# MICROMACHINE

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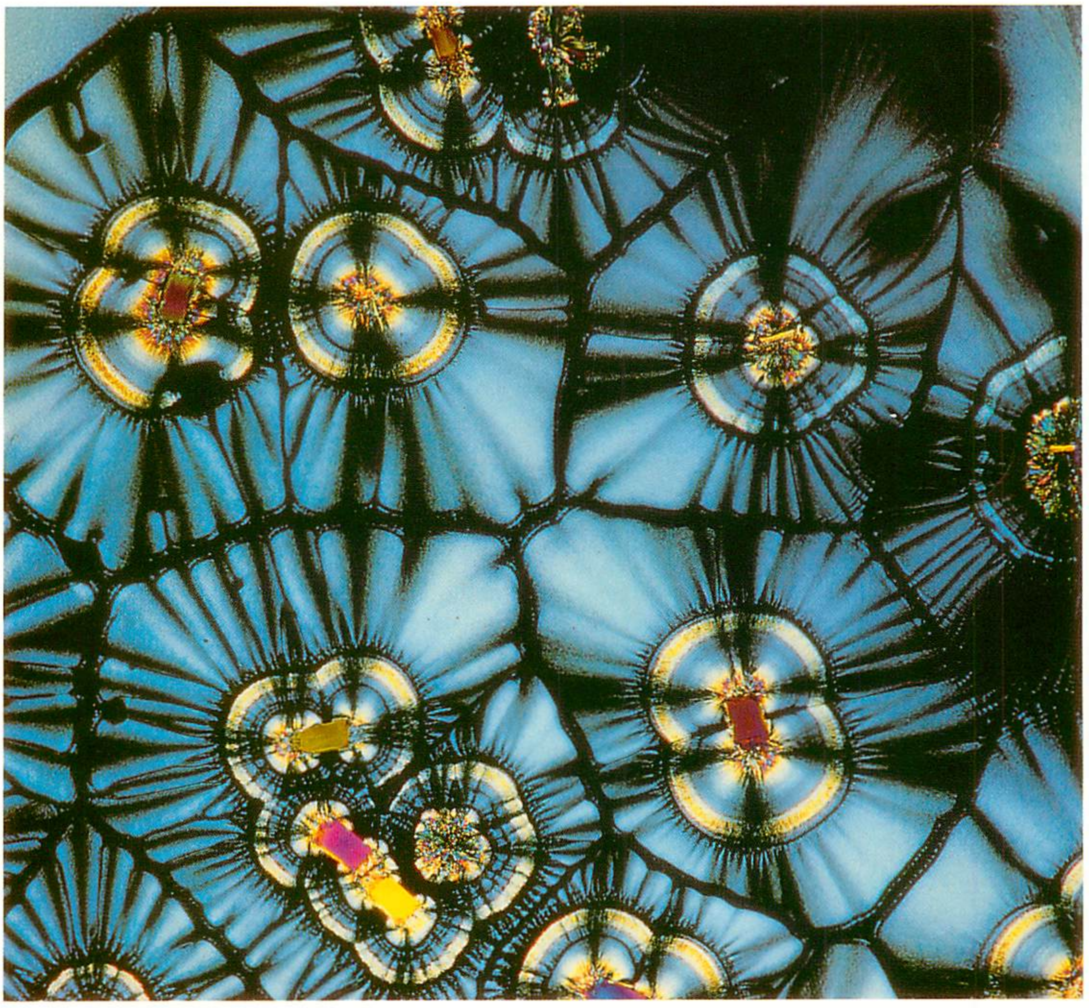


- Trends in Microsensor Technology
- Higuchi Project in KAST
- MMC's R&D Presentation / Evening Seminar
- Members' Profiles
  Seiko Instr. Inc. / Ford of Japan
- Topics, Events

Micromachine Center

# Trends in Microsensor Technology

**Isemi Igarashi**
Toyota Central Research
and Development Laboratories

## The Small Excels the Large

A proverb says that "the large must comprise the small." But in the world of micromachines, like semiconductors, it would be more apt to say that "the small excels the large."

The ultimate aim of the micromachine project, I think, is to develop a quasi minute insect that possesses functions similar to those of living beings and that can be controlled freely by human beings. Unfortunately this aim is easy to state but difficult to achieve.

Nevertheless, I think that the simulations based on hypotheses and suppositions have made it quite feasible to develop such a "quasi insect." Although means and values differ a great deal with the special fields, interdisciplinary studies are actively carried out for practical application of the "quasi insect." They include, for example, the approaches of machinery and precision engineering, applications of semiconductor processing technology, and uses in the field of medical biotechnology. Next, I would like to explain the means of approach, problems, and future issues.

## Superior Properties of Silicon

Silicon and the development of its microprocessing technology have been the driving force behind micro electro mechanical systems. Silicon exists in abundant supply, accounting for about one-quarter of the total amount of substances on earth, and causes no harm to either people or animals. Metallic silicon is the only element that can be mass-produced. High-purity crystalline silicon is essential for the electronics industry, being used in the production of integrated circuits, large-scale integration, and very large-scale integration, and fulfills an intelligent role in all industries.

