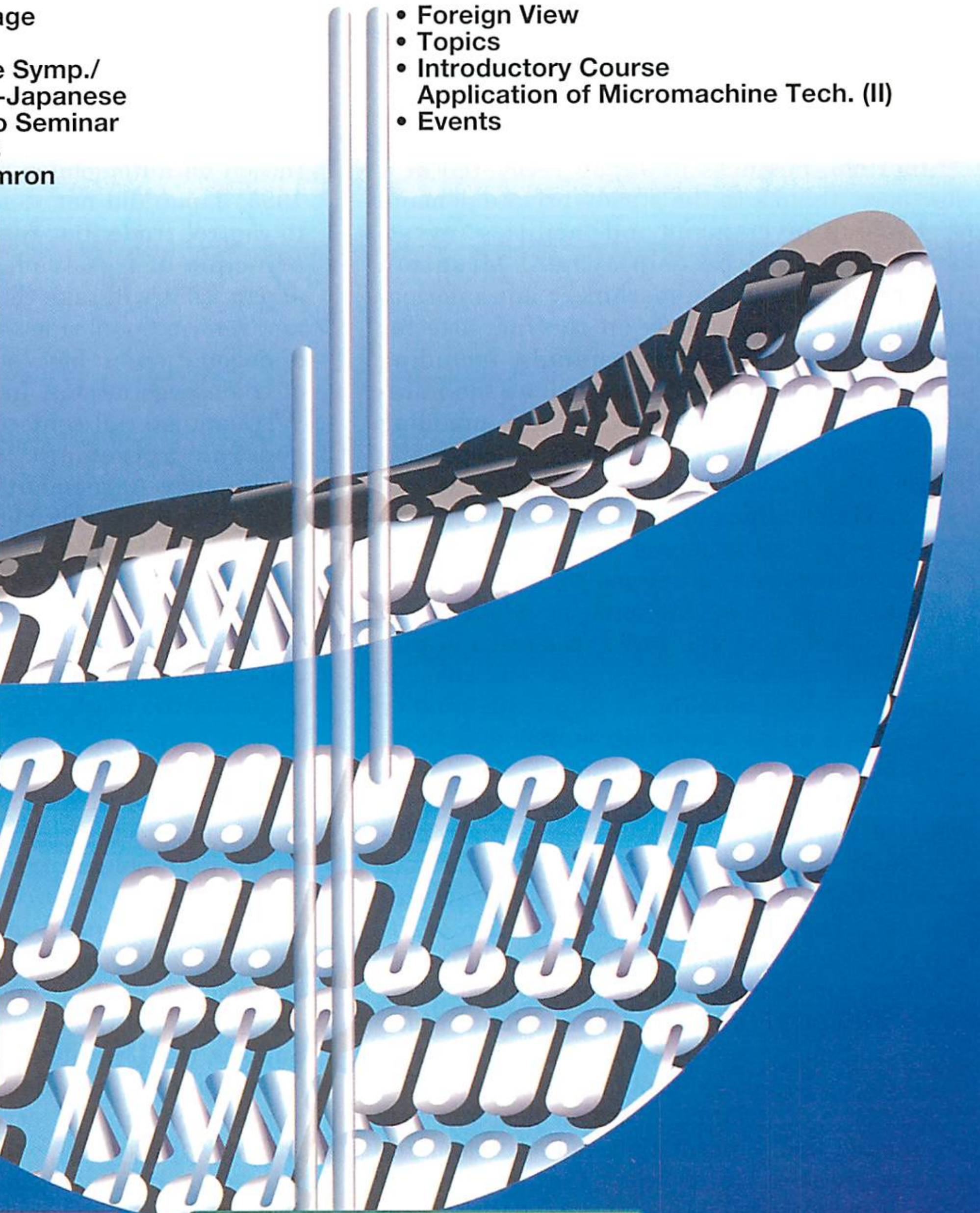
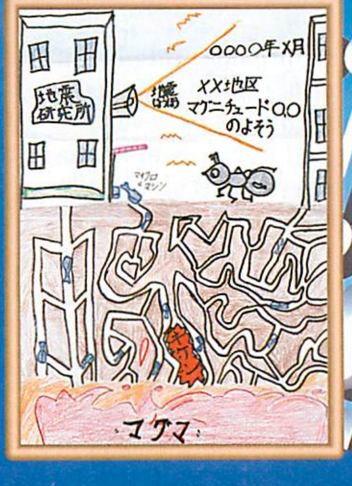
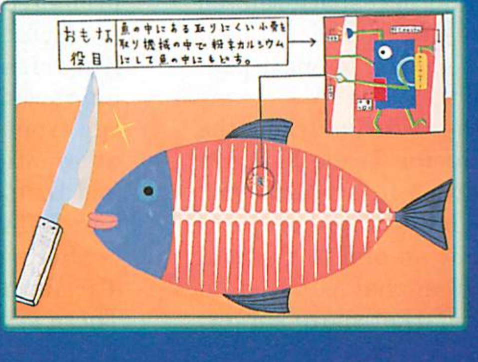
MMC Micromachine
マイクロマシン

Feb. 1997







No. 18

MICROMACHINE CENTER

New Year's Message

Katsuhiro Nakagawa
Director-General
Machinery and Information Industries Bureau
Ministry of International Trade and Industry

Happy new year.

In 1996, business in Japan recovered at a slow pace, thanks to the steady private demand for housing investment and facilities investment, although the employment situation remained tight. In the machinery and information industry, demand is on the increase for products such as mobile terminals, including portable phones and PHSs, as well as the infrastructure for the equipment, rapidly spreading personal computers, and automobiles, especially the so-called recreational vehicles. Now we can see some bright signs in business climate ahead.

However, in the medium or long-term, we are confronted with situations that prohibit too much optimistism. One such problem is the adverse effects that the rapid transition of production to overseas may exert upon employment at home. It will be difficult to provide quality employment and to maintain economic activity in Japan unless we should make even more stringent efforts for fundamental reform in economic structures. Considering the circumstances, in December the government's Cabinet passed *"The Program for Economic Structures Reform."* The program calls for creation of fifteen new industrial fields, correction of high-cost structure for creation of business environment that will be attractive by international standards, and suppression of the public burden to maintain and improve economic activity. The fifteen new industrial fields are medical and welfare-related field, information and telecommunications-related fields, new manufacturing technology-related fields, and aerospace-related fields, and so on. The Ministry of International Trade and Industry (MITI) is going to enact policies based upon this decision.

On the other hand, in the region of trade, the Agreement upon Semiconductor Trade between Japan and the U.S. was settled in August 1996. This built a framework for multilateral cooperation for the new age and put an end to the conventional trade control system that is based on numerical goal setting and market share survey. Taking the same position as it took on the negotiation on automobiles and automobile parts in 1995, Japan did not yield to America's pressure to control trade, but reached agreement on the principle of free trade. It is meaningful to Japan, as it will take the leading role in making new international rules at WTO and other tables of negotiation, to have set up a good precedence of trade negotiation. In December 1996, at the WTO ministerial conference held at Singapore, general agreement on the Information Technology Agreement (ITA) was reached. I think it will be truly meaningful that all tariffs on high-tech products should be abolished according to ITA to expand and balance high-tech trade.

Under these circumstances surrounding Japan, we are going to stress two points in promotion of the machinery and information industry this year.

First, we should further promote intelligent advancement. Introduction of information technology into industries contributes to resolving structural problems in the industries, and it provides a key to economic structural reform through improvement in productivity. MITI has enforced various policies such as promoting the introduction of electronic trading in the general economy, Continuous Acquisition and Lifecycle Support (CALS, integrated information system for support of production, procurement, and application) and electronic data interchange (EDI). This year we will make strong efforts in this area. Intelligent advancement will also be promoted in public sectors such as education, medical and welfare, administration, and libraries for effective public services and improvement of people's life style. Also, technology frontiers will be developed to support the information oriented society in the 21st century, and the supply of software and content of international value will be promoted.

