Essay

Micromachine Technology Reaches a New Stage

Toshiro Shimoyama
Chairman,
Micromachine Center

March 31, 2001 saw the conclusion of the decade-long Micromachine Project, part of the Industrial Science and Technology Frontier Program sponsored by the Ministry of Economy, Trade, and Industry. I would like to take this opportunity to thank the many people from the government, private industry, and academic sectors who have been involved with the Project over the last ten years in a research and/or surveying activity. I would also like to extend my appreciation to all those at the Ministry of Economy, Trade and Industry (formerly the Ministry of International Trade and Industry) in recognition of their support for the Project.

When this Project was launched in 1991, Japan was embroiled in commercial difficulties in the form of trade friction over semiconductors, as well as criticism that it was "freeloading" by benefiting unfairly from the research investment of other nations. The Micromachine Project was an attempt to give Japan an independent research capacity in this area via a completely new approach to research that had never been tried elsewhere. The first phase involved identifying key technology concepts by developing element technology predicated on the idea of machines at the micro level, once the sole preserve of science fiction (such as the movie Fantastic Voyage). The second phase involved the study of systematization technology for integrating the various forms of element technology into machine systems. Overall, the Project was remarkably successful, generating some 530 patent applications and 1,500 research publication papers and presentations (mainly to academic societies).

The Micromachine Project attracted considerable interest from overseas, particularly with respect to its unique approach to industrial research. Many academic groups came to Japan to see the Project. Researchers and experts in Japan and overseas were most impressed. In addition, the Project enjoyed extensive coverage in the worldwide media and became well known in wider society. Last year's Exhibition MICROMACHINE 2000, which featured broadcasts of an experimental prototype system on five programs (including one from the public broadcaster NHK), was the first important step in addressing the national problem of the continuing drift of young people away from science subjects. Despite the ten years lost to the continuing economic downturn, the Micromachine Project has brought Japan closer to the ideals of micromachine technology, which is expected to play a central role in the basic "manufacturing" technology in 21st century.

The Micromachine Center (MMC) was established at the same time as the Micromachine Project with the aim of promoting the technology and providing information worldwide via a range of initiatives. With the conclusion of the Project, micromachine technology has reached a new stage. The first task for us now is to speed up the process of refining the technology to create viable industrial applications. Many other nations, inspired by the work of the Project, are building the necessary infrastructure for design, prototype trials, and production for the development and manufacturing of MEMS. Meanwhile, the MMC is working on practical development in the technology field created through the fusion of micromachine technology and the advantages of MEMS. The second task is to take up the challenge presented by new research areas within the context of nano-technology development around the world.

The nano-technology represents the great unexplored field and the most important branch of technology in the 21st century. This was acknowledged last year when then-president Bill Clinton announced a budgetary allocation of $500 million towards nano-technology development. Nano-technology is a genuinely revolutionary area involving the manipulation of materials at the atomic and molecular level to enable, for instance, the manufacture of materials that are lightweight yet ten times stronger than steel and the detection of cancer cells at a very early stage. But even the most spectacularly advanced nano-technology is not truly useful unless it is complemented by a human interface that appeals intuitively to our basic senses-in other words, human-sized technology is required as well. Micromachine technology provides the bridge, the vital link between nano-technology and human-sized technology. The Micromachine Center is committed to pursuing viable industrial applications for micromachine technology (as described above), while also working to further refine and integrate micromachine technology into nano-technology fields.

The Micromachine Center looks forward to your continued patronage and support in the years to come.

Microsystems Based on the Biological Functions of Insects

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At our laboratory, we are studying on new machinery systems in an interdisciplinary research field between engineering and biology : micromachines, robotics and neuroethology. We are particularly interested in the creation of microsystems modeled on the biological functions of insects and micro-devices designed to help us learn more about biological functions. This article describes some of our main research projects.

Microsensors modeled on the biological functions of insects

We have developed a visual sensor modeled on the compound eyes of insects. Figure 1 shows the visual sensor system consisting of a micro-lens array, a photo-diode array, and an electrostatic microactuator. It is known that insects recognize objects with the aid of minute oscillations of the retina. The visual sensor produces the same effect as the oscillating retina of the insect by scanning the visual axis through oscillating slits operated by the actuator. Significantly, the sensor can be made no thicker than a sheet of paper, making it eminently suitable for the flexible visual devices of the future.

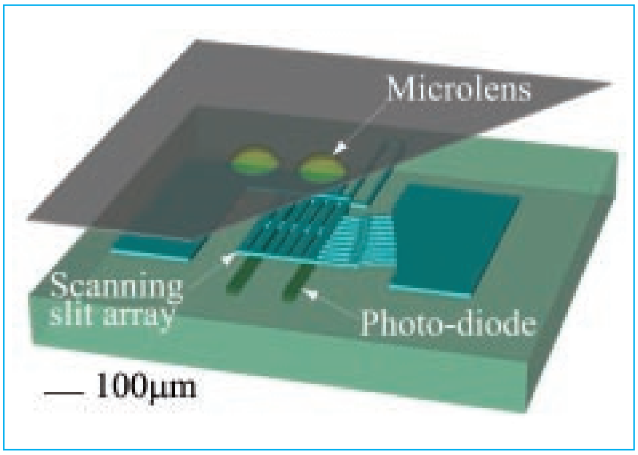

Fig. 1 Visual microsensor modeled on a compound eye

Crickets and cockroaches have thin sensory hairs on a pair of organs extending caudally from the abdomen. Air flow around the insect deflect the sensory hairs, generating mechanical distortion at the base of the hairs which is converted to neurosignals. Figure 2 shows the fabricated air flow sensor modeled directly on this principle. A metal wire is fixed to the center of a supporting cross-beam structure. Movement in the surrounding air causes the wire to bend, generating distortion at the fixed ends of the beams. The distortion is detected by semiconductor strain gauges. We are currently trying to integrate multiple sensors. Similar sensory hairs can be found inside human organs such as the semicircular canals of the inner ear. We are also developing a sensor based on this principle.

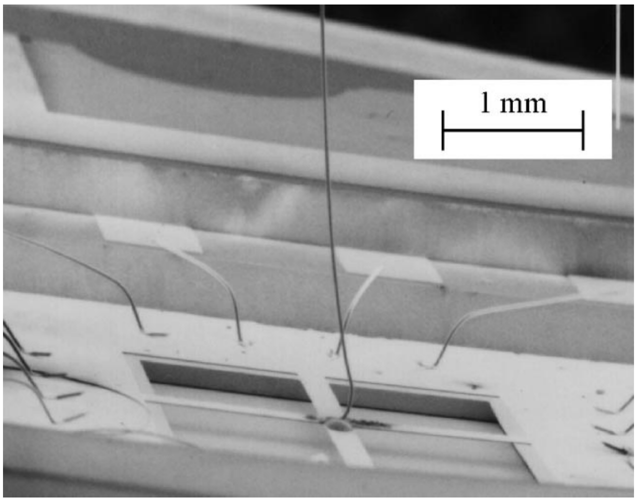

Fig.2 Flow velocity sensor modeled on sensory hairs

Micro-devices for recording biological signals

We are also studying micro-devices for measuring neuroelectric and myoelectric potential in living organisms. We have successfully measured changes in electrical potential on the surface of an insect nerve cord of approximately 100μm diameter by holding it in a micro-electrode clip made of thin-film shape memory alloy (see Figure 3). We are currently developing a wireless telemetry system for mounting on the actual insect that can transmit measurement data back from the electrode.

By integrating the various systems described above, we will be able to measure biological information from an insect without imposing any restriction on its movement or behavior. We are confident that this technology will significantly boost our understanding of the mechanisms underlying insect behavior.

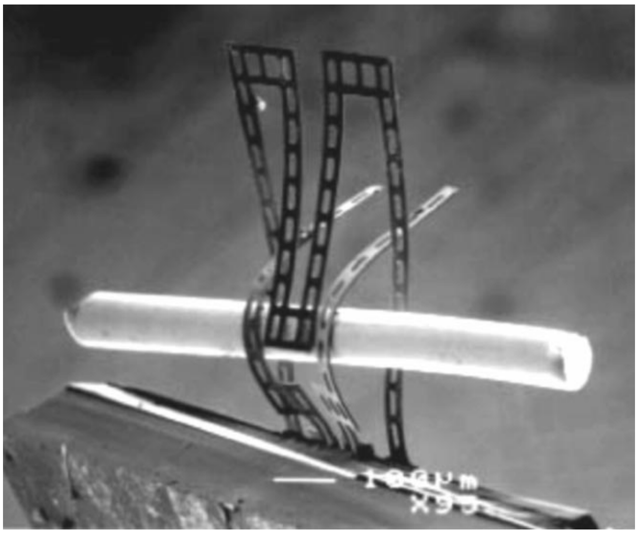

Fig. 3 Microelectrodes for insect neural recording

Activities of the Micromachine Center in Fiscal 2000

I. Investigations and Research on Micromachines

1. The AIST Industrial Science and Technology Frontier Program "Micromachine Technology" (delegated to MMC by the New Energy and Industrial Technology Development Organization [NEDO])

To achieve the goal of the basic plan for R&D (Phase II), research delegated to MMC was actively promoted after pre-final evaluation of this project.

(1) Development of Advanced Maintenance Technologies for Power Plants

① R&D of systematization technology (Experimental wireless micromachines for inspection on inner surface of tubes)

A final experimental system was produced. In metal tubes with curved sections, this system is able to move forward, backward, horizontally and vertically, stop optionally, and recognize its surroundings, as well as detect tube defects.

② R&D of systematization technology (Experimental chain-type micromachines for inspection on outer surface of tubes)

R&D of systematization technology was conducted through the production of an experimental micromachine system composed of a group of machines capable of combining or separating according to the form of the object to be inspected.

③ R&D of systematization technology (Experimental catheter-type micromachine for repair in narrow complex areas)

R&D of systematization technology was conducted through production of an experimental micromachine system capable of entering the equipment of various structures and performing measurements or repairing minute internal flaws.

④ R&D of functional device technologies

R&D was conducted to promote micronization, high performance, and multi-functionalization of functional devices with highly advanced micromachine technology.