The 256-megabit dynamic random access memory (DRAM), which will be applicable in the near future, possesses the capacity of storing the information contained in about one month's supply of newspapers in a size no bigger than a ¥100 coin. In terms of the amount of information that can be memorized, this technology has progressed at the rate of about four times in three years. Table 1 shows the development of performance from the vacuum tube (about 1945) to the germanium transistor (1957-1960) and VLSI (16 megabit DRAM).

Table 1 Trends in Semiconductor Devices

| | Vacuum tube | Ge transistor | VLSI (16M DRAM) |
|---|---|---|---|
| Approximate size | 130mmx45mmø | 7mmx17mmø | 8.2mmx15.5mmx0.7mm |
| Number of elements | 1 | 1 | 17,000,000 |
| Volume per element | 150 $cm^3$ | 0.5 $cm^3$ | $5.3 \times 10^{-9}$ $cm^3$ |
| Relative volume per element | $2.83 \times 10^{10}$ | $9.4 \times 10^{7}$ | 1 |
| Total power consumption | 10 W | 0.2 W | 0.4 W |

The progress of semiconductors over half a century has been truly amazing. Their volume has been reduced to about one-billionth and their power consumption to one part in several hundred millions. This is a triumph for science and technology, which have brought out and utilized the superior properties of silicon. The next step will involve application to micromachines.

## Development of Smart Micro Sensors and Actuators

The goal of developing micro versions of sensors and actuators has just about come into view, thanks to the enormous contribution made by the progress in microprocessing technology for semiconductors, as described above. However, the computer parts, which take charge of the information control, require huge apparatus. The images and photographs that appear on television or in publications almost all have been enlarged by individual sensors and actuators. The computers that maneuver these devices do not appear on the screen. Therefore, the measurements of the sensors and actuators tend to be mistakenly taken to be the size of the micromachine as a whole.

As shown in Figure 1, the micromachine (the ant) actually is connected to a computer and lead wires whose weight is several million times more than its own. Naturally, the micromachine suffers restrictions on its freedom of movement and has to constantly drag along lead wires that weigh several dozen times more than itself. It will be nearly impossible to reduce the size of the computer to that of the micromachine, so now it is necessary to develop a device that can carry out the whole series of work—detecting, evaluating, controlling, and acting. Minute insects move about in the natural world quite freely, without the use of any large computers; micromachines must reach this stage of development.

Simple examples of quasi minute insects include bimetal and positive temperature coefficient (PTC) thermistor. The PTC thermistor, which consists mainly of barium titanate, can detect temperature and control that temperature by emitting heat itself. The development of materials is the decisive factor in the creation of smart devices like this. It is necessary for us to develop materials that carry the functions of computers inside them. The fusion of sensors and actuators will be an important issue from now on.

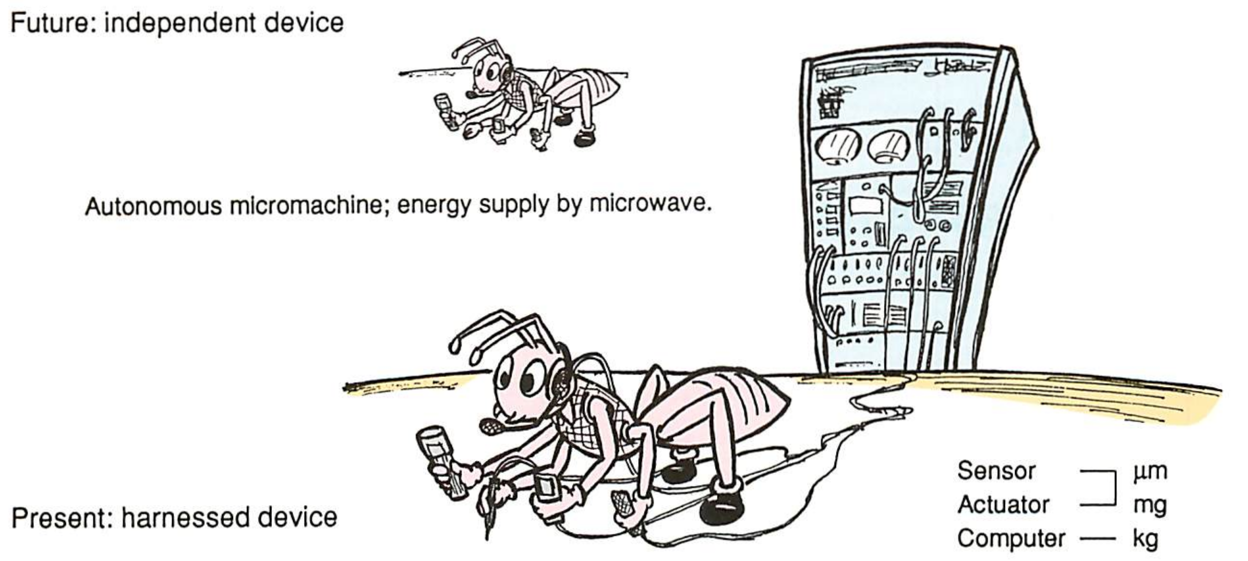


Figure 1 The Present and Future of Micromachines

## Creation of an Active and Autonomous Sensor

Conventional sensors are passive; changes in the sensing part are output as they are as changes in the sensor functions. Accordingly, to obtain information from blood, it is necessary to devise ways of eliminating the influence of the thin membrane, measuring several hundred angstrom, of the protein component, which is the sensitive part. Furthermore, measures to deal with the body's defensive reaction will be the key to ensuring the reliability of sensors that will be implanted in the body for a long time.

