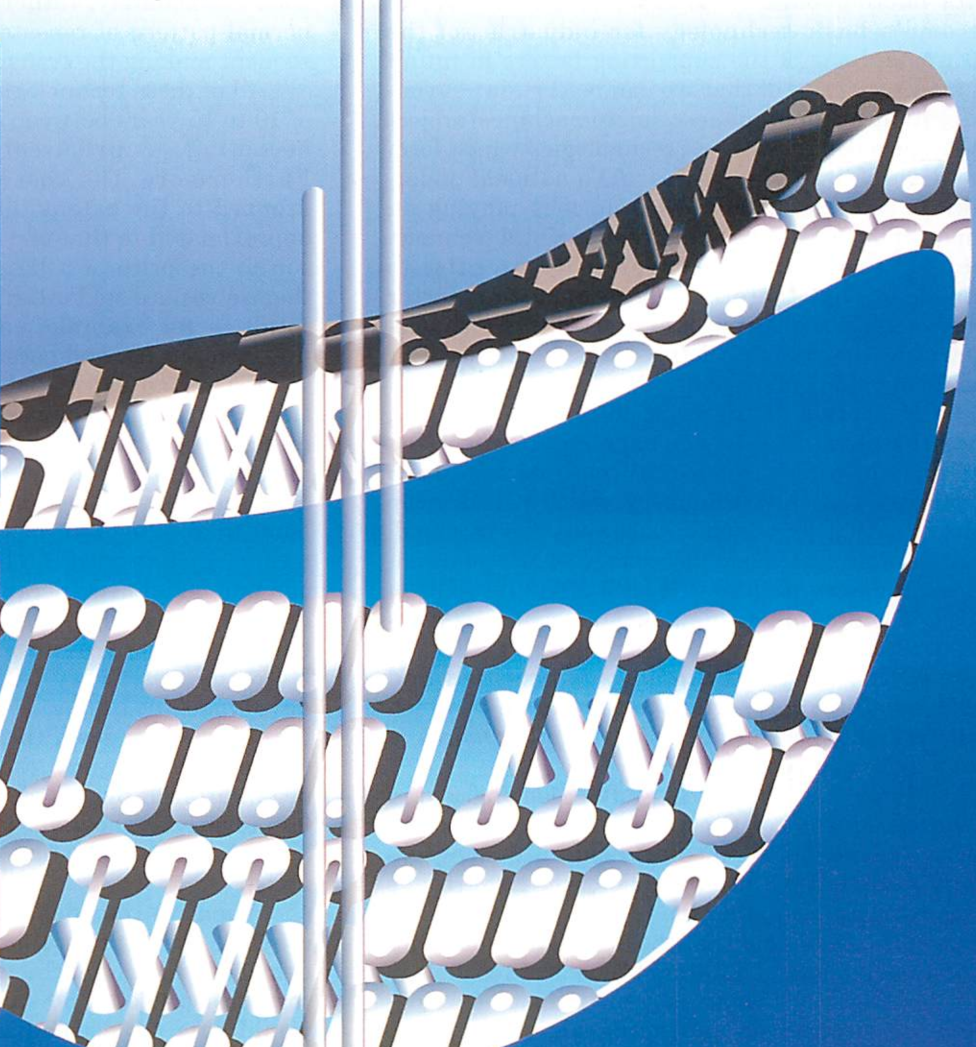
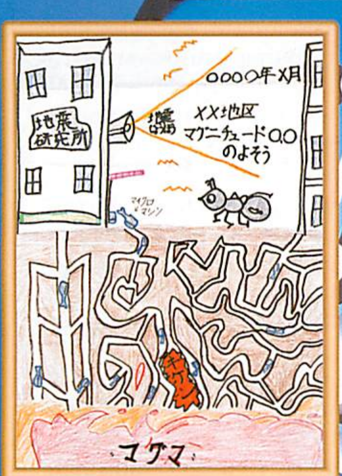
MMC

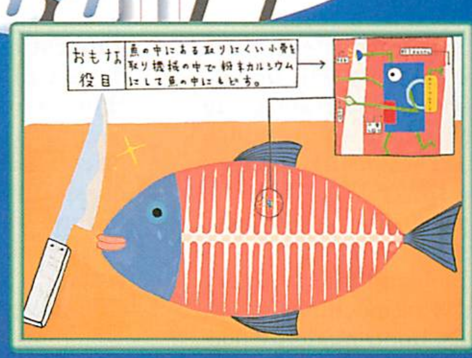
Micromachine
マイクロマシン

May 1997

- Practical Application in the Near Future
- BME Res. at Shiga U. of Med. Sci.
- MMC's Act. in F.Y. 1997/4th Res. Grant/ 3rd Drawing Contest/Takamatsu Seminar
- Members' Profiles
  Olympus Opt./Kawasaki Heavy Ind.
- Foreign View
- Topics
- Introductory Course
  Application of Micromachine Tech. (III)
- Events







No. 19

MICROMACHINE CENTER

Essay

Practical Applications in the Near Future

Prof. Iwao Fujimasa
Department of Policy Research, School of Graduate Studies,
Saitama University

Ten years has elapsed since my first contact with micromachines. Micromachines are set to become a basic technology for industries of the future, and one of the supporting factors in future human society — of that we can be certain. A consideration of the Japanese micromachines project so far reveals a number of technologies which form the seeds of future industries. As a national undertaking, the micromachines project is playing an important role in developing fundamental technologies for the future, however it is essential to remember that there is a more important factor when it comes to the proliferation of this technology within the wider society — this is the need for practical applications.

Irrespective of the type of basic technology, once the physical sciences capable of supporting the fundamental technological concepts have been developed, the only technology which will develop further is that for which applications can be found. For example, the basic technology of the semiconductor industry proliferated only after the goals of development of practical applications such as transistor radios and computers were established. The ease with which a technology is accepted and understood is in proportion to the degree to which that technology is revolutionary, in other words, a demand is required.

Over the past few years I have been engaged in an investigation of the possible applications of micromachines in the medical field. My investigations revealed, to my surprise, that there are already a large number small machines in use in the medical field, and that those designed for application in the next generation of medical technology are the smallest. Those currently under development were conceived as leading-edge technology, while others have been developed as a result of an essential requirement in the medical field. The majority of those in the latter category which have been usefully applied were developed in response to demands from the medical field, the result of which was a body of technology which radically changed medical technology in the late 1980s.

The fields employing the most minute technology are those of so-called interventional therapy — using fine catheters and needles, and microsurgery using endoscopes. The majority of machines developed in this area were initially hand-made by doctors for their own use, and further developed and used immediately, rather than going through the normal pattern of repeated animal trials and subsequent making the transition to clinical use.

All of these technologies have required a period of 10 to 15 years between the first human trial and becoming a practical, usable technology. Furthermore, the cost of these machines has dropped to the extent that current prices can be approximated to that of a small bicycle in comparison to the price of a large sedan. The machines themselves are sold internationally in tens of thousands — for example, various types of catheter, fine stent grafts, and pacemakers.

It is often suggested that the background to this technology is a rapid adoption of surgical methods by physicians. This concept of invasive medicine is particularly notable in the field of cardiovascular problems, an area which accounts for more than 60% of all deaths. The use of catheter technology has been the basis for the development of a number of new therapies using equipment with components in the sub-millimeter range, components which are now in mass production. Unfortunately, very little of this equipment is developed in Japan. These technologies have begun to break down the wall between the physician and the surgeon, and surgeons have recently begun arterial bypass surgery under an endoscope less invasively, however this has yet to be tried in Japan, and the question of why this so naturally arises.

When we consider this situation we can only conclude that a project should be initiated based on demand for micromachines. The current microfactory project would be suitable, however the ideal would be a project dedicated to medical applications. A project encompassing a number of medical applications is envisaged, with development conducted in cooperation with doctors. The focus on therapeutic technology would possibly result in technical problems being raised at the Micromachines Center, however focusing on this possibility cannot be allowed to inhibit progress towards the next generation of micromachines

I recommend the adoption of the fruits of research in the field of micromachines as basic technology for the Japanese medical industry.

Research on Biomedical Engineering

Dr. Satoru Nagata
Shiga University of Medical Science

Introduction

Medical research labs differ slightly from those in the engineering field in that in the majority of cases, disciplines studied depend upon the course — basic disciplines such as anatomy and physiology, and clinical disciplines such as internal medicine and opthalmology, and it is rare to find a research lab dedicated to one discipline. In the graduate school as well, much is classified by course. The Nagata Research Laboratory is allied with engineering in such areas as academic societies and research groups in the world of engineering, and I belong to the Medical Information Center at the Shiga University of Medical Science. This is by way of an introduction to my laboratory, and an introduction of my work, including that on micromachines.

The Medical Information Center at the Shiga University of Medical Science covers a wide range of subjects including medical care, computers, and biomedical engineering (BME) as applied to a variety of subjects, from the use of networks and computers in medical research and education, to research and development in the field of hospital information systems. The center developed as a result of a lack of specialized engineering support available in the Shiga University of Medical Science, a medical college supporting departments of medicine and nursing. My research laboratory deals with the common areas of medicine and engineering from a medical point of view, and we differ from the majority of computer and BME researchers in that we work from a clinical standpoint (see Fig.1). The majority of personnel in the medical department are simultaneously engaged in research and the practice of medicine, in fact only graduate students belonging to particular courses or research laboratories have the luxury of being engaged solely in research. The Medical Information Center therefore endeavors to provide support for simultaneous diagnosis and research, and to create a system of parallel participation in a number of clinical fields.

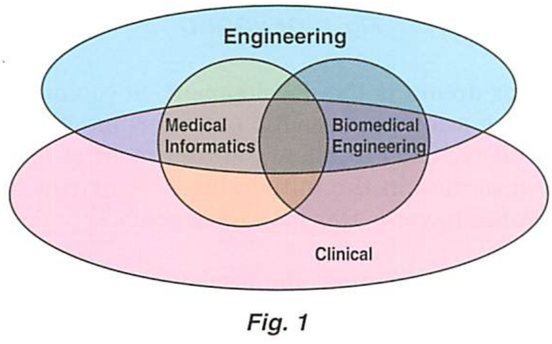


Fig. 1

Research Fields

My research laboratory is engaged in two primary fields — research into the use of computer networks in medical care, and research in BME.

Research into the use of computer networks in medical care covers 1) research and development in integrated medical information systems, and introduction of such a system in the university hospital, and 2) the construction and operation of a network on campus for educational use.

System design in both cases is closely tied to fieldwork. In particular, the integrated hospital information system is very closely integrated with diagnosis and clinical practice, an area in which conventional engineers have very little experience.

Research in the field of BME includes research into micromachines for medical applications, and research in the field of virtual reality for medical applications, as well as research into new types of cardiac catheters, and research into quality of medical images, all coordinated in a horizontally linked system of cooperation between a variety of clinical researchers.

