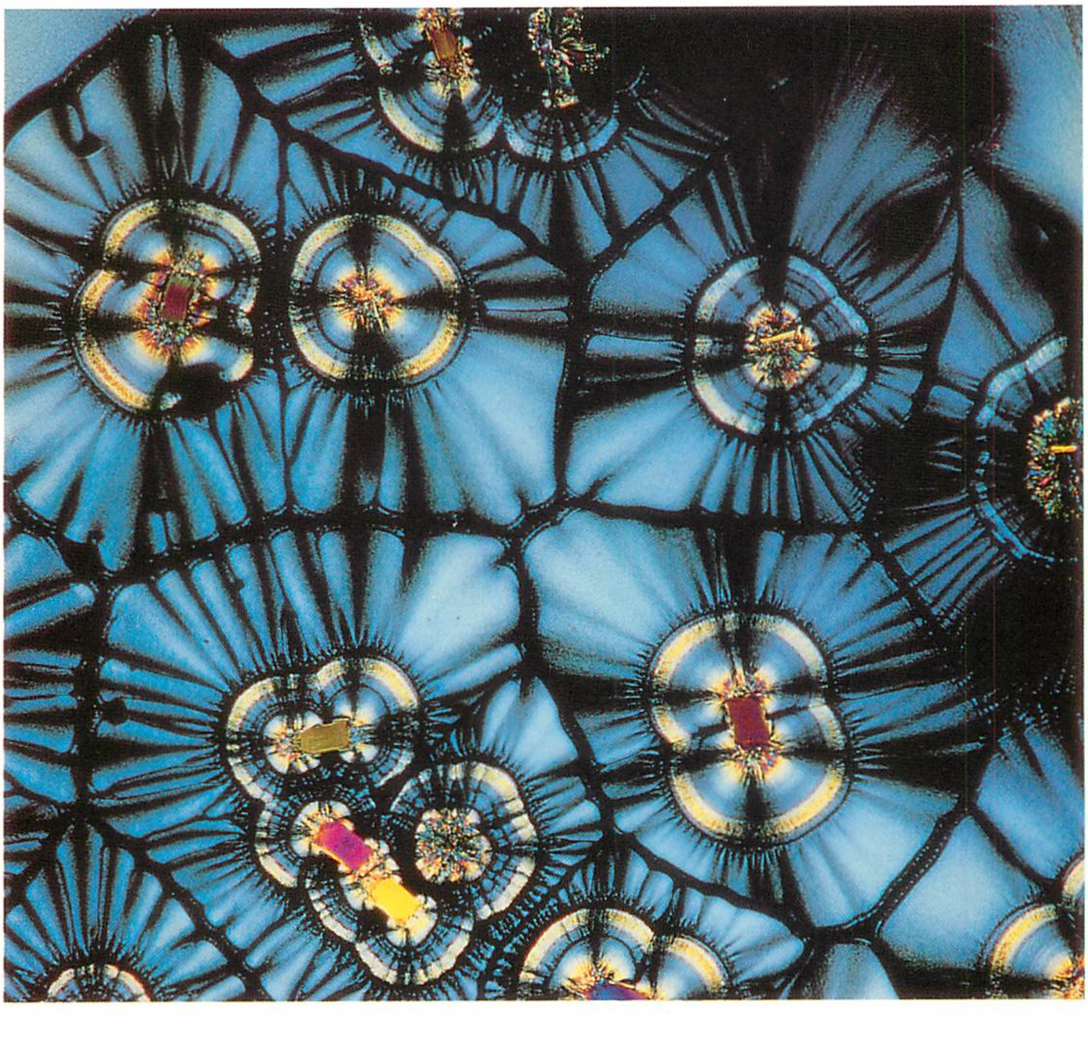
MICROMACHINE

July 1993 No.3



Micromachine Center

ESSAY

Let's Not Forget the Smallness of Micromachines

Keiko Nakamura
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The Meaning of Micromachines

Since about a year ago I have been taking part in a study group that goes by the name of "Butterfly's Dance." The aim of the group, which consists of such people as biologists, insect photographers, computer experts, and mechanical engineering specialists, is clear: To investigate the relationship between the elegant fluttering of butterflies and the structure of their wings, with images of the Japanese children's song "Butterflies Fluttering in the Rape Field" in mind.

A butterfly's wings are said to have several tens of thousands of scales. Perhaps these scales have some kind of relationship with the movement of the wings? We agreed to commence our study by making a videotape of the movement of butterflies and analyzing it. When we looked at the completed video, however, we realized how ludicrous it was simply to say that butterflies flutter. We only examined two types of butterfly—the swallowtail and cabbage white—but it soon became apparent that wing movement differed not only by species but also by individual butterfly.

On reflection, this phenomenon is quite natural. Human beings walk differently even though they all have two legs, so it is wrong to conclude that butterflies all fly around in the same manner. They differ according to each individual butterfly's characteristics and probably also according to subtle changes in the environment at the time. Butterflies no doubt are affected by changes that are almost imperceptible when viewed from the height of human beings.