The development of this type of sensor has long been the dream of medical circles, but it has not yet been carried out. What is required is an active and autonomous sensor that uses a micro actuator to work on a body for a long time and with a high degree of precision in such functions as vibration, pressurization, heating, and medication so as to eliminate any factors of change or to detect and correct them. The absorption, transmission, and reflection of light using a laser beam would also be effective methods. I believe that, if today's advanced technologies in related fields could be brought together, the development of such a sensor would be well within the range of possibility.

## Will the Micro Actuator Become a Powerful Tool?

Five or six years have passed since the first rotation of a turbine with a diameter of less than 100 microns. In June 1993 Japan hosted an international conference called Transducer '93, at which foreign participants outnumbered their Japanese counterparts. More than a quarter of the reports were related to micromachines, and about two-thirds of the participants gathered for discussion in the night session. However, although some steps forward could be seen, there were almost no reports that cleared the hurdles. Papers on three-dimensional microprocessing through sensor integration or silicon-based mechanical quantity sensors were outstanding. But there seems to have been a lot of basic data, such as the many reports about chemical sensors.

One of the main problems concerns micro actuators. It is still uncertain how their functions of rotation and displacement can be used. To do the job, they need force. At the beginning we were asked by people in medical circles whether it would be possible to stitch together minute blood vessels. However, the thread required for the stitching had a much greater tension than expected. As long as existing micro actuators and conventional methods are used, therefore, the task seems to be close to impossible. Accordingly, it will be necessary to conduct research into new methods for joining blood vessels.

If the control of the amount of blood flowing through the minute vessels can be made more reliable and precise through microvalves and micropumps, I think that this project also could be extremely promising.

## Future Issues

The various fields, such as science, engineering, medicine, electronics, and biology, have commenced the pursuit of elementary technology related to micromachines in a scattered fashion. Their needs and objectives are diverse. Mutual cooperation among different areas of research will be an important key for enabling this research to proceed efficiently. And this cooperation should involve not simply the exchange of information at academic meetings but truly revealing exchange, including discussions among researchers about their failures. It is essential that younger researchers should be able to express their ideas freely. I think that public research institutes and senior researchers have a duty to provide such opportunities. In this regard, I believe that expectations in the Micromachine Center will further increase from now on.

# Higuchi Ultimate Mechatronics Project

## The Kanagawa Academy of Science and Technology

**Dr. Toshiro Higuchi**
Professor,
Faculty of Engineering,
The University of Tokyo

### 1. Overview of the KAST Research Project

The Kanagawa Academy of Science and Technology Foundation (KAST) was established by the Kanagawa Prefecture in July 1989. The headquarters and laboratories of this international high-level research and education organization are located at the Kanagawa Science Park in Takatsu-ku, Kawasaki City.

Ten KAST projects are currently underway, each having a life span of three to five years. Each project is conducted under the full discretion of the project leader and have typical budgets of one billion yen for a five-year project. The Ultimate Mechatronics Project, which I have led since its beginning in April 1992, is expected to end in March, 1997. The project staff currently numbers seven full-time researchers, thirteen researchers dispatched from private enterprises, five part-time researchers, and one clerk.

### 2. Ultimate Mechatronics Project

The targets of this project are to develop innovative mechatronics technology that contribute to industrial development, as well as providing useful tools for research in the fields of physics, biology, and medicine, thus contributing to the development of science as a whole.

At the use of extreme environments such as ultra-high vacuum, ultra-clean workspaces, cryogenic conditions, and high pressure are becoming widespread, the demand for the development of robots and automation equipment that can work in such environments is increasing. The Ultimate Mechatronics Project studies the applications of mechatronics in extreme environments, with special emphasis on ultra-high vacuum and cryogenic conditions. To date, research has been performed using non-contact flotation methods such as magnetic levitation and electrostatic levitation. For example, we have succeeded in levitating silicon wafers using non-contact electrostatic attractive force techniques. Additionally, we are also conducting research on piezoelectric elements suited for use under cryogenic conditions, and a precision positioning device that employs this element is being developed.

This project is also pushing the limits of various performance levels in mechatronics technology. For instance, in response to the demand for finer VLSI patterns and for the capability to observe atomic-order biological substances such as DNA, we are challenging the field of ultra-precision mechanics by developing ultra-precise positioning mechanisms and measurement technology with resolutions of nanometer or even angstrom order. Also under development are small ultrasonic motors to drive micro-robots and strong, yet highly efficient electrostatic actuators that act as artificial muscles.