Positioned Between Clinical Medicine and Engineering

In my research laboratory we do not generally take personnel inexperienced in medical practice for participation in research. In recent years a number of students have graduated from the medical faculty and progressed immediately into fields positioned on the border between medicine and engineering and other fields. These students are often considered by their colleagues as being close to, and experienced in, the medical profession, however in truth they have simply graduated from the medical faculty and are mostly without clinical experience. They are nothing more than a product of the current system of licensing for medical practitioners. If one does not obtain a medical practitioner's license after graduating, one is not permitted to engage in medical treatment of patients. For this reason, doctors and nurses practicing in hospitals are only able to accumulate sufficient clinical experience after a few years of having responsibility for patients. The accumulation of knowledge and experience by such medical staff who subsequently leaving the clinical environment is therefore halted at that point.

The Medical Information Center therefore does not permit it's research personnel to leave the clinical environment completely, thus ensuring a medical information system which is active and relevant, and is able to understand the requirements of BME.

I myself am a graduate of Shiga University of Medical Science, and am engaged in the daily practice of opthamology while continuing my research, and all research staff at the laboratory clearly understand this position.

The Medical Information System and the Human Interface

The medical information system began from research at a large number of university hospitals with the introduction of a hospital computer network. From the engineering point of view, such a system requires consideration of information flow, stock, improvements in network efficiency, and the introduction of computers in existing hospitals. In my laboratory we consider the patient as central to the exercise, while integrating the design of the medical information system with the operating format. Unless we are engaged in the actual diagnosis and treatment of patients, we are unable to determine which part of operations is required and which is not, and which section of the information flow is wasted and which is of vital importance.

On this basis, research was initiated in 1986 on an integrated medical information system covering the system of hospital operation. This system is currently implemented in associated hospitals and is undergoing modification and improvement.

In this field, information initiated by doctors is employed as the key in an ordering system, and accumulated treatment data is stored for later use, however the human interface is as yet underdeveloped and further research is required on a more dynamic system employing electronic clinical records. This area is the subject of out current research.

Microsystem Research by Medical Staff

In the BME field, a vital component of our research is the linking of researchers from a number of different medical areas with engineers. Our research is conducted using a variety of approaches which I will introduce below.

Research in the field of micromachines is fairly well advanced in the engineering field, and research into a variety of amazing actuators and micromachining techniques is currently proceeding well. When it comes to the use of micromachines in medicine, however, their development, as well as methods of movement and control inside the body, and the approach towards patients, leaves much to be desired.

Animated graphics illustrating the concept of micromachines for medical use have been produced showing a micromachine moving through arteries and autonomously seeking out and treating sites, however a number of steps have yet to be taken before this becomes a reality. The first step is the accumulation of massive amounts of data on movement of micromachines within the human body. This data is required for safety reasons, for example to ensure that a micromachine does not enter tissue from a minute cranial blood vessel and damage nerves, or damage cells in the walls of blood vessels.

As the next stage, the doctor uses micromachines as one of the pieces of surgical equipment under his control, and must build up a knowledge base containing data on the necessary functions of micromachines, and which micromachine is appropriate for each disorder. Subsequent research is centered on the micromachine, and involves the first insertion of a micromachine into the human body, and with due consideration for safety, it's control to guide it to the target site for surgery or other procedures, and it's subsequent removal from the body. The next step is the appearance of the self-powered micromachine.

We are currently researching movement of micromachines within the body, and methods of control, and in order to promote a general understanding of micromachines for medical applications we have prepared a micromachine concept model in the form of GENGORO (see Fig.2).

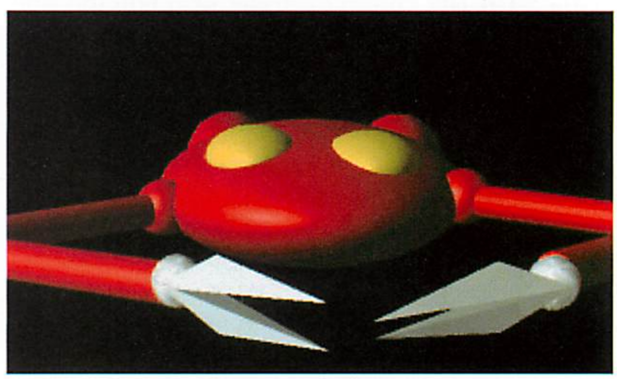


Fig. 2 GENGORO

Our dream is the development, in conjunction with the science of genetic engineering, of a biotype GENGORO to allow the treatment of leukocyte disorders in the initial stages. Our research continues towards this long-term goal.

E-mail: nagata@sums.shiga-med.ac.jp
Visit our site at http://www.shiga-med.ac.jp

Activities of the Micromachine Center in Fiscal 1997

1. Fundamental Policy

Micromachines are composed of functional elements only a few millimeters in size and are capable of performing complex microscopic tasks. The Micromachine Center (MMC) conducts various activities to establish basic micromachine technologies and spread micromachine technology throughout society. It strives to contribute to both development of domestic industry and international community through investigation and research, collecting and providing information on micromachines, and fostering exchanges and cooperation with related organizations in Japan and abroad. In fiscal 1997, MMC will conduct the following activities actively disseminating information from Japan as the fundamental policy.

(1) Investigations and research on micromachines
(2) Collection and provision of micromachine information
(3) Exchange and cooperation with worldwide organizations involved with micromachines
(4) Standardization of micromachines
(5) Dissemination of and education about micromachines

2. Main Activities

2.1 Investigations and Research on Micromachines

The industrial Science and Technology Frontier Program of MITI's Agency of Industrial Science and Technology (AIST) has entered the second year of its second term. To achieve the goal of the basic plan for the R&D (Phase II), the R&D system will be further improved and research delegated to MMC will be actively promoted. Also MMC will exchange technical information with researchers in various countries and provide results of investigations and research for those concerned in and outside of Japan.

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

Based on the R&D results on fundamental device technology in the first phase, the ultimate purpose of this project is to establish technologies applicable to the realization of micromachine systems. These systems are mechanical systems composed of small functional elements that locomote within very narrow spaces in complicated equipment used at power plants and other facilities and inside of the human body. They can also perform intricate work autonomously, and produce small industrial products as a microfactory.

In fiscal 1997, MMC will conduct the following R&D activities.

[Development of advanced maintenance technologies for power plants]

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

R&D of systematization technology will be conducted through production of an experimental system for a wireless micromachine. Inside a metal tube with a curved section, this micromachine will be able to move forward, backward, horizontally and vertically, stop optionally, and recognize its surroundings as well as detect defects of tubes.

R&D topics promoted are: realization of an experimental wireless micromachine for inspection on inner surface of tubes through developing a locomotive device and a microwave energy-supply/communication device as the main technology; systematization of a microvisual device to detect defects and transmit this image with low power consumption, and an optical energy transmission device for energy-supply and communication using light.

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

Systematization technology will be developed through production of an experimental micromachine system composed of a group of single machines capable of combining or separating according to the form of the object to be inspected.

R&D will promote the following topics: creation of an experimental chain-type micromachine for inspection on outer surface of tubes through developing a driving device to propel the machine; systematization of reduction and traveling devices that convert the power of a driving device into movement and a microconnector for combining multiple machines.

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

R&D on systematization technology will be conducted by producing an experimental micromachine system capable of entering the equipment of various structures and performing measurements or repairs of minute internal flaws.

R&D topics promoted are: creation of an experimental catheter-type micromachine for repair in narrow complex areas through developing a multi-degrees of freedom flexible pipe structure as the main device or a manipulator for repair; and systematization of a position detection device composed of micro gyros and a monitoring device using an optical scanner.

(4) R&D of functional device technologies

R&D will be conducted to promote micronization, high performance, and multi-functionalization of functional devices that form the components necessary to realize future micromachine systems and highly advanced micromachine technology.

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

(5) R&D of common basic technologies

R&D will be conducted on common basic technologies such as technologies for control, measurement, design, and evaluation necessary for realizing micromachine systems.

R&D will center on achieving: pattern forming technology for a group of distributed micromachines in which a number of machines form a pattern suitable for work and at the same time conduct inspections; hierarchical group control technology for realizing a ultra-multidegrees of freedom holonic mechanism to move in a narrow and complicated environment: measuring technology for micromachines that measures minute shapes or dynamic behavior of micromachines and the minute power or torque of actuators; and measurement technology by micromachines that conducts micro optical analysis to detect defects inside a pipe.

(6) Comprehensive investigation and research

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

With the Mechanical Engineering Laboratory of AIST, MMC will also conduct joint research to analyze microdevice characteristics, and with the National Research Laboratory of Metrology, joint research to measure minute power and torque.

[Development of microfactory technology]

(1) R&D of experimental processing and assembling technology

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

R&D topics promoted include: Micro processing technology, micro assembling technology, micro fluid technology, micro optical driving technology, micro electric driving technology, micro conveyance technology, and micro inspection technology.

(2) Comprehensive investigation and research

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

MMC will investigate: the downsizing of production systems with microfactory technology that achieves considerable energy, space, and resource savings by microsizing industrial products; analyze economic efficiency of microfactories. MMC will also conduct joint research with the Mechanical Engineering Laboratory of AIST to form a concept for a future microfactory system.

[Research and development of micromachine technology]

(1) Research on micromachine systems

In the medical field, R&D involving the micro-miniaturization and multi-functionalization of micro laser catheters and micro tactile sensor catheters will be conducted. These catheters are the major functional components of a microcatheter for diagnosis and treatment of cerebral blood vessels, an intraluminal diagnostic and therapeutic system.

Also MMC will aim to establish the technology to realize a ultra small liquid synthesizing system that can accurately make up various kinds of liquid of extremely small quantities, including medicines.

(2) Comprehensive investigation and research

Comprehensive investigations and research will be conducted on effectively using micromachine systems for future medical applications. With the Mechanical Engineering Laboratory of AIST, MMC will also conduct joint research on basic design and manufacturing technologies of micromachines.

2.1.2 R&D of Micromachine Materials (Joint research with the Mechanical Engineering Laboratory of AIST)

(1) Research on operating environments for micro functional elements

Research will clarify various characteristics required of the materials by the operating environments of micro functional elements in the fields where introduction of micromachines is expected (industrial fields and medical treatment).

(2) Research on micromachine materials

Detailed investigation will be conducted on various materials for which applications to functional elements of micromachines are experimented.

(3) Feasibility studies on micromachine materials

Experimental examinations will be promoted on improvement in resistance to environments of micro functional elements, dynamic scale effect in micro functional element materials, and manufacturing methods of micro functional element materials by means of the material engineering method.

2.1.3 Investigation and Research on Fundamental Micromachine Technology (activities to help promote the machine industry)

To contribute to the promotion of micromachines and the dissemination of micromachines information, basic technology for the systematization necessary to construct various micromachine systems and promising technology in other fields will be explored and verified. This technology will be promoted jointly in the industrial and academic circles, and improvement of basic micromachine technology will also be undertaken. The following investigations and research will be conducted this fiscal year.