Second, we must promote strategic structural reform in the machinery industry in Japan. There is concern that the machinery industry in

Japan may be losing its vitality because of tardy investment in intelligent advancement and transfer of manufacturing technologies to other countries as enterprises move their production to overseas. Under the circumstances, private enterprises have made ardent efforts such as slashing fixed expenses. However, as competition for the global market heats up more and more, conventional measures have reached their limits. We have to carry out strategic structural reform accompanied by fundamental revision of managerial and business structures. Specifically, it is necessary to make the Japanese machinery industry the base for creation of high additional values through promotion of information systematizing industry such as support to develop the Intelligent Transport System (ITS) and Intelligent Manufacturing Systems (IMS), micromachine projects and other support for technology development for establishing key technologies, and a strategic approach for acquiring international standards.

Although the leading role in strategic structural reform should be taken by private enterprises, I think that, for smooth progress of the reform, the government needs to prepare an environment where free and diverse choice by the enterprises is guaranteed. For this aim, MITI will put its full efforts into enforcing various policies to prepare the business environment in the following aspects: coordination of cooperation among industry, administration, and academic circles to aid creative activities of enterprises; support for venture businesses; deregulation in information, communication, and physical distribution regions; and reform of corporate related systems concerning tax, employment, and so on.

This is the ground plan for machinery and information industry policies in 1997.

I wish for a fruitful year for everybody here at the closing of my speech. Thank you.

The 2nd International Micromachine Symposium Held

The 2nd International Micromachine Symposium was held for two days from October 31, at the Science Hall (Science Museum) in Tokyo.

The symposium preparation took over half a year. At the opening on the first day, Mr. Katsuhiro Nakagawa, Director-General at Machinery and Information Industries Bureau, MITI, Dr. Takeo Sato, Director-General at AIST, MITI, and Mr. Hachio Iwasaki, Chairman of NEDO made guest speeches. Many people attended the two day symposium in spite of heavy rain on the second day of the symposium. The registered participants totaled 430, including 41 participants from overseas including the mission from France.

Prof. Yoshio Tsukio of The University of Tokyo made a keynote lecture titled Micromachine which develops the New Industrial Age. Prof. Tsukio stressed the importance of going out to unknown regions, or frontiers for development of science and technology, and cited cyber space, inner space, and micro space as three such frontiers. He stressed the importance of the relationship between micromachines or micromachine technology and human beings, and pointed out the necessity, while carrying out research, of predicting what new fields of science and technology will be opened up, and what changes will be made in the society beyond the boundary of science by the micro space which is created by micromachines. On the first day, eleven guest lecturers from Japan and abroad presented quite useful lectures. On the second day, presentation was given on the second phase plan of Micromachine Technology Research and Development, the national project being carried by the Industrial Science and Technology Frontier Program, results of the project to date were presented under four themes, and activities of Micromachine Center were explained. The events and lectures were highly evaluated by participants from overseas.

The schedule for the next international symposium was announced and positive participation was encouraged. The schedule and venue of the next symposium are shown below.

Participants at Science Hall

Lecture by Mr. Horst Forster (EC)

3rd International Micromachine Symposium Scheduled

Date: October 30 (Thu.) - 31 (Fri.), 1997
Venue: Science Hall (Science Museum), Kitanomaru Koen, Tokyo

Micromachines open up the new industrial age

Prof. Yoshio Tsukio
Faculty of Engineering, The University of Tokyo

The 2nd International Micromachine Symposium was held two days from October 31. The following is a summary of the keynote lecture "Micromachines open up the new industrial age" given by Professor Yoshio Tsukio at The University of Tokyo.

I presently belong to the Department of Engineering Synthesis, which may sound closely related to micromachine technology. However, as was mentioned in my introduction just now, I graduated in architecture so I'm an amateur in this field. Today I'd like to talk about new potentials for micromachines in the society of the coming century.

In retrospect, throughout the history of science, technology and industry, science made great steps forward when frontiers were opened up. A classical example is the early days of astronomy. This science was built only by observation of stars and planets by eye. Invention of the telescope increased the number of observable stars by thousands times, and contributed much to the progress of astronomy. More recently, the radio telescope made it possible to observe heavenly bodies that were invisible to conventional optical telescopes, and astronomy progressed even further. The same applies to the microscope; whereas the early microscope had the magnifying power of only several tens of times, the recent invention of new types of microscopes such as the electron microscope and the scanning tunneling microscope pushed back the boundary of observation, because of which science has made great progress and so have application technologies and industries.

The important thing is that such inventions closely relate not only to development of science and technology alone but to development of the society as well. The ground rule goes as follows. First, a frontier is extended, making it possible to find new concepts and theories. Once new theories are found, they vitalize industries and new economic activities in a broad sense of meaning. This leads to changes in industrial structures and life styles, and allows former social orders to fall, to be replaced by new social orders. This pattern is observed all through the history of human science, technology, and industry.

We can point to the example of the Industrial Revolution in the 18th century. This

Professor Y. Tsukio

revolution had three major results: discovery of the energy theory, invention of mass production in industry, and formation of the modern social order. These three changes took place as follows. A new view of the world and society that focused on energy was developed in the field of science and technology. The major prior technology before the revolution was mechanics; Scientists and researchers studied what principles make machinery work, and industries were formed based on application of such mechanics. Watches and clocks are typical of the outcome of mechanics. They are the fruits of efforts of scientists and technicians for progress within the bounds of mechanics.

Invention of the steam engine in the 18th century and of the internal-combustion engine in the 19th century made it clear that energy makes great changes in a society. There occurred a tendency to understand many activities in the society in terms of energy. New industries started utilizing energy. In the earliest phase the textile industry soon developed into a variety of manufacturing industries. The new economic activities are briefly described by a single term, mass production. Until then, most products were produced by handicraft manufacturing processes and were supplied to small markets. The Industrial Revolution gave rise to an industrial form where various products are supplied society-wide in massive quantities. This brought great changes to the society and formed various orders and systems of modern society which have lasted to the present.

For example, rapid development of cities was realized only by the economic activities of mass production started by the Industrial Revolution. Speaking more specifically, Manchester and Liverpool are the famous British cities where the Industrial Revolution began. Liverpool was a small port before the Industrial Revolution. Its population was mere a thirty thousand or so in the 1760s. The population increased about 15 times to half a million within a century after the Industrial Revolution started and the town was made a doorway to the world for traders. Manchester had the same rapid rise in population. From about thirty thousand to half a million or so within one hundred years. Many cities all over the world grew with the vast population in flux after the Industrial Revolution. Thus, the foundation of our life changed significantly.

Art also changed greatly after the Industrial Revolution. Bach and Mozart are typical pre-Industrial Revolution musicians. Bach was a composer employed by the church, an organization that was the foundation of the old social orders up to that time. I'm not discussing the value of his music here; my point is that the nature of his works contributed to the church, his employer. Mozart also left many pieces of music from his employment by aristocrats, which was another sector of the Establishment. This was the form of art before the Industrial Revolution. In contrast, Beethoven, a typical artist after the Industrial Revolution, was employed by aristocrats only when he was young, but later he usually composed music and sustained himself through his own efforts. He earned his money by teaching students, selling scores, and holding recitals and concerts. This is because the aristocrats, the former employers of musicians, fell as the society changed. Instead, capitalists and merchants, who formed the new modern society sponsored musicians, and Beethoven worked in a manner suited to that new society.

The same applies to painting. A painter named Velazquez was employed by the royal family of Spain, and although he painted them with a subtly sarcastic touch, basically Velazquez served the royal family by painting their portraits. After Velazquez, Spain had another painter named Goya. He left many famous pictures of people's resistance against unfair and cruel authorities. In these he clearly stated his own view on the society. We can see that this rule (something established in the former social order changes as the society changes) applies also to art.

Politics also changed during the process of the Industrial Revolution. In Britain, two rival politic parties, the Tories and the Whigs, had long been governing the nation. The Tories, supported by landlords and aristocrats whose positions were established in the old social order, held power for a long time. From the mid-19th century the working class and the newly-risen capitalists gained greater power, and the Whigs took power more frequently than before. One of the great politicians among the Whigs was Gladstone, who served four terms totaling 16 years as the prime minister of the United Kingdom in the 19th century.

Technology based on the energy theory, which started with the invention of the steam engine and the internal-combustion engine, not only drastically changed the system of industries and created the new industrial form of mass production, but it also significantly affected social orders, life styles, culture forms, and political trends, thereby giving rise to the new society which was the foundation of the present world. Thus, the frontier not only invites new development of science and technology, but has the power to cause diverse chain reactions that ultimately change the society.