⑤ R&D of common basic technologies

R&D was conducted on common basic technologies such as technologies for control, measurement, design, and evaluation necessary for realizing micromachine systems.

⑥ Comprehensive investigation and research

Comprehensive investigation and research of maintenance micromachines necessary for maintaining future power plants was conducted.

(2) Development of Micro-Factory Technology

① R&D of experimental micro processing and assembly system

R&D was promoted on systematization technology, suggesting its effectiveness, by completing the production of the second experimental system for processing and assembling, capable of manufacturing models of small parts.

② Comprehensive investigation and research

Comprehensive investigation and research was conducted on micromachine technology that is capable of performing leading investigative research, and that is expected to be put to practical use in the field of production. In addition, MMC conducted joint research with the National Institute of Advanced Industrial Science and Technology (former The Electrotechnical Laboratory of AIST on enhancing the performance of micro-electron guns for beam processing.

(3) R&D on Micromachine Technology

① Research on micromachine systems

In the medical field, R&D on miniaturization and the multi-functionality of micro-laser catheters and micro-tactile sensor catheters was promoted. R&D was also conducted on micro scanning imaging units.

② Comprehensive investigation and research

Comprehensive investigation and research was carried out on the applications of micromachine systems to the medical field. In conjunction with the AIST Mechanical Engineering Laboratory, MMC also conducted research on micromachine basic design and manufacturing technologies.

2. Investigative Research for the Development of Responses to the Industrialization of Micromachine-based Systems (delegated to MMC by the Japan Machinery Federation)

Business models for new businesses incorporating micromachine technology were considered.

3. Investigative Research for the Creation of Systems Incorporating Next-generation Micromachine Technology (delegated to MMC by the Mechanical Social Systems Foundation)

Focusing on the industrial sector in particular, we considered the clarification of the roles required of government, academia and industry, and the development of strategies for micromachine technology R&D.

4. Investigation and Research on the Applicability of Emerging Technology in Other Fields to Micromachine Technology

Investigative research was conducted to search out emerging technology in various other fields, to verify its applicability and fusion, and to contribute to its diffusion and promotion.

5. R&D on Micromachine Materials (joint research with the Mechanical Engineering Laboratory of AIST)

The following activities were conducted: (1) Research on the operating environments for micro-functional elements; (2) research on micromachine materials; and (3) feasibility studies on micromachine materials.

6. Investigation of R&D Trends in Micromachine Technology in Japan and Abroad

Review surveys of the latest development centering on international conferences.

7. Activities incidental to other Investigative R&D

Holding of R&D Section meetings, Investigative Research Section meetings, and departmental and general research meetings.

II. Collection and Provision of Micromachine Information

① Collection and storage of information and documents on micromachines
② Maintenance and expansion of the MMC library, with all information listed in a database
③ Publication of a periodical, "*Micromachine Index*" (published 8 times in FY 2000)
④ Publication of a newsletter (on research and administration trends and the like)
⑤ Methods for transmitting data via Internet homepages, such as database construction and data management operations, were considered.

III. Exchange and Cooperation with Worldwide Organizations Involved with Micromachines

1. Research Grants for Micromachine Technology (12 themes in total)

Six new themes and six themes carried over from FY 1999

2. Participation in International Symposiums and Dispatching Missions

① Participation in μTAS 2000(the Netherlands) and ISAP 2000 (Glasgow, the United Kingdom) in May 2000
② Participation in SPIE 2000 Symposium (Santa Clara, U.S.A.) in September 2000
③ Participation in IWMF' 2000 (Freibourg, Switzerland) in October 2000
④ Participation in The 2000 ASME International Mechanical Engineering Congress & Exposition (Orlando, Florida, U.S.A.) in November 2000
⑤ Participation in MEMS 2001 (Interlaken, Switzerland) in January 2001

3. The 6th Micromachine Summit (Hiroshima, April 10-12, 2000)

4. The 6th International Micromachine Symposium (November 9-10, 2000)

Held at Tokyo Science Hall; jointly sponsored by MMC and the Japan Industrial Technology Association.

5. Overseas Seminars

① European Seminars in Poland, Austria and Switzerland in September 2000
② Asian Seminars in Malaysia, Singapore and Thailand in November 2000

IV. Micromachine Standardization

1. International Standardization Program for Assisting New Industries "Standardization of Quality Characteristic Measurement Evaluation for Micromachine Materials" (delegated to MMC by the New Energy and Industrial Technology Development Organization [NEDO])

The Round Robin Test started in FY 2000. In connection with this program, joint research with the Mechanical Engineering Laboratory of AIST was conducted.

2. R&D on Standardization

Consideration of the important elements, and the technological issues involved therein, of the Standardization Program established in FY 1998 has moved forward.

V. Dissemination of Information and Education about Micromachines

1. MMC published a public relations magazine, "MICROMACHINE" (published 4 times in FY 2000, in both English and Japanese)
2. MMC held the 7th Micromachine Drawing Contest
3. MMC held Micromachine seminars within Japan (in Fukui on September 22,2000 and in Tokushima on February 9,2001)
4. MMC produced videos of the 6th Micromachine Summit, the 6th International Micromachine Symposium, the 11th Micromachine Exhibition, and other events
5. MMC twice organized seminars presenting the results of "Research on the Applicability of Emerging Technology in Other Fields to Micromachine Technology in FY 1999" (in Tokyo on July 7,2000 and January 12,2001)
6. MMC hosted a workshop presenting the results of "Research Subjects for the 6th Micromachine Technology Research Grants (FY 1998)" on September 26,2000
7. MMC assisted in the editing and publishing a booklet directed at high school students entitled Industry Graph 2001 Number 189: Our Country's Micromachine
8. MMC held the 11th Micromachine Exhibition on November 8-10, 2000 at the Science Museum in Tokyo

The Research Reports under the 7th 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, as well as to promote further development of micromachine technology and communication between academics and people in the industrial world.

Among the themes selected for the seventh (1999) research grant, one 1-year research project and six 2-year research projects carried over from fiscal 1998 have been completed.

Turn the page for a summary of the research results.

Subjects for the Micromachine Technology Reserch Grant

Research Project Selected for Fiscal 1999

Leader & Co-Worker	Affiliation	Subjects	Period
Assoc. Prof. Takaaki Oiwa	Faculty of Engineerring, Shizuoka University	Coordinate Measuring Machine Using a Parallel Mechanism for Micromachine Parts	1 Year

Carried-Over Projects Selected for Fiscal 1998

Leader & Co-Worker	Affiliation	Subjects	Period
Prof. Masao Washizu	Department of Mechanical Engineering, Kyoto University	Molecular Surgey of DNA based on Microsystems	2 Years
Prof. Kazunori Kataoka Research Assoc. Atsushi Harada	Department of Matenals Science, Graduate School of Engineering, The University of Tokyo Department of Matenals Science, Graduate School of Engineering, The University of Tokyo	Structural Design of a "Chemical Nano-machine" Based on the Self-organization of Polymers and Its Application to Targeting Therapy	2 Years
Research Assistant Prof. Tooru Ooya	School of Materials Science, Japan Advanced Institute of Science and Technorogy	Study on Biomedical Micromachine Using Biodegradable Supramolecular-Assembly	2 Years
Lecturer, Hiroshi Toshiyoshi Prof. Hiroyuki Fujita	3rd Division, Institute of Industrial Seience, The University of Tokyo 3rd Division, Institute of Industrial Seience, The University of Tokyo	Micromachine System for Micro-optical Smart Pixel Application	2 Years
Prof. Shigefumi Nishino Research Assoc. Kiyoshi Takano	2nd Division, Institute of Industrial Science, The University of Tokyo 2nd Division, Institute of Industrial Science, The University of Tokyo	Experimental Study on Fluid Flow and Heat Transfer inside Microchannels Utilizing Micromachining Technology	2 Years
Prof. T. H. Barnes	Physics Department, University of Auckland, New Zealand	Low Noise Feedback Interferometry for Micromachine Servo Actuators	2 Years

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

1. Objective of the research grant
Basic research on basic technology, functional element technology, and systematization technology for micromachines

2. Research period
Theme A : April 2002 - March 31, 2003, or
Theme B : April 2002 - March 31, 2004

3. Application period, theme decision, and funding grant date
Application period : July 10 - October 31, 2001
Theme decision : Middle of March 2002
Funding grant date : End of March 2002

4. How to apply
Send a fax requesting the application form to the Micromachine Center. Be sure to include your own fax number or a fax number where we can contact you.
Micromachine Center Fax : +81-3-5294-7137

5. Qualifications
College or university faculties (professors, associate professors, lecturers and research associates) who belong to academic societies affiliated with the Federation of Micromachine Technology

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

Coordinate Measuring Machine Using a Parallel Mechanism for Micromachine Parts

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1. Introduction

As the formation of high-precision micro-parts having complex 3D shapes is becoming feasible, there is increasing necessity to perform precise 3D evaluations of such parts. Rather than using mechanisms based on the conventional rectangular coordinate system, we proposed a new 3D coordinate measuring machine (CMM) using a parallel mechanism in which active pairs are set in parallel with an output link. In the present study, we will develop a small parallel μCMM using such a mechanism. This paper will give a brief outline of this device and report on the results of studies on the link layout, as well as the trial-manufactured prismatic links (struts).

2. Outline

Fig. 1 shows a conceptual diagram of the parallel μCMM, the basic design principles of which are described below.

(1) A link mechanism consisting of a parallel mechanism with 3 degrees of freedom (DOF) is used in place of the mutually orthogonal slide mechanisms using the rectangular coordinate system.

(2) While the spherical joints are the basic form of reference for conducting precise measurements, calibration is performed based on displacement sensors built into the strut that measure the rotational error of the joint.

(3) The link layout is designed as a retracting mechanism to improve the measuring resolution in relation to the scale resolution. Therefore, the mechanism is larger in relation to the measuring space.

(4) The link layout is optimized to eliminate the effects of joint rotational error and error in the mechanism's parameters on measurement precision.