(1) Exploration of promising technology in basic systematization technology

Promising technologies such as a control method of intelligent micromachines and a measuring method indispensable for systematization will be explored and verified.

(2) Exploration of promising technology in other fields

Exploration will be conducted into promising technologies such as (1) materials and functions necessary to construct particulate micromachine element parts, (2) intelligent structure materials necessary for advanced functionalization of future micromachines, (3) control methods on excellent mechanism and functions of microorganisms, and (4) various systems with advanced functions. The future development of such system is highly possible through integration with micromachines.

2.1.4 Investigation and Research on Creation of New Industries by Micromachine Technology (delegated activities to promote the machine industry)

R&D of micromachine technology to realize highly functional mechanical systems composed of minute functional elements has steadily produced results. These achievements have already been partially incorporated in products, and are displaying their practical effects on society. Full-scale applications of the technology, however, is expected to start in the 21st century when the system is prepared as a practical technology.

This fiscal year, effects of the technology on changes in industrial structure and creation of new industries when micromachine technology is put to practical use in many fields will be estimated.

2.1.5 Study on Applications of Micromachine Technology

Micromachine technology will be further developed by seeking additional R&D projects and applications of new-generation micromachine technology in new fields. Furthermore, technology under development and new-generation technology will be systematized and needs for the technologies according to application in Japan and overseas will be identified.

This fiscal year, (1) the system concept adapting micromachine technology for the lifestyle in the 21st century will be formed, and (2) technical investigations through local surveys in western countries will be conducted.

2.1.6 Investigations on R&D Trends of Micromachine Technology in Japan and Abroad

Development of micromachine technology is rapidly progressing. Determining the latest state of research and development in Japan and abroad and providing the analysis results to engineers and researchers concerned will contribute to promotion of micromachine technology development. It is important to continue these activities, and therefore, this fiscal year MMC will conduct investigations following the previous fiscal year.

2.1.7 Other Activities Incident to R&D

Research committees, subcommittees and general study meetings will be held to successfully promote research and development activities.

2.2 Collection and Provision of Micromachine Information

Information and documents on micromachines in universities, industry, and public organizations in Japan and overseas will be collected, combined with survey results and documents produced by MMC, and made freely available in the MMC library.

(1) Completion and improvement of the library:

Following the fiscal 1996, technical documents and information will be collected and stored. They will be entered into databases for easy access.

(2) Publication of a micromachine information magazine:

Following the fiscal 1996, *Micromachine Index* will be periodically published by compiling the excerpts of technical documents and information, then distributed to the supporting members and related organizations.

(3) Publication of a newsletter

A newsletter containing micromachine information such as research trends and administrative trends will be offered monthly to the supporting members by facsimile.

(4) Compilation of databases, and management and operation of an information management system

Research trends on micromachines will be investigated and the results will be edited as an annual report. At the same time, technical information will be compiled.

2.3 Exchange and Cooperation with Worldwide Organizations Involved with Micromachines

To promote affiliation, exchange, and cooperation with related organizations in and outside Japan, MMC will make research grants to research activities at universities, invite or send researchers and scholars for exchanges, participate in the micromachine summit, and sponsor international symposia and seminars.

(1) Aid for R&D of micromachine technology

To smoothly and efficiently promote micromachine technology R&D, MMC will aid universities in their fundamental research as part of its promotion of joint research with government, industry and academia.

(2) Exchange of micromachine technology researchers

To promote exchanges, authorities will be invited from the United States, Europe, Australia, and others, and Japanese authorities and researchers will be sent abroad.

(3) Dispatch of researchers to overseas countries

Researchers will be sent to Europe and the United States to exchange information with universities and other micromachine related research organizations. In addition, MMC will participate in international symposia and academic meetings to be held in the overseas.

(4) Participation in a micromachine summit and bilateral technical exchange

MMC will participate in the 3rd Micromachine Summit attended by the United States, Europe, Australia and Japan to discuss a wide range of tasks on micromachines. Also opportunities for bilateral technical exchanges will be provided to allow discussion on technical and other matters on micromachines.

(5) Sponsorship of symposia on micromachine technology

To establish and disseminate micromachine technology, symposia will be held and applications of R&D results of micromachine technology overseas and measures to promote this technology will be presented. MMC will sponsor the 3rd International Micromachine Symposium this year.

(6) Joint seminars and workshops overseas

Joint seminars or workshops with local organizations will be held in Europe and Asia in cooperation with JETRO to supplement exchanges of specialists and to widely disseminate results of R&D in Japan to countries keenly interested in developing micromachine technology.

2.4 Standardization of Micromachines (partly delegated activity to promote the machine industry)

To further the standardization planned in the previous year:

(1) Related technical terms will be systematized and translated into English.

(2) Standardization will be promoted through individual detailed surveys of the instrumentation/evaluation method.

(3) Furthermore, to establish international standards at en early stage, cooperation with overseas standardization activities will be strengthened.

2.5 Dissemination of and Education about Micromachines

Dissemination of and education about micromachines will be promoted by publishing and distributing public relations magazines and sponsoring seminars and exhibitions.

(1) As public relations organs, MICROMACHINE (a magazine in Japanese and English) will be periodically published and distributed, and an Internet WWW home page will be effectively used.

(2) Through micromachine drawings contests, publishing guides to Micromachine Center, and producing videos, dissemination of and education about micromachines will be promoted. By sponsoring seminars in Tokyo and other areas, exchanges among government, industry and academia will be promoted.

(3) Micromachine '97 will be held to exhibit the results of the 2nd phase of the Industrial Science and Technology Frontier Program up until now.

(4) As the Federation of Micromachine Technology secretariat, MMC will strive for cooperation among organizations related to micromachines and work to reinforce this cooperation.

Subjects for the 4th Micromachine Technology Research Grant Determined

Subjects for the 4th (FY1996) Micromachine Technology Research Grant were determined by MMC's Board of Directors in March. We received many applications this year too. After careful selection, seven new projects and six projects carried over for the second year, as shown in the table below, were selected to receive grants totaling 19.64 million yen. This research grant system started in 1993 as an independent activity of MMC intending to assist university researchers engaged in basic researches related to micromachines, contribute to further progress of micromachine technology, and promote cultural exchanges between industrial and academic circles.

On March 25, the ceremony of presenting the research grant was held at Tokai University Alumni Association Hall, Kasumigaseki Building, Tokyo. In the ceremony, Dr. Tsuneo Ishimaru, Chairman of MMC as the sponsor and Mr. Makoto Nakajima, Director of Industrial Machinery Division, MITI as a guest, gave speeches, and Prof. Yoji Umetani, Chairman of Industry-Academia Joint Research Committee of MMC, reported the selection results. Lists of grant were presented to the thirteen recipients of the grant by Dr. Ishimaru. Dr. Hisayuki Aoyama, Associate Professor of Shizuoka University (presently Associate Professor of University of Electro-Communications), gave a speech representing the recipients, then seven researchers in charge of the seven new projects presented the outline of their research plans. After the ceremony, a celebration party was held and pleasant talks were made with the grant recipients as the central figures.

The research grant program will be continued in fiscal 1997. The next invitation will be from July to October this year.

Chairman Ishimaru is giving a speech as the sponsor

New Research Projects Granted for Fiscal 1996

Leader & Co-Worker	Positions	Subjects	Period
Hisayuki Aoyama Akira Sasaki	Associate Professor Professor Faculty of Engineering, Shizuoka University	Development of micro devices by miniature robots	1 Year
Masahiro Ooka Yasunaga Mitsuya	Associate Professor, Faculty of Science and Engineering, Shizuoka Institute of Science and Technology Professor, School of Engineering, Nagoya University	Development of micro three-axis tactile sensor	2 Years
Takeo Shinmura	Professor, Faculty of Engineering, Utsunomiya University	A new precision mirror finishing for micromachine elements by the application of magnetic abrasive machining	2 Years
Kazuyuki Minami	Lecturer, Faculty of Engineering, Tohoku University	Fabrication of flexible tube actuator by using laser machining	1 Year
Masaharu Kameda	Associate Professor, Department of Mechanical Systems Engineering, Tokyo University of Agriculture and Technology	On the development of a micro-jet-pump driven by the acoustic cavitation phenomena	2 Years
Katsushi Furutani Naotake Moori	Lecturer Professor Faculty of Engineering, Toyota Technological Institute	Monitoring of piezoelectric element by using induced charge	1 Year
Takashi Miyoshi Yasuhiro Takaya	Professor Lecturer Faculty of Engineering, Osaka University	Fundamental study on the micromachining by using the laser radiation force controlled diamond grain	2 Years

Carried-Over Projects Granted for Fiscal 1995

Leader & Co-Worker	Positions	Subjects	Period
Naoe Hosoda	Research Associate, Research Center for Advanced Science and Technology, The University of Tokyo	Reversible micro bonding	2nd Year
Kouji Ikuta	Professor, School of Engineering, Nagoya University	Micro integrated fluid system using micro photoforming process	2nd Year
Haruma Kawaguchi	Professor, Faculty of Science and Engineering, Keio University	Development of functions in polymer microsphere having on-off function	2nd Year
Susumu Sugiyama	Professor, Faculty of Science and Engineering, Ritsumeikan University	Distributed microactuator using high aspect X-ray lithography	2nd Year
Kahoru Torii Kouichi Nishino	Professor Associate Professor Faculty of Engineering, Yokohama National University	Development of three-dimensional measurement technology for micro flow	2nd Year
Takeshi Nakada	Professor, Faculty of Engineering, Tokyo Denki University	Optical microactuator using ER fluid	2nd Year

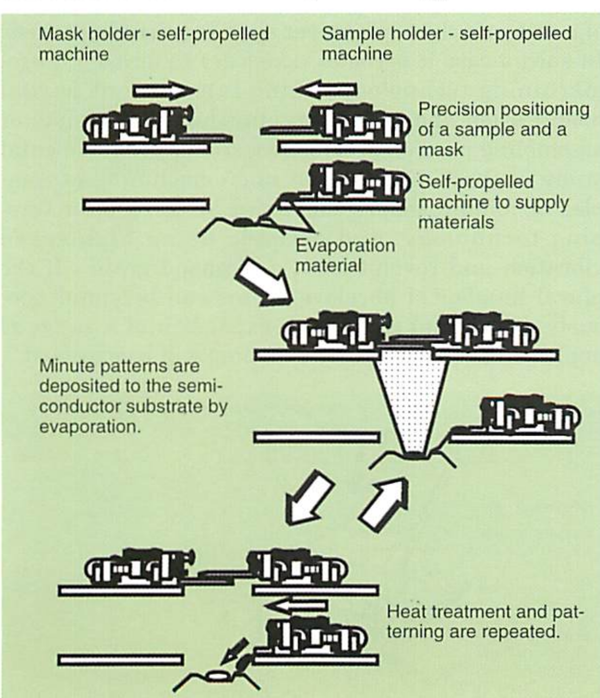
Outline of the New Subjects for the 4th Micromachine Technology Research Grant

Recipients of the 4th research grant

Development of Micro Devices by Miniature Robots

Hisayuki Aoyama, Associate Professor, University of Electro-Communications (formerly Associate Professor of Shizuoka University)

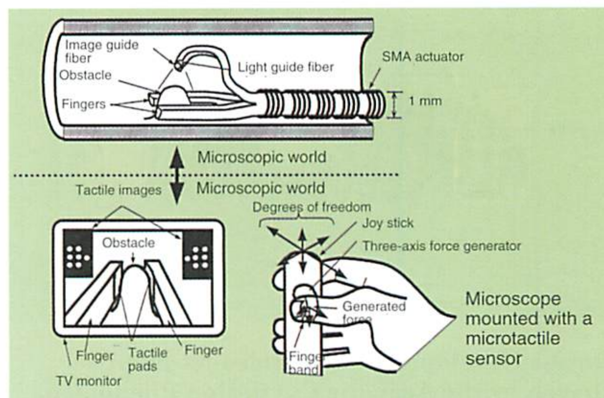
The researchers developed a centimeter size robot (composed of piezoelectric elements and electromagnets) which can move accurately on the freely curved surface. The robot is mounted with a minute surface processor and conducts precision work. The researchers have remodeled it so that it can operate in a high vacuum, and were successful in generation of thin film patterns. In this research, a system is constructed to control these devices, a measuring instrument and a controller distributedly from the general purpose machine. Great expectations are placed on this research as microfactory technology.