As we look into the society today, there is a general standstill in industrial activities, economic activities, and science and technology not only in Japan but in every part of the world. Japan's economy continually grew at a rapid two-digit rate every year until the oil crisis in 1973. However, after the oil crisis, economic growth dropped to 5% or lower. Recently, the economic growth occasionally drops below zero, and even if it rises it's 1% or 2% at best. As symbolized by the figures, current society is suffering more stagnation than in active periods. I think a major cause of this stagnation is the fact that society has nearly completed its survey of the areas which have been considered frontiers so far, and has reached to a period in which it must find and prepare to go for another new frontier. So I'd like to suggest three frontiers to be developed in the future.

The first frontier is cyber space. In the last decade, the information technology field saw revolutionary changes. In the 1980s it became a reality that inexpensive computers are available and everybody can have his own computer. At the same time, open communication across the world from anywhere to anywhere was also implemented. The process of these changes is called the information revolution since entirely new prospects were opened up by the integration and utilization of two technologies that have progressed separately. These are the information processing technology, the essence of which is the computer, and the information communication technology, embodied by the telephone. Here are some figures that tell us the trend: In the U.S., in 1993 55% of all the computers were connected in networks; now the figure has risen to 80%. The corresponding figure in Japan has risen from less than 15% to 35% in the same period. In the coming several years, more than half of the computers, maybe 60% to 70% are expected to be connected in networks. I think this is the essence of the information revolution now taking place before us. Recently, this new application field of completely integrated information processing technology and information communication technology is being referred to as cyber space. It is a matter of course that new technical principles and scientific theories have been found in this frontier. Now it has triggered drastic changes in the economy; the changes are called the virtual economy.

Think of shopping for a necktie. So far, you have always gone to a boutique or a department store to find your choice in the showcase. Cyber business or virtual business changes this process which is taken for granted so generally. You look up home pages in the Internet for shops specializing in neckties, check catalogues of the shops, and order your choice. Within a few days you will take delivery, regardless of where in the world you are, and for this tie you pay half the price they charge in department stores, or even less. Doing business in this virtual economy is a greengrocer who delivers vegetables from farms to consumers across Japan. The greengrocer has a store under the style of *Virtual Greengrocery* on the Internet, and delivers rice, eggs, apple juice, and other produce from all parts of Japan to anywhere in the country within a couple of days. What is revolutionary with this is that in the conventional system, if one is to collect various goods from different sources and deliver them to different destinations, one has to employ hundreds of people and many trucks, and has to process a large quantity of information. In contrast, the Virtual Greengrocery is distributing vegetables from various places to all over Japan on his own from his shop located in a small country town.

Here is another example. A noodle manufacturer in a small local town with about forty employees ships noodles to all over the world. The company used to do business in a smaller area such as a prefecture or several prefectures, but after it found its way into cyber space, orders have been placed from Brazil, the U.S., and China. Such things would be unthinkable in the old days. Business that used to be unattainable in real space has been made possible in cyber space. One may imagine that not only have new economic activities started but social orders are changing drastically.

In the conventional industrial society, as a rule, bigger corporate scale means greater power; the greater a distribution organization, the wider its marketing area. However, according to the rules of cyber space, which has come into existence just recently, size does not necessarily mean power. Smaller bodies retain power equal to that of greater ones, or, if the cost to maintain the organization is taken into account, dwarfs may have even greater power than giants. Thus, the rule of managerial scale is changing.

To date, the supplier side had held the power. Think about a necktie again, for example. Tie manufacturers predict trends and design new ties on their own decision. The ties are manufactured and distributed in a quantity fit for a predicted market scale. Retailers also make a choice of products from various manufacturers to select what should sell well in their shops. Consumer have no choice but to select from those left after several layers of filtering. However, in a newly started production process, consumers can draw tie designs as they like using a computer terminal, and tie manufacturers immediately dye upon receipt of the data. Although this process manufactures and delivers each tie for only one person, it is not costly. On the contrary, it is inexpensive compared to ordinary ties. A revolution has started. The former economic system where the supplier side held power is now being replaced by the new system where the consumer side has the power. Forms of politics and art may change in the near future as they did at the time of the Industrial Revolution. One probable change in art form is that professional designers can be replaced by ordinary people who make designs for themselves.

What is evolving in cyber space, in the viewpoint of technology, is that new technology that integrates information processing and information communication has spread in the society. It has given rise to new economic activities that were impossible in the old society, and taking shape are new social orders that empower the people who play the core role in the new society. I think cyber space will be a huge frontier in the 21st century with a power that will change the society.

The second frontier is inner space. Inner space is a new field started for the aim of discerning the brain. It is possible that what may be like a non-Cartesian science in the science and technology field evolves in inner space.

The great portion of modern science we depend on so much has its origin in the Cartesian philosophy of reductionism and the Newtonian principle of universalism represented by the law of universal gravitation. Descartes distinguished the human being that thinks from his surroundings, and advocated the development of science that deals with the surroundings excluding the human being. This concept gave great momentum to the development of modern science. It succeeded in defining that science should deal only with objective matters and exclude the subject of individuals. Another feat of Descartes is the concept of distinguishing known matters from unknown matters and establishing scientific theories from known matters only. This has contributed significantly to the development of science. On the other hand, the Newtonian law of universal gravitation symbolizes that science holds true universally, regardless of the geographical differences. In the medieval ages, "science" had localism. There was unique "science" in each of Japan, Arabia, and China, which had their own original frames and systems. The Newtonian principle made it clear that what is important is to find theories that hold true everywhere, either on the earth or in outer space. After Newton, any rule that was valid only in a restricted area was no longer a scientific law. This concept made the mainstream of science, and paved the way for the development of modern science.

The primary significance of research on inner space is that it attempts to deal with matters Descartes excluded. The secondary significance is that it deals with personal matters. It is surely a departure from Descartes and Newton. The aim of the non-Cartesian, non-Newtonian science is to investigate the origin of "difference," difference among ideas, views, and the ways of thinking of individuals. From this point of view, future science may take up research methods that aim to examine various subjects for non-universal theories. It is possible that exploration into inner space may bring in some new theories to replace the fundamental scientific principles that have developed owing much to the genius of Descartes, and that have lasted nearly four centuries.

Well, what will bring it to the society, then? One possibility is brisk economic activities that meet the diversity of individuals. Economic activities will cater to differences among individuals, differences in the environment and differences of time, and sift to targeting individuals from conventional targeting the masses. There is no close link yet between research on inner space and economic activities, but there is a probability of future expansion of new economic activities that cater to tastes of individuals. If the process goes further, administrations and industries may also try to meet the demands of individuals instead of mass targeting like the present politics and administration services. Perhaps such a movement will form future social orders. It is fairly probable that differing feelings and various tastes will not be judged by average, minimum, maximum, etc. in the future society.

The third new frontier is micro space. Most of current science and technology deals with systems having Reynolds numbers of 1 or greater. In the world of micromachines, Reynolds numbers are vastly lower. In such a world, it is not yet known whether accumulated scientific and technological principles can be applied. Let's think of power. An energy source that used to be ignored in the realm of conventional technology and industry can be valuable. For example, probably ATP* will be used as an important energy source for artificial technology. There will be such new changes of working principles in science, but the important thing that will evolve in new society is that future society may be reformed by the observation of subjects from a viewpoint that differs from the point of view we have conventionally used to observe subjects of science and technology. For example, medical science has been developed through external diagnosis of human beings. However, application of micromachines offers views of blood vessels and organs from the inside. Inspection methods for plants, which are considerably larger than the human body, have also developed as external checking technologies. In the future, however, no matter how thin a pipe is, there will be at least the potential for technology based on the new concept of checking from the inside.

