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MICROMACHINE

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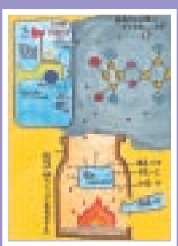

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No. 37

Essay

Energy-Saving Effects of Micromachine Technology

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Mechanical Engineering,
The Faculty of Engineering, Shonan Institute of Technology

Apparently the term "downsizing" originally denoted the trimming down of a company or other organization, although recently it has been used to mean making mechanical systems more compact. The first portable tape recorder, developed by Tokyo Tsushin Kogyo (present-day Sony Corporation), weighed eight kilograms and was driven by a spiral spring. The tape recorder was called "Densuke" by an NHK reporter who carried it on his shoulder while conducting interviews throughout the country. Current cassette recorders weigh about 200 grams, including the power source, or about 1/40 of the Densuke.

Development of the integrated circuit brought about downsizing of sound and data transmitting devices and the current trend of portable equipment. While Densuke required the user to frequently rotate a handle for recharging, today's cassette recorders can operate for nearly ten hours on one AA battery. The difference is primarily due to reducing the size of the mechanism's components from centimeters to millimeters. Accordingly, the energy-saving effects of downsizing were realized.

Since micromachines are characterized by being small and lightweight, technologies for manufacturing and operating these micromachines (micromachine technologies) have emerged to support expectations that micromachines will be exploited in numerous industrial fields. R&D on micromachines to date has yielded a variety of micromachining methods and diverse microdevices. These devices are already being used in areas unseen to us. The Micromachine Center calculated that the production of micromachines has already reached one trillion yen per year and predicts that production will expand rapidly in the future.

The objective of technological development is to create safe and rich lifestyles, but these developments are also increasing the amount of energy consumption. Micromachine technology produces machines on the order of three digits smaller than conventional machines, resulting in an extremely large energy savings. However, this point has been less emphasized. Although the power consumed by mechanical systems should be proportional to the square or cube of its dimensions, a comparison of a previously developed microlathe and a working lathe revealed a proportional power consumption on the order of $10^{1.5}$. The amount of energy saved by this downsizing was not as large as expected. Apparently various micromechanical devices developed to date have exhibited similar results.

The main reason for these results is thought to lie in the micromachining process. A rough estimation of power loss in mechanisms of conventional machines is approximately 10-30%. This value is reached mainly by achieving a form accuracy of 10^{-3}-10^{-4} of the element dimensions. Applying this to micromachines, accuracy of 1 nm to 1 Å is required for element dimensions of 1μm. Currently, however, most micromachine methods have stalled at a precision of 100 nm, which is 10^{-1}-10^{-2} of the element dimensions. While physical phenomena, such as adhesion force are prominent in the microworld, it will be necessary to achieve pinpoint machining control at the nanometer level to actively apply or remove the effects of these phenomena. In other words, nanometer technology is indispensable for further advancing micromachine technology. With this technology, power loss in micromechanical devices can be dramatically reduced. I expect the Micromachine Center to work, from the perspective of energy savings, on advancing micromachine technology that incorporates nanotechnology.

Ultrasound DDS using Microcapsules and Visualization of Oxygen Saturation Levels in Microcirculations

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1. Ultrasound DDS Using Microcapsules

The surfaces of microcapsules collapse when exposed to ultrasound at their resonance frequency. Research on a physical drug delivery system (DDS)[1] is being conducted using this effect on microcapsules filled with drugs, wherein ultrasound is radiated from the surface of the body to administer drugs selectively to an affected organ. This technique is advantageous in that capsules can be broken while simultaneously monitoring the organ and capsule distribution in ultrasonic tomographic images.

We are using F-04E microcapsules manufactured by Matsumoto Yushi-Seiyaku. The microcapsules have an average particle size of 4 microns and can easily be disintegrated by an acoustic pressure of several 10 kPa. Microcapsules were fixed in a thin rubber balloon together with a deaerated medium of high viscosity to serve as a highly concentrated virtual organ. The organ is about 30 mm in diameter with a high concentration and about a $1/10^6$ weight ratio. Fig. 1 is a tomographic image showing observations of the virtual organ by a sector scanning probe with a center frequency of 2.5 MHz that were taken while exposing the organ to a pulse Doppler beam to break the capsules.[2] The Doppler beam is irradiated in the direction indicated by the arrow in the diagram. The brightness of the beam decreases along its trajectory, indicating that capsules in that region are broken. Fig. 2 shows the echographic diagnosis robot[3)4)] to control ultrasound probe on a body surface to radiate ultrasound accurately from the surface.

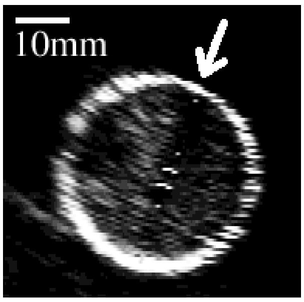

Fig. 1 Using ultrasound beams to break microcapsules in a virtual organ (circular shape)

2. Two-Dimensional Visualization of Oxygen Saturation in Red Blood Corpuscles

Although it is important to elucidate the oxygen supply state of the tissue, until now it has been difficult to visualize actual gas exchange (oxygen movement) in blood vessels of several microns. We used six interference filters of differing wavelengths to elucidate the dynamic state oxygen supply. Based on the multiple regression of the six microscopic images obtained, the amount of hemoglobins in the red blood cells and a two-dimensional image of oxygen saturation was successfully generated.[5]

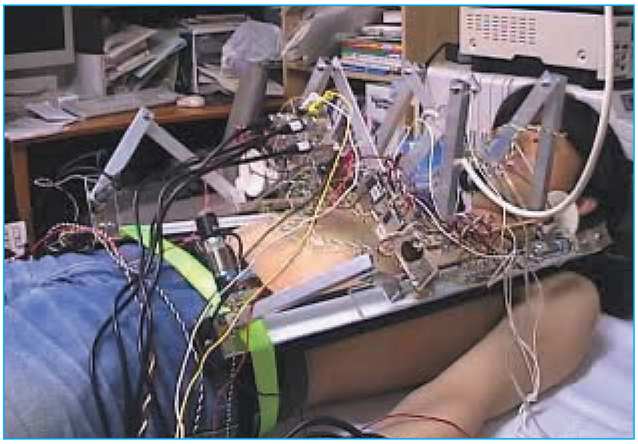

Fig. 2 The echographic diagnosis robot on the body surface to observe the organ and radiate ultrasound

Fig. 3 is a two-dimensional image showing the oxygen saturation level of microvessels in rabbit mesentery. From these two-dimensional images, we can see that the image on the right has a lower oxygen level than the one with near-oxygen saturation on the left.[6] The Fahraeus effect indicating a drop in hemoglobins was observed in two-dimensional images, confirming the effectiveness of the system.