### 3. Research on Micromachines

#### Electrostatic Actuator Research

To make effective use of static electricity in an actuation mechanism, electrodes with both large effective area and extremely fine patterns are required. It follows that we are developing an electrostatic motor with many fine electrodes formed inside a thin insulation film. It has been found that not only can an extremely thin actuator be created using two films, but multiple film layers can be employed as shown in Figure 1 to create an actuator structure capable of higher output power. Performances levels that exceed those of ordinary linear motors using magnetic fields have already been achieved. For example, force output that is 70 times the dead weight of the device can be obtained with this technology. We are now in the stage of solving various application problems, including manufacturing and driving technologies.

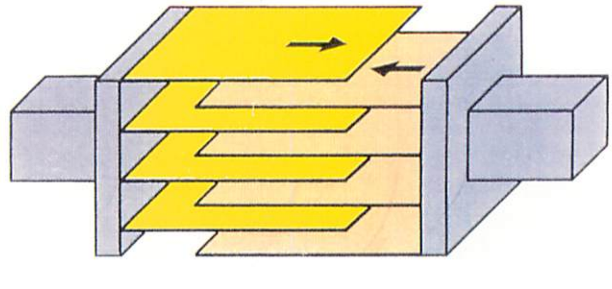


Figure 1 Multilayer Electrostatic Actuator

**Powder Handling by Electrostatic Fields**

For particles with small dimensions, the forces which are induced by electrostatic fields become more significant than frictional and gravitational forces. Currently, methods for transportation and selective separation of particulate powder using an electrostatic field on a manipulation surface are being developed.

**Ultrasonic Micromotor Development**

Since ultrasonic motors feature low speed and high torque, we are conducting research on motor structures for driving large machines, as well as developing an ultrasonic micromotor for micro-scaled robots and machines.

**Applications of Surface Wave Mechatronics**

Development of sensors and actuators using surface acoustic waves (SAW) is in progress. In this regard, we are conducting research on a liquid control micro-device, powder transportation device, and vibration gyro.

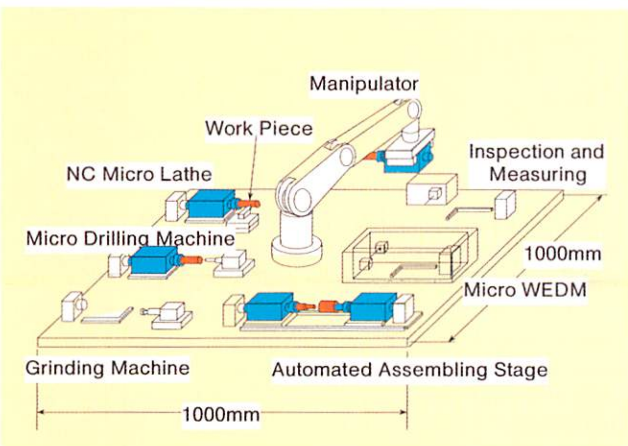



Figure 2 Desktop FMS

**Micromachining Research**

Although the fine machining process of semiconductor technology is currently being applied to the fabrication of micromachines, machining technology which incorporates micron and millimeter-order environments is required for part and die machining of 3-dimensional shapes using various metallic, plastic and ceramic material. Thus, we have created an ultra-precision machine controlled with a 1 nm positioning resolution in four axes. It will be used as a fine-machining research tool of turning and grinding techniques which are required for the fabrication of cylindrical micro-electrostatic actuators, micro-optical parts, grippers for micro-surgery and ultrasonic micromotor parts.

**Micromachine Production System Research**

The requirements of a flexible manufacturing system (FMS) for micromachines are intrinsically different from the FMS for normal-sized products. As the workpiece is extremely small and the machine tool itself both extremely small and light, we have developed a desktop FMS, as shown in Figure 2, and are now test-manufacturing the components.

**Microscopic Manipulation**

Tools used for cell manipulation and measurement of physical characteristics are under development. These include a manipulator incorporating piezoelectric elements, a cell membrane hardness measurement device, and a micro-injector system for automatically injecting DNA into nuclei.

**Development of 3-Dimensional Internal Observation Microscopy**

A 3-dimensional microscopic device which enables observation of the internal structure of micro-organisms or animal samples that have been frozen and embedded in paraffin has been developed. The device performs continuous observation of cross-sectional images which have been repetitively created by slicing off micron to submicron-order thin layers from the sample surface using a cutting blade. Using a computer system to reconstruct the successive cross-sectional image data, 3-dimensional and cross-sectional images of the sample can be viewed in a flexible manner as shown in Figure 3. Further development of a device with nanometer-order resolution will not only require optical microscopic technology, but also ultra-precision observation technology such a scanning tunnelling microscope. Additionally, mechanical technology capable of nanometer-order cutting capability will need to be developed further.

Figure 3 Image of a Tick Created from Cross-Sectional Sample Images

**Ultra-Precision Positioner Research**

The development of a positioning mechanism and resolving scale, which is based on the atomic image of a crystal surface observed by STM, is in progress. Also, research on a fine adjustment device using piezoelectric elements and thermal deformation is being pursued.

# MMC's First R&D Presentation

*Opening greetings by Seiuemon Inaba, Chairman, MMC*

The Micromachine Center's fiscal 1993 Micromachine Technology R&D Presentation was held on November 24 at Tokyo Ginza Gas Hall. This event was held to announce to the public the results of the research and development of the micromachine technology project as a part of the Agency of Industrial Science and Technology's Industrial Science and Technology Frontier Program. This was the first presentation event, and the presentations were centered on the objectives of the project and the details of research and development.