Similarly, while micromachines themselves have to be very dexterous, the influence of the environment in which they are used is also extremely large. Accordingly, the study of living creatures suggests to me that the basic quality required of micromachines is the ability to accurately understand the surrounding environment and respond to it swiftly.

Basic Structure of Living Creatures

Let us examine the various characteristics of living creatures by looking at their structures and functions. Needless to say, the first thing that comes into mind is the cell. The theory that the cell represents the fundamental unit of living creatures was put forward in the nineteenth century, but with the steady advance of biology since then it seems to have become a little stale. Instead, a more contemporary view holds that living creatures are vehicles for genes. Research into genes, and particularly DNA, has made tremendous progress in recent years, and indeed the more understandable genes become, the more attractive they seem.

For example, let us consider viruses. In the past viruses were discovered as the source of disease and in the field of biology were considered to be uninteresting and rather peculiar things that could not be defined as either living or nonliving. Nowadays, however, viruses have come to be seen as the carriers of genes that sometimes even play a leading role in the working of the ecological system. Usually DNA changes through mutation and rearrangement within a vertical linkage between parent and child, but viruses can jump from type to type. (Actually I am writing this manuscript with a splitting headache brought on by an influenza virus, so please excuse the poor quality—the virus is to blame. Maybe this virus passed through a pig's body at some time.) In other words, since viruses have the ability to move genes horizontally, it is possible that they are doing something that we cannot do—shuffling DNA.

In view of this and other examples, it cannot be denied that the movement of DNA is dynamic, interesting, and attractive. When we look carefully at the conditions in which DNA works, however, we see that it is only able to do any spectacular work when it exists within a cell. When the conditions for the DNA's work are provided in a test tube (in vitro), it produces only a little protein—and when you think about it, this is only because some of the basic qualities of a cell have been created artificially.

So to gain a proper understanding of DNA, I think it is important for us to take our eyes away from the flashy activities of DNA itself for a moment and to concentrate our attention on the cells that support its work. I think it is true to say that cells represent the starting point for micromachines, in that they respond accurately to changes in the environment and function

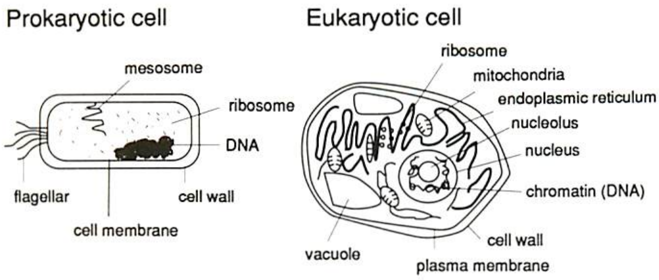

Figure 1 Prokaryotic and Eukaryotic Cells: Eukaryotic cells are larger and more complex and can join together to create multicellular creatures.

extraordinarily well. Looking at the situation from the standpoint of pure biology, as I do, the attraction of cells seems to stand out more and more, so let us turn now to a brief explanation of cells.

Prokaryotic and Eukaryotic Cells

So far I have talked only about cells in general, but actually there are two types of cell with different basic features: prokaryotic and eukaryotic cells. As Figure 1 shows, these two types of cell completely differ in terms of both size and structure.

Prokaryotic cells are single-cell organisms like bacteria. In other words, one cell equals one organism. The ancestors of prokaryotic cells first appeared on earth about 3.5 billion years ago, since when several thousand types of such cell have been born. However, the activities of single cells, needless to say, are limited. In order to cover everything with a single cell and to respond to various environments, prokaryotic cells acquired the ability to metabolize various substances. When we consider this metabolism or chemical reaction, we certainly have to admire the abilities of prokaryotic cells. Some of them are good friends who quite matter-of-factly metabolize such substances as cyanogen and mercury, which are deadly poisonous to human cells.

When prokaryotic cells are viewed as machines, however, they are almost all shaped like a sphere or a rectangular parallelepiped, or at best a spiral. They are capable of moving around only by means of surrounding threads (the artificial reproduction of such cells would still be an extremely difficult task, though).

When it comes to eukaryotic cells, the picture changes completely. When did eukaryotic cells first appear? Fossils and other evidence suggest about 1.5 billion years ago. Eukaryotic cells are thought to have evolved when small cells entered larger prokaryotic cells, and the cell companions cohabited, as it were, and developed new functions. The mitochondria that exist in eukaryotic cells, serving as small organs that produces energy efficiently by making use of oxygen, are thought to have been small cells originally. In other words, the existence of oxygen and the birth of a cell to make use of this oxygen can be said to have created a new eukaryotic cell.

As you probably have noticed, it took 2 billion years from the birth of life to the appearance of eukaryotic cells and 1.5 billion years from the creation of eukaryotic cells to the birth of humankind, so the distance between prokaryotic cells and eukaryotic cells can be said to be wider than the distance between single eukaryotic cells and human beings. (Amoebae are an example of single eukaryotic cells living today.)