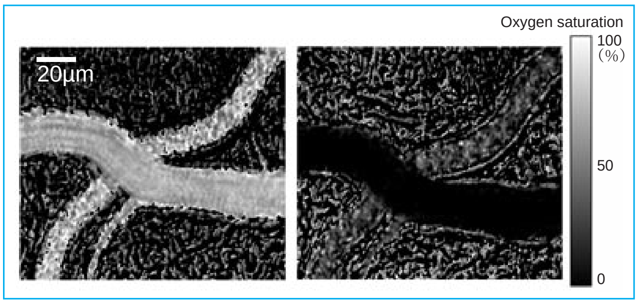

Fig. 3 2D images showing oxygen saturation in microvessels of rabbit mesentery (left: saturated state, right: low oxygen state)

3. References

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Research on the Application of Sprout Multi-Disciplinary Technologies in Micromachine Technology in Fiscal 2000

Since 1992, the Micromachine Center has taken up a diverse range of technology seeds as themes for joint research by academic, governmental, and industrial sectors, all with the aim of reinforcing basic technologies by searching for the technology seeds, especially in the scientific and technological fields, necessary to build various micro systems. In fiscal 2000, research has been conducted along five themes; these five themes are summarized below.

Study on Wearable Energy Sources

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Wearable energy sources are compact energy sources that can be mounted in humans, animals, robots, and the like. Presently, primary and secondary batteries are widely used as wearable energy sources. In the present study, we investigated the feasibility of new wearable energy sources with functions not found in primary and secondary batteries.

By efficiently supplying electricity from chemical fuels having an energy density 1-2 digits greater than batteries, wearable energy sources using chemical fuels are advantageous in that they have potential for achieving a high energy density and high output density. Moreover, unlike secondary batteries that must be recharged, the new wearable energy sources can be continuously used simply by refilling them with fuel. By combining a reusable compact generator with an easily recyclable fuel cartridge, this type of energy source is more environmentally friendly than primary and secondary batteries that accompany such problems as organic matter and waste. Hence, these wearable energy sources support a recycling society. Currently, micro-fuel cells, silicon micro-gas turbine generators, and the like are being studied as energy sources.

Since automatic generating and charging systems free the user from secondary battery charging and fuel refilling, these systems are suitable for such applications as portable health care terminals, which require that a minimum of mental and physical burden be placed on the user, and animal tracking devices or polar environment observing equipment, on which maintenance is not practical. Technologies for automatic generating systems used in wristwatches and noncontact electrical supply systems used in wireless ID tags are employed as base technologies of these automatic generating and charging systems.

This paper discusses examples of wearable and compact energy sources, including fuel cells, fuel reformers, automatic mechanical generators, thermoelectric generators, noncontact electrical supply systems, double-layer capacitors, thin film batteries, and heat engines. The paper also clarifies the current state and future of wearable energy sources used in place of primary and secondary batteries and their relationship with micromachine technologies.

A Study on Applied Technologies for Microchannels

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Progress in microfabrication technology has spurred advances in the density and performance of electronic devices, typified by the CPU, and has increased the power of semiconductor lasers. At the same time, we have seen developments in R&D on micromachines, microreactors, and other micro-equipment, as well as in applied research using this equipment. A problem common to all these devices that has been raised is how to dissipate heat with high heat flux from micro-domain. The heat dissipation from microprocessors around the year 2006, for example, is projected to be about 100 W/cm^2. That from high-power diode lasers is estimated to reach 100-500 W/cm^2, while the APS, a next-generation X-ray source, is expected to reach 2000 W/cm^2. In order for these devices to operate properly, a large amount of heat generated therein must be removed to maintain a low temperature (about 100℃ or less). It is an extremely severe requirement to remove high heat flux under a law temperature difference. In fact, technology used in extreme thermal environments, such as to protect a space shuttle reentering the Earth's atmosphere or nuclear reactor barriers wherein it is necessary to dissipate heat of high heat flux under a high temperature difference, is said to be insufficient to remove heat generated in these micro devices. When considering that the thermal resistance $R = \Delta T/q$, defined by the maximum temperature difference ΔT between the device and ambient environment and the heat flux q as parameters for evaluating the severity of heat removal, it is apparent that we must urgently develop a low-heat resistance technique for dissipating heat.

To achieve this, Tuckerman, et al., proposed a method for removing heat from electronic devices using microchannels, clarifying the heat transfer characteristics and indicating the effectiveness thereof. This technique can conceivably be applied not only to cooling of electronic devices, but also to high-performance micro heat exchangers and the like. While related research activities are being actively pursued, the use of this technique is not yet practical for such applications. This is because heat transfer characteristics of microchannels have not been sufficiently sorted out and the concept and technologies for applying this technique have not been organized in a form readily understandable by technicians and researchers of fields outside of thermal engineering.

From this background, we studied a microchannel cooling technique from the perspective of designing microchannel heat sinks. This paper, entitled "A Study on Applied Technologies for Microchannels," reports the following.

(1) Asserting that microchannel cooling technology differs from conventional cooling technology in that it has a smaller thermal resistance, we indicated why the use of microchannels can achieve a low thermal resistance. We also clarified in which cases it is best to use microchannel cooling technology, by organizing each cooling technology's scope of application according to temperature and heat flux.