The presentation was crowded, with about 280 participants filling both the 1st and 2nd floors of the hall. The presentation began with an opening address by Dr. Seiuemon Inaba, chairman of the Micromachine Center, followed by the guest address of Dr. Chihiro Watanabe, deputy director-general of MITI's Agency of Industrial Science and Technology.

Then, Dr. Naomasa Nakajima, professor in the Faculty of Engineering at The University of Tokyo, gave his key lecture. Dr. Nakajima talked of the lead-in design method, an effective method in the research and development of basic and variable technology such as the micromachine technology. In the lead-in design method, the R&D is conducted by simulating the mechanical system, also including any technological elements not yet established at that point such as virtual technological elements.

Next, Mr. Hiroshi Kasai, director of the Industrial Science and Technology Frontier Program, gave a general lecture on the current status and future progress of the research and development of micromachine technology. He introduced six issues for the future: the search for application fields, establishment of evaluation techniques, issues when starting research on new technologies, issues on setting target figures, international contribution, and the cooperation of industry, government, and academia.

Lectures on the introduction and the current status of research on micromachine technology in national laboratories were then given by Dr. Yoshitaka Tatsue, director of the Mechanical Engineering Laboratory, Dr. Kunikatsu Takase, director of the Electrotechnical Laboratory, and Dr. Akira Umeda, senior researcher (on behalf of Dr. Yoshihisa Tanimura, Director of the National Research Laboratory of Metrology).

These were followed by lectures on virtual systems for industrial and medical applications, and structuring devices and element technology currently under development, by Chairman Mr. Hideharu Tanaka of the Micromachine Center's Research and Development Sub-Committee, and other section chairmen.

Research, as well as the technical innovations of micromachine technology, is without precedent. The micromachine technology itself is also a basic technology, and thus has very many issues yet to be solved. In this light, we decided to divide the research period into two phases. In the Phase I, we have assumed the "Advanced Maintenance System for Power Plant" to be the industrial application system, and the "Intraluminal Diagnostic & Therapeutic System" to be the medical application system. Research in the form of experiments and logical development is in progress to materialize the potential application of the technical methods of the micromachine system in component technology.

We introduced how, with the start of the micromachine project, we have made a general investigation of the current status of micromachine technology and surveyed domestic and overseas R&D trends in fiscal 1991. In fiscal 1992, we decided upon the direction of the research and development, and devised the assumed industrial application system concept to facilitate the effective and efficient progress of the project.

The presentations were mostly introductions of the technologies, rather than technological presentations, since the scope of the technology within this project is very wide and research on most of the technology has just started. However, the presentations were significant in that this was the first event to introduce the details of the overall micromachine project to the public. Participants were from diverse occupations throughout industry, so we were able to reconfirm how high the expectations are for micromachine technology in a wide range of fields.

Details of the presentations mentioned above are available in the draft collection, Micromachine Technology Research and Development Presentation (1993). Contact the Planning Department of the Micromachine Center to obtain a copy.

*Participants at the presentation*

# Report of Evening Seminar
## (The First and Second Seminars)

### 1. Introduction

As announced in the Event Information in the previous issue, an Evening Seminar is held every month, beginning in September 1993. In this issue, the contents of the first and the second seminars are introduced.

### 2. The First Evening Seminar

The first Evening Seminar was held on September 14 (Tue.), starting at 3:30 p.m. at the Sasakawa Hall and 65 people attended. The lecturer was Dr. Isao Shimoyama, associate professor in the Department of Mechano-Informatics, Faculty of Engineering, The University of Tokyo, who lectured on "Results of Research and Investigation on Microscience and Engineering — Mechanical Dynamics."

He emphasized the importance of recognizing scale effects in micronization. Because area is proportional to length squared, and volume is proportional to length cubed, if objects are made smaller in geometrical similarity, forces proportional to area, such as compressive strength and frictional force, are under relatively greater influence than forces proportional to volume, such as gravity. For this reason, he insisted, micromachines should have optimum microstructures which differ from traditional systems and structures.

Dr. Shimoyama suggested that to find these microstructures, the systems and structures of insects that have survived through natural selection are good models. As a concrete example of this idea, he showed an impressive movie in which artificial ants and butterflies, known as insect model robots, were made and manipulated.

During the question-and-answer period, the discussions ranged from technological questions of numerical values to debates on the usefulness of simulation and the concepts of micronization. The participants showed much interest.

*Participants talking with Dr. Shimoyama at the buffet after the first seminar*

### 3. The Second Evening Seminar

The second Evening Seminar started at 3:30 p.m. on October 20 (Wed.), at the Sasakawa Hall with 51 participants. Dr. Nobuo Omae, associate professor in the Department of Precision Engineering, Faculty of Engineering, Osaka University, gave a lecture on "Results of Research and Investigation on Microscience and Engineering — Tribology."