The living creatures that we see around us—human beings, dogs, whales, elephants, cherry trees, lilies—consist of nothing other than eukaryotic cells. Basically these cells measure about 10 μm (although they vary a lot; nerve cells, for example, stretch for several meters). In the human body, there are no more than about 200 different types of cell. It probably surprises you that human beings can do so much with just 200 types of cell, which seems few compared to the number of component types in a machine. Moreover, these 200 types of cell are all eukaryotic. Although these cells appear extremely small when viewed through ordinary senses, as microsystems they actually seem quite large.

First of all, the fact that, as I explained above, an efficient system of oxidation was essential to supply these cells with sufficient energy indicates the difficulty of meeting the conditions for turning this size into a basic unit. In addition, eukaryotic cells contain a structure called the cytoskeleton, which cannot be found in prokaryotic cells. When it comes to the movement of substances within the cell, too, simple diffusion does not suffice for this size. Roads are necessary to carry necessary things to necessary places. The cells therefore have a highway network that is much denser than that of major cities but nonetheless functions without any congestion.

In view of these aspects, it can be understood that 10 μm is actually very large when considered in terms of a microsystem that responds to the environment and functions properly. Of course, existing machines and our ordinary senses tell us that 10 μm is quite small enough. Even as far as micromachines go, this size is probably a little too small. As I explained at the beginning, however, it is essential for micromachines to exert substantial influence over small changes in the environment that are imperceptible in our daily lives. I think that studying the structure and functions of cells, which perform so wonderfully well in responding to the environment, provides an excellent opportunity to remember something that tends to be forgotten in the one-sided process of producing machines.

H. Fujita Laboratory, Institute of Industrial Science, The University of Tokyo

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1. Micromechatronics

Our laboratory is studying micromechatronics using micromachining based on semiconductor IC technology. The goal of micromechatronics is to make a system which combines the mechanical elements and electric/electronic elements at the micro level. Such a micro system is called a micro electro mechanical system (MEMS).

We are taking three basic approaches to MEMS research:

① Study of microactuator and other element devices and their application,
② Study of micromechatronic system architecture and control method, and
③ Study of micromachining.

Other fields are being studied jointly with other seven laboratories belonging to the "Micromechatronics Research Group" in the Institute of Industrial Science. For example, the study of mechanical micromachining is lead by Professor Takahisa Masuzawa in Mechanical Engineering Division, and the atomic-level, superprecision mechatronics, by Associate Professor Hideki Kawakatsu in Mechanical Engineering Division. In the future, we hope to establish an integrated system which would include atom manipulation, MEMS, miniature machines, and microscience and engineering as fundamental studies.

2. Outline of the Laboratory

The Institute of Industrial Science is located in Roppongi, the cultural center of Tokyo. The Institute is a place for creation and exchange of advanced technological information. Fujita Laboratory of the Institute is engaged in activities including international exchange. Currently, the Lab staff consists of 10 members led by Technical Official Manabu Ataka and includes four graduate students, one foreign postdoctoral researcher (a graduate of the University of California Berkeley), and two joint researchers from corporations.

Our process facility focuses on semiconductor micromachining, and is capable of the total process from mask design through micromachining, observation, and evaluation, excluding mask manufacturing and depositing of polycrystalline silicon and nitride film.

The most important goal in managing the use of facility is to achieve the maximum degree of freedom and the shortest time of process. Fortunately, our activities are limited to micromachining with little possibility of contamination, so we are able to perform vapor deposition and electroplating of various metals, including gold, as well as etching with KOH solution. We can also make electrostatic actuators in 1-3 days through "surface micromachining using a single mask," which starts with a wafer coated with an oxide film and polycrystalline silicon film on a silicon substrate. Such a system is very important as it allows an idea to be tested immediately and improved as appropriate. In Japan and overseas, too much equipment sometimes creates too many restrictions, which can limit the range of studies.

3. Research Themes

3.1 Devices and their applications

We make microactuators that are driven by electrostatic force, piezo effect, repulsion and electromagnetic force between superconductors and permanent magnets, and thermal expansion.

A typical microactuator using electrostatic force is a comb-shaped electrostatic actuator. This is a 2-4 μm thick silicon thin film, processed by anisotropic etching using plasma, to open a 0.2-1 μm gap and make the interdigiting comb-shaped electrodes of the fixed part and the moving part. It can be moved 3-7 μm by applying approximately ten volts. The moving part is supported from four sides by long, thin beams 2 μm wide and 200 μm long, and is suspended about 2 μm above the substrate. In order to obtain a submicron gap, special attention was