(2) A theoretical analysis was conducted on the heat transfer in microchannels and the basic characteristics of heat transfer were given. We also described the scope of application of experimental correlations for conventional systems and factors that come out when using microchannels.

(3) We described the heat transfer and flow characteristics of microchannels with or without a phase change and pointed out that phase change caused a large pressure loss.

(4) Microchannel cooling characteristics were clarified when using water or air as the working fluid, and factors coming out when using air were noted. Next, we described our views on conducting an optimal thermal design of the microchannel heat sinks and gave an optimal design rule.

(5) In order to evaluate quantities of heat transfer characteristics for the microchannels, it is necessary to perform accurate measurements of each physical quantity. From this perspective, we summarized methods of measuring flow rate, velocity, temperature, and pressure and provided example.

(6) Techniques for reducing flow resistance and enhancing heat transfer are important for increasing the microchannel's performance. We studied techniques that have been proposed thus far and investigated their applicability to microchannels.

(7) Lastly, we provided various examples of microchannel production and practical use.

Elucidating Fluid Phenomena in Microchannels and Studying Applications of Microchannels in Micromachine Technology

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In relevant studies conducted thus far, it is clear that applications of micromachine technology to systems aimed at chemical and biochemical analyses and synthesis are progressing. There are now many studies being conducted in this field. At the 4th International μTAS Conference held in May 2000 at the University of Twente in the Netherlands, 134 papers selected out of 230 contributed were presented. Nearly 500 people from 22 countries participated at the conference. There has also been a sharp increase in research presentations on this field at conferences on MEMS, Transducers, HPCE, and other conferences, indicating a definite increasing interest in the topic.

In light of the above conditions, the present study again focused on microscale fluid phenomena and microfluidic systems, the importance of which is gradually being recognized. This year's study particularly emphasized fluid behavior in microspaces, the characteristics of its chemical reaction processes, as well as techniques for its measurement and evaluation. As a continuation of previous studies, we summarized examples of developing microfluidic devices used as components in microfluidic systems and their example applications to genome/proteome analysis. This paper also includes information on European trends in this field.

Since the ratio of surface area to volume increases in microspaces, forces incurred by the fluid, such as surface tension, are relatively large. The fluid has a laminar flow due to its small Reynolds number. Chemical reactions can be performed quickly and efficiently because the interface between two different contacting fluids is relatively large; the distance of molecular diffusion can be shortened; and it is easier to uniformly control such conditions as temperature.

In measuring and evaluating microscale flows, shear stress is the most common measurement in flow fields on an object's surface. For a long time, shear stress sensors using a thin film heater were proposed. Electroosmotic flow was used for pumping the fluid in electrophoresis on microfluidic devices. However, determining the flow profile in this case is an important measurement for evaluating a separating function . There have been reports on experiments for studying the effects of the zeta-potential that determines the driving force of the fluid in electroosmotic flow and examples of measuring flow in microchannels using a particle image velocimetry (PIV). An experiment using color reaction was performed to evaluate the mixing properties of a micromixer, while much research has been reported on microfluidic devices, micropumps, microvalves, and micromixers based on new principles and constructions are emerging. Reports on microvalves include pneumatic normally-closed valves using PDMS, a plurality of valves arranged in one channel that can be used as a peristaltic pump, horizontal valve structures formed by a DRIE process. A new concept of microvalves using hydrogel was proposed. Reports on micropumps included a diaphragm pump using a piezo bimorph actuator, pumps using continuous electrowetting (CEW), and a bubble pump. Two kinds of micromixer are proposed ; one is using an electrohydrodynamic (EHD) effect to generate convention, and the other is using a bubble pump to actively disturb the two-liquid interface.

Some example applications of microfluidic devices in genome/proteome analysis are already being implemented. In the example of incorporating capillary electrophoresis on a microchip, ninety-six microchannels are arranged radially to perform high-speed processes. Products emerging with an eye to the market include sixteen microchannels formed on a 4-inch wafer. Studies are being performed on integrating two-dimensional gel electrophoresis, an important method in proteome analysis, and a mass spectrometer on a microchip. Separation by protein electrophoresis has been implemented on a microchip in an attempt to automate the proteome analysis by connecting the microchip to a protein analyzer.

The end of this paper talks about the state of research in Europe, introducing IMTEK at the University of Freiburg and describing the research system there, as well as discussing the commercialization trends of microsystems in Switzerland. In the future, it is important that we consider how we can strategically construct systems such as those represented in Switzerland from the research stage to production and commercialization in order to further develop micromachine technology that has been fostered in Japan and to make such technology useful in the real world.

Fusing Micromachine and Space Development Technologies

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Institute of Space and Astronautical Science

Launching satellites into orbit currently requires several million yen per kilogram. As a result, developing lighter, smaller and less power consuming and more compact onboard equipment has been one of the most important issues in space development.

The U.S. is far ahead in R&D on applications of micromachine technology in space. While it is common knowledge that conventional satellites weigh from several hundred kilograms to several tons, designs for manufacturing a one-kilogram satellite primarily from silicon material have been published. Most functions required by a satellite-i.e. sensing, attitude control, data processing, communications, command processing, power supply, solar cells, thermal control, structure, and the like-can in principle be created on a silicon substrate using semiconductor lithography.

Accelerometers, gyros, infrared sensors, and microgravity sensors that apply micromachine technologies being developed on the ground are also being studied for an extremely large broad of space applications. Many are already at a stage of practical use in space.

On the other hand, microthrusters used for orbit and attitude control are considered important as being unique to space. There have been many published researches on the application of micromachine technology to the development of valves and nozzles, such as cold gas jet thrusters that eject compressed gas from nozzles at a high speed. While much research has been performed on methods of ejecting a liquid by applying heat with a microheater, microthrusters employing an array of micro-solid propellant , and methods for obtaining an efficient microforce by accelerating ions in a pulse, these technologies still require much development effort before being used in real space missions.

Additional research is being conducted on applications of micromachine technology on a wide range of components for use in space, including relays and switches, filters, pumps, DC/DC converters, and solar cells.