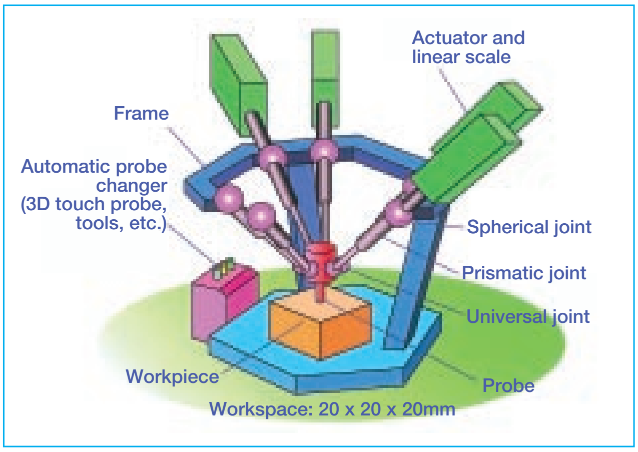

Fig.1 μ-CMM using a parallel mechanism

3. Link Layout Design

The link layout was studied to reduce the effects of errors in parameters and joint rotation on movement of the probe in order to further improve measuring resolution. We used singular values in a Jacobian matrix as a function for expressing the magnitude of the above effect. For purposes of comparison, the radial position of the spherical joint on the base and the size of the measuring space (100 × 100 × 100mm) were set equivalent to the conventional parallel CMM. The stage radius, probe length, and position on the measuring space along the Z-axis were set as design variables. Fig. 2 shows the layout of the links for the parallel μCMM based on this design. The actual size of the parallel μCMM is expected to be about 1/2-1/5 the dimensions given in the diagram.

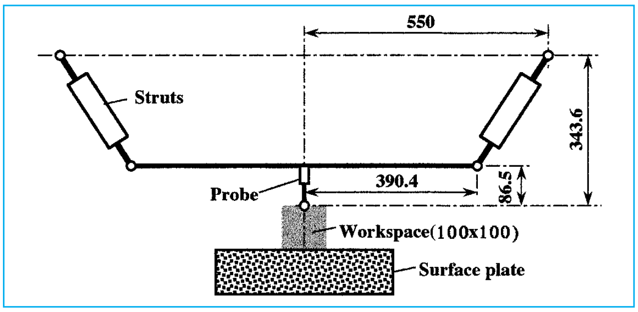

Fig.2 Link configuration after optimal design

4. Prismatic Links

Next, an outline will be given for the trial prismatic links. Fig. 3 shows a photo of the link. An inchworm mechanism having a layered piezoelectric element was used as the actuator. The theoretical drive resolution was set to 2nm or less. An advanced linear measuring unit (scale) having a precision of ±0.1μm and a resolution of 2nm or less is also built into the link. Velocities were measured when applying a load in the form of weights having masses of 10-400g. From these measurements, it is clear that the velocity is nearly proportional to the size of the load, and the links have a thrust of more than 4 N per link. Next, positioning with closed loop controlwas performed using the measuring unit as a feedback sensor. The time required for performing a 10-μm step positioning process was within 0.1sec.

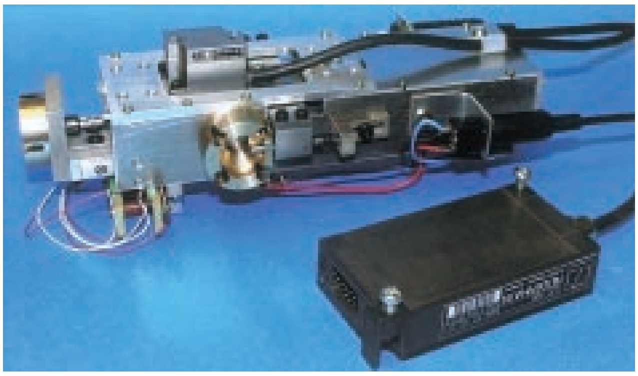

Fig.3 Photo of the trial-manufactured prismatic link

5. Conclusion

As described above, we proposed a small 3D CMM employing a parallel mechanism of 3 DOF with the aim of measuring the dimensions and geometric deviation of 3D parts, such as micromachine parts. The link layout was designed and trial prismatic links were manufactured and evaluated. Future plans call for studying the effects of the elastic deformation and rotational error in the joints unit on thermal deformation of the links.

Molecular Surgery of DNA based on Microsystems

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Professor,
Department of Mechanical Engineering, Kyoto University

1. Introduction

In recent years, research has intensified on μ-TAS and other such systems that fabricate chemical systems to be integrated on a chip. Although μ-TAS in its present state is not really micro-sized, the samples are provided in an aqueous solution, that is, as a bulk sample. Hence, by further miniaturizing these systems, we should be able to develop an ultimate chemical system capable of treating molecules individually. DNA is thought to be the most suitable target for manipulation on the molecular level, because DNA molecules contain the fundamental blueprints of life and can easily multiply molecules. In the present study, we researched a method of "molecular surgery" for fixing a single DNA molecule to a fixed surface in order to cut or otherwise alter the molecule.

2. Molecular Surgery of DNA

Just as a patient is fixed to an operating table in normal surgery, the DNA molecule, which is the target of our molecular surgery, must also be fixed to a surface. It is also necessary to stretch the DNA molecule in a linear shape in order to access the desired location. The author and others developed a method using the electrostatic field in a micromachined electrode to stretch the DNA and anchor the ends of the molecule. As shown in Fig. 1, enzyme cutting at a specified position is achieved by laser-manipulated micro-particles on which DNA-cutting enzymes are immobilized.

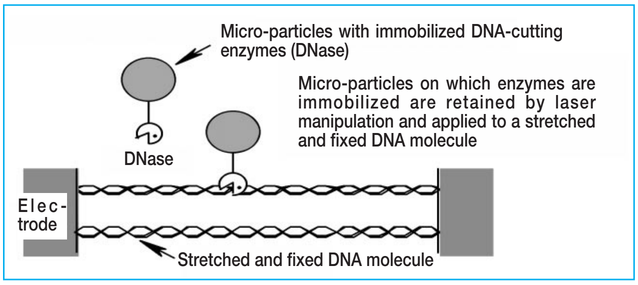

Fig.1 Conceptual drawing of DNA molecular surgery

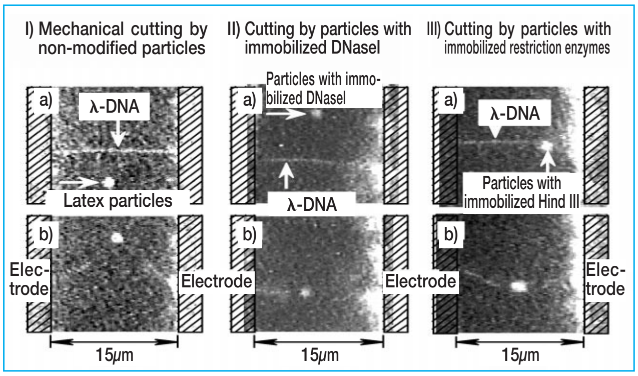

Fig.2 Molecular surgery of DNA

Fig. 2 shows photos of the cutting operations. In Fig. 2 I), latex particles on which enzymes are not immobilized are pressed against the DNA. Mechanical cutting does not occur until the DNA has stretched 1.5 times its natural length. In Fig. 2 II), DNaseI are immobilized on particles that are pressed against the DNA for cutting the DNA without relation to its base sequence. Cutting occurs the moment the particles contact the DNA. In Fig. 2 III), restriction enzymes are immobilized on the particles for recognizing and cutting a specific sequence. In this case, cutting occurs only when the particles contact the sequence to be cut (see Fig.2 III b).

3. Developing Microprobes for Molecular Surgery

In order to perform molecular surgery at a high resolution, we developed a probe for molecular manipulation, as shown in Fig. 3. The probe is formed of a substrate having a sharp point and three or more spherical particles fixed to the top surface of the probe. By retaining the particles on the substrate independently by a laser beam, the probe is designed to push its pointed tip, on which enzymes are immobilized, on a desirable position and at a desirable orientation. The probe is first manufactured as a cantilever structure by performing Si anistropic etching on the substrate. The micro-particles are then fixed to the substrate by a molecular linker, and the structure is broken off at the root.

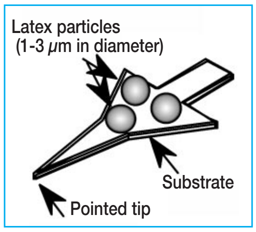

Fig.3 Microprobe for manipulating molecules

Fig. 4 shows an example for controlling the orientation of the probe. By deflecting a single laser beam at a high rate of speed using a galvanometer mirror, each of the three particles are trapped through a time-division method. Translational and rotational movement of the probe is then achieved by moving the micro-particles while maintaining their relative positions to one another.

4. Conclusion

Micromachine technologies, such as micromachined electrodes and micromachined probes, are powerful means for interfacing with the molecular nano-world and macro-world. Based on our current direction, we anticipate breaking away from conventional biochemical methods, in which molecules are collected in a test tube base, and developing new biotechnologies capable of performing deterministic manipulation on specific molecules at specific positions.

