MMC

2003 8

MICROMACHINE



MMC Activities

# The Research Reports under the 9th Micromachine Technology Research Grant

This research grant program started inviting applications in 1993 as a part of the independent activities of MMC. The purpose of the program is to assist college and university staff engaged in basic research on micromachines, and to promote further development of micromachine technology and communication between academics and people in the industrial world.

Among the themes selected for the ninth (2001) research grant, nine research projects, including six 2-year projects carried over from fiscal 2000 and three 1-year projects of fiscal 2001, have been completed.

The following are four summaries of the research results of the carried over projects.

Carried-Over Projects Granted for Fiscal 2000

| No. | Subjects | Leader and Co-Worker | Affiliations | Period |
|---|---|---|---|---|
| 1 | Development of Highly Light-Sensitve Film Systems for Micro-Relief Formation and Their Applications | Prof.Takahiro Seki | Professor, Department of Applied Chemistry, Graduate School of Engineering, Nagoya University | 2 Years |
| 2 | Electrochemical Immobilization of Engineered Protein for micro TAS | Prof.Tetsuya Haruyama | Professor, Department of Biological Functions and Engineering, Kyushu Institute of Technology | 2 Years |
| 3 | Development of Nano-Probe System for Nano-CMM (Coordinate Measuring Machine with nanometer Resolution) | Prof. Kiyoshi Tamakasu | Professor, Department of Precision Engineering, The University of Tokyo | 2 Years |
| | | Prof. Ryoshu Furutani | Professor, Department of Precision Engineering, Tokyo Denki University | |
| 4 | Micro Hand System Capable of 3-D Tracking | Prof. Tatsuo Arai | Professor, Department of Systems Innovation, Graduate School of Engineering Science, Osaka University | 2 Years |
| | | Dr. Tamio Tanikawa | Senior Researcher, Division of Intelligent Systems, Advanced National Institute of Science and Technology | |

Affiliations as of May, 2003.

## Development of Highly Light-Sensitive Film Systems for Micro-Relief Formation and Their Applications

**Takahiro Seki**, Professor, Department of Applied Chemistry, Graduate School of Engineering, Nagoya University

### 1. Introduction

Recently a method has been found for forming relief structures by exposing polymer films containing azobenzene molecules to patterned laser light, causing the material to migrate laterally. Our group developed a system capable of rapidly inducing mass migration within seconds by exposing a flexible liquid crystal polymer to light. In order to increase our understanding of this mass migration phenomenon and to contribute to micromachine technology, we studied the feasibility of using this system as a conveyor for other materials.

### 2. Development of Novel Polymers

By introducing oligo(ethylene oxide) into the polymer as a copolymer, we developed an azobenzene polymer in which mass migration is induced with high sensitivity. Using this polymer, we found that relief formations can be preserved, even at temperatures of 250 degrees celsius, by cross-linking the hydroxyl end group of the ethylene oxide. We learned it is possible to overcome properties that run counter to highly sensitive light-induced migration and the preservation of stable formations. Fig. 1 is an image taken through an atomic force microscope of a relief formed with a grid-shaped mask.

### 3. Photo-Conveyance of Functional Materials

Using this phenomenon of migration in film materials, we studied the inducement of migration in other functional materials (Fig. 2). This study showed us that migration is possible in dyes, conjugated polymers, and particles on the order of nanometers. This knowledge is expected to become a new elemental technology for micromachines.