Micromachine technology is extremely compatible with space development where developing smaller equipment is a key issue. It is essential to promote communication between space engineers on the needs side and micromachine engineers on the seeds side. Many in the space community share a sense of crisis in having fallen behind America and, therefore, a strong sense of urgency to construct compact space equipment. On the other hand, Japanese ground researchers in micromachines possess some of the world's top level techniques and hope to expand their applications. Therefore, communication between the two parties should be extremely beneficial to both. Equipment used in space requires an extremely high level of reliability to operate in such severe conditions as vacuums, high temperatures, low temperatures, radiation, vibration and shock during launch. Attempting to clear these hurdles is a positive goal for ground micromachine technologies.

Investigative Study into the Integration of Micro-Flying & Micromachine Technologies

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It has been considered from the beginning of the development of micromachines that small flying devices could be used in the retrieval of information from disaster areas, nuclear power-generation plants, and other locations for which access may be difficult. Furthermore, a number of such unmanned flying devices are now being put to use in disaster areas and other similar locations. As element technologies for this type of small flying device, micromachine technologies including micro actuators and micro sensors are required.

In this research, we first conducted an investigation into the current state of unmanned aerial vehicles(UAV) which are now being put to practical use. The UAVs covered in this report vary from several tens of centimeters to approximately one meter in size. In Japan, these small UAVs are used during volcanic eruptions to photograph the areas of damage around the volcano's crater, to measure the thickness of volcanic-ash buildups, and for other similar tasks. Overseas, on the other hand, research and development is also being carried out for military purposes, and in recent years, this technology has been implemented for border security, highway patrol activities, narcotics control, waterway administration, and fire-prevention activities among others. Fundamental research is progressing in terms of aerodynamics for low Reynolds numbers, and recently, as a result of the attention being paid to the wings of insects of an identical size, research is also being carried out on flapping-wing flight for low Reynolds numbers.

Next, we studied the development of micro-actuators for application to small flying devices. Generally speaking, if the scale of the flying object is small, the actuation suitable for this object will also change accordingly. During this study, we investigated both the effect of reducing the scale of the actuation as used in jets and other modern aircraft, and also flapping and other types of actuation unique to small flying devices. In terms of achieving the driving forces required to allow flight, many reports have dealt with propulsion using propellers and jets. And while research into flapping-wing type propulsion continues, many problems remain to be overcome before this technology may be put to practical use. A method for the supply of energy will also be required so that flight may be achieved, and technologies such as solar batteries, microwaves, and polymer batteries are expected to prove useful in this regard. In the case of jet propulsion, however, the combustion of chemical fuels is an efficient means of propulsion.

Finally, we carried out an investigation into the sensors generally used in today's airplanes and also into those sensors which can be used in the control of small flying devices. Research has been carried out regarding visual sensors, accelerometer-type sensors, GPS, laser scanners, altimeters, and the like; furthermore, these are currently being put to use in autonomous helicopters. This type of element is crucial in the control of the position and attitude of the device, and valuable research in this field is expected to increase in the future.

The 7th International Micromachine Symposium

The 7th International Micromachine Symposium will be held on October 31 (Wed) and November 1 (Thu), 2001 at the Science Hall in the Science Museum, in Kitanomaru Park, Tokyo.

This is the 7th International Micromachine Symposium since the 1st International Micromachine Symposium was held in 1995 with the aim of establishing and disseminating micromachine technology, as well as providing an enlightenment to various industries. In particular, this symposium have features to present the results of the just-completed Industrial Science and Technology Frontier Program(ISTF), which aimed to initiate micromachine technology in the world.

This symposium was planned by the organizing committee (chairman: Professor Naomasa Nakajima, The University of the Air) and the program and guest speakers were decided by the program committee (chairman: Professor Hiroyuki Fujita, The University of Tokyo). Furthermore, in order to reflect international points of view and to fill up the content of the symposium, an advisory board has been established with 9 European and American representatives who participated in the 7th Micromachine Summit held in Freiburg, Germany in this May.

In all, 16 guest speakers (4 from abroad, 12 from Japan) will present lectures on the first day. During the Session 1, opening remarks will be given by chairman of Micromachine Center, and guest speeches will be given by the guests form Ministry of Economy, Trade and Industry (METI) and New Energy and Industry Technology Development Organization (NEDO). After that a special lecture will be given by Professor Fumio Kodama of The University of Tokyo, entitled "The Micromachine based Business Model." Professor Kodama is expected to give invaluable talks on industrialization of micromachine technologies.

Concerning the industrialization of micromachine technologies, five lectures will be presented in the session 2.

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

R & D Strategies for Micromachine Technology:
Prof. Isao SHIMOYAMA, The University of Tokyo
Manufacturing Outlook (tentative):
Prof. Susumu SUGIYAMA, Ritsumeikan University
Outlook for IT (tentative):
Mr. Hironobu KUWANO, NTT Cyber Solution Laboratories
Medical Application (tentative):
Prof. Mitsuo OKANO, Tokyo Women's Medical College
Integrated Chemistry -State of the Art and Scenario Toward Industry Innovation:
Prof. Takehiko KITAMORI, The University of Tokyo

In the afternoon, we have three sessions.

The first session will be "Overseas Activities". We invite three foreigners to present lectures on current trends, such as the example of applications, the activities of manufacturing clusters in EU, and the research environment of Micromachine.

Session 3: Overseas Activities

The Activities of The Five Euro Practice Manufacturing Clusters:
Mr. Rober TURNER, NEXUS/KBI Commercial Ltd, U.K.
Radio Frequency Identification:
Prof. Hekki SEPPA, VTT Finland
MEMS Research Environment:
Prof. Yitshak ZOHAR, Hong Kong University of Science and Technology

For the next session will be "Innovative R & D," we invite three people to introduce the innovative Micromachine technologies that will be expected evolution.

Session 4: Innovative R&D

Light Driven Mass Migration in Nano-Hybrid Polymer Films :
Prof. Takahiro SEKI, Tokyo Institute of Technology
Development of Visual Prosthesis :
Dr. Toru YAGI, Nagoya University
Nanophotonics and Micromachine/MEMS :
Prof. Satoshi KAWATA, Osaka University

For the final session of the first day will be "Micromachine in the Last Decade and future Outlook". We invite four speakers including one foreigner to present lectures on R & D of Micromachine in the last decade and future outlook on Micromachine technologies.