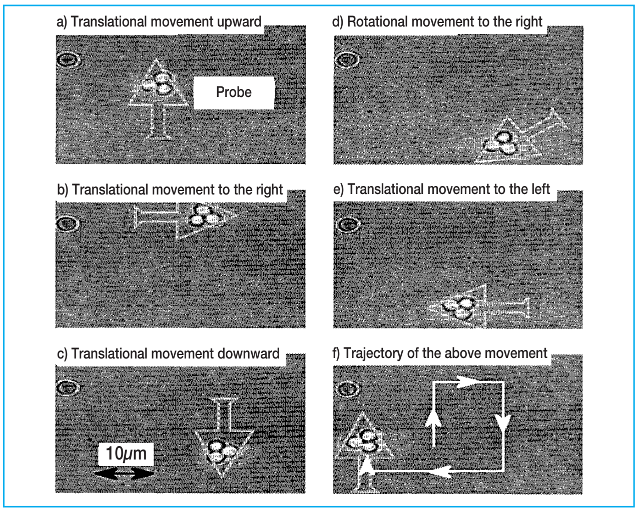

Fig.4 Translational and rotational movement of the probe

Structural Design of a "Chemical Nano-machine" Based on the Self-organization of Polymers and Its Application to Targeting Therapy

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1. Introduction

The capacity to work effectively in microspaces is important in the field of micromachine technology. Focusing from such viewpoint, there are many kinds of available molecules in nature. Enzymes, for example, serve as a biological catalyst that, when catalyzed under mild conditions in an organism, can generate numerous organic reactions with phenomenal speed and selectivity. Hence, enzymes can be considered a type of natural micromachine. However, their use *in vivo* often limited due to their instability and antigenicity. In particular, solving these problems is a major issue in the field of site-specific enzyme delivery. In this study, we prepared core-shell type multimolecular assembly entrapping enzyme molecules in the core (see Fig.1), which were formed from the mixture of charged block copolymer (polyethylene glycol-block-poly α,β-aspartic acid) with an enzyme (egg white lysozyme) driven through electrostatic interaction in an aqueous solution. We studied the utilities of the "chemical nano-machine" to perform appropriate biochemical reactions under various conditions.

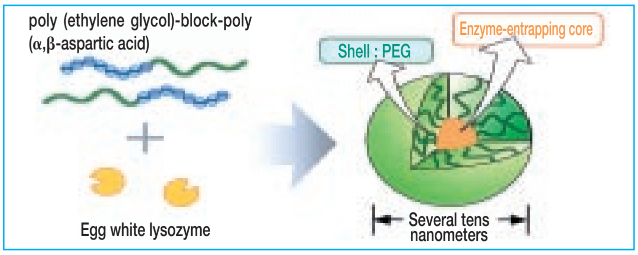

Fig.1 Chemical nano-machine entrapping enzyme in the core

2. Environmental-Responsive Chemical Nano-machines

We confirmed that core-shell type multimolecular assembly entrapping enzyme in the core, as shown in Fig.1, exhibited a reversible formation with the change in the ionic strength (NaCl concentration) in the aqueous solution. Enzyme was entrapped in the core at a low ionic strength, but was released from the assembly when the ionic strength was increased. The enzyme once again returned to the core of the assembly after the ionic strength was lowered. It was applied this behavior as on-off control system of enzymatic reaction. In order to evaluate enzyme activity, a substrate (bacterial cell) with larger size than the assembly was used. There observed no activity, when the enzyme was entrapped in the assembly (low ionic strength), since the enzyme could not interact with the bacterial cells. However, increasing the ionic strength, the enzyme was released from the assembly and could easily interact with the substrate, at which enzyme activity was shown (see Fig.2). It was also confirmed that this process was repeatable, and enzymativactivity could controlled through the reversible formation of core-shell type assembly.

3. Chemical Nano-machine System Using the Core of Assembly as Enzymatic Nanoreactor

As mentioned above, the enzymatic reaction is controlled through the reversible formation of the assembly. Such assembly has another possibility as applied material by using the core of the assembly having the structure shown in Fig.1 as an enzymatic reaction field. Thus, it was evaluated the enzyme activity of lysozyme in the core of the assembly. In this evaluation, the substrate with relatively small size, which could diffuse into the core of

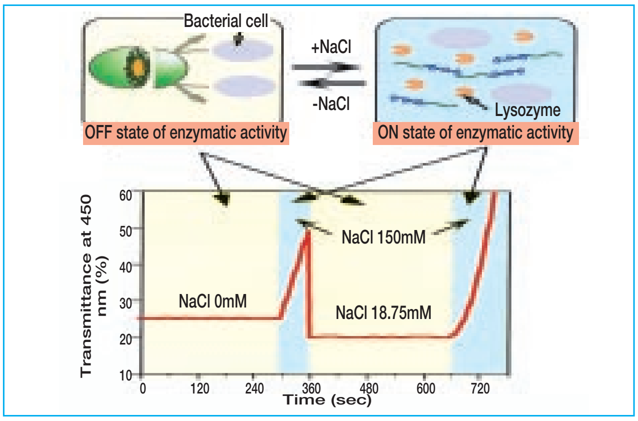

Fig.2 On-off control of enzymatic activity synchronizing with reversible formation by an external stimulus

the assembly, was used, and enzymatic activity was evaluated through the monitoring of the release amount of p-nitrophenol. Fig.3 shows the results of observing the generation of p-nitrophenol directly after combining the enzyme by itself and entrapped in the assembly with the substrate solution. These results showed that an enzyme reaction occurs even when the enzyme is entrapped in the assembly. Interestingly, the reaction rate of enzyme in the core of the assembly was twice as fast with free enzyme. By determining the kinetic constants of enzymatic reaction, it was confirmed that the enhanced effect of enzymatic reaction was induced by the effective condensation of the substrate to shell-layer of the assembly. Hence, the shell-layer might work as a reservoir for the substrate. This suggests the possibility of further encouraging the enzyme reaction without chemically conjugation of the enzyme with polymers, by increasing the affinity of the substrate and the shell-forming segment.

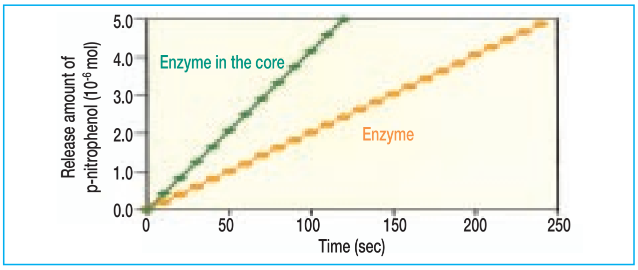

Fig.3 Release profile of p-nitrophenol with enzymatic reaction using the core of the assembly as a reaction field

4. Conclusion

Using self-organization between an enzyme and a synthetic polymer, we prepared multimolecular assembly with an average particle size of 50 nm having a core-shell structure for entrapping the enzyme. The formation of the assembly exhibited a reversible behavior that could be controlled by external stimuli (modifying the ionic strength). It was confirmed that such external stimuli can be used to turn the enzyme activity on and off. We also confirmed that the core of the assembly could be used as a nanoscopic enzymatic reaction field. Based on such interesting behavior, the assembly could be aptly named a "chemical nano-machine." This system shows great promise not only in enzyme targeting, but in various fields as a diagnostic tool.

Study on Biomedical Micromachine Using Biodegradable Supramolecular- Assembly

Tooru Ooya
Research Assistant Professor,
School of Materials Science, Japan Advanced Institute of Science and Technology

1. Introduction

Recently there has been a general trend of growing expectations throughout the world in the fields of nanoscale science and nanotechnology. Strategic approaches are important in the design of biomedical micromachines for controlling molecular forms from nano to micro level. This study focuses on the supramolecular structure and cylindrical shape of polyrotaxanes, in which numerous alpha cyclodextrins (α-CDs) are threaded onto a polyethylene glycol (PEG), to investigate the effects of a particular polyrotaxane structure on the function of molecular recognition.

2. Enhanced Enzymatic Recognition by Supramolecular Structure of Polyrotaxanes

In synthesizing the polyrotaxane, a peptide sequence phenlyalanylglycylglycine (FGG) is introduced at the ends of the polyrotaxane as the oligopeptide group. FGG itself can be completely degraded by an exo-peptidose, such as aminopeptidase M (AP-M). From the result of in vitro experiment, it was found that FGG in FGG-terminated PEG that had not been threaded through the α-CD cavity degraded only 30%. This indicates that increased while molecular weight due to conjugation of FGG and PEG are chemically bonded and interaction between the AP-M and FGG terminals. On the other hand, degradation of FGG-terminated polyrotaxane completely proceeded, indicating that the interaction increases again due to α-CD threading through the PEG (see Fig.1). Since the *Km* value was about 1/22 of the FGG-terminated PEG, it was suggested that the supramolecular structure of the polyrotaxane actually improved the enzymatic recognition.

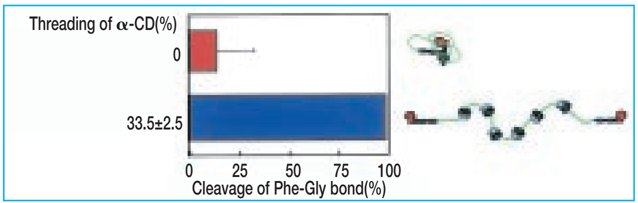

Fig.1 The effects of α-CD threading on the terminal tripetide degradation by aminopeptidose M

3. Recognition of polyrotaxane-Biotin Conjugates

Approximately 300-400 hydroxyl groups exist along the cylindrical structure in one molecule of polyrotaxane. If numerous water-soluble ligands are introduced, it is expected that the ligands become oriented along the cylindrical structure of the polyrotaxane. Based on the hypothesis biotin was introduced into the polyrotaxane and its interaction with streptavidin (SA) precoated on the surface of a sensor was analyzed using a surface plasmon resonance (SPR) appratus. From the SA binding curve during the coating process, the surface density of the SA was estimated at 2.5×10^{-5} nmol/mm^2. Based on a theoretical length estimated on the presumption that the polyrotaxane-biotin conjugate is cylindrically shaped, a polyvalent interaction such as that shown in Fig.2 is considerable. The biotin introduced into the polyrotaxane was recognized by SA which was confirmed from the binding curve when adding the solution containing the polyrotaxane-biotin conjugate. This demonstrates that molecular designs introducing ligands in cylindrical structures of polyrotaxane can be used as probes for recognizing specific receptors.