*Dr. Omae giving his lecture at the second seminar*

"Tribology" is a general term for lubrication, friction, and wear technologies and is an essential technology for creating highly reliable motion in micromachines. Tribological characteristics are greatly influenced by the forces acting between the surfaces, and the forces are very sensitive to surface conditions. The lecturer said the film of monoatomic layer in the order of angstroms adsorbed on the surface greatly changes the frictional force and wear loss.

Then Dr. Omae spoke about the microtribology in magnetic disc storage between the recording media and the floating head. He compared it with traditional tribology and referred to the possibility of applying it to micromachines. He also spoke about the influence of water molecules adsorbed on the surface of a solid and presented the most recent research data and the problems to be discussed in the future. The lecture covered matters seldom discussed in daily life, so many people listened with fresh interest.

Many members of the audience have actually struggled with the problems of tribology, and the question-and-answer session after lecture included a lively discussion with concrete examples.

### 4. Conclusion

After each lecture, the lecturer and participants enjoyed a buffet, during which the lecturer was asked questions which had not been done easily during his lecture. They chatted familiarly, exchanging new information on micromachines firsthand, and in this way an hour and a half passed too soon.

The Micromachine Center plans to continue the Evening Seminars as an opportunity to promote mutual understanding and friendship among people concerned with micromachines.

# Seiko Instruments Inc.

## 1. Introduction

Today, we visited the head office of Seiko Instruments Inc. (SII) in Makuhari, near Tokyo. This head office building was completed in June 1993 and everything is brand-new here. Geographically speaking, the building is in a corner of Makuhari new metropolis, adjacent to Makuhari Messe and Chiba Marine Stadium. The building has 26 floors aboveground and resembles an open fan. This building approaches how future office building should be, and various measures are tested here: "put out all lights in the building at 8 p.m.," which aims to make more efficient use of time and to encourage employees to live a more leisurely life: "installation of on-line network system" for more effective communication through an in-house local area network (LAN); "creation of conversation lounge" to facilitate communication among employees. There is even "a massage room" that employees can visit during working hours. As this is a company that manufactures watches, some of their measures are "conscious of time" and others "emphasize personnel as individuals." In this building, about 2,000 employees are working toward a goal of creating a business park out of accumulated "soft" technologies.

## 2. Characteristics of Technology Development (hi-tech based on watches)

SII was established in 1937 as a watch manufacturer. Since its foundation, the company has tried to increase the accuracy of mechanical watches. With the evolution of quartz watches and digital watches, they promoted electronization and have applied their precision processing technologies fostered through watch manufacturing to various fields, under the slogan "hi-tech based on watches." These fields include analysis and measurement instruments, such as fluorescent X-ray coating thickness gauges, FIB, and STM; computer-aided design (CAD)/computer-aided manufacturing (CAM) systems and computer peripheral equipment, such as color hard copiers; electronic components, including ICs, quartz oscillators, and small batteries; and machine tools, including internal grinding machines. SII also handles electronic dictionaries and ordering systems. Each new product results from employees being conscious of the 3Is in SII's company philosophy. The 3Is are

- Innovation of people and technology
- Interface between people, between people and technology, between people and society
- Instruments that offer affluence to people and society

*SII Head Office Building in Makuhari*

## 3. How to Tackle Micromachine Technology

A wristwatch is probably the smallest machine available to people for everyday use. Among its parts, some are smaller than 1 mm. What micromachines do is to make parts smaller and to create various devices. This is a field that coincides with the future direction of SII, which is a wristwatch manufacturer and has one of the world's most excellent processing technologies for precision machinery.

A watch motor is smaller than 10 mm and is designed to use a small amount of electricity to generate enough power to move the hands. Now an attempt is under way to make a smaller motor and at the same time to increase the power generated. More specifically, the research seeks to develop a high-torque motor that uses ultrasonic waves. We can see an example of this new watch in the showroom on the first floor. In this showroom, various products created by SII are exhibited, including a microrobot.

This microrobot has won many consecutive contests, and its excellence is widely known. This was the first time we saw it, and we felt as if it was a toy rather than a machine because it was only 1 $cm^3$ in size. Only after we actually operated the microrobot and made it go forward or turn did we really understand that it was a robot. In addition, SII conducts research related to micromachines, such as research on processing technology for three-dimensional micro structures, development of microsensors, and research on the world's smallest motor.

We left the SII head office in Makuhari with a feeling that offices and working spaces in the 21st century would be something like this, after having actually seen a microrobot moving in a modern building.

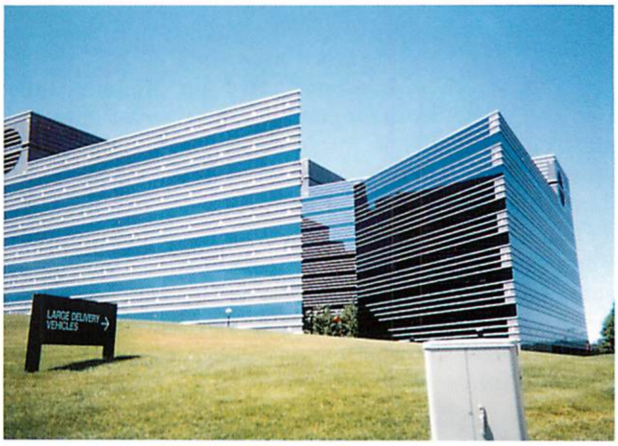
# Ford Motor Company (Japan) Ltd.