Session 5: Micromachine in the Last Decade and future Outlook

MEMS Development in the Last Decade :
Associate Prof. Norman C. TIEN, University of California
Practical Use of Micromachine in Industry :
Dr. Kunihiko HARA, DENSO Corporation
Micromachine Research in Universities in the Last Decade :
Prof. Hiroyuki FUJITA, Tokyo University

On the second day, the results of R & D of Micromachine technology under the ISTF program by METI will be presented. Firstly, Mr. Hata, Director General of Industrial Technology Development Dept. generalizes the fruits of R & D of Micromachine technologies.

Then, four working group leaders will deliver the results of R&D in the second phase and followed by researchers who represent the company joined this project will announce the results of details of their R & D.

Followings are the title and speakers.

Session 6: Results of Micromachine Technology Project in ISTF Program

Results of the R & D of Micromachine Technology Project :
Mr.Yukihiro HATA, Director General, Industrial Technology Development Dept. NEDO

Overview of R & D in Micromachine Project :
Dr. Kuniki OHWADA, Chairman, R&D Committee, Micromachine Center
Experimental Wireless Micromachine for Inspection on Inner Surface of Tubes :
Dr. Nobuaki KAWAHARA, Micromachine Center
Experimental Chain-type Micromachines for Inspection on Outer Surface of Tubes :
Mr. Munehisa TAKEDA, Micromachine Center
Experimental Catheter-type Micromachine for Repair in Narrow Complex Areas :
Mr. Ryo OHTA, Micromachine Center
Experimental Microfactory System for Processing and Assembling :
Mr. Kazuyoshi FURUTA, Micromachine Center
Research of Artificial Muscles :
Mr. Roy KORNBLUH, SRI International
R & D of Microbattery for Micromachine Applications :
Mr. Kanji KUBA, Mitsubishi Materials Corp.
Micro Laser Catheter :
Mr. Shigeru OMORI, TERUMO Corp.
R & D on Micro Tactile Sensor Catheter :
Mr. Hiroshi TOSAKA, Olympus Optical Co., Ltd.
A Study for Pattern Generation of Micromachines :
Mr. Yasuo OTSUKI, KAWASAKI HEAVY INDUSTRIES, LTD.
A Study on Hierarchical Group Control :
Mr. Taku SASAKI, MITSUBISHI HEAVY INDUSTRIES, LTD.
A Study on Hierarchical Group Control :
Mr. Taku SASAKI, MITSUBISHI HEAVY INDUSTRIES, LTD.
Miniature Gas Sensor using Micro Borometers and Micro Variable Infrared Filter :
Mr. Hitoshi HARA , Yokogawa Electric Corp.

The 12th Micromachine Exhibition will be held on the ground floor of the Science Museum from October 31 to November 2,2001. We believe that this symposium and the micromachine exhibition will provide you a great opportunity to understand the cutting edge of micromachine technologies and we suggest you to attend both events. Participants in this symposium can enter into the micromachine exhibition by simply showing your participation card.

The deadline for applications to attend the symposium is October 27, 2001. However, as for as seats are available, applicants will be accepted on the day so that as many people as possible can attend this symposium.

Akita Micromachine Seminar

The Akita Micromachine Seminar was held on the afternoon of September 14, 2001 at the Akita Prefectural Industrial Technology Center in Akita City. It was organized by the Micromachine Center, Akita Machine & Metal Association, Akita Prefectural Industrial Technology Center, and Akita Production Technology Society.

This seminar was chaired by Mr. Mutsuo Watanabe, Production Technologies Department Head of the Akita Prefectural Industrial Technology Center. Following a welcoming speech from Mr. Tsuyoshi Sato, Executive Director of the Akita Machine & Metal Association, a number of speeches were presented. Specifically, Mr. Takayuki Hirano, Executive Director of MMC, made a speech concerning "The MMC's Activities"; Mr. Yuichi Ishikawa, Principal Research Scientist of the National Institute of Advanced Industrial Science and Technology, spoke on "The Features of Micromachine Technology"; and Mr. Tsuneji Yada, General Manager of the MMC, presented "An Overview of the Micromachine Project".

In addition, as part of an introduction to the research results of MMC's supporting members, Mr. Munehisa Takeda, Group Manager of MITSUBISHI ELECTRIC CORPORATION's Advanced Technology R&D Center, spoke about "The Experimental Chain-Type Micromachine for Inspection of Outer Tube Surfaces"; Mr. Hiroshi Yamada, Research Scientist of TOSHIBA CORPORATION's Corporate Research and Development Center, made a speech concerning "High-Density Three-Dimensional Packaging for a Microvision System"; and Mr. Hitoshi Hara, Assistant Manager of Yokogawa Electric Corporation's Micromachining Laboratory, spoke about "1cm^3 Carbon Dioxide Sensor with a Microbolometer and Infrared Filter".

During the interval, Mr. Munehisa Takeda and Tsuneji Yada conducted a presentation of the "Micro Generator" (MITSUBISHI ELECTRIC CORPORATION), and the "In-pipe micro inspection machine (DENSO CORPORATION)" (TOSHIBA CORPORATION), two portable exhibits of micromachine technology that had been brought to the seminar. This provided an excellent opportunity for the seminar participants to become more familiar with micromachine technologies.

With a total of 45 people present - 20 individuals from 13 companies in Akita Prefecture and another 25 individuals from universities, research centers, public agencies, and other similar organizations - the seminar was both well attended and of considerable significance.

FANUC LTD.

Seiuemon Inaba
Executive Adviser, Honorary Chairman
(the First Chairman of Micromachine Center)

Achievements of the Micromachine Project and the FANUC ROBOnano U*i* Machine

1. Development of Micromachines

FANUC Ltd. engaged in the development of ultra precision micromachining technologies under the guidance of MITI's Micromachine Project (the Industrial Science and Technology Frontier Program). Our ultra precision micromachining technologies have recently enjoyed increased usage in the manufacturing of molds for optical devices, small electronic components, and the like. In this paper, we introduce some achievements of the Micromachine Project.