4. Inhibiting Peptide Transporter (PepT1) function by Dipetide-Polyrotaxane conjugates

This work was carried out collaboration with Professors Akira Tsuji and Dr Ikumi Tamai of Kanazawa University, Department of Pharmaceutical Sciences. A dispeptide of varyl-lysine (Val-Lys) that is transportable via peptide transporter (PepT1) was introduced into numerous hydroxyl groups of polyrotaxane. PepT1 is well known to be expressed in the small intestine on the brush border membrane of intestinal epithelial cells. In the in vitro experiment, we studied the capacity of the polyrotaxane cylindrical structure of the synthesized Val-Lys-polyrotaxane conjugates to inhibit transporting (uptake) of a dipeptide derivative (glycylsarosine; GlySar), which is specifically recognized by the PepT1. It was confirmed that the conjugate included about 46 molecules of Val-Lys in one molecule of polyrotaxane. The uptake of GlySar was decreased by adding this conjugate to a Hela cell culture medium in which PepT1 was stably expressed. When converting the concentration of Val-Lys to the same concentration of Val-Lys-introduced dextran or Val-Lys-introduced α-CD, the inhibition is weaker than when using Val-Lys-introduced polyrotaxane. This suggests that the cylindrical structure of the polyrotaxane is effective in the interaction between Val-Lys and PepT1. Therefore, it is suggested that Val-Lys in the conjugate polyvalently interacts with PepT1 (see Fig.3).

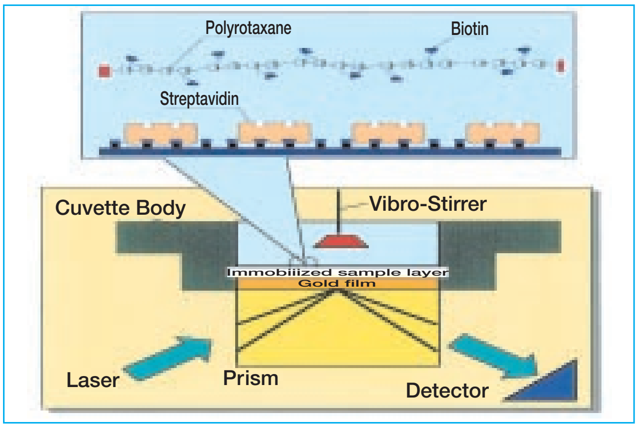

Fig.2 Image of polyvalent interaction between a polyrotaxane-biotin conjugate and streptavidin in a surface plasmon resonance (IAsys, Affinity Sensors)

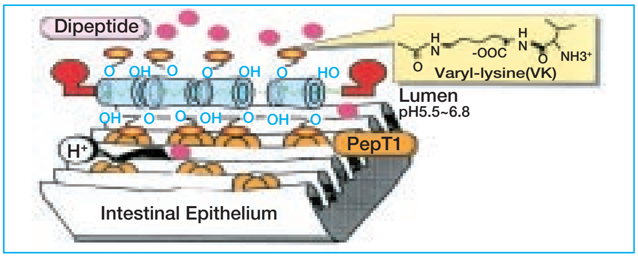

Fig.3 Illustration of Inhibiting transport of dipeptide is inhibited by polyvalent interaction between a polyrotaxane-VK conjugate and PepT1

5. Conclusion

The above results indicate that the supramolecular structure and cylindrical shape of the polyrotaxane is useful for (1) forming an enzyme-substrate complex and (2) controlling receptor recognition.

Micromachine System for Micro-optical Smart Pixel Application

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Hiroyuki Fujita, Professor,
3rd Division, Institute of Industrial Science, The University of Tokyo

1. Introduction

We designed and manufactured two-dimensional micro-mechanical optical scanners and evaluated their properties with the aim of applying smart pixels in optical communication switching. Smart pixels are used to integrate mechanical, electrical, and optical devices in a micro three-dimensional space.

2. Micro-mechanical Smart Pixels

Fig.1 shows a conceptual view of a micromachine system, the objective of the present study, employing smart pixels to integrate micro-mechanical (MEMS) elements. This system includes an array of optical input fibers and optical beam steering elements (scanners) using micromachines. The optical switching function is achieved by projecting an optical beam onto corresponding output ports. As shown in the diagram, a lens, diffraction grating for wavelength selection, and filter are inserted between the input and output fibers to magnify the beam scanning angle.

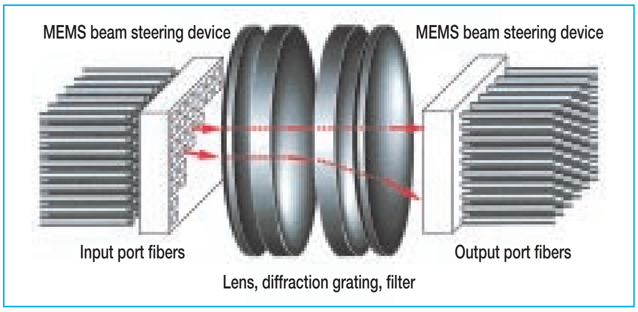

Fig.1 Concept of micro-mechanical smart pixels

3. Two-Dimensional Torsion Mirror Laser Scanner with Electrostatic Actuators

Fig.2 shows an electrostatic torsion mirror device serving as a two-dimensional optical scanner, using a micro mirror to reflect light. The transter function of this device has large nonlinearity and crosstalk. Hence, complex feedback control would be needed to achieve precise positioning control in a device for modifying the optical path of smart pixels, for example. In order to simplify transient control for switching, we developed a reliable open-loop control method and an analytical model. The drive voltages are determined based on this model. Fig.3 shows the reflected beams projected on a grid pattern grating. With this construction, it was possible to prevent beam aberration and to shorten the switching time. The construction can also contribute to lowering signal leakage if the switching paths are arranged skillfully.

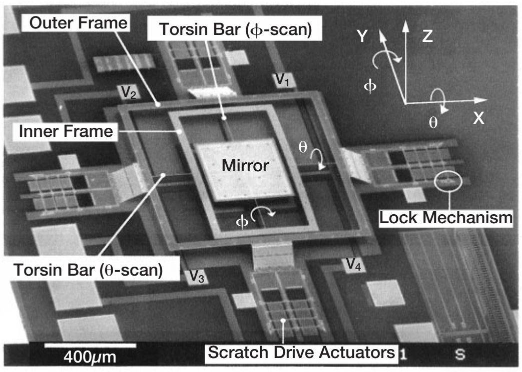

Fig.2 Two-dimensional torsion mirror laser scanner

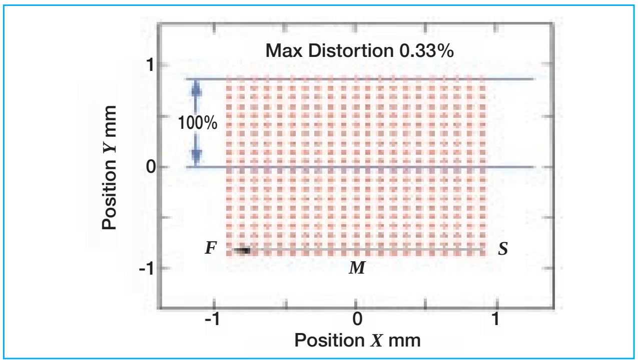

Fig.3 Results of scanning with the mirror scanner

4. Micro-lens Two-Dimensional Laser Scanner

Fig.4 shows an optical transmission scanner employing the XY movement of a micro lens. Unlike the mirror type scanner, the lens movement and scanning angle of the light are linear. Further, the lens can be maintained at a desirable position. Four polysilicon scratch drive actuators are employed to drive the lens. The lens position (scanning angle) is controlled through the counting of voltage pulses.

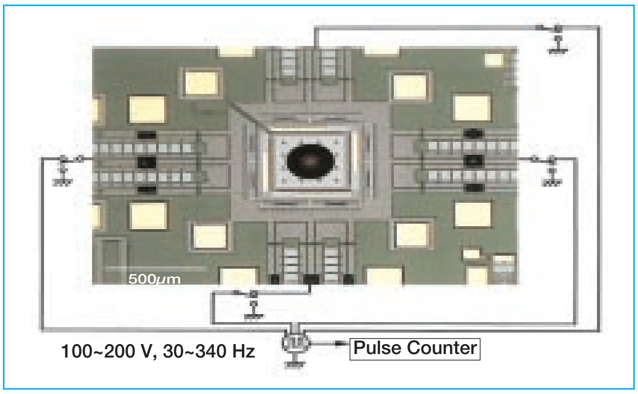

Fig.4 Two-Dimensional micro-lens laser scanner

5. Conclusion

As described above, we developed two types of trial optical scanners: a reflection type and transmission type, evaluated their performances, and built an analytical model. We were able to gather much data on process yields inherent in surface machined devices, failure modes during operations, and analytical methods. We would like to further reduce the size of these devices and attempt to integrate them with an actual control drive circuit.

Acknowledgments

The results of this study were obtained through joint research conducted during FY 1999 and 2000 in the laboratory of Prof. Ming C. Wu of UCLA's Electrical Engineering Department.

Experimental Study on Fluid Flow and Heat Transfer inside Microchannels Utilizing Micromachining Technology

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Kiyoshi Takano, Research Associate,
2nd Division, Institute of Industrial Science, The University of Tokyo

1. Introduction

As channels are being manufactured with increasingly smaller inner diameters, we are beginning to see the emergence of a peculiar thermohydrodynamic effect. This suggests that estimations on the normal scale can produce major errors, making it impossible to estimate the flow and heat transfer characteristics of a fluid with precision. The present study is aimed at determining the channel diameters at which specific thermal and flow phenomena occur and clarifying the characteristics of such phenomena. In general, heat transfer increases with decreases in the equivalent diameter. However, we hypothesized that heat transfer may reach a maximum value at a certain diameter. It is conceivable that the results of this study will provide valuable information for many fields with broad applications.

2. Experiment Methods and Equipment

Fig.1 shows an overall view of the equipment used in the experiment. The equipment comprises a (1) fluid supply system (micro-pump, buffer tank, filter, pressure gauge of diaphragm type, and flowmeter), a (2) fluid heating and vacuum insulation system (constant temperature bath and vacuum pump), and a (3) cooling-fluid supply system (constant temperature bath, pump or air blower, and magnetic flowmeter).