## 1. Introduction

In this issue, we will introduce Ford Motor Company (Japan) Ltd., a general supporting member of the Micromachine Center. Ford Motor Company (Japan) Ltd. (Ford of Japan) has its head office located in Minato-ku, Tokyo. Ford of Japan was established mainly to sell Ford cars in Japan but it also includes many other Ford organizations. Among these is the Ford Technology Development Laboratory (FTDL) located near Kanagawa Science Park.

We visited FTDL which has just recently begun its activities and is the organization of Ford of Japan directly connected to the Micromachine Center.

FTDL is a part of the Ford Electronics Division (ELD) in the United States and is one of ELD's technology bases in Japan. Our introduction to FTDL will center on its role in Japan and the development of micromachine products in the United States.



*Technology Department of ELD*

## 2. The Role of FTDL

Ford Motor Company develops and produces many of the components necessary for automobile assembly. The Automotive Components Group (ACG) of Ford, based in Dearborn, Michigan, is in charge of these activities and has five divisions. ELD is one of the ACG divisions and is in charge of the development and production of automotive electronics including powertrain, vehicle controls, audio and driver information, and safety electronics. The building shown in the photograph is a state-of-the-art "intelligent" building, which houses a part of the technology department of ELD.

Although Japan's automotive industry is at a turning point, there are still many areas of the industry's advanced electronics technologies which are of interest. It is because of this that FTDL was established as a base for Ford to observe technology developments in Japan.

One objective of FTDL will be to actively participate in academic conferences or activities initiated by research organizations and to learn advanced technologies while representing Ford in Japan. At the same time, FTDL will be developing specific technologies by making the most of the regional features and advantages of Japan.

## 3. Micromachine Technology Development in the U.S.

Element technologies and components required to develop products at Ford are procured from both within and outside of Ford. The same is true for such devices as sensors and actuators that use micromachine technology.

Ford Microelectronics, Inc. (FMI), located in Colorado Springs, Colorado, is in charge of micromachine devices within Ford. There, they undertake the development and production of micromachine devices by means of bulk and surface processing method. All the related technology resources of Ford are available there. Although they currently supply only Ford, in the future they may carry out their development and production to supply components and products to other companies.

In Japan, research and development activities for technologies related to micromachines involve many approaches, some of which are different from those used in the United States. Because of this, FMI and FLD are very interested in micromachine research and development in Japan. This makes micromachinery a suitable research area for FTDL since it is a technology that asserts Japan's regional features and advantages.

## 4. After the Interview

We now understand how Ford is learning advanced Japanese technologies through FTDL and expecting further technological developments in this specific field.

The Micromachine Center wishes to be of service for the international promotion of technological developments related to micromachine technology and to cooperate with foreign organizations like Ford on its technological developments.

## ★ TOPICS

## Visit of the JTEC/WTEC Mission

The American mission visited our Micromachine Center (MMC) in September 1993 to investigate the status of micro electro mechanical systems (MEMS) in Japan. This mission was supported as one of the Japan Technology Evaluation Center (JTEC) projects. JTEC is mainly funded by the National Science Foundation (NSF) and was established in 1983 to compare and investigate American and Japanese technologies through joint study by American universities, private enterprises, and government agencies. These studies have been published as the JTEC Report.

The main objective of this visit was to investigate micromachining technology. There were ten members in the mission which visited some 20 organizations during their one-week stay, including the MITI's Office of ISTF, national research laboratories of the MITI's Agency of Industrial Science and Technology, MMC, and private enterprises which are the supporting members of MMC.

These visiting members queried MMC on such processes as how multiple private enterprises shared a research theme (this is also a national project of MITI), how the participating enterprises were chosen, and how the results were evaluated. Our responses to these questions were (1) MITI's Agency of Industrial Science and Technology presents the objectives, duration, budget, scale, etc. of the project, (2) New Energy and Industrial Technology Development Organization (NEDO), an affiliated association of MITI, invites public participation, which is answered by (3) presentation of the development plan by private enterprises and organizations that desire participation. Later, (4) NEDO chooses the private enterprises and organizations to participate in the project. (5) The Agency of Industrial Science and Technology evaluates the results after the five years Phase I of the project.

In mid-November after the visit, JTEC held a workshop on the results of the investigation which is presented in the report.

## IARP Workshop on Micromachines Held

The IARP (International Advanced Robotics Programme) workshop on Micromachine Technologies and Systems was held in Tokyo from October 26 to 29, 1993. IARP is one of the programs for international research cooperation on high technology, which focuses on high-tech industrial robot technology. In 1992, Japan started the MITI's project "Micromachine Technology" after the project on ultimate work robots, and announced the holding of a workshop on micromachines. Following this announcement, the workshop was held last autumn. A total of 130 participants from 13 countries attended the workshop. The opening day on Oct. 26 featured a laboratory tour to the Tsukuba Science City, which included the Tsukuba Research Center of Yaskawa Electric Corporation, the Mechanical Engineering Laboratory, Electrotechnical Laboratory, and National Research Laboratory for Metrology of the Agency of Industrial Science and Technology. Participants were given details on the research underway, shown around the laboratories, and discussed about their researches. The results of research and R&D systems of various countries were presented in 21 lectures in Tokyo on Oct. 27 and 28. The Micromachine Center also gave six presentations. On Oct. 29 another technical tour visited Fanuc Ltd. at the foot of Mt. Fuji, where presentations of the research and tours of the laboratory were given.