2. Introduction of Ultra Precision Micromachining Topics

Ultra precision micromachining technologies are an attempt to improve the age-old mechanical processes, such as cutting and grinding, from a micro to a nano level based on our own developed FANUC ROBOnano Ui machine. A single-crystal diamond tool is used to cut microstructures, forming a surface roughness at the nano-level. According to statistics by the Aachen University of Technology (RWTH Aachen) in Germany, although 40% of techniques applied in micromachining use etching methods and 30% cutting and grinding methods, the cutting and grinding methods are the most precise of existing techniques.

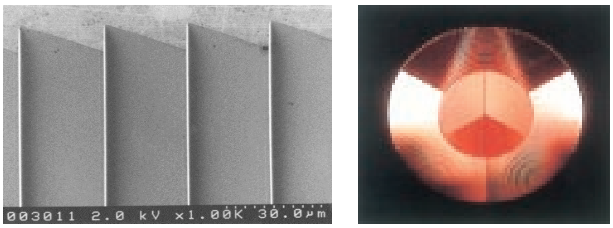
One ultraprecision micromachine technology is the machining of microgrooves, as in diffraction gratings. Ordinarily, the grooves are arranged at intervals of microns. In addition to their application in scales and the like, these grooves are used as light focusing devices and, in terms of applied technologies, have attracted much attention as molds for manufacturing light-guiding panels used in liquid crystal displays.

Fig. 1 The FANUC ROBOnano Ui friction-free ultra precision nanomachining tool

Recently, this technology has been used in the ultraprecision micromachining of a mold for forming front-light panels used in cellular phone LCDs.

Another technology for machining rows of even finer grooves within microgrooves has become practical. The use of this technology has expanded in dental care.

Technical development has accelerated on the practical use of ultra precision machining for microstructures other than ordinary simple grooves. Mirrors, lenses, and the like applying free-form groove processing made possible by a shaper engraving and having multiple focal points for one light source show promise as a new generation pickup method for CDs and DVDs.



(a) Microgrooves channels formed in the light-guiding panel of a liquid crystal panel at a pitch of 25 microns

(b) Integral tri-focal diffraction grating with a diameter of 2 mm

Fig. 2 Examples of ultra precision micromachining

3. Achievements and Future Challenges

It is my belief that the present R&D confirmed that the existing diamond processing method achieves superior surface roughness to lithography and etching processes. This view is already spreading through the micromachining industry and is thought to be one major achievement of the Micromachine Project that concluded in March of this year.

At FANUC LTD., we were able to further develop ultra precision micromachining technologies through the ROBOnano Ui machine. It is my hope that this will contribute to the field of micro and nano technologies.

Fujikura Ltd.

Koichi Inada
Senior Managing Director,
Research and Development Headquarters

1. The Challenge of Micromachine Technology

Fujikura has conducted microjoint research for the Industrial Science and Technology Frontier Program completed last fiscal year as part of our advanced technology R&D on functional devices. We developed technologies for stacking silicon devices in a three-dimensional structure by forming through-hole interconnections in a silicon wafer. Currently, several of these elemental technologies have been applied to actual devices and are being incorporated in R&D on practical applications.

2. Development of Micromachine Technology

Several element technologies are required to form through-hole interconnections in silicon wafers. In following the sequence of the formation process, we first form through-holes in the silicon wafer. While we are studying general technologies for forming through-holes, such as deep RIE and laser processing, we are also forming through-holes with a high aspect ratio using optical excitation electropolishing. This type of electropolishing is one method of wet etching and is distinctive for its low per-hole cost and ability to form through-holes at a aspect ratio of 100 or higher, which is not possible with other methods. Fig. 1 shows a cross-section of through-holes formed in a silicon wafer by the optical excitation electropolishing method. Issues remaining in this process are how to optimize electropolishing conditions, how to improve the quality of the through-hole walls, and how to increase the speed of electropolishing.

Subsequently, an insulating layer must be formed on the walls of the through-holes. Although thermal oxidation layers are currently used, this technology cannot be employed when a device has already been formed on the silicon wafer. For this reason, we are attempting to develop a technology capable of forming an insulating layer on through-hole walls with a high aspect ratio at a low temperature of 400℃ or less.

Finally, the through-holes are filled with a conductor for forming an electrical connection. As the aspect ratio of the through-holes increases, the number of feasible technologies becomes limited. In addition to an electroless plating method, we are currently investigating a molten metal suctioning method for drawing melted solder into the through-holes. A method that makes it possible to introduce conducting metal quickly using simple devices can reduce processing costs while improving the airtight seal of the through-hole interconnections.