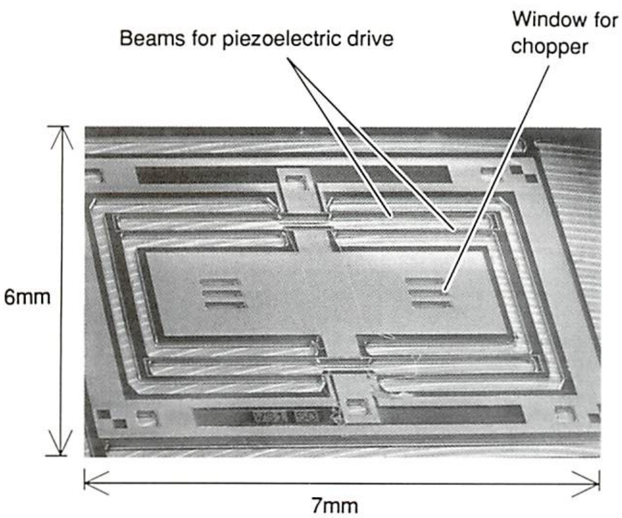


Fig. 1 Quartz Optical Chopper

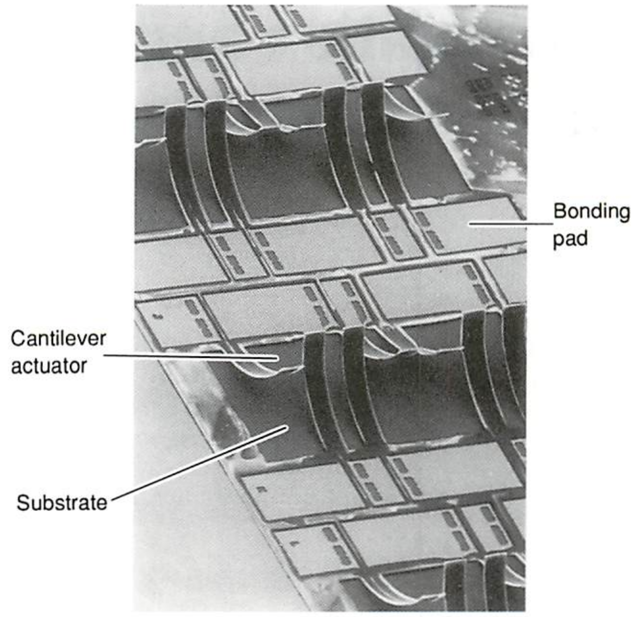


Fig. 2 Artificial Ciliary Actuator Array

paid to precision control of patterns and the development of the new process of adjustment and fixture of the moving part after releasing.

An example of a piezoelectric microactuator is the optical chopper with quartz microstructure shown in Fig. 1. This monolithic microchopper utilizes the transparent nature, piezoelectricity, and micromachinability of the quartz. It is also small enough to fit within a 5mm X 5mm square.

In addition, we have developed various application devices including a monolithic tunnel current unit (0.5mm X 0.5mm square) which moves in parallel to the substrate surface, and superconductive magnetic levitation microactuator which operates in a vacuum.

3.2 System architecture

The advantage of MEMS is not its small size alone, but also the fact that "a number of elements with integrated sensors, electronic circuits, and actuators can be manufactured simultaneously." To take full advantage of this fact, we are proposing a parallel coordinated micro motion system. Just as a number of ants, with each individual moving autonomously, can cooperate to carry a large piece of food, a number of smart microsystems are arranged so that they can perform a task while communicating with and assisting one another. This is a micro version of the autonomous distributed system, a new system concept that has been attracting considerable attention recently.

Currently, we are studying the method of system configuration and control and the development of actuators suitable for parallel coordinated movements. Fig. 2 is an example of such an actuator, the artificial ciliary actuator.

3.3 Micromachining

The processing method plays an important part in micromechatronics. Currently, our laboratory can successfully process silicon, quartz, polyimide, metal, and other types of materials. Fig. 3 shows a nickel electrostatic micromotor developed jointly by IBM Research, Tokyo Research Laboratory and our laboratory. The rotor, which is only 120 μm in diameter and 7 μm thick, can rotate at 10,000 rpm, driven by electrostatic force.

There are many other research themes not mentioned in this article. If you happen to be in the Roppongi area, please stop by our laboratory to see our work for yourself.

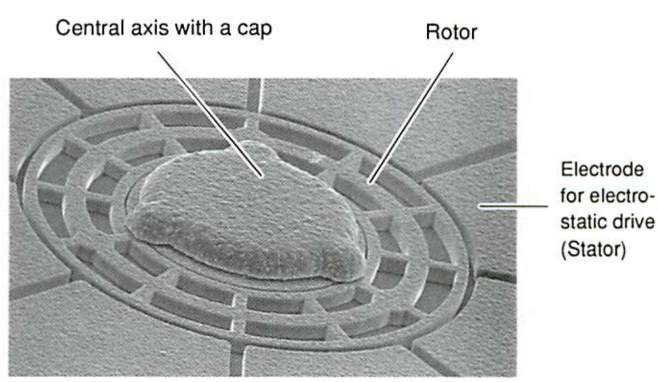


Fig. 3 Nickel Electrostatic Micromotor (120 μm in diameter, 7 μm in thickness)

Investigation and Research Activities of the Micromachine Center

—Independent Activities (Part 2) —

In order to advance research and development of micromachine technology and disseminate its use in various industrial fields, the Micromachine Center (MMC) has been conducting The Industrial Science and Technology Frontier Program, "Micromachine Technology" delegated by the Ministry of International Trade and Industry's Agency of Industrial Science and Technology. The MMC is independently investigating fundamental problems in this field and is studying the current state of R&D and technological applications of micromachines in Japan and abroad.