You may doubt the importance of changes of viewpoint, but I am sure of it. For example, during the Renaissance, a new drawing technique called perspective representation was invented. This had significant effects upon the society. Before then, Western pictures were drawn as the eyes of gods in the heavens. Few pictures were drawn from a viewpoint on the ground, and they were exceptional. Recall the Mona Lisa, or La Gioconda. In this picture, the lady and the background landscape are drawn on much differing scales. The landscape is seen by the eye at a very height, as if it represents the view of God looking down upon the earth. However, at the zenith of the Renaissance, most pictures were drawn from the earthly human eye. Cities, people, everything drawn in pictures represented the view of a person standing on the ground. It is understood that this point of view evolved into the system of thought called humanism, which concerns human affairs. This tells us that a shift of the point of view can make drastic changes in the society. Although the micromachine is important for technology and industry, it is rather more important because it may shift the scientific point of view from the outside to the inside, thereby exerting causing significant changes upon society.

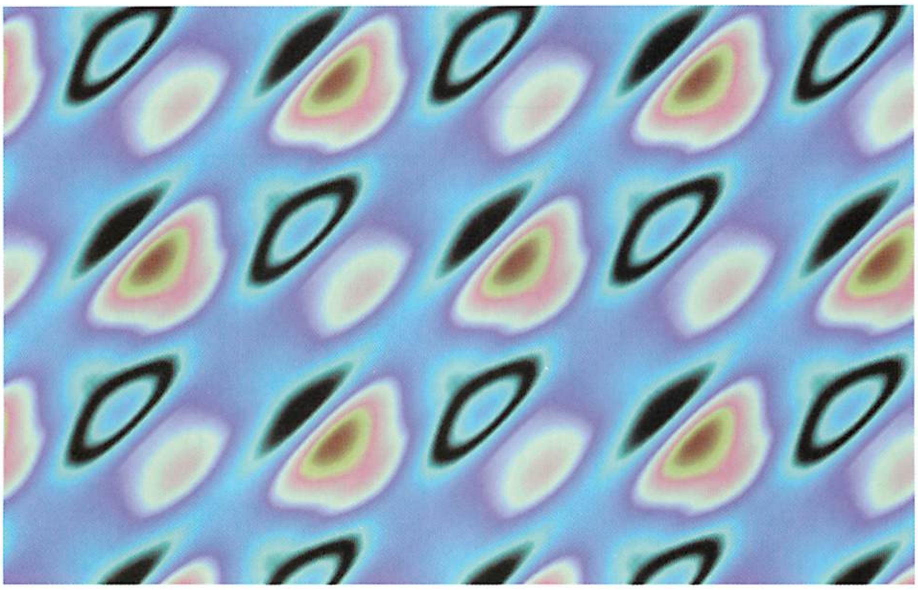
I think the changes will lead to construction of an economic society where manufacturing of micro products has greater significance. If we look into the history of economic activities, large products are generally expensive and account for a great portion of the economy. Heavy iron, huge ships, and heavy automobiles were significant in the economy. Small products were less significant in the overall economy. However, from now on, the share of small things will increase, and this will lead to various social changes.

Another important point is that in the future society probably various orders will mingle. Complexity, which is a concept resulting from research at Santa Fe Research Institute, is about to set a trend and is expected to shape a new part of science. Although it was generally accepted that science cannot be built on factors that have not been proven to exist the complexity concept has developed techniques suggesting the feasibility of treating an entity that includes unproven factors. This implies that micromachines may have a potential to create a new society where orders observed from the outside coexist with orders detected from the inside. Observation from the inside means that products will be created not only according to universal principles as in the manner of conventional science, but also by tailoring for individual subjects. This affects the society, and diverse views of value will coexist within the society. I think a "one and only" science based on universal principles such as the Newtonian law of universal gravitation will end, and it will probably be reshaped into a world where diverse sciences established on locality such as Japan or Arabia will develop and coexist.

I hope you will keep in mind this prediction that micromachines will not only develop new science and technology, but will open up micro space, the new frontier, which will have a great potential to change the world beyond the boundary of science.

I have discussed micromachines as seen by the eye of an amateur in this field, and things that the present opening of the new frontier will bring on in the future society. I hope my speech will be a hint for your study.

* : *ATP (adenosinetriphosphate): High energy compound which has an additional phosphate group to adenosinediphosphate (ADP). Indispensable energy carrier in metabolism of all living things.*



Seventh Exhibition on Microsystem Technologies (MST Japan '96)

In the future, micromachines are expected to spread to various sectors of the economy and to play an important role in our lives.

For the three days from October 30 to November 1, 1996, the Micromachine Center and Micromachine Society (Tokyo) held an exhibition on microsystem technologies at the Science Museum. Centered on the theme "Micromachines — A Dream Fostering Technology," the exhibition was attended by a wide range of people associated with micromachines and applied fields. Those attending included researchers and developers, engineers, company managers and executives, and researchers in public and private research institutes, universities and technical colleges, as well as specialists and buyers in the R&D, design, technology, production-manufacturing, and management-administration areas of various industries. The exhibition informed these people about micromachine research in their own fields and provided access to information on research in other fields as well, suggesting new technological possibilities or ways of resolving technical problems.

With 58 companies, organizations, universities, and research institutes exhibiting the latest technologies and micromachine research results, the seventh micromachine exhibition was Japan's largest ever, and a wide range of exhibits were displayed.

A large proportion of the exhibits were micromachine manufacturing equipment, various kinds of actuators used as components, and micromachine testing and measurement technologies.

For companies involved in the research and development of micromachines, the exhibition was an excellent opportunity to publicize technology, equipment, and products. For university, public, and private research institutes, it provided an opportunity to present research results; and for companies, to introduce new products and technology to the market.

Attracted by the concurrent Second International Micromachine Symposium also held on October 31 and November 1, many micromachine specialists and engineers visited both from Japan and all over the world, making the exhibition an excellent opportunity for the international exchange of micromachine-related information.

As many as 3,169 visited the exhibition over the three-day period, intently reading descriptive panels or receiving more detailed verbal explanations from attendants on hand to explain the exhibits.

Main Exhibits

- **Micromachines**
  Prototypes / Applied Products / Practical Models
- **Microcomponents and their Application Systems**
  Actuators / Sensors / Electronic Devices / Micromechanics parts
- **Micromechatronics related Systems**
  Microelectronics / Microoptics / Micromechanics
- **Molecular Machine related Technologies**
  Molecular Designing
- **Micromachine related Fabrication Systems and Materials**
  Fabrication Systems: Micromachining / Bonding / Lithography / Thin Film Fabrication / Microprocessing / Ultra-precision Processing
  Materials: Metals / Magnetic Materials / Polymers / Ceramics / Semiconductors
- **Micromachine Evaluation Technologies and Equipment**
  Analysis and Evaluation Systems: SEM / TEM / STM / AFM / Protein Analyzer
  Simulation / CAD

Opening ceremony of the Exhibition on Microsystem Technologies

A scene from inside the exhibition hall

Anglo-Japanese Workshop on Microengineering and the Global Environment

As part of the "Investigation and Research into Applications of Micromachine Technology" program, a workshop was held in the United Kingdom to discuss environmental applications. At that time, representatives from the MMC visited major micromachine technology research institutes in Europe to investigate technical trends.

• Overseas workshop (United Kingdom)

Date: November 13 (Wed.) to 15 (Fri.), 1996
Place: The Cosener's House (RAL facilities, Rutherford Appleton Laboratory)
Sponsors: MCIG (Microengineering Common Interest Group) and MMC
Participants:
United Kingdom and Germany: 18 (From Imperial College, RAL, British Nuclear Fuel Limited, Exitech Limited, etc.)
Japan: 10 (Hiroaki Tao, Chief Researcher, National Institute for Resources and Environment, AIST, Tokio Kitahara, Mechanical Engineering Laboratory, AIST, six others, Investigation and Research Committee Working Group, and two representatives from the Micromachine Center)

Outline:

Dr. Tao outlined Japan's efforts to solve environmental problems and described the micromachine technology needed for environmental diagnosis, particularly for the development of miniature, lightweight chemical analyzers. Then Prof. Howard Dorey (Imperial College), Workshop Chairman, talked about environmental measures taken in the United Kingdom and explained corporate expectations in environmental monitoring and sensor development.