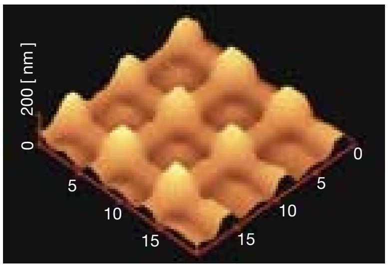



**Fig. 1 An example AFM image of a relief formed by light-induced mass migration**

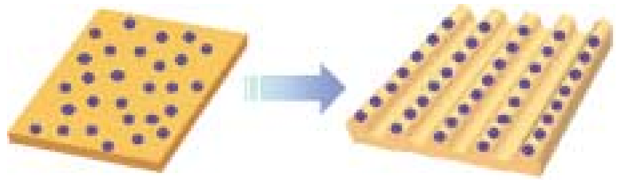


**Fig. 2 A conceptual drawing showing patterning by conveyance of functional materials using light-induced migration**

## Electrochemical Immobilization of Engineered Protein for micro TAS

**Tetsuya Haruyama**, Professor, Department of Biological Functions and Engineering, Kyushu Institute of Technology

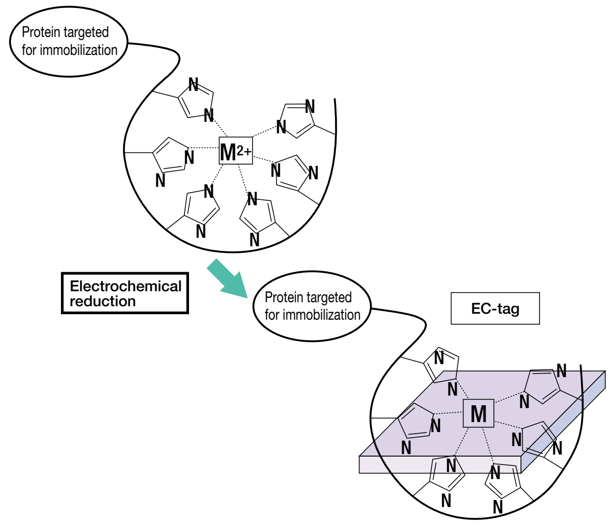
### 1. Introduction

Proteins like enzymes and antibodies have specific affinities, catalytic activity, and other superior functions. Devices that make use of these functions include bioreactors and biosensors achieved through immobilized enzymes and immunosensors achieved through immobilized antibodies. We have seen many attempts to develop devices by reducing the size of these bioreactors and biosensors and employing them as micro total analysis systems($\mu$TAS) for applications in health care or food inspection. However, various restrictions make it difficult to immobilize functional proteins on a miniaturized site. In this study, we controlled the molecular orientation of immobilized protein and attempted to develop an electrochemical immobilization method for reversibly immobilizing protein.

### 2. Genetical Insertion of EC-tags and Electro-chemical Immobilization of Proteins

A principle of immobilization is to genetically add an EC-tag sequence (an amino acid sequence to become a divalent metal-ion coordination site) into the amino acid sequence of an immobilized protein and to configure divalent metal ions in this EC-tag site. We discovered a method of immobilization in which the coordinated metal ions are restored from two valences to zero by applying a reduction potential to the protein in this state at an electrode surface. At this time, the protein is immobilized on the surface of the electrode (Fig. 1). Protein immobilization performed according to the above process is stable even after ceasing the potential application and can be separated through a counterreaction.

Fig. 2 shows an atomic force microscope photo of an experiment using this method to immobilize a model protein on the end of a cantilever. In this example, the applied potential is focused on the radical end through an edge effect to achieve protein immobilization only around the end of the cantilever. This suggests the possibility of orientational immobilization of monomolecular proteins using the extreme radical end solid phase. Further, this method of immobilization can be used universally for many proteins by genetically inserting an EC-tag in the amino acid sequence of the protein. The potential for designing molecular orientation using this method has engendered great promise for its applications.




Patent application No. 2003-069924

**Fig. 1 Hypothetical scheme of EC tag-protein immobilization**

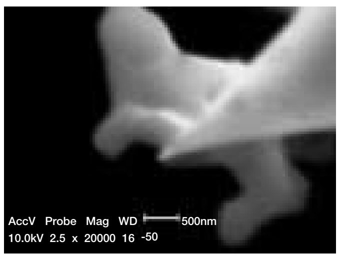



**Fig. 2 SEM photograph of protein immobilized on the end of a cantilever by an EC-tag**

## Development of Nano-Probe System for Nano-CMM (Coordinate Measuring Machine with Nanometer Resolution)

**Kiyoshi Takamasu**, Professor, Department of Precision Engineering, The University of Tokyo
**Ryoshu Furutani**, Professor, Department of Precision Engineering, Tokyo Denki University

### 1. Introduction

When developing micromachines and small optical elements, it is necessary to perform traceable 3D measurements of the micromachine and its parts or the optical element in nanometer resolution. While practical technologies for traceable measurements of surface shapes on a nanometer scale have been made achieved with scanning tunneling microscopes and atomic force microscopes, a measuring machine for measuring three-dimensional sizes and positions has yet to be adequately developed. Thus, it is necessary to develop a 3D measuring machine with nanometer resolution, that is, a nanometer coordinate measuring machine (nano-CMM). The probe system in this nano-CMM has been deemed the most difficult to develop. In this study, a nano-probe system was developed by combining mechanical contact with optical sensing of that contact.

### 2. Development of the Nano-Probe System

As shown in Fig. 1, the nano-probe system has a mechanically supported stylus ball that contacts the object to be measured and employs an optical system for directly sensing displacement of the ball. With this method, it is possible to construct a 2D or 3D sensing system with stable nanometer resolution for measuring objects having various surface aspects. Fig. 2 shows the construction of the nano-probe system and its prototype. A small ball having a diameter of 0.5 mm or less contacts the object, while an optical sensor comprising a laser and a quadrant photodiode detects the movement of the ball during contact. The overall size of the apparatus is approximately 100 x 30 x 30 mm, enabling the apparatus to be mounted in the Nano-CMM. The resolution of the prototype nano-probe system was evaluated and determined to be capable of achieving 10 nm or less resolution. Further, when performing 2D measurements, crosstalk and the like occurred between the X and Y axes. However, having achieved a resolution of about 10 nm, the probe system can be applied for the Nano-CMM.