Development of Micro Three-Axis Tactile Sensor

Masahiro Ooka, Associate Professor, Shizuoka Institute of Science and Technology

This is a micro, three-axis, tactile sensor which can be mounted on a microscope. It has been thought to be impossible to realize this device because the structure of cells arranged in the form of an array naturally becomes complicated and large. This research proposes algorithm to detect changes in a conical, ultra miniature contact (made of silicone rubber) by image processing using an optical waveguide type, single-axis, tactile sensor. This research also purposes to detect the vertical component of force from changes in the contact area and the horizontal component of force from the range moved from the origin (displacement in 2 degrees of freedom). By this, provision of a micro three-axis tactile sensor is expected.



A New Precision Mirror Finishing for Micromachine Elements by the Application of Magnetic Abrasive Machining

Takeo Shinmura, Professor, Utsunomiya University

Precision machining, precision grinding, and micro electro-discharge machining are comparatively simple shaping methods of micro parts for micromachines. When these machining methods are used, minute burrs are formed on the edges and the processed surfaces are not mirror surfaces. In this research a flexible magnetic brush 2-5 mm long is formed from magnetic abrasive grains. By revolving a micro part between the brushes, a three dimensional, minute and intricately curved shape is ground along its uneven surface. Mirror finishing is realized and burrs are removed without lowering the accuracy of the shape. This processing technology should have a wide range of applications.

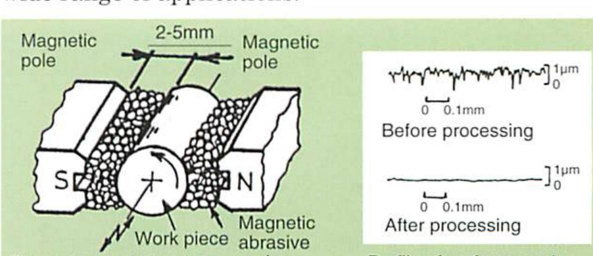
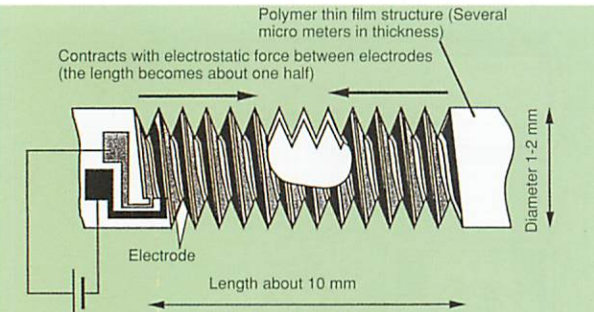


Diagram showing processing by magnetic abrasive machining

Profile of surface roughness before and after processing

Fabrication of Flexible Tube Actuator by Using Laser Machining
Kazuyuki Minami, Lecturer, Tohoku University

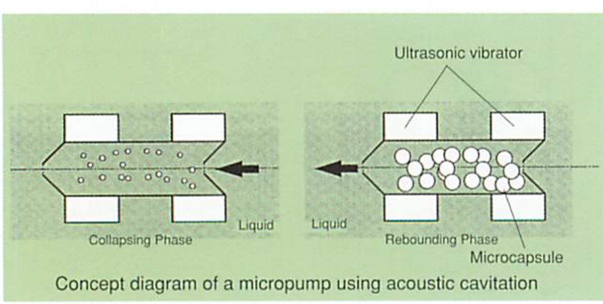
It is difficult and not practical to mount an actuator on the cylindrical surface of devices such as an active catheter. This research intends to produce a flexible tube actuator by combining a method to create shape by three-dimensional laser ablation processing and a technique to three-dimensionally deposit thin film such as polymer evaporation. This actuator has the same external diameter as the interventional catheter, but has a minute bellows structure and a metal electrode inside the structure. By applying low voltage to the electrode, the actuator contract with the electrostatic force. Since it is an electrostatic actuator, it is driven by low voltage, but generation of large power and large displacement is expected.



Flexible tube actuator

On the Development of a Micro-jet-pump Driven by the Acoustic Cavitation Phenomena
Masaharu Kameda, Associate Professor, Tokyo University of Agriculture and Technology

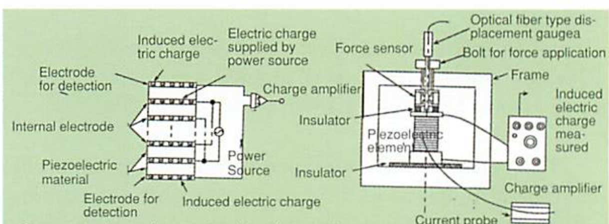
A DOD type ink jet printer injects ink using displacement of the piezoelectric element. This research aims to develop a compact pump with a large volume of discharge. The pump will use a resonance phenomenon of bubbles in the vibrational pressure field, called acoustic cavitation, in the place of the displacement of the piezoelectric element. In the pump, valves which restrict a liquid flow to one direction are attached to both ends of a cylinder. Microcapsules are enclosed in the cylinder, and liquid is carried to one direction by expansion and contraction of the capsules. This is caused by the pressure of the internal liquid fluctuated by external vibrators. Since the operational principle is simple and the scale is highly variable, the pump has a wide range of applications. The uses could include accurate injection and a pump for medical usage.



Concept diagram of a micropump using acoustic cavitation

Monitoring of Piezoelectric Element by Using Induced Charge
Katsushi Furutani, Lecturer, Toyota Technological Institute

Strain-voltage curves of Piezoelectric elements show hysterisis, and the degree of deformation differs between the courses when applied voltage is increased and decreased. Accordingly, when it is necessary to control the trace of the deformation, it is necessary to add a displacement sensor. Because a displacement sensor or a force sensor is large in size, no matter how small a piezoelectric element may be made, it is impossible to make an actuator compact. With this research to decrease displacement hysterisis, miniaturization of a system is aimed at estimating the degree of deformation or its generation. This will be accomplished by measuring the electric charge induced to the external conductor by the internal electric charge of the piezoelectric element, and to control the trace of the degree of deformation without placing a displacement sensor.

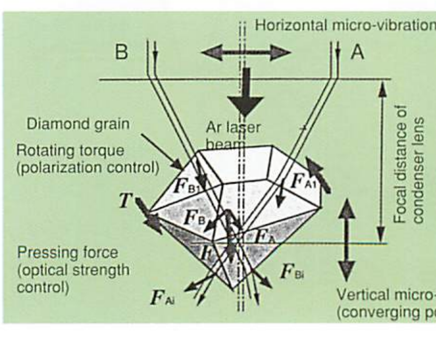


Concept chart of a method to detect electric charge induced by a lamination-type piezoelectric element

Structure of experimental equipment

Fundamental Study on the Micromachining by Using the Laser Radiation Force Controlled Diamond Grain
Takashi Miyoshi, Professor, Osaka University

To meet individual requirements for micromachines for medical use, it is necessary to modify part of a micromachine whenever such requirements arise. In such a case it becomes necessary to develop micromachining technology taking into account partial modification and processing, finishing processing, or assembling processes. This research is a fundamental study of three-dimensional micromachining of complex or minute shapes conducted by using laser trapping technology, and actively using high-speed vibration and revolution of a diamond grain. If the plural number of abrasive grains can be simultaneously driven and controlled, expansion of a range of applications such as partial lapping will be expected.



Driving of a laser radiation force controlled diamond grain

3rd Micromachine Drawing Contest Award Ceremony Held

The Micromachine Drawing Contest was initiated to promote better understanding of and enhancing familiarity with micromachines among primary school and junior high school pupils. These students will be the support and driving force of Japan in the 21st century. The 3rd contest was held this year. The winning drawings for the first and second contests appeared on the cover pages of the Micromachine Center's PR magazine and are being used in many ways to effectively publicize and disseminate activities of the Micromachine Center.

Pupils of primary and junior high schools in Nakaicho, Ashigarakami-Gun, (Kanagawa Prefecture) and Nagaokakyo City (Kyoto Prefecture) and a primary school in Narashino City (Chiba Prefecture) were invited to participate in the third contest. The supporting member companies of MMC cooperated.

184 drawings from the primary schools and 192 drawings from the junior high schools were submitted. Twenty works received prizes after passing the preliminary jury. The following is a list of schools entering the contest.

Entry schools

- **Category of primary school**
  - Nakamura Primary School (Nakaicho)
  - Inoguchi Primary School (Nakaicho)
  - Chohoji Primary School (Nagaokakyo City)
  - Okubo-higashi Primary School (Narashino City)*
- **Category of junior high school**
  - Nakai Junior High School (Nakaicho)*
  - Nagaoka Fourth Junior High School (Nagaokakyo City)

* School prize awarded

The award ceremony was held on March 26 at the Tokai University Alumni Association Hall, located on the 33rd floor of Kasumigaseki Building, Chiyoda-ku, Tokyo. About 40 people attended, including the winners, judges and guests. After the opening speech by Dr. Tsuneo Ishimaru, Chairman of the MMC, Mr. Michio Hamano, Director for Development Program, Agency of Industrial Science and Technology, MITI, made a guest speech to the children. In his speech he stressed the importance of technical development and R&D activities. Mr. Hamano said:

"When I was about the same age as you (children), I dreamed what would be possible 30 years later, in the 21st century. For example, I dreamed human beings might be able to speak with animals, cancers could be cured, or a robot like Tetsuwan (a cannonball arm) Atom might actually be made. Unfortunately, however, these dreams are not yet realized. On the other hand, technologies have advanced beyond the imagination of those days as shown in miniaturization of computers. Although people have been enjoying conveniences in their life, not only advantages. Today hay fever, AIDS, and global warming are having considerable effect on the human society. Continued efforts are still necessary for us to improve our life. To realize this, technical development and R&D activities are important. The 21st century is your age. Although steady efforts are necessary to realize our dreams, I wish you will make every effort toward your future, without forgetting your dreams."