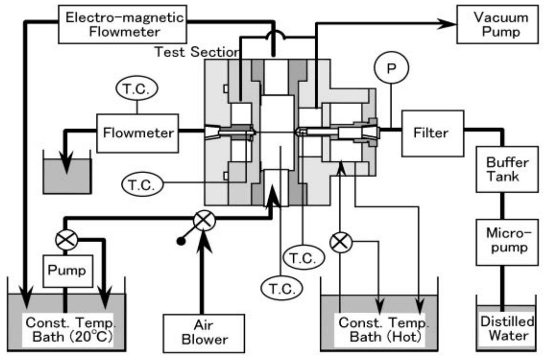

Fig.1 Overview of equipment used in the experiment

Fig.2 shows a detailed construction of the test section in the experimental equipment. Since the test section should be designed to drastically reduce heat loss around the microchannel, all parts except the fluid heating unit at the inlet are made of an acrylic resin. Fluid is introduced through the test liquid inlet (1), where it is heated to a prescribed temperature (50°C) by circulated hot water (2). Subsequently, the fluid passes through a vacuum chamber (3) and is introduced into the microchannel (6). During the experiment, measurements are taken of the fluid temperature at the inlet and outlet of the microchannel, flow rate of the fluid, temperature and flow rate of the cooling water, and pressure of the fluid at the inlet to the microchannel.

3. Results

As for the friction factor on the normal scale, f, the f-Re value is fixed at 64. In the present experiment, however, the f-Re value was approximately twice that on the normal scale. While this is considerably higher than results of microchannel measurements reported thus far, the reason for this high value has not been identified at this stage. Fig.3 shows the measurements taken of the average Nusselt number Nu_i in the channel.

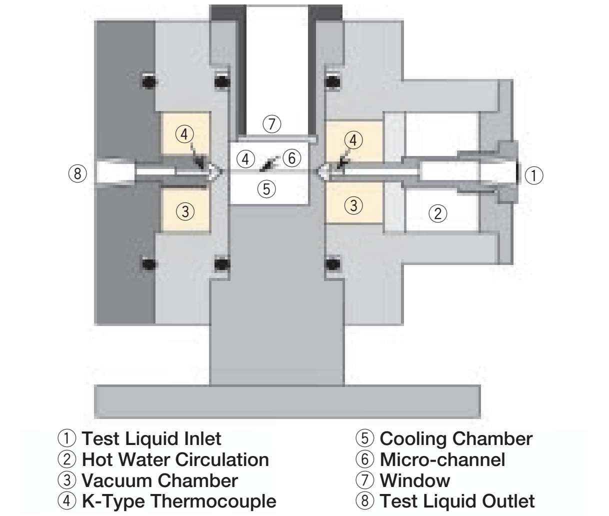

Fig.2 Detailed construction of the test section

The Nusselt number Nu_i in the present experiment was within a range of about 0.7-1.0. This value is clearly smaller than the fixed value 4.36 for laminar flow at a constant heat flux on the normal scale and is 1.7-3 times higher than the results of Choi, et al. Further, the Nusselt number Nui was clearly shown to be dependent on the Reynolds number Re, as the Nusselt number Nui decreased along with decreases in the Reynolds number.

4. Conclusion

The following conclusions were made after analyzing measurements of the coefficient of friction and the average Nusselt number Nu_i in a microchannel having an inner diameter of 52.9μm and a length of 30mm.

(1) The average Nusselt number exhibited heat transfer characteristics thought to be inherent in microchannels, including a value lower than the normal scale and decreases dependent on the Reynolds number.

(2) From the above results, a diameter near the lower limit that exhibits heat transfer characteristics on the normal scale is optimal for the design of heat exchange devices. However, this issue needs to be examined further in the future.

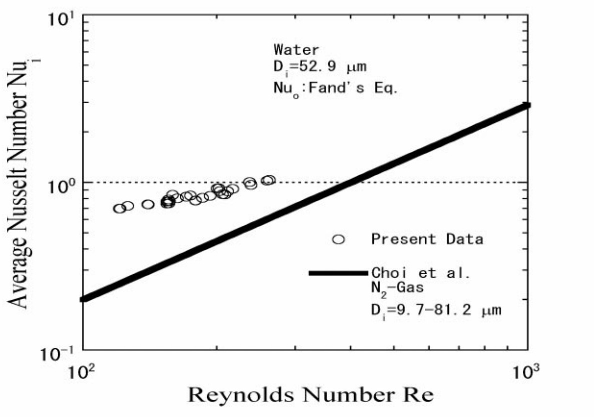

Fig.3 Measurements of the average Nusselt number

Low Noise Feedback Interferometry for Micromachine Servo Actuators

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Professor,
Physics Department, University of Auckland, New Zealand

1. Introduction

In this project we have developed the new technique of feedback interferometry for micro machine applications where displacement measurements to an accuracy of a few nm are desirable. Feedback interferometry has the potential to measure phase rapidly, with high accuracy, using simple optical systems, but its performance limits have not been know until now.

We have for the first time determined feedback interferometer accuracy, the conditions under which they are stable, and their noise performance. We tested our theory in the laboratory using a prototype high-precision feedback interferometer. It was capable of measuring movements with a repeatability of λ/80, and linearity better than λ/100.

2. Principles

Fig.1 shows a generic feedback interferometer. The output intensity of the interferometer is used to control the phase in one arm of a two beam interferometer. The instrument measures the interferometer phase ϕ_i which in a micromachine system might - for example - arise from movement of the other interferometer mirror. By solving the feedback interferometer equation:

$$Io/B=1+\cos(\phi_i+GIo/B) \cdots\cdots\cdots\cdots(1)$$

we find that the interferometer output intensity Io varies linearly with phase. Interferometer phase can then be determined directly from the output intensity (Fig.2). The system can track accurately over several wavelengths.

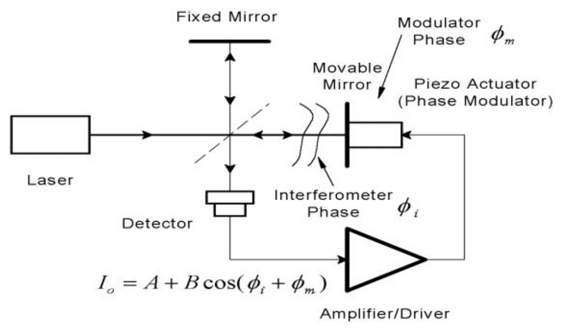

Fig.1 Feedback Interferometer

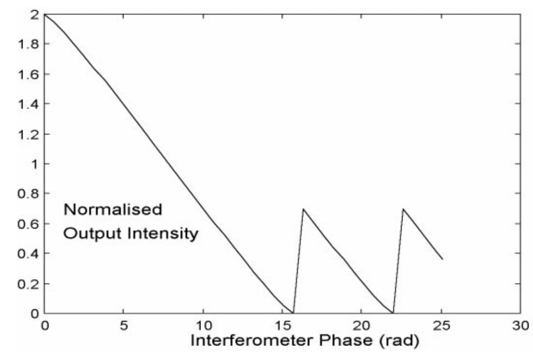

Fig.2 Feedback Fringe Profile

3. Experiments and Results

Fig.3 shows our prototype interferometer to compare the accuracy of feedback interferometry with conventional phase-stepping and heterodyne techniques.

Feedback is applied via mirror M2, with mirror M1 moved by piezo actuator to vary interferometer phase.

Fig.4 shows the interferometer accuracy. The phase from feedback interferometery is linearly related to that phase stepping with repeatability of λ/80.

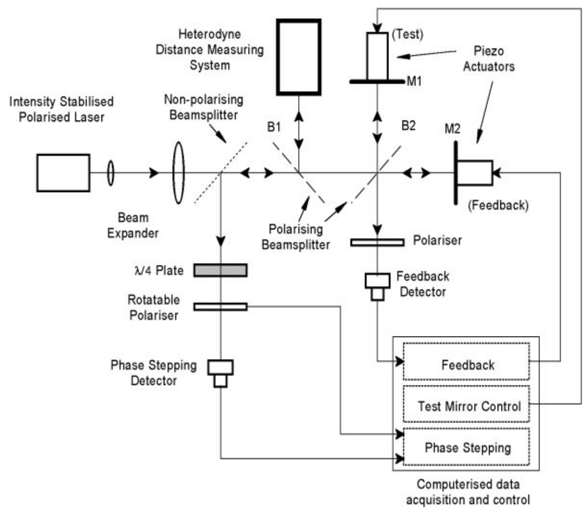

Fig.3 Experimental Interferometer System

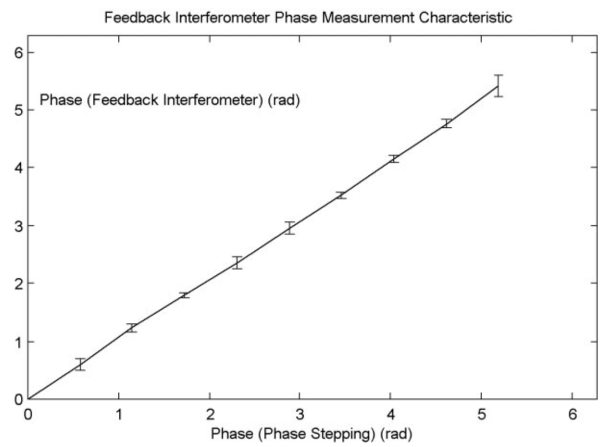

Fig.4 Phase Measurement Characteristic

4. Conclusion

We have shown that feedback interferometry is a promising candidate for application to micromachines. It is capable of high accuracy and linearity with a simple opto-electronic system that can be made to operate at high speed.

Members' Profiles

Toshiba Corporation

Nobuyuki Toyoda
Deputy Director
Corporate Research & Development Center

1. Achievements of Micromachine Technology

Under the Industrial Science and Technology Frontier Program, Toshiba, along with Denso and Sanyo Electric, has developed an "Experimental Wireless Micromachine for Inspection on Inner Surface of Tubes" for applications in confined areas like the narrow piping in electric power plants. This "microrobot" can move along a pipe having a diameter of 10 mm, while transmitting images ahead and debris inside the pipe. The microrobot is driven by energies received wirelessly from external microwave and laser sources.