### 3. Conclusion

As described above, we developed a nano-CMM and a nano-probe as basic tools for developing future micromachines. However, there are many issues that remain unresolved before these devices can be actually used, such as establishing a method for calibrating the measuring machine, improving reliablity of measurements, and evaluating the device's aging.

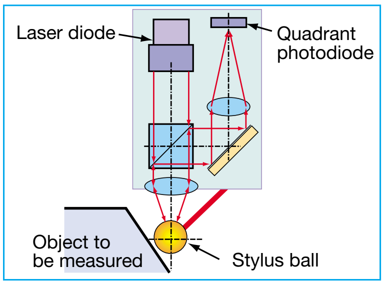



**Fig. 1 Basic principles of the nanoprobe system**

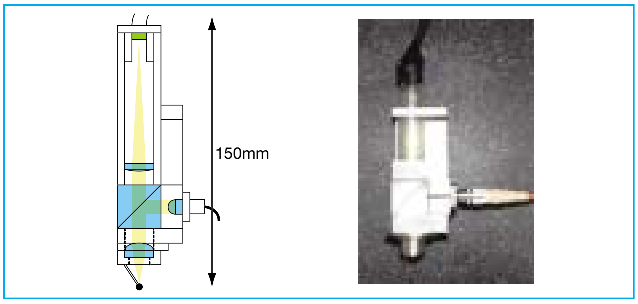



**Fig. 2 Construction of a nano-probe and its prototype**

## Micro Hand System Capable of 3-D Tracking

**Tatsuo Arai**, Professor, Department of Systems Innovation, Graduate School of Engineering Science, Osaka University
**Tamio Tanikawa**, Senior Researcher, Division of Intelligent Systems, Advanced National Institute of Science and Technology

### 1. Introduction

We have been developing an automated micromanipulation system for handling and machining micro-objects under a microscope. In order to perform such auto-micromanipulations, we have developed a system for automatically focusing the target object, a system for recognizing the object in the focal plane and detecting its position, and a micro hand system that integrates these two systems in order to control a two-fingered micro hand to pick up objects while automatically tracking the movement of the object.

### 2. Auto-focusing system

A characteristic quantity for determining the vertical relationship between the object and the focal plane of an optical microscope is found based on RB data of an image around the object near the focal plane. Accordingly, we developed a system for automatically tracking the focal point of the microscope on the micro-object by deriving an algorithm for focusing the object based on this condition. We configured a system that applies the same principle of controlling the micro hand in the direction of height for tracking the fingertips of the hand at the focal plane. We achieved a tracking speed of 0.1 Hz (12 $\mu$m p-p).

### 3. Auto-handling a moving micro-object with the micro hand

Using template matching, the positions of the fingers and the object in the focal plane are automatically detected. Sufficient tracking accuracy for moving objects in the focal plane was achieved using a 60 x 60 pixel template. We achieved auto-calibration required for accurately positioning the micro hand by combining the auto-focusing with position detection in the focal plane. Fig. 2 shows the absolute positioning accuracy achieved through the calibration, which ensured within about 2 $\mu$m.

By integrating the above functions, objects could be picked up automatically with the micro hand. Fig. 3 shows the micro hand performing a high-speed process to automatically pick up a glass particle 5 $\mu$m in diameter.

In the future, we will apply these achievements in automanipulations targeting such moving micro-objects as active cells.

**Fig. 1 Overview of the system**

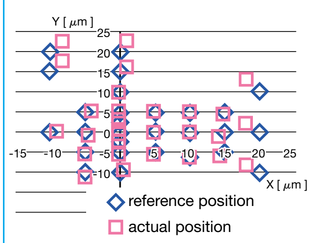



**Fig. 2 Positioning accuracy with calibration**

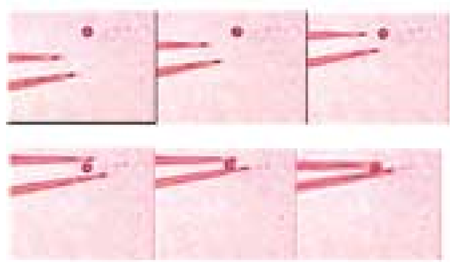


**Fig. 3 Automated object handling**

# Activities of the Micromachine Center in Fiscal 2002

## I. Investigation and Research on Micromachines

Research activities were aimed at towards gaining a clear understanding of the trends in micromachine technologies and industries and conducting investigations of and research on new technological issues regarding the fusion of micro- and nanotechnologies, as well as making adjustments appropriate for the multidirectional expansion of micromachine technology.