As examples of the relationship between environmental problems and micromachine technology, the Working Group Committee introduced the energy-saving effects of microfactories, and the microlathes and piezoelectric manipulators that make up the microfactories. In the medical field, a presentation was made on the effect of reducing medical wastes by minimal invasive diagnosis and treatment using catheters, for example. A photovoltaic device central to monitoring equipment and an active pixel sensor (image pick-up element) were presented in relation to environmental problems, and an example of applications of micromachines to a new, environmentally friendly design method (green design) was introduced. Representatives from the MMC described some of the research results of Phase I and research plans for Phase II of the Industrial Science and Technology Frontier Program. The MMC also introduced applications of micromachines to environmental problems, as envisaged by children in the micromachine drawing contests. All the presentations were enthusiastically received.

UK representatives introduced a single-chip chemical plant and processing technology for such devices as micromass spectrometers. Generally, R&D activities were shown to be directly linked to industries seeking low-cost processing technologies, including LIGA technology.

• Research Institutes Visited

Visits were organized to Catholic University of Leuven in Belgium and to RAL and Exitech Limited of the United Kingdom, where facilities and research were observed.

Catholic University of Leuven emphasizes research into the medical applications of mechanical and chemical sensors, and has succeeded in implanting a telemetering system into a living body. RAL's Central Microstructure Facility, which has electron beam, focused ion beam, reactive ion etching, and excimer laser processors, conducts research mainly into microprocessing technologies in cooperation with corporations and universities. Exitech Limited is a manufacturer of excimer laser processing systems and conducts research into unique three-dimensional polyimide processing by controlling mask movement and using halftone masks.

The workshop and visits to the research institutes gave participants a glimpse into micromachine research in Europe and some useful insights into the linkage between environmental problems and micromachine applications.

Keynote speech by Prof. Dorey

Nagano Micromachine Seminar

Jointly sponsored by the Precision Technology Research Institute of Nagano Prefecture, the Nagano Prefecture Techno-Highland Development Organization, the Asama Technopolis Development Organization, the Precision Processing Technology Research Association of Nagano Prefecture, and MMC, this seminar was held at the auditorium of the Precision Technology Research Institute of Nagano Prefecture in Okaya City on the afternoon of October 1, Tuesday, 1996.

The seminar introduced recent micromachine technology as well as specific microscopic processing research results with special significance for Nagano Prefecture from the "Micromachine Technology" project of the Industrial Science and Technology Frontier (ISTF) Program promoted mainly by the MMC. Takayuki Hirano, Executive Director of the MMC, and Dr. Yuichi Ishikawa of the Mechanical Engineering Laboratory, Agency of Industrial Science and Technology, delivered lectures respectively titled "The Activities of the MMC" and "An Outline of Micromachine Technology." The following ISTF program research results were also presented.

"Micromachining Technology for Ceramics Using SR"
Mr. Hiroshi Okuyama, Harima Research Laboratory, Sumitomo Electric Industries, Ltd.
"Ultramicroprocessing"
Mr. Kiyoshi Sawada, Basic Research Laboratory, Fanuc, Ltd.
"Microfluid Devices and their Assembling and Processing Technology"
Mr. Takeshi Harada, Mechanical Engineering Research Laboratory, Hitachi, Ltd.
"Microfactory and Microprocessing Technology"
Mr. Kazuyoshi Furuta, Technology Control Department, Seiko Instruments, Inc.

Nagano Prefecture has divided itself into four policy-based regions, and seeks to promote and develop precision and electronics industry-related companies in the Prefecture through such public bodies as the Precision Technology Research Institute of Nagano Prefecture. For this purpose, the Prefecture provides technical guidance in micromeasurement technology, microprocessing technology, surface treatment technology, electronic technology, and filming technology, opens its facilities to companies, conducts R&D into applications, and develops human resources. The precision and electronics industry-related companies in Nagano Prefecture are some of Japan's most technologically advanced in precision processing, and manufacture multifunctional, highly integrated products by micronizing components. Rather than being satisfied with the status quo, these future-driven companies tend to have a keen interest in more advanced microprocessing technology, such as production technologies relating to the micronization of product components. Recognizing that micromachine technology is a key future production technology, such companies showed a keen interest in the seminar. About 100 people attended, including representatives from about 30 precision and electronic industry-related companies in Nagano Prefecture, and the staff of the Precision Technology Research Institute of Nagano Prefecture, the venue of the seminar. A lively question and answer session followed the lectures, completing a very meaningful seminar.

The seminar in Nagano

AISIN COSMOS R&D CO., LTD.

President Takanobu Hori

1. Micromachine Technology Policy

Compared to the rapid development of electronics miniaturization, the pace of miniaturization in machinery has been slow. Since the application of micromachine technology, however, the situation has begun to change drastically. According to Aisin Cosmos' President Hori, R&D into micromachine technology will result in new approaches and technologies and realize electro-mechanical systems with new functions that will revolutionize existing products. At present in the field of organic mechanisms, Aisin Cosmos has focused its efforts on the research and development of fluid devices (such as pumps) and automotive microsensors, and the Company's engineers are enthused with the dazzling potential of micromachine technology. Aisin Cosmos realizes that it is important to understand the basics of design and manufacturing, and to have tangible applications or products in people's daily life.

2. Developing Micromachine Technology

Friction, viscosity, and heat are the basic problems at the micro level. To produce new approaches and new technology, Aisin Cosmos believes it is important to first tackle these technical problems. For this reason, Aisin Cosmos is, for example, researching and developing micropumps capable of continuously handling very small volumes of liquid. Fig. 1 shows a optically driven peristaltic micropump developed recently. This pump was inspired by the bloodsucking technique of mosquitoes. A mosquito's bloodsucking pump, which consists of double bulbs made up of a buccal pump and a pharyngeal pump, is partitioned from the tip by a levator labii superioris, a pre-pharyngeal valve, and a post-pharyngeal valve. The valve is opened and closed by a valve muscle, which controls the direction of blood flow. A mosquito sucks blood with a pressure differential greater than 10 times that of the human heart's and at a speed faster than 10 cm per second[1]. Placing diaphragms on the side walls of the liquid channel enables the diaphragms to be used as active valves.

Light provides the driving power to this pump. Since high energy can be supplied to local areas via an optical fiber, the pump can be used in places where electric wiring should be avoided such as within blood vessels. Optical actuators can deliver relatively high driving power to a micropump by utilizing the evaporating gas pressure generated from the liquid-gas phase change of operating liquid. Although development is still at the stage of development, the pump may be further integrated with optical power supply and more effective driver. Currently, Aisin Cosmos is working on optical wave guide channel for power supply and fabrication of a three-dimensional flow channel using micro-stereo lithography

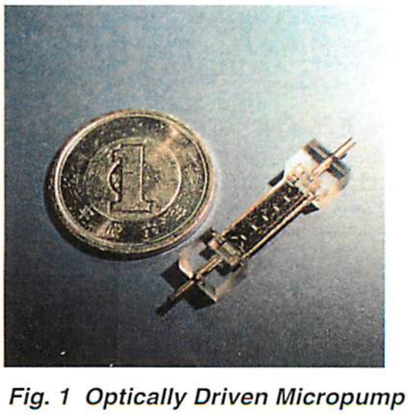


Fig. 1 Optically Driven Micropump

Fig. 2 shows an example of microgripper manufactured by micro-stereo lithography.

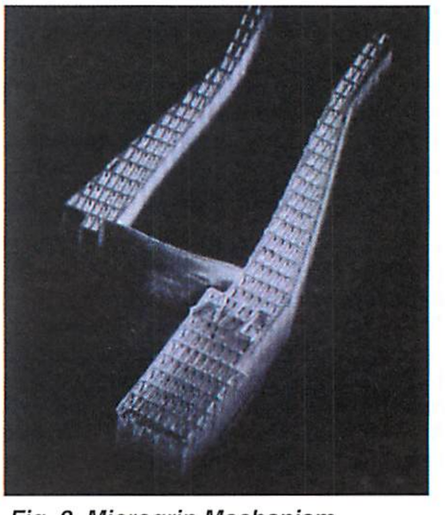


Fig. 2 Microgrip Mechanism

3. Future Efforts

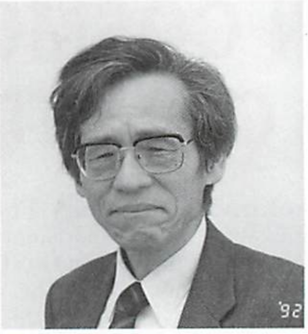
Micromachine technology is not only an extension of conventional manufacturing, but also based on new concepts and ideas. Micromachine technology will therefore produce not only improves in existing products, but will also create entirely new market. In the future, with the rapid progress of computerization and the graying of society, demand will increase for more user-friendly, safe, and reliable products. Aisin Cosmos is determined to contribute to human society by actively utilizing micromachine technology and developing better products.