Prof. Hirofumi Miura, Division of Engineering, Graduate School, The University of Tokyo and the chief judge in the contest, explained the process of judging and commented on the drawings that won high-ranking awards.

In this contest, a drawing concerning hay fever, which had not been submitted in previous contests, won the best entry prize in the category of primary school. Seeing the hay fever drawing, I felt that hay fever has one thing in common with micromachines. While it is necessary to purify the air to cure hay fever, the clean air is also necessary to produce micromachines. Micromachines are produced in a clean room in a similar way to developing photographs. If 20 ant-shaped micromachines are produced in a clean room where several hundreds of motes exist in one cubic feet, the micromachines become defective. Motes attach their bodies during the production process and when they are completed the micromachine number is reduced to only 5 or 6. A cleaner room is required when electronic circuits are produced. If people suffering from hay fever enter such a clean room, perhaps hay fever may be eliminated.

Next is the drawing which won the best entry prize in the category of junior high school. This drawing illustrates use of a micromachine for restoration of paintings. I was impressed with the idea of using a micromachine as a machine by noticing that a micromachine is invisible. In the ordinary restoration work, paintings are covered by curtains and cannot be seen from the outside. However, if restoration is conducted using a micromachine with a function to distinguish motes and paint, famous pictures will be appreciated even during the restoration work. Concerning the first prize winning drawings in the categories of primary and junior high school, respectively, a micromachine to detect bacteria is a dream of human beings and a micromachine to regenerate a rubber eraser is an excellent idea. I enjoyed judging these excellent ideas.

Following this comment, other prize winning drawings were announced, and certificates of commendation and prizes were handed to the winners. Yumi Sannomiya, the best entry winner in the category of primary schools is a 6th grader at Nakamura Primary School in Nakaicho. Taro Bove was selected as the best entry winner in the category of junior high schools. He is a third grader at Nakai Junior High School in Nakaicho. Other prize winning participants were announced. School prizes went to two primary and junior high schools that submitted the most applications.

Finally, the two best entry winners expressed pleasure at winning and told about their hopes and expectations of micromachines. After the ceremony the primary and junior high school boys and girls watched the portable exhibits of micromachine technology with sparkling eyes. After seeing micromachine technology for the first time a reception party was enjoyed by the students.

Commemorative photo of award winners

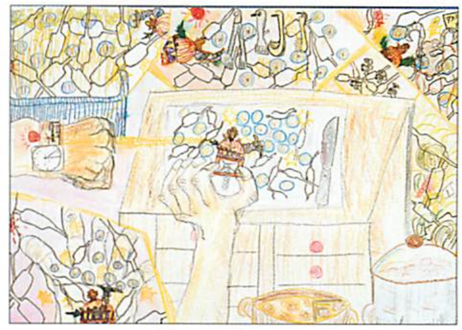
Winners of the Third Micr

•Category of Primary School

Best Entry Prize
I Don't Mind Hay Fever.

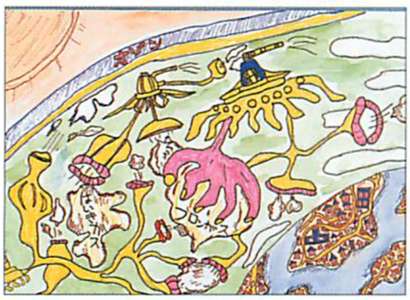
Yumi San-nomiya
Nakamura Primary School (6th grade)

First Prize
O-157 Detection and Terminator Machine



Urara Ozawa
Inoguchi Primary School (6th grade)

Second Prize
Device to Absorb Ozone-depleting Gases

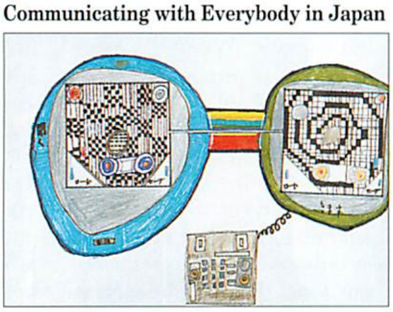


Yuma Ozawa
Inoguchi Primary School (5th grade)

Second Prize
Attack Vermin!

Ryohei Fujibayashi
Inoguchi Primary School (5th grade)

Third Prize
Communicating with Everybody in Japan

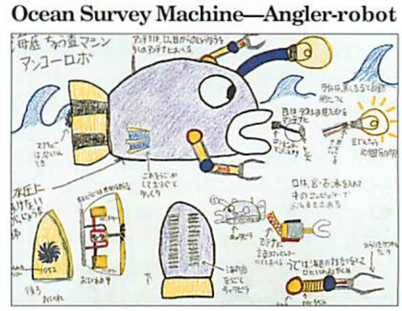


Tetsuya Haseyama
Inoguchi Primary School (5th grade)

Third Prize
Fertilizer Machine

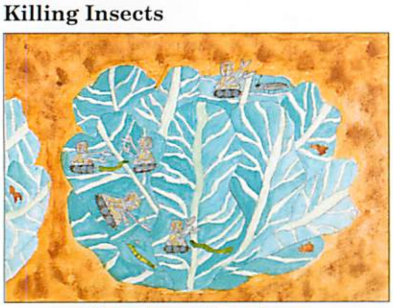
Tomoya Shirakabe
Inoguchi Primary School (6th grade)

Third Prize
Ocean Survey Machine—Angler-robot



Kosuke Yamada
Okubo-higashi Primary School (5th grade)

Honorable Mention
Killing Insects



Takahiro Nakahara
Inoguchi Primary School (6th grade)

Honorable Mention
Dentist Machine

Mitsuhiro Kondo
Chohoji Primary School (5th grade)

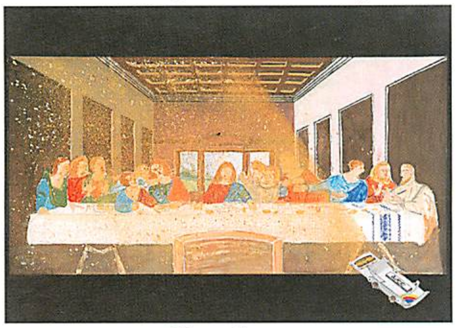
Good Idea Mention
Micro Police Bees

Eriko Fukuda
Okubo-higashi Primary School (6th grade)

machine Drawing Contest

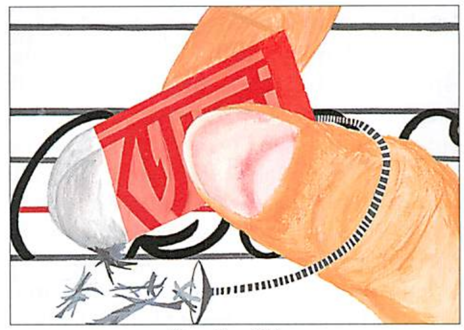
•Category of Junior High School

Best entry prize
Machine to Help Restore Art Objects



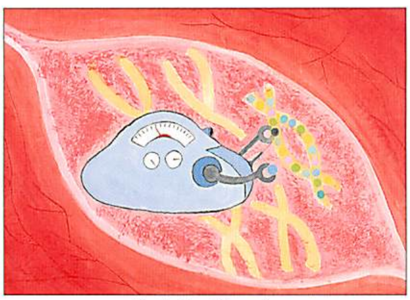
Taro Bove
Nakai Junior High School (3rd grade)

First Prize
Let's Use it Repeatedly



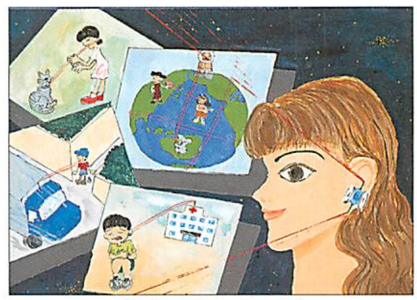
Kuniko Miya
Nakai Junior High School (3rd grade)

Second Prize
Gene Recombination Device



Satoko Kondo
Nakai Junior High School (3rd grade)

Second Prize
Personal Satellite



Yuko Morohoshi
Nakai Junior High School (3rd grade)

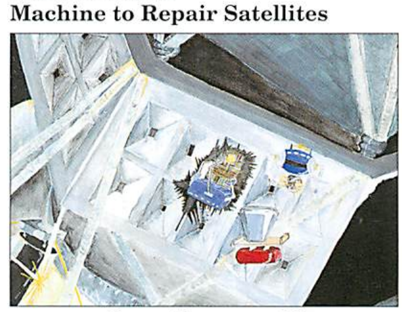
Third Prize
Capsuled Gastrocamera

Tomoko Kurahashi
Nakai Junior High School (3rd grade)

Third Prize
Loving Eye

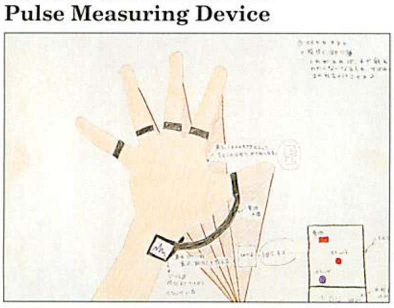
Hiromi Makita
Nakai Junior High School (3rd grade)

Third Prize
Machine to Repair Satellites



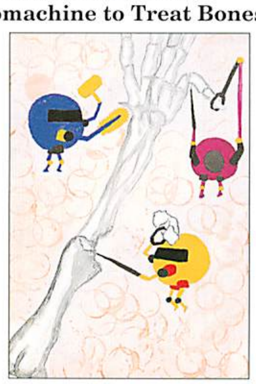
Sawa Yamaguchi
Nakai Junior High School (3rd grade)

Honorable Mention
Pulse Measuring Device



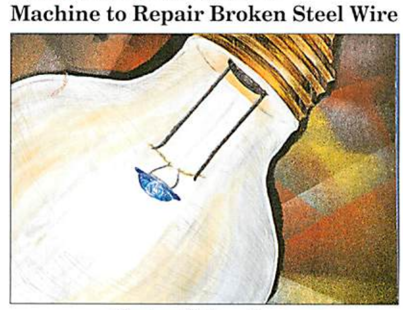
Maki Takino
Nagaoka Fourth Junior High School (1st grade)

Honorable Mention
Micromachine to Treat Bones



Shogo Kidokoro
Nakai Junior High School (3rd grade)

Good Idea Mention
Machine to Repair Broken Steel Wire



Yuka Shinojima
Nakai Junior High School (3rd grade)

Takamatsu Micromachine Seminar

The Takamatsu Micromachine Seminar was held at the Hotel New Frontier in the city of Takamatsu in the afternoon of January 16th 1997. The seminar was jointly sponsored by this center and the Shikoku Industrial and Technical Promotion Foundation, and with the support of the Shikoku Bureau of International Trade and Industry, the Shikoku National Industrial Research Institute, the Shikoku Economic Association, and the Shikoku Productivity Head Office.