### 1. Investigative research for the high-efficiency micro-chemical process technology "Microchip Device/System Database Construction" project (recomissioned by New Energy and Industrial Technology Development Organization [NEDO])

This project involved the systematic collection into a comprehensive database of information concerning hardware design, measurement technology, and technological issues, obtained in each process of designing, manufacturing, and evaluating microchip devices.

**(1) In addition to considering the data framework and information suitable for inclusion in the database, we designed an operational format that includes two-way connections with databases containing highly relevant documentary information.**

**(2) Basic specifications for the test database were designed, and a software company commissioned to create the database software.**

### 2. Studies on the future prospects of micromachine technology

As we anticipate the industrialization of the micromachine technologies developed thus far, from a technological perspective we must also strive toward further miniaturization in this new technological system of micromachines. With regard to applications, MMC is pursuing the possibilities for the fusion of micromachine technologies with technologies in other fields such as medical care and biotechnology. Against this background of growing demand for a multidimensional approach, MMC established a "long-term vision subcommittee" and conducted research related to planning directions for micromachine technology development and roadmaps for the main technologies.

### 3. Studies on R & D trends for micromachine technology in Japan and abroad

MMC set up a think tank to consider trends in R&D both in Japan and abroad; conducted exploratory analysis of the latest situation regarding the rapid expansion, both domestically and internationally, of micromachine technology and research trends; and built up basic technological data that contributes to the advancement of micromachine technology.

### 4. Investigation and Research into the Applicability of Basic and Sprout Micromachine Technologies

This joint study between industry and academia is aimed at encouraging the establishment of theories in micro and nano science and engineering and probing for technological seeds necessary for promoting the merging and application of micro and nanotechnologies. Research related to the fields of cell manipulation and nano-optics also continued on from the previous year.

#### (1) Research Related to Cell Manipulation

As in the previous fiscal year, technology themes suitable for government promotion were considered and proposals for projects prepared. As part of the decision process, a workshop entitled "Cell Manipulation Technology for the 21st Century" was held on February 10, 2003.

#### (2) Research Related to the Field of Nano-Optics

A subcommittee was established to examine research related to the field of nano-optics, and three specific technological areas —(1) basic nano-optics technology, (2) nanostructure building technology, and (3) nano-optics response technology — were selected for consideration.

### 5. Research on Constructing a System for Evaluating the Micromachine Market

With the aim of building up an economically consistent database of micromachine-related market statistics, a subcommittee was convened to consider issues related to the creation of a market-estimation system; methods were chosen and statistics compiled.

### 6. Investigation and Research on Scale Interface (commissioned activities to help promote the machine industry)

From the perspective of scale interface, MMC will study the trends for optical devices in demand for next-generation optical communications and evaluate the sophisticated functionality possible by fusing micromachine technologies and nanotechnologies. To this end, an investigative committee was set up to consider scale interface-related technologies and, within the committee, two subcommittees (looking at standards and dimensional precision, respectively). In addition to considering the present situation regarding technology and technologies of the future, the committee prepared a report identifying problems experienced by users, as well as issues and problems associated with dimensional measurement.

### 7. Research related to simulation systems for MEMS-design and analysis support (commissioned by the Mechanical Social Systems Foundation)

MMC set up an investigative committee to examine issues related to simulation systems for MEMS design and analysis support, as well as a panel to look at related technologies. These groups conducted surveys on such topics as existing software, analytical tools, and basic specifications for user-friendly systems about simulation systems for MEMS design and analysis support that can be utilized effectively by businesses (particularly foudry service enterprises) and universities — in other words, software systems to efficiently design and analyze MEMS.

### 8. Research related to technology development strategies in the MEMS industry (commissioned by NEDO)

MMC and the Nomura Research Institute were commissioned by the Ministry of Economy, Trade and Industry to jointly prepare a draft plan for the "MEMS Project" to be launched in 2003 as part of the Ministry's "Focus 21" program. In order to obtain comments from the public, MMC established a committee to consider technology strategies and held a workshop.

## II. Collection and Provision of Micromachine Information

Information and documents on micromachines in universities, industries, and public organizations both in Japan and overseas have been collected and combined with survey results complied and documents produced by MMC, and made freely available in the MMC library.