1. Investigation and Research Concerning Fundamental Technology

Research on micromachine technology has only a short history and poses many problems that cannot be clarified by a simple extrapolation of traditional technologies. To establish basic micromachine technology, fundamental studies such as an understanding of the characteristics in the micro environment and the employment of new theories and ideas are of importance.

The illustration at right shows the technological items necessary for the development of micromachine technology and the fields in which it is to be applied. The Agency of Industrial Science and Technology of MITI has approved the items shown in this project. The Micromachine Center is conducting the project, and to strengthen the basis of the technology, has now begun to find and evaluate new technological "seeds," discover promising new ones, and cultivate them in cooperative industry-university research programs.

Four fields will be highlighted in fiscal 1992:

(1)Micro Science and Engineering

(a) Tribology: Tribology in the mesoscopic area is one factor essential for the practical and reliable application of micromachines; the current state of research in this field will be investigated, and new technological seeds will be verified experimentally.

(b) Mechanical dynamics: With the micronization of mechanisms, the dynamic relations between these mechanisms and the environment change dramatically. Mechanisms appropriate for micromachines will be investigated from the viewpoint of dynamics.

(2)Materials

(a) Materials for microactuators in industrial use: The characteristics and processing methods of various actuator materials suitable for micronization will be investigated and examined experimentally and theoretically. New technological seeds will be sought.

(b) Materials for microactuators for medical use: Conditions required for actuators and their materials in medical use will be analyzed, and promising technological seeds and aspects worthy of further research will be clarified.

(c) Biocompatible materials: The interaction between blood or soft tissue and the material and design of a surface structure will be investigated. Minimization of biological reaction and assurance of a fixed period of functioning of the micromachine will be accomplished by developing biomaterial design and related research items.

(3)Design

(a) Design theory of micromachines: Investigations will be made of the analysis of the scale effect in micro- mechanisms, dependence on the environment, and design examples. The differences from the designs of traditional machines will be manifested and actual methods and problems will be presented.

(4)Control

(a) Intellectual control of micromanipulator: The special nature of the operating conditions of micromanipulators for micromachines will be considered, investigation made into the necessary element technology, and the aim and potential problems in the intellectual control system identified.

2. Building a Micromachine Technology Data Base

For the smooth progression of research in The Industrial Science and Technology Frontier Program, "Micromachine Technology" by MITI's Agency of Industrial Science and Technology and projects related to micromachines by other institutions, and to stimulate the use and dissemination of the results, the Micromachine Center is pursuing the following research in its ordinary course of work with the goal of building a micromachine technology data base.

(1)Survey of the current state of micromachine R&D

The MMC is surveying the current state of micromachine R&D and collecting information on micromachine patents granted. These studies are to be augmented. To provide the latest information to those concerned, contact will be maintained with research institutions and individuals involved with micromachine technology both domestically and worldwide, and their substance and results reviewed and analyzed.

(2)Survey of the application of micromachine technology

Micromachine technology is expected to be utilized in various industrial fields in the future, as shown in the illustration. Part of the technology is already in use in the making of microsensors. Current applications and the potential for use in other fields will be determined to confirm its practical aspects and to stimulate interest in the area.