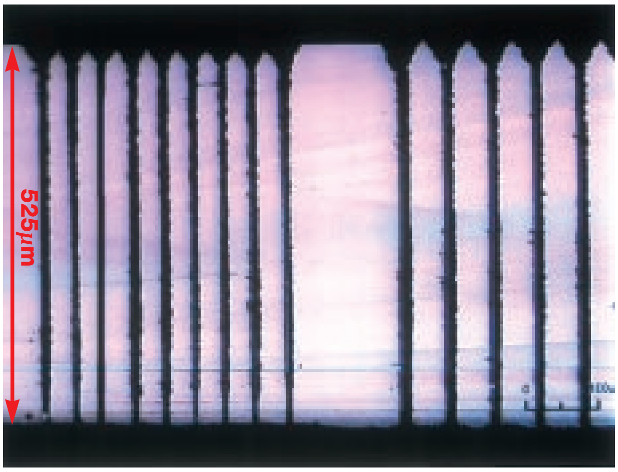


Fig. 1 Cross-sectional view of the through-holes

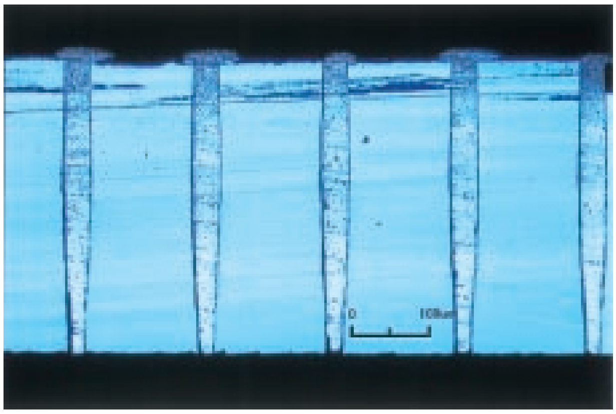


Fig. 2 Filling through-holes with tin by molten metal suctioning

3. Future Challenges

We would like to continue developing technologies for forming through-hole interconnections in silicon wafers. In addition, we hope to develop techniques for applying micromachine (MEMS) element technologies developed thus far to a wide range of semiconductor packaging and mounting fields.

Medical Applications for Micromachines Part 3

Iwao Fujimasa,
Professor,
National Graduate Institute for Policy Studies

The Quest for Minimally-Invasive Technologies and the Development of Micromachine Operating Systems

Today, we would be correct in saying that medical-use micromachines are currently in existence. Furthermore, efforts towards the implementation of minimally-invasive practices are currently taking shape in all fields of medicine, and in terms of medical applications for micromachines, these efforts are opening up a wide range of possible uses. When providing treatment as part of medical care, there is no alternative but to act in a way which is invasive to living bodies, and accordingly, it is often considered that the necessary invasive actions should be carried in full, whereas non-required invasive actions should be limited to a minimum. As a result, the number of invasive surgical operations will become fewer.

Around the same time as the Micromachine Project began, minimally-invasive surgery in which a laparoscope was used to perform remote operations was also started, thus realizing at last a tangible revolution in medical operation practices. The keyword in the achievement of this revolution was "miniaturization." In Japan, however, medicine in the same field has failed to reflect this fundamental transformation in operation practices. One of the reasons for this failure lies in the fact that the majority of medical appliances and tools were still imported from overseas; consequently, no domestic companies or corporations were capable of taking on the associated development work. In addition, whether considering the actual operating theatre or the industry in general, this field was hindered by a lack of appreciation and understanding of micromachines and the associated technologies. Nevertheless, the reason for this insufficiency is a simple one: in terms of device-usage methods, there was very little grasp of those mechanical systems which relied on manual dexterity and skill. Specifically, it was simply considered that such devices merely transformed operations which had traditionally been carried out by hand in such a way that they were now performed remotely through a narrow operating channel.

Medical-technology developers in other countries, however, did not share this opinion. Rather, it was felt that in this field in particular, surgical technologies should be re-established in the form of mechanical medical systems. Furthermore, in order that all surgical operations could be re-designed for minimally-invasive systems, there was a desire to determine which sections of living bodies could be adopted as targets for this approach; to determine in which way physical quantities could be measured; to determine how monitoring and observation would be carried out; and to determine the best possible operation methods. In terms of operations carried out via a small trocar, it would be necessary to configure a system for the measurement and control of living bodies using micromachines. In 1999, merely ten years since the first cholecystectomy using a laparoscope, the FDA approved two practical, remote-robot operation systems-namely, Zeus from Computer Motor and Da Vinci from Intuitive Surgical. Furthermore, simultaneous to the start of a wide range of minimally-intrusive operation practices in the US, Canada, and Europe, development also began on system development for coronary-artery bypass operations-a field of operations for which, although there is considerable demand, cases for practical implementation are few and considerable difficulties are felt to exist with regard to the implementation of remote-operation practices. Graft bypass operations on coronary arteries performed without an artificial heart and during which the patient's heart is still beating constitute anastomosis (or pump-off) procedures. The implementation of small micro hands which can also be fitted to beating hearts for arterial anastomosis, in combination with motion scaling of the movements of surgeons' hands, has led to the birth of a remote procedure for this type of operation. In this field, however, there is no classification between orthopedics and internal surgery: rather, the specific method of treatment of the disease or sickness in question is taken into consideration, and action is then taken by integrated medical teams using both robot operation systems and also systems for the planning and implementation of operations which use combined data from medical MRI, x-rays, and CT image devices.

With regard to the technical elements of a micromachine system for inclusion in this type of medical-operation device, a drive method will be necessary to generate a suitable level of torque for the required operations, and it will also be necessary to provide materials which are not harmful to living bodies. Furthermore, a requirement for re-evaluation of the design of these machines may arise based on information relating to viscosity, blood coagulation, and the formation of bubbles when working with liquids; based on information relating to sterilization, antibacterial agents, and other similar issues; and also based on a wide range of restriction conditions determined using said information. It is important to remember that the majority of systems now being put to successful use integrate these principles with combined, high-level medical expertise and knowledge of how to avoid the corresponding problems, and also with unique, industrial technologies.

Medical Micromachines and Gene Therapy

Many now wonder how medical micromachines may be used in terms of gene therapy-the mainstay of post-genome medical technologies. We can all envisage a medical-care environment in the near future where practical treatment will involve the determination of an individual's genes, the identification of any unique abnormalities in these genes, and the implementation of genetic methods precisely matched to said individual. However, it is currently possible only to identify specific disease genes, to load a virus or some other vector with the required genes, and to relay the corresponding genetic information to the entire body. Even if micro and nano-achining could be used to successfully create a DNA chip, genetic therapy will remain an unattainable dream without development of the necessary medical methods; accordingly, the limits of development in this field will restrict our ability to create tools for medical therapy.A post-genome era where all genetic information is fully understood and where the corresponding approach to development is clearly defined may arrive sooner than we think. And although it will then be necessary to identify the tissue or cells where the sickness is occurring, and to implement genetic operations only for that section, no effort is currently being made towards these goals. The reason: micromachine engineers are not present at this type of medical operation.