### 1. Maintenance and Expansion of the MMC Library (990 publications as at March 31, 2003)

### 2. Publication of a Micromachine Periodical ("Micromachine Index")

### 3. Publication of a Newsletter

### 4. Database Construction and Data Management System Operations (indexed full-text retrieval)

## III. Exchange and Cooperation with Worldwide Organizations Involved with Micromachines

### 1. Participated in the 8th Micromachine Summit (Maastricht, the Netherlands: April 30-May 2, 2002)

### 2. Held the 8th International Micromachine/Nanotech Symposium (Science Museum in Kitanomaru Park, Tokyo: November 14, 2002)

### 3. International Exchange and Dispatch of Researchers

Norichika Fukushima, manager of the Research Department, visited the Netherlands (Twente University) and Germany between January 30 and February 6, 2003, to examin R&D trends in micro fluids-related fields.

### 4. Constructing a foundry network system

In order to further the industrialization of micromachines, particularly MEMS, upgrading of foundry facilities is vital. To this end, MMC established the Foundry Service Industry Committee to organize businesses providing foundry services, to set up a network system to improve services and to consider ways such a system could be developed. As means of disseminating information, the MMC also set up its own Internet homepage and participated in various lectures and seminars.

### 5. Establishing a forum for the exchange of micromachine technology

A workshop on micro fluids was held; lecturers were invited from universities to speak on technology trends at international conferences on micro-fluids-related topics and information and opinions exchanged.

## IV. Standardization of Micromachines

In micromachine technology and other newly established fields of systemized techniques as well, there is an urgent need for the standardization of terminology, measurement, and evaluation methods. The MMC worked towords it, taking international initiatives into perspective.

### 1. Creation of an international standard as a method for evaluating the properties and measuring methods of thin film materials

The results of R&D on measuring and evaluating the properties of thin materials, conducted as part of the NEDO Research and Development for Standards project that ended in 2001, were considered for inclusion in proposals for international standards.

### 2. Investigation and research on micromachine standardization

The results of this research have been transmitted worldwide, encouraging international standardization while exercising initiative in establishing international standards. With regard to terminology, MMC submitted a specifications proposal to IEC/TC47 and supported deliberations through such actions as compiling comments. With regard to measurement and evaluation, MMC continued selecting and prioritizing items standardization items. An international standardization workshop was also held at the 2nd International Standardization Forum in Tokyo in July.

## V. Dissemination and Education about Micromachines

### 1. Publication of a Public Relations Quarterly Magazine "MICROMACHINE"

Vol. 39 to 42 were published in Japanese only.

English versions are available on the MMC website:http://www.mmc.or.jp/

### 2. Micromachine Drawing Rally (Implemented in 2002 as a small-scale means of gathering and utilizing micromachine drawings)

### 3. The 13th Micromachine Exhibition (Science Museum in Kitanomaru Park, Tokyo: November 13-15, 2002

### 4. Administration of the Federation of Micromachine Technology

Served as secretariat for the Federation of Micromachine Technology to link and strengthen micromachine-related organizations.

### 5. Workshop presenting the results of grant recipient projects for the 8th Micromachine Technology Research Grants (FY 2000) on September 17, 2002

# An Introduction of MMC's Activities: Future Vision for Micromachines

It is certain that micromachine technology will play an important role in a variety of social and economic fields in the 21st century and will contribute to improving the quality of our lives. However, today's severe socioeconomic environment does not allow us to foresee the prospects for micromachines accurately.

With the successful completion of Japan's first national micromachine project, conducted over a ten-year period, we are now working on new endeavors aimed at further development of micromachine technology. One of these endeavors is to create viable industrial applications based on results obtained through R&D on advanced technologies. Among other things, Microelectromechanical Systems (MEMS) technology is increasingly used for various applications and furthering its industrialization has become a major objective of ours. The second endeavor is a top-down approach to the nanotechnology research that originated from the U.S. National Nanotechnology Initiative (NNI). Nanotechnology is not truly useful unless it is complemented by a seamless interface with human-sized technology, which is the role micromachine technology should assume.

There is no precedent for any nation having attempted to accomplish these objectives. Given the fact that Japan remains in structural change ten years after the economic boom ended, pursuing these objectives entails great financial risk and considerable effort, as well as requiring diverse expertise and knowledge of researchers in industry, government, and academia. Therefore, a compass is needed by which we can proceed to unexplored disciplines based on the current developments in micromachine technology.

Last year, the Micromachine Center formed a committee for deliberating the long-term prospects of micromachine technology (Chairman: Prof. Isao Shimoyama, Department of Mechano-Informatics, Graduate School of Information Science and Technology, The University of Tokyo). The committee has compiled their deliberations and investigations in an interim report entitled "A Future Vision for Micromachines."