Reference

1) Toshiaki Ikeshoji, Mosquitoes, The University of Tokyo Press

Yoshihiro Naruse
Deputy Research Director, Electronics Field
Aisin Cosmos R&D Co., Ltd.

OMRON Corporation



Tsuneji Yada

1. Committed to Micromachine Technology

Omron strives to keep the sensors in its products abreast of trends in micronization technology. However, Omron is convinced that conventional technology will soon reach inherent limits of miniaturization, and is therefore looking to the micromachine concepts that have emerged out of semiconductor technology. The result will be a new paradigm based on a merger of semiconductor and machine technology. Omron believes that this approach offers the technical solutions to push back the limits to micronization.

For this reason Omron participates in the Industrial Science and Technology Frontier Program for micromachines and is actively involved in the miniaturization of recognition devices.

2. Development of Micromachine Technology

The most well known and best image-recognition device uses a CCD camera. However, because this approach requires a computer with high image-processing capability and only works in brightly illuminated environments, it is very difficult to apply CCD cameras to micromachines. To get around this problem, Omron reduced the processing capacity required for scanning by oscillating a mirror by mechanical resonance and by scanning the light reflected by the mirror.

The advantages of this method are that less power is required to move the mirror and that recognition lighting is unnecessary because light is irradiated. Fig. 1 shows the equipment developed for this.

As shown in this figure, a mirror and a pole to support the mirror comprise a resonance system with a natural vibration mode for bending and twisting the pole. Accordingly, when the mirror is irradiated by the laser, the light reflected from the mirror is scanned horizontally and vertically.

The light projected in this way does not return unless there is something in front of the mirror. Accordingly, if pole deflection is detected, the direction of the light projected can be ascertained, and the returning light indicates that an object is present in that direction. The environment can thus be recognized by photodetecting devices that detect the light returned. This figure shows how these devices are integrated on silicon wafers using silicon processing technology.

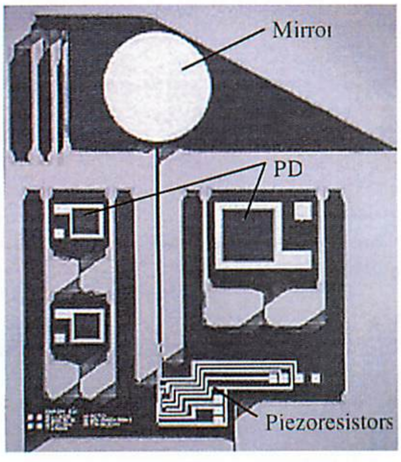


Fig. 1 Experimentally prepared Scanner

This equipment was fabricated to the fixed dimensions set by Phase I of the Industrial Science and Technology Frontier Program and has been confirmed as having the necessary performance functions. However, the equipment was far from perfectly integrated because an ordinary power source was used to oscillate the resonant system and the mirror. A standard piezoelectric element power source was used but as this could not be satisfactorily miniaturized, a thin-film piezoelectric element was developed.

Of the several methods to produce piezoelectric thin film, Omron favors the sputter method. The resultant equipment shown in Fig. 2 has a piezoelectric performance normally only seen in bulk material and equaled nowhere else in the world. Omron is confident that this will lead the way to further miniaturization.

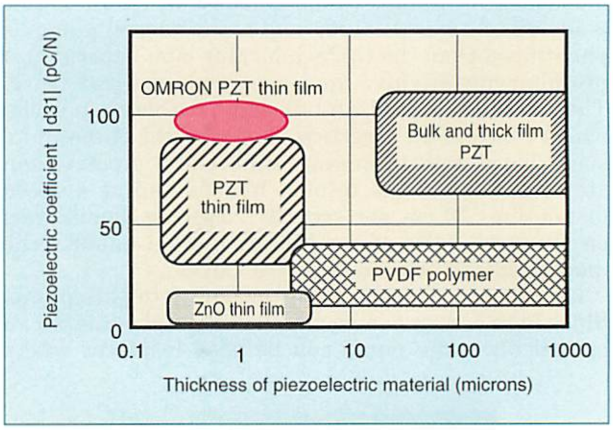


Fig. 2 Characteristics of PZT Thin Film

3. Future Efforts

The research conducted over the past five years has resulted in the means to miniaturization, but the peripheral components to be integrated as a single miniaturized system are still not developed. Many problems still remain to be solved before micromachines are fully realized as a technology.

Tsuneji Yada
Advisor, Corporate Research & Development H.Q.
Omron Corporation

Interview with Prof. Paolo Dario from Italy

Prof. Paolo Dario, who is a professor of Medical Robotics and Mechatronics at the Scuola Superiore Sant'Anna in Pisa, Italy, took part in the Second International Micromachine Symposium at the Science Museum in Tokyo. We had an interview with him regarding current research activity on Microengineering at the Microfabrication Technologies Laboratory of his university.

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

A: The Microfabrication Technologies Laboratory (MiTech Lab) was established in 1991 as part of the Advanced Robotics Technologies and Systems (ARTS) Laboratory of the Scuola Superiore Sant'Anna, a public University located in Pisa, Italy. Micro technologies are investigated by a team of about 25 researchers comprising graduate students, postdocs and research associates. The main mission of the MiTech Lab is to investigate the theory and to develop the technologies for fabricating miniature components and systems. The MiTech Lab pursues a multidisciplinary approach to the field of microengineering. In fact, the MiTech Lab is particularly focused towards the design and fabrication of miniature components and their integration into complete miniature machines (like microrobots).

Q: ***What kind of projects are being carried out in your laboratory?***

A: Our lab has a number of projects, mainly on medical applications and we are involved in system integration. We are interested in approaching Microsystems especially from mechanical field and biological field through various technologies. We are working on research and exploitation of various processing technologies such as microstereolithography, LB film, laser machining and LIGA and Silicon micromachining. The outline of the projects we are engaged in is as follows:

1) Shape Memory Alloy Micro-Actuators for Medical Applications: We have developed a semi-autonomous microrobot capable of inchworm locomotion based on shape memory alloy microvalves and intended for inspections of the colon and minimally invasive surgery.

2) Intelligent Neural Interface: An implantable miniature interface incorporating a microfabricted silicon die and a polymer guidance channel has been fabricated. The nerve can regenerate through it. The final applications should be the control of prostheses for amputees and the stimulation of limbs in spinal cord injured persons.

3) Micro Total Chemical Analysis Systems: The aim is the design and fabrication of a miniaturized laboratory for chemical analysis.

4) Minimal Invasive Arthroscopic Surgery: We are designing innovative steerable microfabricated tools foe surgical intervention by arthroscopy in the knee.

Q: ***How is your institute financed?***

A: At the moment, we get most of our funds from EU Programs, such as ESPRIT for Information Technology, BRITE-EURAM for Automation, BIOMED for Biomedical Engineering, etc. We are getting funds also from private companies and from Italian industries.

Q: ***What do you think micromachine research should pursue?***

A: There are two trends in achieving miniaturization. One is an extension of the Si process seen in MST or MEMS, and the other originates from the field of micromechatronics. The former is very important since it may contribute to miniaturization, upgrade of functions and low-cost fabrication in large scale. The latter may determine important advances in the industrial world, at the moment especially in Japan. I think both trends are important and needed in exploiting the revolutionary potential of microsystems and micromachines. This is why our approach is strongly multidisciplinary. I believe that these two trends should supplement each other to generate a large market in the future.

Q: ***At the end, could you tell us your dream about micromachine technology?***

A: I should like to see applications of micromachines to become practical, in particular, of course, those that we investigate (like the medical ones). Moreover I am very much interested in seeing further development in basic research and student education which are both a very important factors for the ultimate success of the field of micromachine.