This seminar explained recent micromachine technology and introduced some of practical results of the current Micromachine Technology Research and Development Project undertaken as part of the Industrial Science and Technology Frontier (ISTF) program.

Lectures were lead by Akira Yokozawa, head of the Promotion and Education section of the Shikoku Industrial and Technical Promotion Foundation, Yoichi Kimura, Director-General of the Shikoku National Industrial Research Institute, Yohsuke Kinouchi, professor at the University of Tokushima, and Akira Shimizu, professor at Ehime University.

Lectures were on three topics — The Development of Micromachine Technology of the ISTF program, MMC's Activities, and An Outline of Micromachine Technology by Tsuneo Hamano, Director for Development Program, MITI's Agency of Industrial Science and Technology, Hajime Arai, Secretary General of MMC, and Tetsuya Sudo, senior researcher of the Agency of Industrial Science and Technology's Mechanical Engineering Laboratory, respectively.

A special lecture was given by Hiroaki Misawa, professor of the University of Tokushima on The Use of Lasers for 3-dimensional Machining and Handling.

Results of the ISTF Project were presented in the following lectures.

Micropump
Yoshihiro Naruse
(Aisin Cosmos R&D Co., Ltd.)
Rotary Microactuator
Takefumi Kabashima
(Tsukuba Research Laboratory, Yaskawa Electric Corp.)
Nondestructive Testing Device
Shinichiro Aoki
(Opto-Electro Mechanics Research Laboratory, Matsushita Research Institute Tokyo, Inc.)
Environmental Recognition Device
Osamu Toyama
(Central Research Laboratory, Mitsubishi Cable Industries, Ltd.)

The sponsors and supporting organizations in Shikoku cooperating in this seminar promote original and advanced research and development, and support the creation of new industries as a means of promoting the development of industry in the prefectures of Shikoku.

For this reason there was considerable interest in this seminar from the point of view of the effective application in industry, society in general, and in everyday life, of machine technology which is a fusion of such diverse technical fields as microengineering and technology of microfunctional elements. Approximately 60 persons from throughout Shikoku participated in the seminar, including personnel from 20 companies and two universities, as well as sponsors and supporters, contributing to an active exchange of views, and making the seminar a significant and useful event.

Inside the Takamatsu Seminar

OLYMPUS OPTICAL CO., LTD.

Atsushi Yusa, Director of Corporate Research Laboratory

1. Efforts toward Micromachine Technology

Research and development of micromachine has been activated by research into microdevice elements using silicone micromachining technology. This technology started in the latter half of the 1980s and research related to the Micromachine Project of MITI began in 1991. Micromachine applications are being explored in various areas such as information and communication, medical, and fundamental science. OLYMPUS OPTICAL CO., LTD. has promoted its operations in the medical and health, image and information, and industrial related markets. To increase value added and reduce costs of products supplied to these markets, micromachine technology has become indispensable. For example, in medical services low invasive diagnostic and remedial technologies, which harm human bodies less than other methods, are increasingly being sought as we enter into the 21st century and an increasing aging society. To realize such medical needs, OLYMPUS makes efforts at the development of functional elements such as micro sensors and actuators. These use micromachine technology and R&D activities of micromachining and assembling technologies.

2. Development of Micromachine Technology

Technology is necessary in order to remotely and actively guide an observation or treatment function when using ultra fine endoscopes or catheters during narrow intra-luminal diagnosis or treatment or other low invasive intra-luminal surgeries. Figure 1 shows an example of "multi-degrees of freedom tubular manipulator," a prototype manufactured to study such access functions as stated. This manipulator has multiple degrees of freedom by combining several flexible structures 1 mm in diameter toward longitudinal direction, and has a hollow structure so that an observation or treatment function can be arranged inside the manipulator. A thin shape-memory alloy plate (SMA plate) was used for an actuator to flex a manipulator. To control flexibility of the SMA plate with large hysterisis, a heater to drive SMA by heating and a temperature and distortion sensor were integrated on a polyimide thin film. By combining a polyimide thin film with an SMA plate, flexible control of a manipulator was realized.

An operator inserts an endoscope or catheter into a body by holding the end and feeling a tactile impression within the intra-luminal wall directly in his or her hand. As micronization of endoscopes and other devices progresses, tactile information like this becomes hard to obtain. Therefore, development of a function to detect tactile sensations (tactile sensor) will be required in order to improve insertion techniques and provide greater safety for living bodies.

Figure 2 shows an example of an optical micro tactile sensor. This sensor uses a surface emitting laser (SEL) as a light source, and has a minute resonator created by arranging an external mirror formed by a silicon diaphragm on the SEL and a photo diode (PD) for SEL output detection under the SEL. When external pressure is applied to a pressure cell (silicone rubber) which covers the silicon diaphragm, the diaphragm is displaced by several micrometers, and changes in SEL output accompanying the displacement and are detected by the PD. This optical sensor is characterized by that full signal output and can be obtained even if it is micronized.

3. Future Efforts

Research and development activities of micromachining technology of micromachine and functional elements technology are steadily ongoing. Microsensors and microactuators are such examples. Integrating multiple functions and assembly technology has become important in achieving practical usage of micromachine technology in the future, and we at OLYMPUS will strive for R&D in this direction.

Kazuhisa Yanagisawa, General Manager, Integrated Precision Technology Development Department, Olympus Optical Co., Ltd.

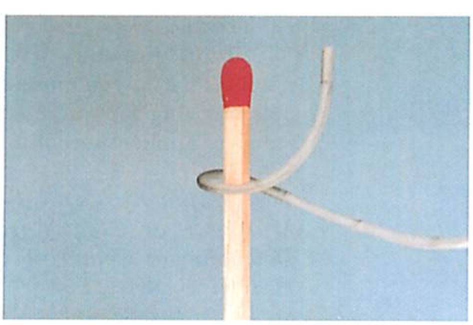


Fig. 1 Tubular manipulator with multi-degrees of freedom

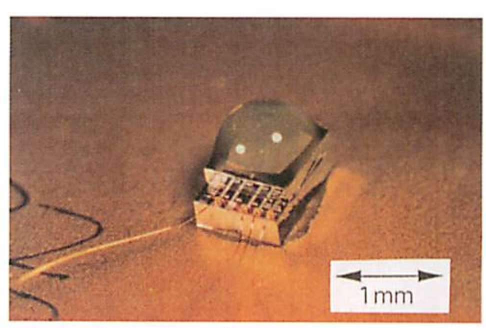


Fig. 2 Optical tactile sensor

KAWASAKI HEAVY INDUSTRIES, LTD.

Yoshimitsu Kurosaki

1. Policy toward Micromachine Technology

An industrial robot, a representative of so-called mechatronic products, is one of the KAWASAKI's products. Electronics technology, micronization, high performance and high function control devices are being emphasized. However, when mechanical and electrical systems of robots are objectively viewed, it is noticed that robots have not become much smaller during the past 10 years. It seems difficult to drastically change robot structure by the progress of electronics technology alone.

Development of micro mechanisms or sensors is of course an interesting theme, but it is wasteful to limit the application of the technology only to micromachines. We would like to place our great hope on micromachine technology seeking the possibilities of producing a robot with a completely different mechanism from the existing one or applying the robot to quite different fields from the present one.

2. Development and Application of Micromachine Technology

Kawasaki Heavy Industries conducted studies on technologies of mechanism and control of an actuator with three degrees of freedom in the first phase from 1991 to 1995 of the Industrial Science and Technology Frontier (ISTF) Program. And in the second phase of the ISTF Program started in 1996, we have been studying pattern formation technology of a group of micromachines.

Figure 1 shows an "actuator with three degrees of freedom", a prototype manufactured in the first phase. This actuator enables rotary motion with three degrees of freedom by driving it with cooperatively controlled multiple piezoelectric elements. Because this actuator has a structural characteristic that can be miniaturized, it is proposed to apply the actuator for joint mechanism or mobile mechanism of micromachines used to check or inspect narrow spaces of plants.

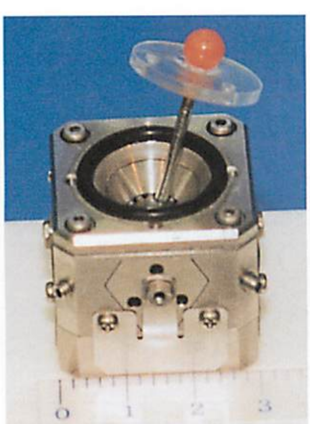


Fig. 1 Actuator with three degrees of freedom

On the other hand, application to robot arm joint mechanism noticing its mechanical advantages can be considered. Because one joint mechanism allows motion with three degrees of freedom, the structure of the existing robot arm which is composed of a motor and a reducer may be drastically changed.

We are now examining the possibility of applying this actuator to work robots in space in addition to robots to check and inspect in plants. In space requirements for generated torque is weak because of nongravity, but instead, compact and light weight robots are needed, and therefore, robot arm designs are not restricted by the conventional concept.

As mentioned above, micromachine technology may be applied in interesting ways in space as well as micro spaces on the ground.

3. Future Efforts

The results in the first phase showed the possibility of applying unconventional actuator mechanism to micromachines for checking and inspections in plants as well as to robot arms used in space. To realize this possibility, we will have to collect basic data, realize miniaturization of driving circuits, and reduce power consumption. Based on the results, expansion of micromachine applications can be expected.

In the second phase, studies on pattern formation technology of a group of micromachines are being undertaken. Important technologies in this pattern formation are those related to communication and control. What communication means can be taken under the limited environment, and in what way micromachines can act as a group under the restricted communication environment. These are interesting subjects.

Simultaneously with micronization of mechanisms, to study communication and control technologies suitable for micromachines will lead to a wider range of applications of micromachine technology.

Yoshimitsu Kurosaki, Associate Director, General Manager of Electronic & Control Technology Development Center, Technology Group, Kawasaki Heavy Industries, Ltd.

Asian Industrial Technology Congress 1997 Report

1. Outline

The Asian Industrial Technology Congress (AITC) in which this center participates was sponsored by the Hong Kong Polytechnic University and held at the Convention and Exhibition Center in Hong Kong between the 6th and 8th of January 1997.

AITC 97 is a platform for the presentation of technologies and products in the manufacturing, communications, environmental fields which may be useful to industrial activity in Hong Kong and the rest of Asia, and the introduction of these technologies to personnel in the academic and industrial sectors.

Four personnel from the supporting member companies and this center attended the congress for the purpose of presenting leading machining and assembly technology.

2. Lecturers and Topics

Lecturers attending the congress from the supporting member companies and this center were as follows.