In this project, Toshiba was in charge of developing a "CCD Microvision System" to be mounted on the front of the microrobot. The microvision system comprises a color video camera with built-in focusing mechanism mounted on a 2-DOF universal head, all powered-driven, in the body-size of 25 mm in length and 8.9 mm in diameter. In developing this system, we achieved various advances in camera size and image quality that have not been paralleled under such restricted energy conditions and transmission capacity.

We also developed various element technologies necessary to develop this microvision system, including micromachining, high-density three-dimensional packaging, electrostatic micromotor, and thin catadioptric system technologies. We further developed assembly technology for integrating the above components and a method for constructing images to support the small transmission capacity, along with technical development on systematization.

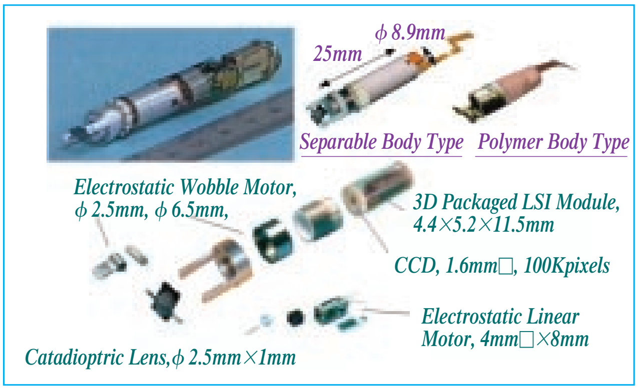

Fig.1

2. Future Activities

In addition to mounting the microvision system on the in-pipe inspection microrobot, we hope to apply this system to new applications using the entire system or individual element technologies. The first applications that come to mind are in the security and medical fields. In terms of the former, the development of information network services as household and social infrastructures is likely to make wireless image transfers from remote locations possible in the near future. The microvision system is expected to have few restrictions in the number and location of installation because of its ability to freely change viewing angles and the fact that it has 1/1000 the volume of conventional devices.

In the medical field, it is likely that the microvision system can be applied to examination apparatus used in laparoscopic and endoscopic surgery, which are now receiving much attention as minimally invasive operating methods that allow quick recovery period. By combining the

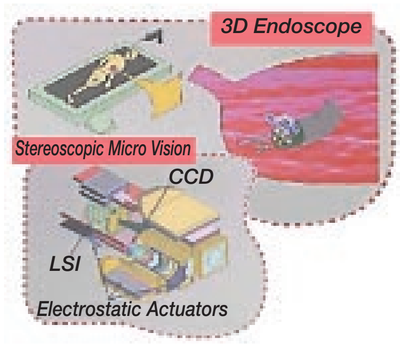

Fig.2

micro-sized CCD unit and electrostatic linear motor mounted in the microvision system, it is possible to construct a stereoscopic camera that can fine-tune the three-dimensional effect and should contribute greatly to examinations and surgery.

We also developed new systems applying some of the element technologies that were developed in the microvision system for the trial production and verification of practical devices. In Fig. 3, the electromagnetic micromotor has been applied to an in-pipe inspection robot with wheels. An electromagnetic motor having a diameter of 5 mm is mounted on a 7-mm diameter case for a 400,000-pixel CCD. Observing the inner pipe walls are performed using a focusing mechanism formed of a shape-memory alloy (SMA). The robot can observe debris as small as 20μm in a pipe with a minimum diameter of 20 mm. Powered by wiring, the robot can be used in environments in which microwaves or lasers cannot.

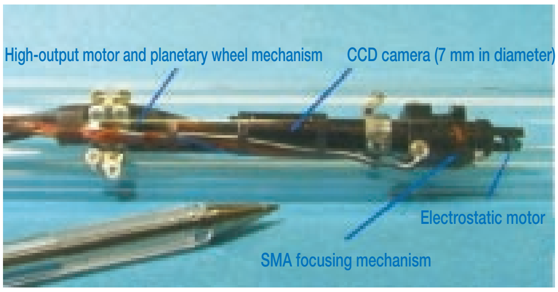

Fig.3

3. Future Stances

Other conceivable applications for the microvision system include PDAs and robot eyes. We plan to continue these studies as deemed appropriate for satisfying the needs of society.

Hitachi, Ltd.

Hiroshi Ohki
General Manager
Mechanical Engineering Research Laboratory

1. The Challenge of Micromachine Technology

Hitachi Ltd. manufactures a comprehensive array of electrical machinery and appliances, such as nanometer-sized electronic devices, consumer products, power and energy systems, and industrial machinery. We supply products and services in a wide range of fields and are implementing projects on a global level.

Micromachine technology is a cutting-edge basic technology that will shape the 21st century. The Mechanical Engineering Research Laboratory is chiefly responsible for R&D on micromachines at Hitachi Ltd.. The entire research laboratory is working together on this research and development with the aim of incorporating our basic technologies in mechanical systems as a base to provide the best customer solutions in such fields as medical and human-care, the environment, information, and communications.

2. Development of Micromachine Technology

Hitachi, Ltd. participated in the planning for "Micromachine Technology," part of the Industrial Science and Technology Frontier (ISTF) Program sponsored by the Ministry of Economy, Trade, and Industry that was completed in March 2000, and oversaw research and development on element technologies and system integration technology for developing a microfactory, the concept of which is a micro-sized system for producing small numbers of many products. The anistropic wet etching process for single-crystal silicon, which Hitachi, Ltd. has developed over many years, is gradually having a rippling effect on the creation of micromachines, which will benefit society.

2.1Achievements of the Industrial Science and Technology Frontier Program

In overseeing the research and development on a microfluid operation technology, we developed a microfluid operation device for supplying corrosive working fluid for micromachining and a holding device for assembling microparts. By incorporating surface treatment and forming techniques on a micrometer order, we developed a microfluid sealing method for rotary driven trochoid and scroll pumps. In this way, we achieved a micro size while maintaining high output. These features were applied to a fluid pump for supplying fluid and a vacuum pump for holding microparts. Both devices were then incorporated into a trial microfactory system to verify the processing and assembly operations of a microgear. Fig.1 shows a holding device (vacuum chuck; outer diameter of 7mm and length of 26mm) mounted on the end of a microarm (manipulator) used in assembly operations. The holding device conveys a microgear having a diameter of 2.6 mm.

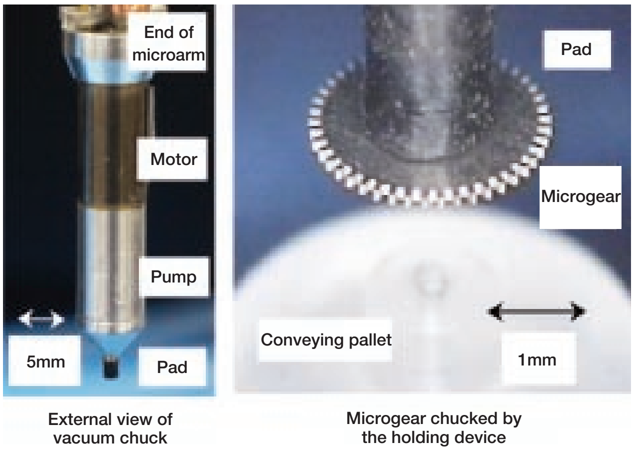

Fig.1 Vacuum chuck and operation of chucking microgear

2.2Achievements in Silicon Micromachining Technology

We applied silicon micromachining technology to the development of a small sized water quality monitor the size of an A4 sheet of paper (1/100 the conventional volume). This device contributes to human safety and health management by automatically measuring residual chlorine and the like in water pipes for general households that have extremely limited installation space. The primary feature of this device is that it employs microfluid channels produced by silicon anisotropic wet etching (see Fig.2).

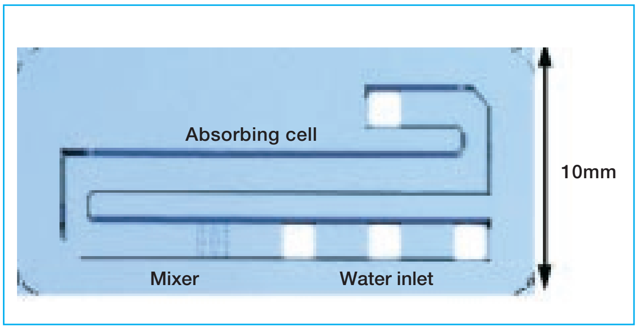

Fig.2 Microfluid circuit for a small sized water quality monitor

3. Future Stances

In our future challenges, we would like to apply the achievements of the Industrial Science and Technology Frontier Program to the field of micro total analysis systems (μTAS) to develop an analyzer for medical and environmental applications.

Introductory Course

Medical Applications for Micromachines Part 2

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Professor,
National Graduate Institute for Policy Studies

From Macro to Micro

From the beginning of the development of micromachine technologies-now proceeding for over ten years-it has been considered that the field of medical care held the potential for the most important, and furthermore, most basic demands. This time also saw the start of the transfer of practical technologies from the macro world to the micro world-or in other words, to the sub-microscopic world-with the field of medical care being represented in the form of micro surgery. The principal reason for this lay in the fact that medical care had become focused on treatment; furthermore, this in turn resulted from the dimensional change which occurred in the field of medical care over the past ten-odd years: Specifically, treatment began to move away from classical, macro applications such as the removal of unneeded organs or, for example, the injection of medicines over the entire body, and it started to develop in a world where cells, tissue, or even organs which were less than a centimeter in size or even smaller became the primary subjects for application. Cells are the primary elements of life; accordingly, a realization developed that as the subject for application of medical technologies became smaller and smaller, it would become possible to conduct medical activities which would be more significant in terms of human life. In addition, it also became possible for several medical technologies from the micro world to be put to developmental use.

In the case, for example, of surgical practices-as represented by micro surgery-over fifty percent of all related fields now involve actions requiring a loupe or microscope; furthermore, micro-forceps and micro-scalpels have now been applied to use for these tasks. Even in the case of the endoscope operations which have revolutionized the world of surgery over the last ten years, these have become characterized by micro-remote operations carried out via a trocar of less than one centimeter in diameter. Originating from manual industrial methods, these operations have begun to change in a fundamental way through the incorporation of rapidly-developing video-data technologies and also through the implementation of technologies from the world of artificial-reality sensing. Already, a large portion of the scalpels, syringes, and micro catheters which are used for the purpose of actual in-body operations in the microscopic realm are provided as one-application, throwaway devices, and for this reason, the majority of the associated technologies now require mass-production processes which employ industrial technologies. It may be said, therefore, that the world of micromachine technologies has now for the first time developed a need for industrial operations.