### Contents of the report:

**1.** Introduction: Why is a vision required now?

2. Prospects for micromachine technology (short-, mid-, and long-term)
3. Approaches to the development of industrial applications
4. Collaboration among industry, government, and academia (the roles of business, government, universities, and MMC)
5. Technical roadmaps in ten major fields, including a support system to improve the quality of life for the elderly (safety, security), a bio-nanosystem, a medical care roadmap (applications of microtechnology and nanotechnology in the medical field), a health care roadmap, environment-related sensors, intelligent tagging (logistics system), information and telecommunications (sensor-based network), next-generation robotics, a space-based MEMS system, and a roadmap for innovative micromachine manufacturing technology

## An outline of the interim report is given below.

## 2. Prospects for micromachine technology (short-, mid-, and long-term)

Micromachines have been developed for use in a wide range of industrial products, including sensors, moving microparts, chemical analyzer parts, optical parts, and the like. In addition, micromachine technology is expected to support technological bases in the information and telecommunications industry, the biomedical industry, and the automobile industry. Optical MEMS, RF-MEMS and sensors show promise for micromachine industrialization in the short term, while there is considerable potential for industrialization in fields based on biotechnology or microfluid systems from a long-term perspective.

## 3. Approaches to the development of industrial applications

The following issues must be resolved in order to progress smoothly from the current R&D phase to a new phase in which new devices and products are created and put into practical use.

- Meeting needs from potential technical users
- Sharing intellectual properties, such as designs and manufacturing know-how
- Developing such infrastructures as a foundry and a design center enabling start-up companies to design and manufacture new devices and products immediately without the burdens of initial investment and personnel management
- Expanding the opportunities for personnel recruitment training and developing tools to assist in design and simulation

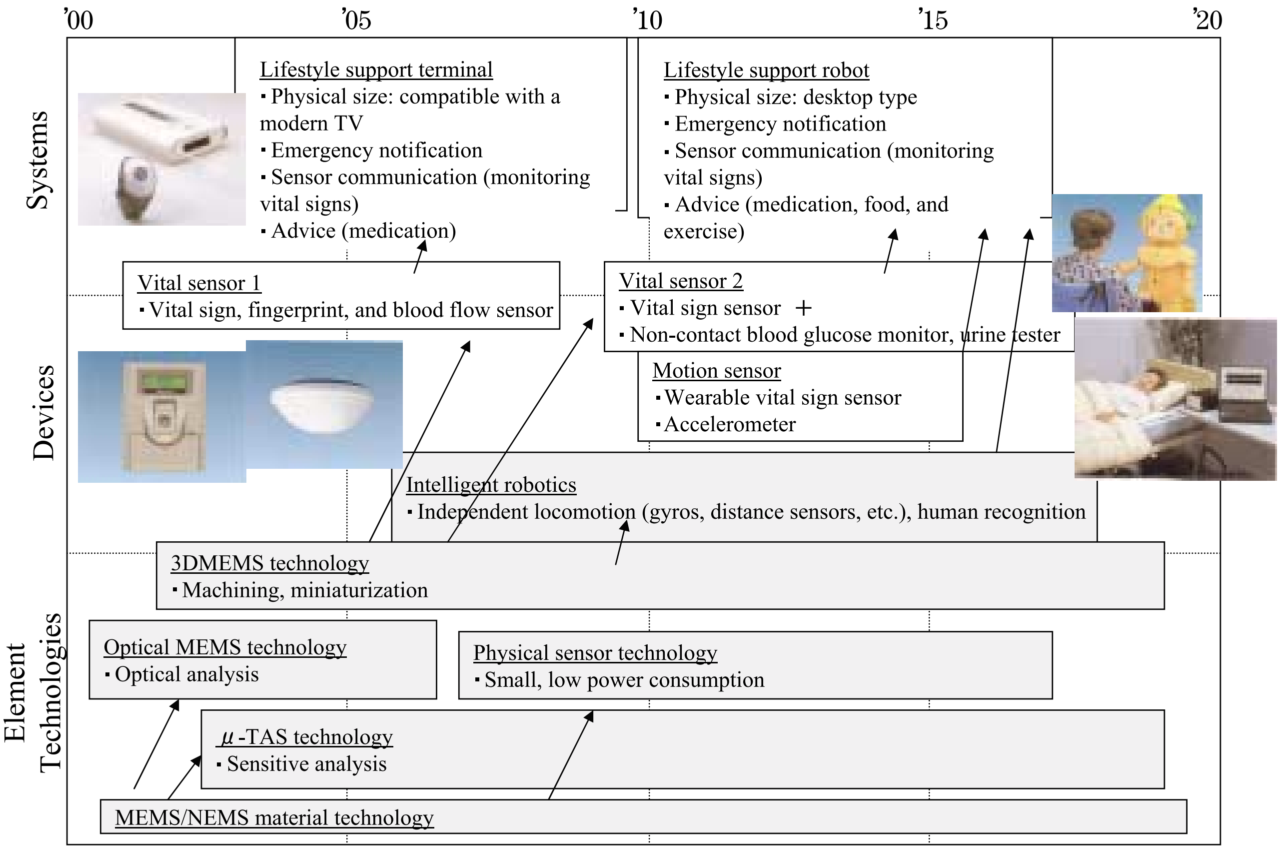
## 4. Collaboration among industry, government, and academia

While Japan's move toward global development has put its economic and industrial structures in a transitional stage, collaboration among industry, government, and academia is indispensable for accomplishing new objectives. Industry expects the government to support long-term, high-risk research and development and to promote infrastructure. Industry, on the other hand, must commercialize its developed technologies. Academia is expected to create human resources and information on basic and advanced technologies.