- Masao Kamiguchi (Fanuc Ltd.)
  The Intelligent Machine with AI Function
- Hiroyuki Funamoto (Seiko Instruments Inc.)
  Development of Superplastic Forging Techniques for Mass-Production of Titanium Alloy Watch Cases
- Tsukasa Komura (Denso Corp.)
  Application of Silicon Dynamic Focusing Mirrors to Bar Code Readers
- Yuichiro Takahashi (Micromachine Center)
  Microfabrication Processes for Micromachine Technology

The temperature in Hong Kong in January was a pleasant 18°C. During the three days of the congress approximately 150 lectures were given in six conference rooms within the Convention and Exhibition Center, and many discussions were held. Japanese participation, in addition to ourselves came from universities, national research institutes (Mechanica Engineering Laboratory and others), their personnel making technical presentations.

Lectures were given primarily by participants from Asia, (Hong Kong and China), however lecturers from Europe and North America also participated to produce a round of vital and energetic discussions.

The Micromachine Center's presentation at the manufacturing technology session involved a video on the topic of micromachine technology, specifically on the first phase results in relation to machining and assembly technology, and subsequent discussions. The Micromachines Center's home page was also introduced. Questions were received from participants from Hong Kong and China following the presentation, and we felt the high level of interest in micromachine technology.

Convention and Exhibition Center

Asia Seminar

Seminars were held in Malaysia and Singapore with the cooperation of JETRO as a means of initiating networks, and exchanging micromachine technology, with the countries of Asia.

(1) Asia Seminar in Malaysia
—Forum on Micromachine Technology—

Date and time: January 14th 1997, 9:00am to 0:30pm
Location: SIRIM Berhad Auditorium
Sponsors: Micromachine Center
JETRO Kuala Lumpur Center
SIRIM Berhad

Lecturers and Topics;

- Takayuki Hirano (Executive Director, Micromachine Center)
  The Importance and Future Prospects of Micromachine
- Tadashi Hattori (Denso Corp.)
  The Current Status of Micromachine Technologies in Japan
- Tsuneji Yada (Omron Corp.)
  Micro 2-D Recognition Device
- Ryo Ota (Olympus Optical Co., Ltd.)
  Medical Application of Micromachine

Approximately 180 participants attended from universities, industry, and research organizations.

A number of technical questions were tabled, as well as questions related to the suitability of the direction of the current research and development program in Malaysia. Informal discussions following the seminar with local academics and researchers revealed a desire to pursue research in this field in Malaysia, and included questions on the best methods of achieving this goal. We felt that the seminar successfully fulfilled a role as a bridge on technical matters.

(2) Asia Seminar in Singapore
—Developments in Microsystem Technology and Micromachines—

Date and time: January 17th 1997, 9:00am to 5:30pm
Location: Gintic Institute of Manufacturing Technology Auditorium
Sponsors: Micromachine Center
Gintic Institute of Manufacturing Technology

Lecturers and topics were the same as in the Malaysian seminar. Three items were presented from Singapore.

- Dr. Tay Eng Hock (Singapore National University)
  Some MEMS Development Work at the National University of Singapore
- Dr. Zou Quanbo (Nanyang Technological University)
  Miniature Silicon Condenser Microphone with Corrugation Technology
- Dr. Zheng Hong Yu (Gintic Institute of Manufacturing Technology)
  Laser Micromachining

Approximately 50 participants attended in Singapore.

The majority of questions were technical in nature. Questions related to whether it was desirable to begin micromachine research in Singapore at fundamental level, and what kind of development was desirable — questions which impressed upon us the unique international nature of Singapore.

This seminar was held subsequent to the Asia Forum of October last year, and it introduced the micromachine research being conducted in Japan to a large number of participants in both countries. It enabled significant exchange between the two countries and Japan, and we felt that it was of great significance. Many experiences of practical research were related, and great things are expected in the future in Asian research in the field of micromachines.

The Asia Seminar in Singapore

MEMS 97 Held at Nagoya

The MEMS workshop (IEEE) was held at the Hotel Nagoya Castle in Nagoya, Japan between the 26th and 30th of January.

This current MEMS was the 10th international workshop with the highest number of participants ever — 442 participants from 15 countries, in comparison to 401 participants at MEMS 96 in San Diego. By far the largest number of participants, 287, were from the host country Japan, followed by 57 from the USA, 19 from Switzerland, and 11 from Germany and other nations of Europe.

Three quarters of the participants were from Asia, with 28 participants from Korea, and a further 15 participants from the rest of Asia excluding Japan.

A total of 95 presentations were made, of which 39 were in the form of oral presentaiton (including four invited speakers), and 56 in poster form. Approximately half of the presentations 45 were from Japan, with 25 from the USA, 11 from Switzerland, and five each from Korea and Germany. Two presentations from Denso Corp., and one each from Mitsubishi Electric Corp., SRI International, Aisin Cosmos R&D Co., Ltd., Mitsubishi Cable Industries Ltd., and Olympus Optical Co. Ltd., were given under the umbrella of the ISTF Project.

Broadly classified, 36 presentations were of devices and systems involving optics and fluid flow, 27 were of manufacturing and machining technology including packaging and integration, ten of actuators, nine of sensors, three of design modeling, three of materials characteristics, and a further seven were classified as miscellaneous. The increase in the number of presentations of devices and systems which were applications of simple actuators and sensors was notable in contrast to the previous year, where presentations were primarily of simple actuators and sensors.

In light of the tradition of these workshops of not holding parallel sessions the auditorium was large enough to seat approximately 400 participants simultaneously. The auditorium was almost full during the entire workshop, and each presentation was approximately 25 minutes in length, presentations being followed by vigorous discussions. Posters presented given during the afternoon of the 28th, with active discussion being heard from all booths.

The Micromachine Center established a display booth adjacent to the auditorium on the 27th and 28th. This display booth included an introduction of the work of the center, as well as four portable displays and descriptions of a laser light driven micropump by the Aisin Cosmos R&D Co., Ltd., photovoltaic micro devices by SANYO Electric Co., Ltd., a 1 mm diameter SMA tube type manipulator by Olympus Optical Co., Ltd., and an in-pipe micro inspection machine by Denso Corp. The displays were the subject of much interest from both local and overseas participants, many expressing amazement that such small machines were actually moving, while at the same time paying close attention to the technology employed, and engaging in vigorous discussions as befits research personnel.

MEMS 98 is scheduled for January 25 to 29th in Heidelburg in Germany. Applications close on September 15th 1997.

The MEMS 97 Auditorium

The Micromachine Center Display Booth

Third Micromachine Summit to Be Held Soon

MMC promotes international exchange activities to advance and disseminate micromachine technology. Since it sponsored the first Micromachine Summit in Kyoto in 1995 as part of these activities, the Summit has steadily developed and been rewarded well.

In the second Micromachine Summit held in Montreux, Switzerland in 1996, MMC was designated as the permanent secretariat to maintain the records of the summit conferences and follow up the next conference. At the same time it was agreed the third Summit would be held in Canada.

In the third Summit, in addition to the 10 member countries of Australia, Canada, France, Germany, Italy, Japan, the Netherlands, Switzerland, U.K., and the U.S.A., representatives of four countries/region (China, Korea, Sweden and Taiwan) will be newly sent to promote further development of the Summit. Preparation is being made by the organizing committee with Dr. G. Guild of Simon Fraser University, Canada, as the central figure. The conference will be held for three days from April 28 - 30 in Vancouver.

Nineteen people including the five-member delegation and observers consisting of supporting member companies will participate in the Summit. The Japanese delegation is as follows:

Chief Delegate
Naomasa Nakajima, Professor, Division of Engineering, Graduate School, The University of Tokyo
Delegates
Toshiro Shimoyama, Chairman, Olympus Optical Co., Ltd.
Tsuneo Ishimaru, Chairman, Denso Corporation
Sadao Moritomo, Vice-President, Seiko Instruments Inc.
Takayuki Hirano, Executive Director, MMC

Chief delegates of the 14 countries/region will report (country/region reviews) on the state of micromachines in their respective countries/region. The following six topics will be discussed:

1. Standardization
2. Healthcare
3. Environment
4. New Horizons and New Materials
5. Transportation
6. Information Technology

Expected chief delegates of the participating countries are shown below.

Expected chief delegates

Country	Chief Delegate	Affiliation
Japan	Prof. Naomasa Nakajima	The University of Tokyo
Australia	Prof. Ian Bates	Royal Melbourne Institute of Technology
Canada	Mr. Gordon Guild	Micromachining Technology Centre
China	Prof. Zhao Ying Zhou	Tsinghua University
France	Prof. Daniel Hauden	LPMO-CNRS
Germany	Prof. Wolfgang Menz	Albert-Ludwigs-Universität Freiburg
Italy	Prof. Paolo Dario	Scuola Superiore Sant'Anna
Korea	Prof. Min-Koo Han	Seoul National University
The Netherlands	(pending)	
Sweden	Dr. Ingemar Lundstrom	IFM-Linkopings Universitet
Switzerland	Prof. N.F. de Rooij	University of Neuchâtel
Taiwan	Dr. Min-Shyong Lin	Industrial Technology Research Institute
U.K.	Prof. Howard Dorey	Imperial College
U.S.A.	Prof. Richard Muller	University of California, Berkeley

Interview with Prof. Mark G. Allen from U.S.A.

Prof. Mark G. Allen, a professor at Georgia Institute of Technology in Atlanta, U.S.A., visited Japan to participate MEMS '97 held in Nagoya this January. We had an interview with him regarding current research activity on micromachine technology at his laboratory.

Q1:*Could we have some information about your institute?*

A1: The Georgia Institute of Technology is located in Atlanta, Georgia, in the United States and it is a university that is devoted to science engineering education. It has approximately 13,000 students including undergraduate, master's and doctoral students. I joined in the institute in 1989, and founded the micromachining research effort there. We have approximately 20 researchers working in our laboratory in the MEMS area. Regarding our facilities, there is a 700 m2 cleanroom and there are a number of smaller laboratories, these are not cleanrooms, for testing, characterization, packaging and probing of MEMS devices.

Q2:*What kinds of research in micromachining technology are being carried out in your institute?*

A2: We are working in several different areas. A first area is magnetic actuators, a second is packaging, and a third is using micromachining techniques to create integrated passive elements, such as resistors, capacitors, and inductors in electronic packages. We are also working in the areas of fluidic actuators and high temperature sensors.

Q3:*What kind of new technology will be needed in the near future for micromachine research?*

A3:I think that one important area is expanding the size of the substrate which we use in micromachine devices to allow us to have larger areas on which to put millimeter scale devices; in particular, this is important for magnetic microactuators, so I think an important technology is the use of larger area lithography for batch fabrication of millimeter scale devices. I think that the incorporation of new materials into micromachined devices is also very important. We have well developed technology for silicon and silicon related materials, we need to develop the materials technology for metals and for the other related materials to the same point, so they can be as useful for the micromachine devices.

Q4:*Could you comment on the current situation of MEMS R&D in general?*

A4:I think it is very exciting time for MEMS, many researchers as well as many companies are seeing the commercial potential for MEMS devices, they are moving away from the stage of curiosities into the stage of useful products, and it is a very exciting transition. I think that we will see the MEMS field continue to grow at a very fast rate as more people realize the importance of this technology.