(3)Survey of micromachine technology data

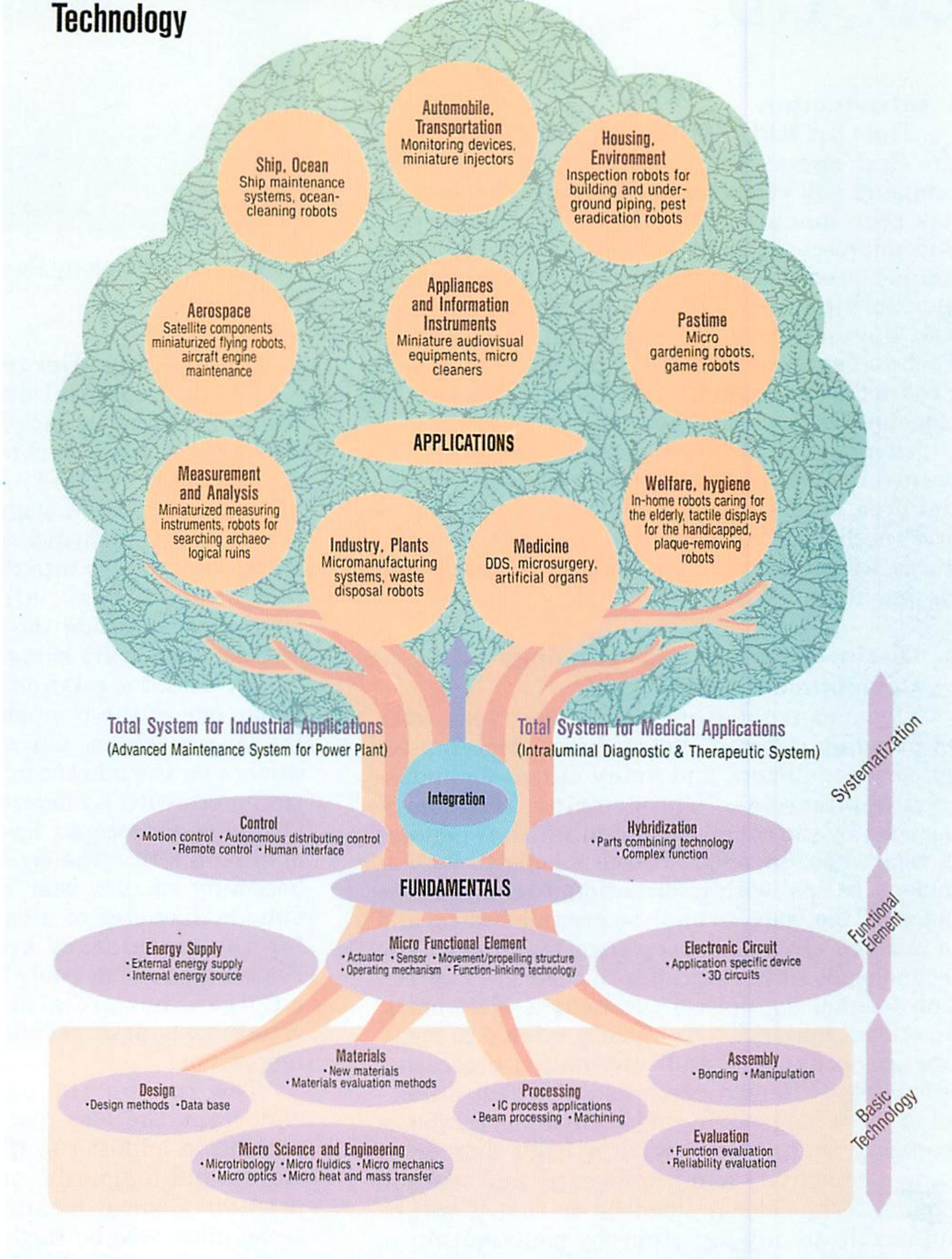
The latest data will be collected with the cooperation of institutions and researchers involved. Those data will be released in an accessible form for their active use and dissemination.

(4)Building of data bases and information provision

The results of the investigations mentioned above will be tallied and put into the form of an R&D data base, an application data base, and a technology data base so that the latest information will constantly be renewed and made available.

Concrete procedures for carrying out items (1) - (4) will be drawn up in fiscal 1992 for use in the investigations to be conducted during and after fiscal 1993.

R & D Fields on Micromachine Technology



OLYMPUS OPTICAL CO., LTD.

1. Introduction

The OLYMPUS OPTICAL CO., LTD. made the first microscope in Japan. Next year the company will celebrate its 75th anniversary. It has been manufacturing cameras, endoscopes, and microscopes as well as other miniaturized unique precision instruments. How are these instruments produced? Learning that research and development is conducted at Olympus Technology Research Institute at Utsugi and Product Development Center at Ishikawa in Hachioji, Tokyo, we visited the former.

Olympus Technology Research Institute was opened in 1989 and is located in a quiet residential area close to the Tama River. In a liberal and intellectual atmosphere, flextime is introduced without a signal-bell for the opening and closing hour.

2. Distinctive Mark of Technology Development in Olympus

Olympus is interested in various fields, such as imaging, information, medicine, biotechnology, semiconductors and many others for industrial applications. The principle technology pursued by the company and to which it adheres is related to "to see." To see means to look at images, to deal with information, to examine the inside of the body, to analyze organic bodies, and to observe ultra-microscopic worlds. Seven key technologies have relevance to their goal: precision technology, optical technology, electronics, functional materials, technology related to medicine, biotechnology, and information processing technology. 'Sensing technology' which utilizes all of these leads to "seeing." Olympus combines 'sensing technology' with a high degree of human sensitivity and intelligence, and seeks to expand technological potential so that it will be applicable to any age, thereby contributing to the evolution of human society.

Thus, in addition to its well-known products like cameras, Olympus has been developing products that are in the forefront of the age: aspherical lens, magneto-optical disc drive, optical card system, ionographic printer, microcassette recorder, scanning tunnel microscope, super-multiautomatic analyzer, ultrasonic endoscope, and bar code reader. Mechanical processing technology of micron order, molding technology, measuring technology of nanometer order, and sensor technology represented by the SIT (electrostatic induction transistor) image sensor support each product developed by Olympus.

Olympus Technology Research Institute at Utsugi

3. Challenging Micromachine Technology

The technological development of micromachines is still in its incipient stage, but clearly it is closely related to current devices as well as devices to be produced in the future by Olympus. Micromachine technology is applicable to many areas, including medicine. Small diameter endoscopes that can go into the body without discomfort, machines allowing complicated microsurgery inside the body, and capsule type micromachines are being studied..