## 5. Technical roadmaps in ten major fields

These roadmaps were developed with a focus on systems adopting micromachine technology. The roadmaps were created for ten fields, while devices and element technologies required in each field were examined based on each of the envisioned systems. As an example, we have included a roadmap for the support system to improve the quality of life for the elderly (5-1). Households with single and married elderly people account for nearly 50% of the aging society in Japan. We have examined systems and MEMS devices needed for these systems that are primarily designed for elderly people who do not need nursing care. An objective of these systems is to improve the quality of life for these people by preventing diseases and eliminating anxiety.

The achievements based on recommendations in this interim report will be published in a book around this fall.




Roadmap for a Support System to Improve the Quality of Life for the Elderly

# Matsushita Electric Works, Ltd.

**Hiroshi Kikuchi**
**Senior Managing Director in Charge of Technology**

## 1. Endeavors in Micromachine Technology

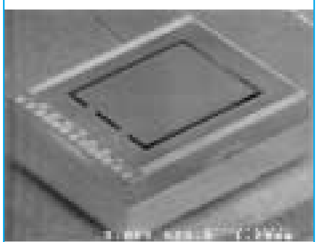
Since its establishment in 1981, the Semiconductor Technology Development Center of Matsushita Electric Works has worked on developing and accumulating knowledge on semiconductor device related technologies such as semiconductor relay devices designed for use at our company. Beginning from the mid-90s, we shifted our development emphasis to MEMS and began in earnest to develop technologies for MEMS devices, such as pressure sensors and accelerometers, in order to enhance the silicon wafer processing technology we had developed thus far. Making maximum use of our infrastructure at that point, we began providing a service to develop trial products for users in-house and launched a MEMS foundry service in January 2002. Our foundry service covers everything from device trial manufacturing to mass-production.

## 2. Development of Micromachine Technology

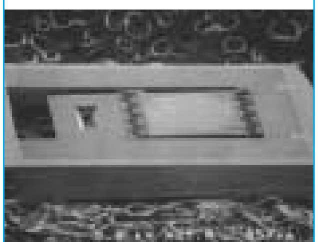
Matsushita Electric Works has already marketed pressure sensors and accelerometers manufactured through bulk micromachining and has produced a total of fifteen million sensors to date. In addition to these sensor devices, we have developed microrelays, microvalves, and other actuator elements that have been well received by academic societies overseas, for example.

We have also enhanced our machining technology to support this production and have made high-precision micromachining possible through Deep-RIE etching that can achieve a high aspect ratio and machining using SOI wafers, a technology in which our company specializes.

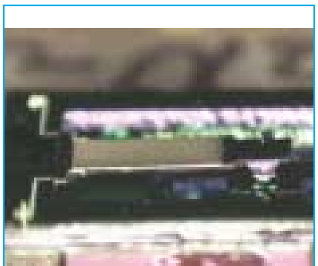
In addition to wafer machining processes for forming MEMS, our company has the technical knowledge of such processes as packaging design, silicon/glass anodic bonding, low-stress wafer dicing, die bonding, and wire bonding and performs a wide variety of services in the foundry service. We also possess a 3D circuit processing technology called MIPTEC (microscopic integrated processing technology) for forming microcircuits in paokage.



Accelerometer



Microrelay



Microvalve

High-aspect machining

## 3. Future Endeavors

We see the applications for MEMS expanding into numerous markets. MEMS are expected to have not only automobiles, as they have in the past, but also a wide variety of applications in mobile communications such as cellular telephones, robots, entertainment, security, environment, energy control, health and medical equipment, and the like.

We have ranked MEMS as the most important device of the future and will contribute to the development of not only our own products, but also the entire MEMS industry, by developing large MEMS projects through our foundry.

MIPTEC (microscopic integrated processing technology)

**Worldwide R&D**

# Kitamori Laboratory, University of Tokyo; Micro Chemistry Group, Kanagawa Academy of Science and Technology; et al.

The Kitamori Laboratory has conducted research on integrating chemical and biotechnological systems on microchips on the basis of applied spectroscopy techniques. The research is broadly divided into four categories: extremely basic research on chemical reactions and the behavior of fluids in microspaces and nanospaces, basic technology research necessary for integrating chemical and biotechnological systems on microchips, applied research on the practical use of integrated microchemical systems, and commercialization research on problems to be overcome for practical use of microchip-integrated devices.