Q5:*How do you feel about Japanese micromachine research activities?*

A5:I recall there were a number of very nice papers from the Micromachine Center presented at the MEMS '96 meeting in San Diego. Many of the individual devices that will be fabricated as part of this program motion, are very nice structures and I am very glad to see now the second stage of the project is beginning where the structures will be able to be merged into systems, and shown to be useful for application.

Q6:*Finally, could you tell us your dream about micromachine technology?*

A6: My dream is that micromachining technology will become important parts of the every day life of the every day person, and that person never know it, because the micromachined devices are performing their jobs so well, so efficiently. When we get to that point, I feel that micromachined devices will be making a significant impact in the real world.

(MMC Staff, Kazuhiro Tsuruta)

Applications of Micromachine Technology (III)

This time — the final issue of "Application of Micromachine Technology" series — the application of micromachines in the maintenance field is dealt, and examples of maintenance robots and their applications are introduced.

1. Introduction

Modern mechanical equipment is subject to constant development as it becomes more accurate and complex, and requires maintenance in order to maintain it's functionality. This maintenance is vital for the safety, reliability, quality, and economy of the equipment, and consideration of ease of maintenance is therefore an integral part of the design process for equipment.

In this context, there is considerable interest in small maintenance robots for inspection and repairs in cramped and inaccessible locations, locations in which disassembly is not possible, and dangerous locations. Maintenance is often dirty and dangerous work, and the benefits of such maintenance robots in these circumstances is therefore significant.

Applications cover a wide range of equipment including transport machinery, power stations, gas piping and steel, petroleum, and chemical plants — areas which include equipment and facilities vital to modern industrial society, and which provide the basis of our economy. The maintenance of these equipment and facilities is therefore of major importance.

In the field of transport equipment, microcatheters are already in use in the maintenance of jet engines, allowing inspection of turbines without disassembly. In addition to turbine inspection, there are a considerable number of fields in which micromachine technology is applicable for maintenance to guarantee safety of equipment.

Table 1 shows the maintenance expenditure in the manufacturing sector, estimated as 9 trillion yen. When this is included with maintenance expenditure of the non-manufacturing sector such as power generation, and service industries, annual expenditure amounts to 23 trillion yen[1].

Table 1 Annual Japanese Maintenance Expenditure

Field	Plant maintenance (× trillion yen)
Manufacturing industries	9.50
Non-manufacturing industries	
① Water supply	0.235
② Power generation	2.00
③ Communications	1.40
④ Gas	0.10
⑤ Aviation	0.21
⑥ Building maintenance	2.20
⑦ Civil construction	7.50
Total	23 trillion yen (approx.)

2. The Development of High Performance Maintenance Technology for Use in the Power Generating Industry

One of the targets of the Industrial Science and Technology Frontier (ISTF) Project of MITI is the development of a high performance maintenance system to maintain safety and reduce maintenance costs of large-scale power generation equipment by rapid and thorough inspection and repair, without disassembly, in inaccessible locations in heat exchangers and piping. Spaces of less than 20 mm are quite common in heat exchangers and steam turbines, and the piping through which the heat transfer medium is circulated, and these components are often very complex and convoluted so that periodic inspections require disassembly of the turbines and heat exchangers. In nuclear power plants the reactor is shutdown once every 1 to 2 years for inspection, each inspection requiring a period of approximately 100 days, with personnel being subjected to radiation while work is in progress. The desire for a maintenance system using micromachine technology for the process of disassembly → inspection → repair → assembly is therefore most desirable.

Power plant maintenance may require work in cramped and complex passageways, while on the other hand maintenance may be required over a very wide area. In the former case a system employing catheters is effective, as is the use of complex robots in maintenance of the fine tubes in heat exchangers, however in the latter case the use of a number of robots working in cooperation is considered most effective[2]. The three maintenance systems shown in Fig.1 are currently the subject of research and development under the auspices of the ISTF Project[3].

3. Microinspection Machine

Fig.2 shows a microinspection machine developed under the auspices of the ISTF Project[4]. With a diameter of 5.8 mm and an overall length of 20 mm, it fits inside 8 mm piping, and is inertia-driven[5] while searching for cracks in the pipe walls using an eddy current sensor. This model is a prototype connected with the conventional pipe inspection machine

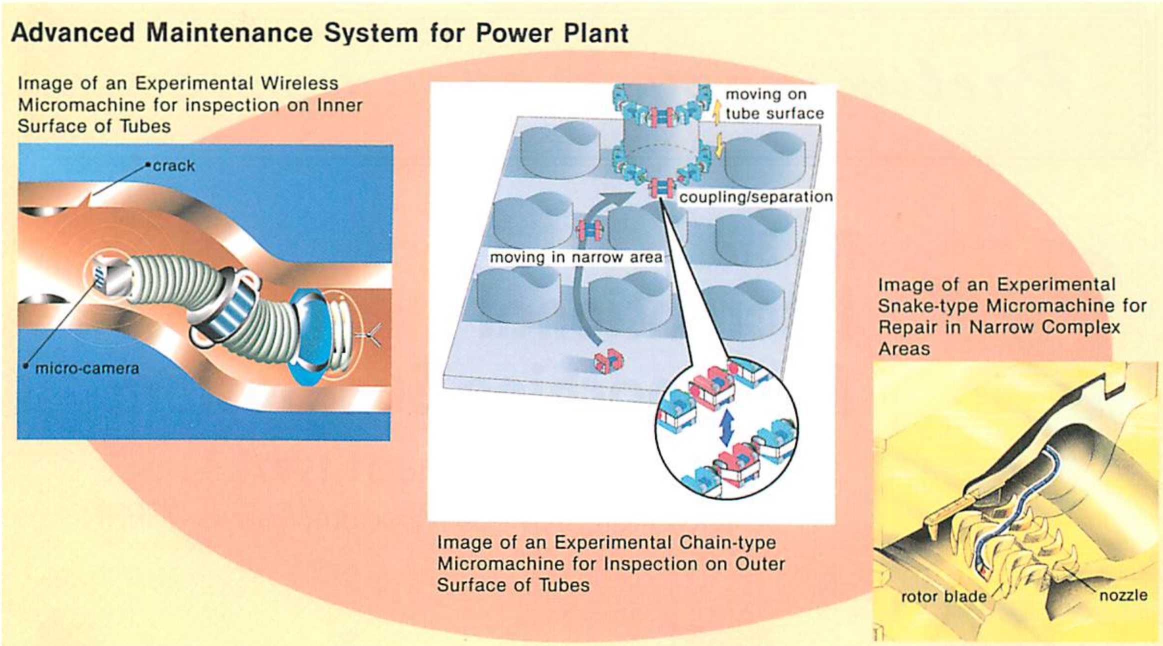


Fig.1 Development of Advanced Maintenance System for Power Plants (Source: Guide to Micromachine Center)

as used in power plants.

Inertia-drive uses the expansion and contraction of an actuator for movement. It's simple configuration (expanding-contracting actuator, inertia body, clamp) allows it to move forwards and backwards without internal wear or friction, and as such is particularly suited to micromovement.

The PZT stack piezoelectric actuator (2 × 3 × 9 mm) used in microinspection machines is supplied in an extremely small (60 μm thick) and lightweight (0.084 g) package (see Fig.2 for a section diagram). This extremely thin 3-dimensional package is produced through a fusion of the various technologies of precision machining, plating, and etching.

As the temperature of the actuator rises above 100°C while in operation, the actuator includes silicon cooling fins attached using a technology for direct bonding of dissimilar materials without the use of adhesive layers[6], and thus provides improved cooling effects.

Fig.2 Micro Inspection Machine by Denso Corp.

The eddy current sensor at the tip has a diameter of 2 mm consisting of approximately 200 turns of 50 μm wire and is able to detect cracks approximately 10 μm in width. This microinspection machine is able to operate in both air and fluid (fluorinate).

4. Summary

The microinspection machine shown in Fig.2 is a simple system with movement and inspection functions. Future research under the ISTF Project into minimizing power requirements, integration of control functions, and further circuit integration, of devices is expected to result in a more sophisticated maintenance system as shown in Fig.1.

References

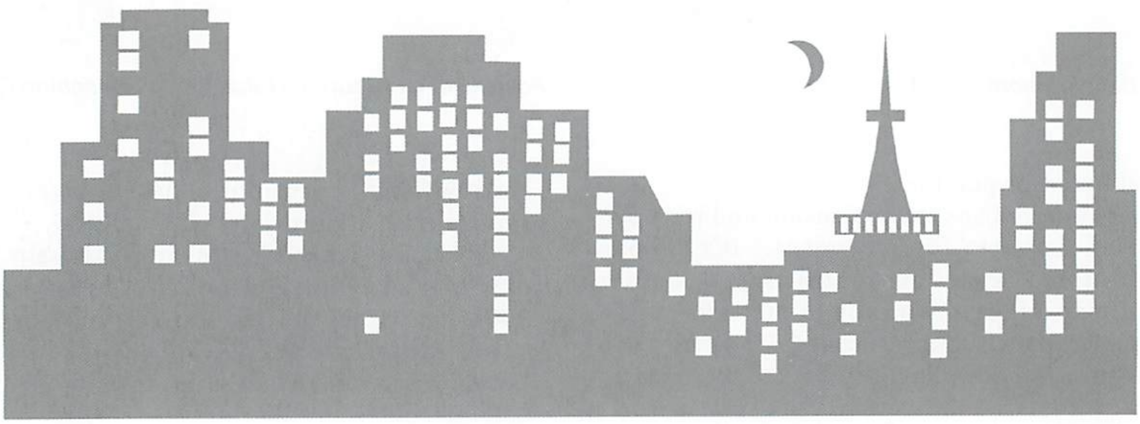
1) Report on a Survey of Economic Effects of Micromachine Technology (1995), The Micromachines Center.
2) Report on a Survey of Microrobot Development (1994), Japan Industrial Robot Association
3) Micromachines Center pamphlet
4) T. Idogaki et al., 193-198, (1995) Symposium on Micro Machines and Human Science
5) T. Higuchi et al., JSPE-54-11, 2107-2112, (1988)
6) M. Nagakubo et al., Proc. of IARP workshop on Micromachine Technologies and Systems, 78,(1993)

Preliminary Announcement

The 3rd

International Micromachine Symposium

will be held on **October 30 and 31,1997**
at Science Hall, Science Museum, Tokyo, JAPAN



Micromachine Exhibition '97

will be held on **October 29▸▸ October 31,1997**
at Science Museum, Tokyo, JAPAN

The Detail will be announced later.

MICROMACHINE No.19

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

Takayuki Hirano, Executive Director, Micromachine Center (MMC)
5-F, Niikura Building, 2-2, Kanda-tsukasacho, Chiyoda-ku, Tokyo 101, Japan
Tel: +81-3-5294-7131, Fax: +81-3-5294-7137
Internet 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: May 12, 1997

MMC