## Overseas Visitors

We were honored by the visit from Prof. Dr. R. Hütter of Eidgenössische Technische Hochschule (ETH) of Zürich, Switzerland in mid-November 1993. ETH is planning to begin the Micro Systems (and Nano Technology) project in 1996. We introduced the activities of the Micromachine Center.

In early December 1993 we also welcomed the visit from G. N. D. Guild, president of the Micromachining Technology Center Ltd.(MTC) at Saimön Fraser University in Canada. The MTC has special interest in medical applications. It is an organization, much like MMC, that provides research and development services to Canadian enterprises engaged in micro electro mechanical systems, and enables innovative product development without requiring special investment in facilities or technical expertise. We established a close professional relationship with MTC, especially regarding the exchange of information.

# EVENTS

## Decisions on Regulations, Personnels, etc. for Federation of Micromachine Technology

The Federation of Micromachine Technology was founded in April 1993 with 29 members who are representing micromachines of various fields. Proposed regulations for this federation have been reviewed by each member since then. On October 13, 1993, Operations Council of the Federation was held in Nagoya-City and proposed regulations were approved and established as they are and related officers were also been named. Further, proposed admission of new members was approved.

**1. Officers appointed**

Operations Council
- Chairman:
  - Dr. Hiroyuki Fujita
- Councillors:
  - Dr. Naomasa Nakajima and 29 others (One councillor representing each regular member organization)

Board of Directors
- Executive Director:
  - Dr. Hiroyuki Fujita
- Directors:
  - Dr. Iwao Fujimasa
  - Dr. Toshio Fukuda
  - Dr. Naomasa Nakajima
  - Mr. Takayuki Hirano

**2. Newly admitted members**

- Japan Society of Mechanical Engineers:
  Dynamics, Measurement and Control Division
- Nagoya Industrial Science Research Institute:
  Mechatronics Research Committee
- Foundation for Promotion of Advanced Automation Technology

Due to the formal decision on regulations, officers, etc., it is expected that more and more constructive activities of Federation of Micromachine Technology such as sponsorship, cosponsorship and support of seminars or symposium relating to Micromachines will be promoted.

Note: Secretariat Office of Federation of Micromachine Technology

c/o Micromachine Center
3rd Floor Sanko Bldg.
3-12-16 Mita, Minato-ku, Tokyo 108
Tel. : 03-5443-2971
Fax.: 03-5443-2975

## Evening Seminars

The Micromachine Center holds an Evening Seminar every month to increase mutual understanding and friendship among the industries, government authorities, and universities concerned with micromachine technology. In 1992, as entrusted by the Mechanical Social Systems Foundation, the Center conducted "Research and Investigations on Basic Technologies of Micromachine Systems." This fiscal year, to introduce the results of the research and investigations on seven subjects in microscience and engineering, material technology, design technology and control technology, the chief researchers of each subject will give a series of lectures as follows:

**Date and Time:**
Third Wednesday of each month from September 1993 (subject to change)
Two hours from 3:30 p.m. (question-and-answer period included)

**Place:**
Conference room at the Micromachine Center or another conference room (Buffet after the lecture)

**Subjects:**
February 16, '94:
Materials for Industrial Actuators····
Koji Ikuta, Associate Professor, Department of Computer Science and System Engineering, Kyushu Institute of Technology
March '94 (tentative):
Control Technique····
Yoji Umetani, Professor, Department of Control Information Engineering, Toyota Technological Institute
(Lectures for subsequent months are not yet decided.)

**Participation Fee:**
Supporting members ····¥2,000 per person
Non-members ····¥5,000 per person
(Buffet and tax included)

**Application and Reference:**
Research Department, Micromachine Center
(Ms. E. Fujii and Mr. H. Narumiya)
Sanko Building, 3rd Floor, 3-12-16 Mita, Minato-ku, Tokyo
Tel: 03-5443-2971 Fax: 03-5443-2975

## Invitation to Join the General Supporting Membership

The Micromachine Center (MMC) was established on January 24, 1992, with the approval of the Minister of International Trade and Industry. Its objective is to promote the dissemination of micromachine technology in Japan, and contribute to the development of Japan's industry, economy, and the advancement of international communities.

MMC would like to invite your interest and support for its projects and activities—and call for your direct support through membership in MMC itself.

Membership privileges include:

1. Participation in surveys and research undertaken by MMC, and use of the results.
2. Use of delegated survey, research and development results not classified as secret.
3. Participation in study groups and other activities of the center.
4. Use of MMC's data bank.
5. Receipt of publications.

Membership requires an initial payment of ¥ 4 million and annual dues of ¥ 2 million.

For further information, please contact the General Affairs Department of the Micromachine Center.

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