(MMC, Editorial Staff; Takashi Kurahashi)

15th IARP-JCF Meeting

On October 4 and 5, 1996, the 15th International Advanced Robotics Programme - Joint Coordinating Forum (IARP-JCF) was held in Karlsruhe, Germany.

This forum has been held each year since 1982 to promote international cooperation in the development of advanced robot technology. Representatives of 10 countries: Australia, Austria, Canada, France, Germany, Italy, Japan, the United States, Spain, and Russia, attended, and lively discussions were held on the direction of the future development of robot technology. (The United Kingdom and China were not represented this time.)

The meeting began with the introduction of a report by Mr. Georges Giralt (CNRS System Research Institute) of France, which acted as the forum's secretariat, on the direction of future robot technology development. Next, individual countries introduced trends in advanced robot technology. As examples of concrete projects, Japanese representatives presented papers on the future of R&D into "friendly network robotics," a leading research project started in fiscal 1996, and on micromachine technology, a project of the Industrial Science and Technology Frontier Program. In addition, four micromachine technology experimental systems, now reaching their second phase, were introduced. Participants were especially interested in the Japanese research into a wide range of technologies focusing on unique systems.

In the United States, France, Germany, and Italy, the focus of robot development has shifted from the development of robots to replace humans in the performance of hazardous or repetitive tasks, to the development of symbiotic-type robots that work alongside people in non-technical areas. With sensors and monitoring devices that function as human-machine interfaces, micromachine technology is one of today's most important technological areas.

Specific examples of micromachine technologies developed outside Japan were a US table-top-sized manufacturing device known as a "minifactory" (its assembling manipulator has only two degrees of freedom, making it simpler than the Japanese "microfactory" being developed in the Industrial Science and Technology Frontier Program) and a Russian motor with a diameter of 2 mm, part of a medical micromachine.

After these examples, lively discussions were held on the technologies introduced. Then, directions in the development of robot technology and the activities policy of IARP were presented for approval.

Participants:

Australia	**S. Ramakrishnan** (Rama) (Representative)
Austria	**Peter Kopacek** (Representative)
Canada	**David G. Hunter** (Representative)
France	**Georges Giralt** (Representative)
Germany	**Manfred Dreher** (Government representative)
	Tom Martin (Secretariat representative)
	Ursula Frey (Secretariat)
	Rudiger Dillmann (Secretariat)
	Gerd Hirzinger (Specialist)
Italy	**Giuseppe Mosci** (Representative)
	Giulio Sandini (Specialist)
Japan	**Michio Hamano** (Representative, Agency of Industrial Science and Technology)
	Kiyoshi Komoriya (Mechanical Engineering Laboratory)
	Kazuhiro Tsuruta (Micromachine Center)
United States	**Norman Caplan** (Representative)
	Takeo Kanade (Specialist)
Russia	**Valery Gradetsky** (Representative)
Spain	**Jose de No** (Representative)

Asia Forum

On October 29, 1996, as part of its independent international exchange activities, the Micromachine Center held an Asia Forum in the Center's conference room. Concurrent with The 2nd International Micromachine Symposium and the Seventh Exhibition on Microsystem Technologies (MST Japan '96), this new forum aimed at promoting scientific exchange and building a network among people of the Asia region involved in micromachine technology.

The forum was chaired by Professor Tomomasa Sato of The University of Tokyo. Mr. Katsuya Makiuchi, Deputy Director of Industrial Machinery Division, Ministry of International Trade and Industry, attended as a guest and members of International Committees organized by the Micromachine Center were present as observers. The Center's activities and the current state of R&D into micromachine technology in Japan, focusing on the Industrial Science and Technology Frontier Program, were introduced. Asian participants presented the progress they had made in micromachine technology. Although it varied somewhat from country to country, each country's progress in micromachine technology was communicated to all. In the discussion session, Japan's Industrial Science and Technology Frontier Program and its future applications attracted many questions and suggestions from other countries, and the session went over its scheduled time.

The Chairman's summary was presented at the close of the forum. The conclusions of the forum were:

- ASIA FORUM was fruitful to know each other.
- ASIA FORUM has established new network on Micromachine Technology in Asia.
- More active interaction may be helpful for domestic development.
- Continuation of ASIA FORUM is meaningful.

This forum was the first attempt to directly link Asian countries and regions interested in micromachine development and was a meaningful exchange.

The party following the forum was attended by Mr. Makoto Nakajima, Director of the Industrial Machinery Division of the Ministry of International Trade and Industry, and by people from companies supporting the forum. The party provided an excellent opportunity to exchange opinions and was a great success. Hopes for next forum within a few years were also expressed.

Participants in the Asia Forum from outside Japan were:

China	**Prof. Zhao Ying ZHOU,** Tsinghua University
Hong Kong	**Dr. H. C. MAN,** The Hong Kong Polytechnic University
Korea	**Prof. Min-Koo HAN,** Seoul National University
Malaysia	**Dr. Chok Ngee CHONG,** SIRIM Berhad
Singapore	**Dr. Libo ZHOU,** Gintic Institute of Manufacturing Technology
Taiwan	**Dr. Min-shyong LIN,** Industrial Technology Research Institute
Thailand	**Mr. Prasert AKKHARAPRATHOMPHONG,** Chulalongkorn University

A scene from the Asia Forum

Application of Micromachine Technology (II)

In this issue, microfactories and examples of their application embodying micromachine technology in the industrial manufacturing field will be reported.

1. Introduction

In present factory production systems, even if the final products are small, manipulators and other structural elements have high rigidity to suppress deformation under dead weight or by processing reaction force. Consequently, the manufacturing system is significantly larger in relation to the product (parts), meaning a great loss of energy and factory space. For instance, small precision instruments such as watches and cameras are composed of parts on the millimeter scale, but are manufactured by milling machines and robots of human size (meter scale) in order to maintain accuracy. Theoretically, the work necessary to lift a component of about 1 g vertically 40 mm is a mere 4 mJ. However, an assembly robot to do this consumes about 75 J. In this example, actual energy consumption is about 20,000 times the theoretical requirement.

2. Microfactory

In the manufacture of small industrial products or small quantities of chemical products, energy consumption at the factory is drastically reduced by miniaturizing the manufacturing system to a relevant size to the product, because required energy for operating a manufacturing system is roughly proportional to the volume, weight, and transportation distance of the system. A reduction in the size of a manufacturing system also reduces the materials required for building the factory. Naturally, space is also saved. Flexibility of the system can also be expected.

A microfactory is a desktop factory size. To make microfactories a reality, it requires micro devices of various functionality manufactured by micromachine technology. Also, the system configuration of a microfactory has to be different from that of a conventional manufacturing system to exploit the advantages of micromachines.

Recently, various micro processing technologies are being used to manufacture mechanical components whose dimensions are of the order of several tens of micrometers or motors and actuators that are smaller than millimeter scale. A micro lathe as little as 3 cm^3 shown in Fig. 1 has been developed. Thus, microfactories have become very feasible.

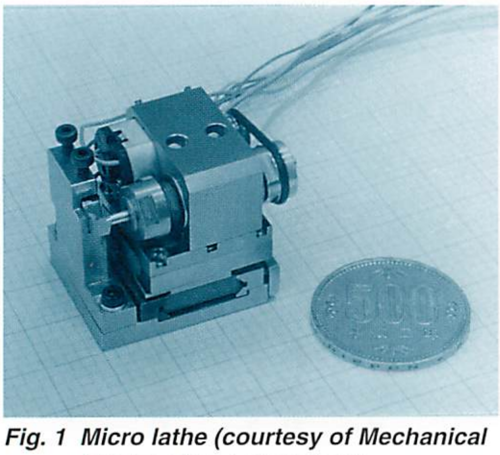


Fig. 1 Micro lathe (courtesy of Mechanical Engineering Laboratory)

3. Application Examples

Microfactories are advantageous because they: (1) conserve energy and resources, (2) save space, and (3) are flexible. These merits are utilized well in microfactories, as explained below.

3.1 Desktop Fabrication System

Fig. 2 is a conceptual diagram of the desktop fabrication system. The example system is for manufacturing small mechanical devices; it consists of three stations and a carrier unit connecting them. Its size is small enough to fit on a desk. This system has functions to process, assemble, check, transfer, control, and maintain.