We found a relationship between the endoscope, one of the company's main products, and the micromachine. Olympus first put the gastrocamera on the market in 1950, and then the gastrocamera with a fiberscope in 1963. Since then Olympus endoscopes have held a market share of around 80%. The size of these instruments is becoming smaller year after year, and now the outside diameter of a cardiovascular fiberscope for the circulatory system is only 0.5mm. Endoscopes are not only used to see the inside of an organ, but are also used in diagnosis (an ultrasonic endoscope) and in surgery with a peritoneoscope.

The smaller the outside diameter of the endoscope the less discomfort there is to the patient; in addition to the fiberscopes for observation and diagnosis, other instruments to be used for medical treatment through the endoscope must also be further reduced in size. An endoscope must be flexible, with the frontal portion capable of bending 240 degrees to carry out its function inside the body. This is the reason why development of high power micromachine actuators is required.

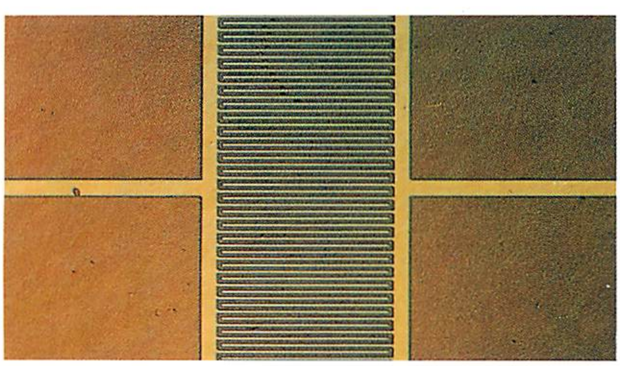
This is what we learned about the relation between micromachines and the Olympus instruments represented by the endoscope. Aiming the broad application of micromachine technology toward products for better human life, research, development, and production technology are integrated in an effort to advance and develop this technology. Wishing them every success, we left the Olympus Technology Research Institute at Utsugi.

KAWASAKI HEAVY INDUSTRIES, LTD.

Today, we are visiting the Akashi Works of KAWASAKI HEAVY INDUSTRIES, LTD. Kawasaki Heavy Industries was established almost 100 years ago. The company is classified as a general manufacturer of ground/marine/air transportation systems such as vehicles, ships, and aircraft, but the company's business includes a variety of fields such as nuclear power, plants, pollution control equipment, steel structures, robots, material distribution, and construction machinery. In addition to providing individual products, the company now promotes inter-division activities which aim to apply the unique technologies of each division to products made by other divisions. A good example is the next-generation Shinkansen cars that utilize aircraft technology. Unlike other heavy industrial equipment manufacturers, Kawasaki Heavy Industries makes consumer products such as motorcycles and jet skis. Interestingly, the same company that made the tunnel boring machine used in digging the tunnel under the Straits of Dover and the bridge piers of the world's largest Akashi Bridge also produces the highly popular motorcycle Zephyr.

Two development centers to serve as a system for quality assurance for these products and for research and development of new products and technologies were established last fall; the Production Technology Development Center and the System Technology Development Center are valuable additions to the two technical institutes. A high-tech engineering base is also being planned for construction in the Kanto area in the near future.

We visited the Akashi Technical Institute and the System Technology Development Center, located at the west end of the Akashi Works. The complex consists of the main building and a number of laboratory buildings, where subsidiary companies performing material testing and analysis share space. From the top of the main building, we can see the panoramic view of the Setonaikai (Inland Sea) and Awaji Island. To the east is the majestic view of the piers of the Akashi Bridge now under construction.


ZnO-SAW Sensor


Akashi Technical Institute and System Technology Development Center

Akashi Technical Institute consists of eight research departments: Physical Application & Technology, Strength, Material, Mechanical Engineering, Engine Technology, Thermal Technology, Chemical Technology, and Opto Engineering. The total number of employees is approximately 260. In addition to traditional heavy industry element technologies such as strength and materials, recent successes include research on free electron laser and other high energy beam technology, thin film technology, bioreactors and other biotechnology, and superconductivity application technology.

The System Technology Development Center consists of six departments including Planning & Control and Research Departments, with approximately 150 employees altogether. The Center is responsible for activities ranging from research and development of electronics/control and system technologies to development of products and education/training programs.

The Physical Application & Technology Research Department of the Akashi Technical Institute and the Research Department of the System Technology Development Center play a central role in the research and development of micromachines. In order to achieve the goal of "developing a very small and smart rotational joint with three degrees of freedom," the following research themes have been selected: manufacturing technology of microactuators integrated with sensors, joint design and control technology with three degrees of freedom, supervisory control technology for moving objects, etc.

The Physical Application & Technology Research Department is developing surface acoustic wave (SAW) sensors and various other thin film sensors through research into functional thin film technology and sensor technology. The thin film sensor technology is applied to the development of actuators.

The Research Department is developing on the technologies of robot analysis, design, and control completed in the past for "advanced robot project," and is currently creating basic models and conducting simulation studies.

After seeing the thin film formation experiment and the control performance test using industrial robots and after listening to the explanation that advanced technologies and know-how of all the company's divisions will be utilized as needed, we felt quit certain of the success of the micromachine projects.