Of these four categories, the basic research has been conducted at the initiative of the Kitamori Laboratory and the basic technology research at the initiative of the Micro Chemistry Group in the Kanagawa Academy of Science and Technology (KAST). The applied research has been advanced as a joint research project with private companies. The Institute of Microchemical Technology (IMT), which we started as a venture company, is responsible for commercialization research. The New Energy and Industrial Technology Development Organization (NEDO) also takes part in some areas of applied research and commercialization research. Our group cooperates with all aspects of the research and development. There are no defined boundaries separating the four categories of research, allowing us to work flexibly according to the research topic. Incidentally, the Micro Chemistry Group became a permanent laboratory to succeed the five-year "Integrated Chemistry Project" that was successfully completed in March. Our research is organized around these four research groups, in which some fifty researchers-about twenty students, seven permanent researchers including professors, seven postdoctoral fellows, several technical assistants, IMT employees, and researchers from private companies-are engaged.

Experiments and simulations conducted in the basic research surprised researchers by shedding light on unrevealed chemical phenomena. The findings include the acceleration of chemical reactions (enzyme reactions, etc.), the formation of vortex structures near the two-phase (liquid-liquid) flow interface regardless of low Reynolds number flows, and the appearance of disordered flow at the interface. In addition, it was found that water approaches the properties of ice at normal temperatures in a mesospace, which is slightly larger than a nanospace.

The basic technology research provided us with a new methodology for integrating normal macrochemical processes on microchips, thereby nearly completing the first step aimed at establishing the principle for "what to do and how to do it." Now, we have begun the second step in which more complicated systems, such as a 3D system and the system consists of liquid and gas phase, are integrated on microchips.

The applied research enabled us to develop a microanalysis device system. With conventional analysis systems, we had difficulty analyzing disease markers and environmental pollutants because of the highly skilled techniques required. However, the new microanalysis device reduced the analysis time to several tens of seconds instead of half a day, demonstrating superior performance and effectiveness on actual samples. For the field of chemosynthesis, we also developed an innovative chemosynthesis device capable of reducing reaction time and processing time, improving efficiency and yield, and controlling an intermediate reaction through instantaneous heating and cooling. Moreover, we developed a new device for cell culture equipped with a life-sustaining function to supply oxygen and nutrients for a microculture vessel created on a microchemical chip. The device provided us with the prospect of developing a device for use in time-consuming experiments and assays on cells and microorganisms.

In the commercialization research, we developed a mass-production system of microchemical chips, a microchip reader equipped with highly sensitive sensors and microsystems for performing diagnoses and health checks and monitoring the environment and are close to completing the prototypes. With the chemosynthesis plant, a gel manufacturing plant the size of a small building was scaled down to the size of shoe cupboard. Despite the downsizing, the gel manufacturing plant has a production capacity of thirty tons per year, which exceeds that of a large-scale plant. The world's first microchemical plant has entered pilot operations through our joint research partner Tosoh Corporation.

IMT, a university-launched venture company, offers standard and custom-made microchemical chips and thermal lens microscopes capable of highly sensitive sensing and serves to restore and disseminate university research findings by providing research materials, enabling inexperienced researchers and engineers to engage in research quickly and easily.

Since there are no foreseeable commercial markets for original technologies, small-scale companies are expected to pioneer the development of new technologies and establish a foundation for creating a new market before major companies can enter. Hence, it is not an exaggeration to say that a process resulting in the creation of a new industry from a university-developed original technology is more an experiment than a pragmatic approach. We work to develop an industry, government, and academia relationship in which universities; enterprises; the Ministry of Economy, Trade and Industry; the Ministry of Education, Culture, Sports, Science and Technology; the Ministry of Agriculture, Forestry and Fisheries; NEDO; the Japan Science and Technology Corporation (JST); the Japan Society for the Promotion of Science (JSPS); and others continue to provide us with considerable support.

We couldn't produce microchannels and microstructures on a microchemical chip smaller than a micron with microfabrication technique. However, we started a new study aimed at constructing a nanoscale infrastructure in a micron-size space in order to develop chemical and biotechnological devices superior in functions and integration capability. The research is based on a concept called a "Nano Bio-Physico-Chemical Architecture". We are looking for a breakthrough in chemical and biotechnological fields through the development of new nanotechnologies, such as nanoscale structures and chemical patterning, reaction and fluid control systems actively applying interface and surface properties, and cell control based on these nanostructures.

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