Even in terms of the localized application of drugs, no all-purpose technology currently exists, and as previously mentioned, it is now widely appreciated that the consolidation of data using future medical-imaging devices will allow the remote insertion of tiny injection catheters into organs, tissue, and cells. Accordingly, there is now a pressing need for the development, not of non-invasive, but of minimally-invasive technologies for the transmission of DNA or medicines to those specific areas where they are needed. For this reason, exciting possibilities are now offered by developments such as Georgia Tech's injection device-a device which employs countless micron-level needles in an area of several tens of microns square. In the near future, we may see a wide range of practical applications for minute catheters being conceptualized and refined in the operating theatre and other locations where medical techniques are implemented; furthermore, such developments would make today's cardio-surgery technologies seem similarly backward as those of a mere twenty years ago, when PTCA and EP catheters used for myocardial infarctions were not yet available. We need to appreciate the degree to which medical treatment will be changed by the arrival of methods which will allow specific locations to be targeted and operated upon in a mechanical fashion. We must appreciate also that these new methods and technologies were originally realized in the operating theatre and other similar locations.

When we view the current situation as described above, the fundamental technologies for the application of micromachines and nano-engineering to medical treatment can be considered as being already in existence. In order that a leading position may be achieved in this industry, it will be crucial for engineers with vision to be present in the operating theatre and other similar locations where medicine is practiced. Today, more than ever before, there is a pressing need for engineers to introduce into these environments all micro and nano-machining technologies which may be put to practical use.

TOPICS

Micromachine Seminars in Europe

Seminars were held in Helsinki and Athens as part of an industry trade mission dispatched to Europe by the Japan External Trade Organization (JETRO) from June 16 to 24, 2001. The seminars were organized jointly with local research institutions and organizations involved in the micromachine field in Finland and Greece. The objective of the two seminars, which are described below, was to disseminate information about micromachine technology in Japan and to provide opportunities at each location for interaction with specialists in this field.

Lectures by members of the Japanese mission

Speaker	Organization	Presentation Title
Takayuki Hirano	Micromachine Center	The Future Prospects of Micromachines
Haruo Ogawa	OLYMPUS OPTICAL CO., LTD.	Micro-Assembly Systems
Tatsuaki Ataka (Only in Finland)	Seiko Instruments Inc.	The Experimental Microfactory System in Japanese National R&D Projects
Shinichiro Kawakita	DENSO CORPORATION	Development of Autonomous Mobile Microrobots
Munehisa Takeda	MITSUBISHI ELECTRIC CORPORATION	Multiple Distributed Micromachine Systems
Masaya Kakimoto	Micromachine Center/ SUMITOMO ELETRIC INDUSTRIES, LTD.	Applications of Deep X-ray Lithography

1. Japan-Finland Summit Seminar

The Helsinki seminar was held on June 18, 2001 as part of the PRESTO program sponsored by Finnish National Technology Agency(TEKES). More than 110 participants enjoyed this grand event. Five presentations were made by representatives of Finnish private sector, including Nokia, and the National Research Center(VTT). The following day (June 19), visits were made to VTT, automobile sensor maker VTI, and Tampere University of Technology.

2. Greece-Japan Joint Workshop on Microsystems

This seminar was held at "NCSR-Demokritos",Greek National Center for Scientific Research, on June 21, 2001. Approximately 50 participants attended and Greek speakers made six presentations. The following day (June 22), visits were made to IMEL (Institute of Microelectronics) and IMS (Institute of Material Science).

With Greece-Japan Joint Workshop participants at NCSR-Demokritos

Application Deadline Approaching for the 9th (Fiscal 2001) Research Grant Themes on Micromachine Technology

The Micromachine Center, through the establishment and diffusion of basic technology in the micromachine field, aims to contribute to the growth of Japan's industrial economy and to international society. To this purpose, the center conducts studies and research in a wide range of fields involving micromachine technology, gathers and provides data, and in conjunction with micromachine-related organizations both within Japan and overseas, is involved in research exchange and collaboration, the diffusion of micromachine technology, and public education activities.

This research grant program has been offered every year since its inception in 1993. The program's purpose is to assist college and university staff engaged in basic research on micromachines, as well as to promote further development of micromachine technology and communication between academics and people in the industrial world. The program is being offered again this year and applications from researchers in micromachine-related fields are welcome. Prospective applicants should refer to the details below.

1. Objective of the research grant

Basic research on basic technology, functional element technology, and systematization technology for micromachines

2. Research period

Theme A: April 2002 - March 31, 2003 (1 year)
Theme B: April 2002 - March 31, 2004 (2 years)

3. Application period, theme decision, and funding grant date

Application period: July 10 October 31, 2001
(Valid if postmarked on or before October 31.)
Theme decision: Middle of March 2002
Funding grant date: End of March 2002

4. How to apply

Send a fax requesting an application form to the Micromachine Center. Be sure to include your own fax number or a fax number where we can contact you.

Micromachine Center Fax : +81-3-5294-7137

5. Qualifications

College or university faculties (professors, associate professors, lecturers, or research associates) who belong to any of the following societies or associations: Intelligent Materials Forum; The Japan Society of Applied Physics; The Society of Instrument and Control Engineers; The Society of Polymer Science, Japan; Japan Society of Next Generation Sensor Technology; The Japan Society for Precision Engineering; The Institute of Electrical Engineers of Japan; Japanese Society for Medical and Biological Engineering; The Japan Society of Mechanical Engineers; Japanese Society for Artificial Organs; The Biophysical Society of Japan; Japan Society of Drug Delivery System; Japanese Society for Biomaterials; The Robotics Society of Japan;Personal Computer Users Association; Micromachine society; Research Committee on Micromechatronics

6. Other

(1)Total funding granted: Approximately 10 million yen
(The upper limit for a single research project is ¥2 million for theme A, and ¥3 million for theme B.)
(2)After the grant is decided, we may ask recipients to carry out their research in collaboration with supporting member enterprises of the Micromachine Center, as one of the objectives of this project is to encourage communication between enterprises and academics.
(3)Contact: Research Department, Micromachine Center
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Tel : +81-3-5294-7131
Fax: +81-3-5294-7137
Contact Personnel: Mr. Hodono
E-mail: hodono@mmc.or.jp

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