★ TOPICS

VISITORS FROM ABROAD

Early this year, Prof. Dr. W. Mentz of the German KfK (Kernforschungszentrum Karlsruhe GmbH) visited the Micromachine Center (MMC). We discussed about standardization of micromachine technology. Research and development on micromachines is now interdisciplinary in Japan and emcompasses over various fields, so that standardization of the technology such as definition of technical terminology was the first step in this country. In Germany, micromachine standardization is being promoted to assure the interface in micromachine system including the compatibility of various elements planned for development in future. Here at the MMC, micromachine standardization is viewed as an important feature, and it will be advanced in close coordination with KfK.

On March 22 of this year a mission of 10 members of the Center for Micro-Electronics (CME), an association of the electronics industry in Netherlands, came to the MMC. They also visited various other organizations in Japan, Taiwan and Singapore to learn the actual status of industries related to micro-electronics and their research and development activities. During their visit here they were given a brief explanation of the MMC's activities.

VOICE

A Little Girl's Wish

In the fall of 1992, a little girl and her parents came by to the Micromachine Center (MMC). Her father, finding out on TV that micromachine research was being carried out for medical applications, had apparently inquired here and there before being directed to us.

The girl was suffering from Peutz-Jeghers Syndrome, a disease in which numerous polyps form in the stomach and intestines. "When the doctor first found polyps in our daughter's stomach and large intestine, he removed them by endoscopic surgery," her parents explained: "yet, a polyp in the small intestine can cause intussusception -- the intestine folds up inside itself. Well, about two years ago, this is exactly what happened. The doctor had to open her abdomen to extract it. Then, last summer, she had to have polyps removed from her large intestine again. The doctor says that polyps in the large intestine can usually be removed by endoscopic surgery but, depending on where they are, even a first-rate surgeon would have a hard time extracting them all, because the highest technology is required for this."

I listened sympathetically. When they had finished speaking, I gave them an outline of the national large-scale project called "Micromachine Technology" that was being advanced at the MMC. I explained that yes, we were conducting research work on the future application of micromachines to various fields including medicine, but that the technology was still in an infant stage and would require much time to develop. Even with this, her father was elated -- "Just the fact that there is a project, that there are people working on this, gives us hope for the future."

The little girl, who had been quietly listening all along, suddenly spoke up. "Please, mister," she said, "please invent a robot that will fix my tummy without another operation."

The MMC has notified such wishes like this little girl's to researchers around the world, and has stressed the necessity and importance of micromachine technology.

Micromachine technology is neither just for eminent researchers in special fields nor individual companies. It is for people, people who are aware of what we are doing and are waiting for us to help them. We must keep this in mind as we endeavor in promoting research and development to be able to put micromachines to practical use as soon as possible.

FEDERATION OF MICROMACHINE TECHNOLOGY ESTABLISHED

On April 20, 1993, participants from 20 organizations gathered at an inaugural meeting held at the Science Museum in Tokyo. At 1:00 p.m. that day the Federation of Micromachine Technology was officially established.

Composed as it is of academic and research societies, and other organizations particularly interested in micromachines, the Federation is a comprehensive body bringing together those in various fields, while respecting the independence of each organization. Temporary managers elected were Naomasa Nakajima, a professor of The University of Tokyo and a representative of the Micromachine Society, and four other persons.

Micromachine research requires a broad sharing of knowledge and information and strong interdisciplinary cooperation among those in the diverse fields of science, technology and industrial development. With the importance today of working together internationally and fostering outreach, formation of the Federation of Micromachine Technology is believed very timely and hopes are high for the role it will play.

Membership in the Federation will, as a rule, be made available to organizations, and individuals or enterprises with an interest in this area are encouraged to join one of the member organizations.

As of the date of establishment there were 28 participating members such as the Robotics Society of Japan. As well as participating in the overall efforts of the Federation, the Micromachine Center will be active in functioning as the secretariat.

Invitation to Join the General Supporting Membership

Micromachines are minute devices capable of performing complex, microscopic operations, despite being composed of functional elements less than a few millimeters in size. It is believed micromachines have strong potential use across many industrial spectra, particularly in areas requiring sophisticated, advanced maintenance technology in response to increasingly complex and precise machine systems and in medical services where sensitive, advanced medical technology is required, but with minimal discomfort to patients.

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 promotes research and development work under the Industrial Science and Technology Frontier Program "Micromachine Technology," a 25-billion-yen mega-project begun in 1991, delegated by the Ministry of International Trade and Industry's Agency of Industrial Science and Technology.

The center will also engage in independent research, promote cooperative research involving industry, government, and academia, and organize international symposia on micromachine research and development.

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.

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MICROMACHINE No.3

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

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3-F, Sanko Building, 3-12-16, Mita, Minato-ku, Tokyo 108, Japan
Tel: +81-(0)3-5443-2971, Fax: +81-(0)3-5443-2975

Change of Address: Please send old address label and new address to the publisher.
Editorial and Production Management: Japan Technical Information Service (JATIS)
Date of Issue: July 20, 1993

Cover : polarization micrograph of vitamin C
(Credits: M. Akiyama)