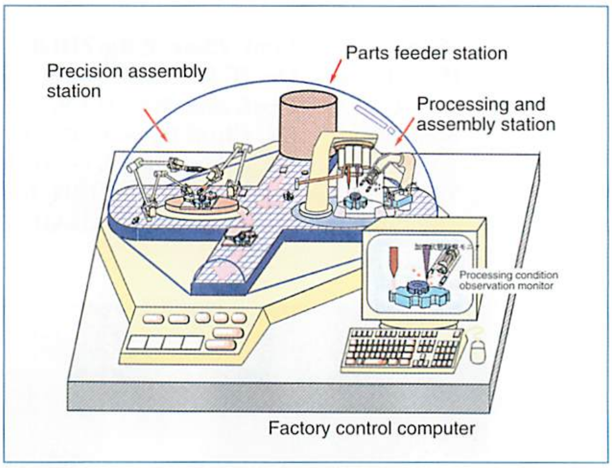


Fig. 2 Desktop fabrication system

The manipulator is for holding and handling small parts. As a manipulator gets smaller and lighter, its inertia reduces, which means faster motion with higher accuracy. If individual manipulators are smaller, more manipulators are accessible in the same work space, making it possible to process or assemble multiple components at the same time. As a result, the degree of freedom in the manufacturing system and product design increase, the performance of the products is improved, and the creation of unique products is expected. A smaller manipulator means shorter distances and times for the transportation between processing stages, improves productivity, and saves space. Because energy consumption in a manufacturing system is reduced as the volume of the system becomes less, energy saving effects by fabrication in such micro systems will be considerable. Fig. 3 shows

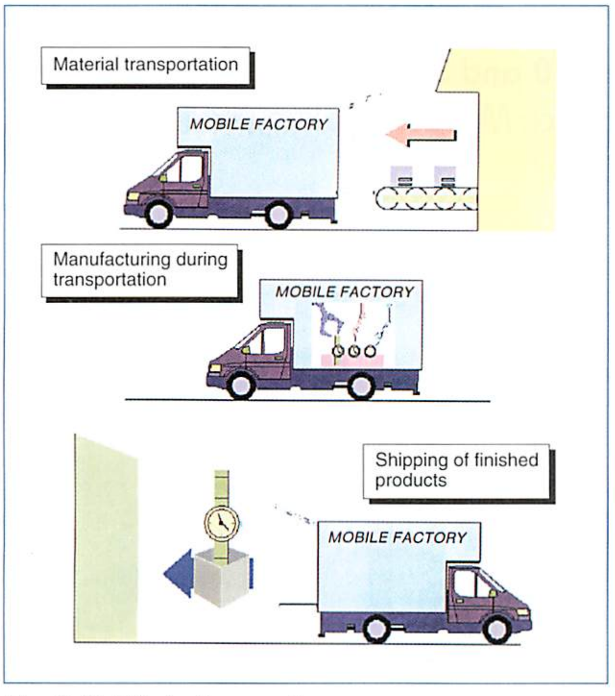


Fig. 3 Mobile factory system

another application example of such a manufacturing system, which runs while being transported on a truck.

Since the entire factory volume is small, if clean ambient air is required in the work environment, air conditioning energy is also drastically saved compared to cases where conventional large clean rooms or clean benches are used. Thus, energy saving effects are multiplied. The entire manufacturing system can be placed in controlled atmospheric gas or a vacuum, which makes it easy to manufacture in a special environment. For example, functional elements, devices and hybrid ICs can be manufactured without clean rooms, and pharmaceuticals and medical equipment can be manufactured on a through-line process in a small sanitized room.

3.2 Micro Chemical Plant

The micro chemical plant system consists of the micro fluid system composed of pumps and micro piping for carrying liquid or gas, and reaction chambers where chemical reactions take place. Since chemical reaction takes place on the interface between two (or more) reactants, the reaction of micro reactants completes instantaneously. This assures that even a highly exothermic, hazardous chemical reaction can be carried out safely. Also, difference of concentration between the reactive interface and the inside is reduced, making homogeneous chemical reaction possible. Since loss of materials left unreacted or residue in the piping is reduced, necessary products can be produced in the necessary quantities whenever it is necessary, at a high yield rate.

Apart from manufacturing, this system is also valid for analysis. Use in a blood or DNA inspection system conserves specimens and expensive inspection reagents. In a liquid or gas inspection system, small transportable systems make field analysis easier. Especially for environmental monitoring of water, air, etc., sampling and analysis can be done at the site simultaneously.

With the use of micro chemical plants, conventional factory processes such as DPE of photographs can be moved to homes and offices. Fig. 4 shows an example of an application for an over-the-counter manufacturing system for cosmetics. This is a hypothetical system which could be installed in a small shop for checking user's skin conditions on that day and manufacturing optimum skin care products in the necessary quantities.

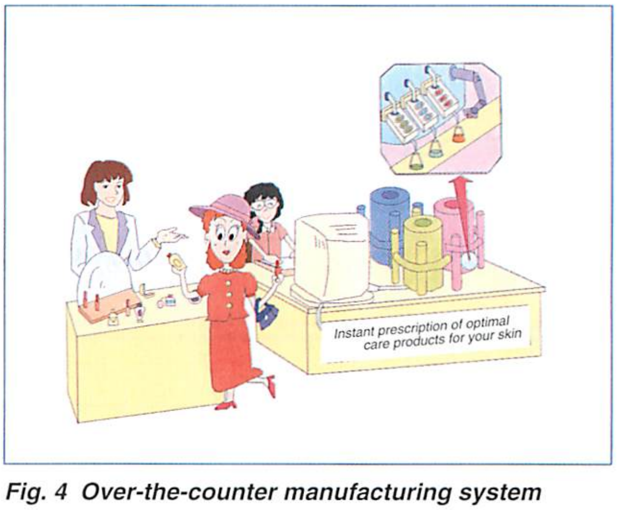


Fig. 4 Over-the-counter manufacturing system

References

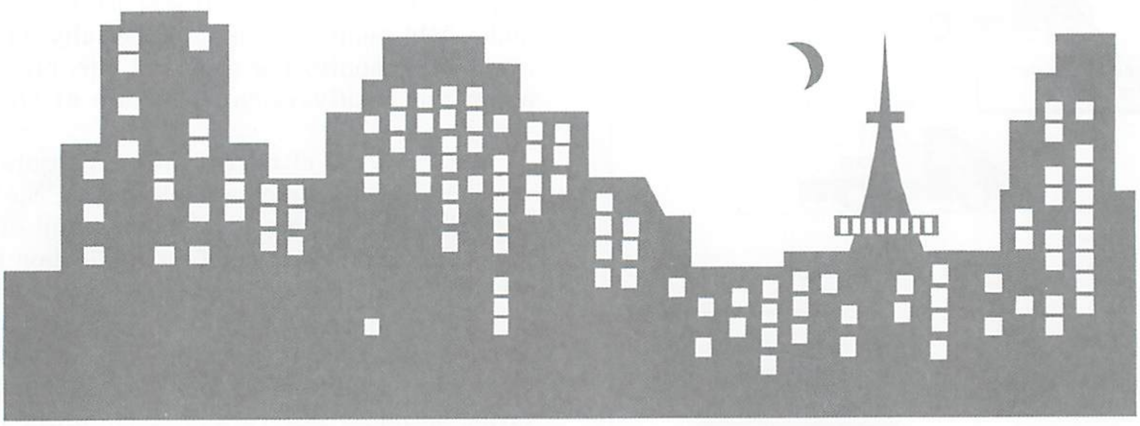
1) N. Kawahara et. al.: to be published in J. Microsystem Technologies (1997)

2) T. Kitahara et. al.: Proc. of Second International Micromachine Symposium (1996), p.59.

Preliminary Announcement

The 3rd International Micromachine Symposium

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



Micromachine Exhibition '97

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

The Detail will be announced later.

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Takayuki Hirano, Executive Director, Micromachine Center (MMC)
5-F, Niikura Building, 2-2, Kanda-tsukasacho, Chiyoda-ku, Tokyo 101, Japan
Tel: +81-3-5294-7131, Fax: +81-3-5294-7137
Internetn Home Page http://www.iijnet.or.jp/MMC/

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