From Micro to Nano

Occurring almost simultaneous with the start of transition from macro to micro for those items subjected to medical-treatment practices, the subjects of examinations also began to switch from microscopic cells and metabolites of a certain density towards cell-internal organelles, genes, and minute volumes of immune-system substances; similarly, such examinations have also begun to deal with items and substances which are more important with regard to life control. Since the dimensions of cell-internal substances now correspond to the nano level, and because it is now necessary to handle extremely low densities measured in nanomoles, it may be said that a shift from micro to nano is beginning to occur for examination items. We cannot allow ourselves to ignore the passage over the past ten-odd years-as characterized by the human genome project and the like-of the science of biomedicine into the realm of the nanometer.

Although the development of biomedical examination elements and devices has been overlooked during the course of previous micromachine projects, it may be taken for granted that bio-elements, chips, and the like will be incorporated into the next generation of micromachine and nanomachine technologies. Furthermore, the last few years have seen rapid development both in the field of industrially-manufactured DNA chips, protein immunochips, and the like, and also in the field of micro-inspection elements as typified by on-chip labs which are put to bed-side use as liquid inspection chips; these developments, too, may be considered as a natural matter of course. As indicated by the announcement of the DNA chip in 1997, the development of post-genome technologies in the field of biomedicine is being carried out with its aim set squarely on the nano world; furthermore, bio-industry has begun creating a huge industrial base for the twenty-first century. Naturally, medical technologies have also started to directly handle items such as tissue and cells, and deserving of particular attention is the commencement of studies within the field of genetic medicine focused on intracell injection methods for substances with dimensions between several microns and several-hundred nanometers. These studies have been started due to the meaningful medical treatments for a wide range of sicknesses which will be possible if remote operations can be used to inject a specific DNA probe into a target cell.

The Arrival of Nano Quantum Systems

Suitable handling technologies will be required in order that substances and items of nano-dimensions may be directly operated on, and the majority of these correspond to micromachine technologies. In this world, however, problems lie hidden in the nano region-the region where micromachines now reside. The DNA base pairs as used by biochips are of several nanometers in dimension, and on-chip labs handle material volumes which are less than a nanomole (i.e., 10^{-9}) in concentration. As indicated recently by many researchers, the reduction of dimensions which accompanies the shift toward micromachine technologies has, when considered from the point of view of material units, reached the realm of several molecules, and further reduction to the quantum level cannot be avoided. The materials which are subjected to direct operation in the majority of medical-chemistry examinations have material volumes of the nanomole level. Since a solution containing 6×10^{23} molecules per liter is said to have a concentration of one mole, one cubic millimeter of a one nanomole solution will contain 6×10^{5} molecules. Accordingly, in the world of nanomole examinations where elements of ten microns in size are used, an examination chamber containing one nanomole of solution will actually hold a $1/10^{6}$ fraction of this number-in other words, 0.6 molecules. Micro-TAS (total analysis system) and other similar technologies recently under development have incorporated this dynamic, open-system world; accordingly, this indicates entry into the realm of quantum-wave mechanics, where physical laws become uncertain with regard to classical and deterministic theories.

Meanwhile, in the case of micromachining technologies where the one-micron barrier has already been broken, the size of the examination elements which this creates has dropped to a level measured in cubic-micron units. In micromachines which have been manufactured with dimensions close to one micron, the majority of macro-world rules will not be applicable with respect to induction of the chemical reactions which handle the substances contained. Analysis in the micromole range has recently become the most commonly-applied, and with the exception of those cases which handle protein structures and other substances of a certain degree of size, it may be said that for this type of analysis also, a solution must be found for the electronic-related uncertainty problems in systems which perform analysis using commonly-applied electrochemical electronic reactions. If nanomoles are to become the subject of operations, this world will expand to include technology where today's regularly-produced micromachines have sides of one-hundred microns, and it is quite possible that new technologies will be required for examination and material-identification purposes. In other words, if the world of micro electromechanical systems were to coincide with the world of organisms containing aqueous solutions, this would lead to the start of the creation of, not a micro world, but a nano world; furthermore, it should be emphasized that biomedical micromachines have already entered the realm of the nano machine, and that further reduction to the level of nano-quantum systems is an inevitability.

TOPICS

The 7th Micromachine Summit

The 7th International Micromachine Summit was held for three days from April 30 to May 2,2001, in Freiburg, the cultural and economic hub of southern Germany.

The Summit was attended by 72 delegates representing a total of 20 countries and regions. The Japanese delegation consisted of four presenters and five observers.

Based on the principle, "ideas are transferred by the people" the summit gave participants a opportunity to present new information to others, to use in further research or to develop applications in industry. The Summit was jointly chaired by two leading professors from Albert-Ludwig University in Freiburg : Prof. Wolfgang Menz (also director of the IMTEK Research Institute) and Prof. Jan G. Korvink.

The central topic of the 7th International Micromachine Summit was MEMS education. The MEMS education programs in some countries are designed to boost numbers of engineers and technicians based on the needs of the marketplace, as exemplified by BASIC (Biology, Automation, Semiconductors, IT, and Communications). The MEMS education program in Japan, was introduced in a presentation on how the Micromachine Center is helping to have a dream and interest held in young children's mind for science and technology through an "annual Micromachine Drawing Contest" and distribution of educational videos on micromachines. The presentation has had considerable success from the viewpoint of showing charm points of science and technology and drawing eyes of young people through the smallest robots, micromachines. The 8th International Micromachine Summit will be held in April next year in Maastricht, Netherlands.

THE SEVENTH INTERNATIONAL MICROMACHINE SYMPOSIUM

1. Date : Oct.31 and Nov.1, 2001
Oct.31 (09:30-17:40, reception 18:00-20:00)
Nov.1 (09:30-)

2. Venue : Science Museum, 2-1 Kitanomaru-Koen, Chiyodaku, Tokyo

3. Admission fee : ¥15,000 (including proceedings, reception)

4. Acceptance window : Micromachine Center International Exchange Dept.
Tel :03-5294-7131 (+81-3-5294-7131),
Fax:03-5294-7137 (+81-3-5294-7137)

5. Acceptance closing : Oct. 19th (Fri),2001

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October 31, 2001

9:00 –	Registration	
Session 1 : Opening		**Chairman : Mr. T. HIRANO**
9:30 – 9:35	Opening Remarks	Mr. Toshiro SHIMOYAMA, Chairman, Micromachine Center
9:35 – 9:42	Guest Speech	Mr. Iwao OKAMOTO, Director-General, Manufacturing Industries Bureau, METI
9:42 – 9:50	Guest Speech	Mr. Tsutomu MAKINO, Executive Director, NEDO
9:50 – 10:30	Special Guest Speech: Micromachine Based Business Model (Tentative)	Prof. Fumio KODAMA, Tokyo University
Session 2 : The Path to Micromachine Industries in the 21st Century		**Chairman : Dr. S. HIRAI**
10:30 – 10:50	R&D Strategy for Micromachine Technology	Prof. Isao SHIMOYAMA, Tokyo University
10:50 – 11:10	Manufacturing Outlook (Tentative)	Prof. Susumu SUGIYAMA, Ritsumeikan University
11:10 – 11:30	Application for IT (Tentative)	Dr. Hironobu KUWANO, NTT Cyber Solution Laboratories
11:30 – 11:50	Medical Application (Tentative)	Prof. Mitsuo OKANO, Tokyo Women's Medical College
11:50 – 12:10	Integrated Chemistry – State-of-the -Art and Scenario Toward Industrilal Innovation	Prof. Takehiko KITAMORI, Tokyo University
12:10 – 13:10	✻✻✻✻✻✻✻✻✻ Lunch ✻✻✻✻✻✻✻✻✻	
Session 3 : Activity in Overseas		**Chairman : Mr. R. MAEDA**
13:10 – 13:40	Status of Five Clusters in EU (Tentative)	Mr. Rob TURNER, Operating Manager,NEXUS
13:40 – 14:10	Radio Frequency Identification	Prof. Heikki SEPPA, Finland, VTT
14:10 – 14:40	MEMS Research Environment	Prof. Yitshak ZOHAR, Hong Kong University of Science and Technology
14:40 – 15:00	✻✻✻✻✻✻✻✻✻ Break ✻✻✻✻✻✻✻✻✻	
Session 4 : Innovative R&D		**Chairman : Prof. H. FUJITA**
15:00 – 15:20	Light Driven Mass Migration in Nano-Hybrid Polymer Films	Prof. Takahiro SEKI, Tokyo Institute of Technology
15:20 – 15:40	Development of Visual Prosthesis	Dr. Toru YAGI, Nagoya University
15:40 – 16:00	Nano-photonics and Micromachine/MEMS	Prof. Satoshi KAWATA, Osaka University
Session 5 : Micromachine in Past Decade and Future Outlook		**Chairman : Prof. I. SHIMOYAMA**
16:00 – 16:20	Contribution of Micromachine Center(Tentative)	Prof. Hirofumi MIURA, Kogakuin University
16:20 – 16:50	MEMS Development in the Last Decade	Associate Prof. Norman C. TIEN, University of California
16:50 – 17:10	Practical Use of Micromachine in Industry (Tentative)	Dr. Kunihiko HARA, DENSO Corporation
17:10 – 17:30	Micromachine Research in Universities in the Last Decade	Prof. Hiroyuki FUJITA, Tokyo University
18:00 – 20:00	Reception Party at KKR Hotel Tokyo	

November 1, 2001

Session 6 : Results of Micromachine Technology Project in ISTF Program

Session 7 : Closing

Pictures on the cover : Winning artworks in the Micromachine Drawing Contest
Micro-Pupfish, Mr.Ripe-Fruit, Schedule Diary for the Future, Micromachines Bring Hope (from top to bottom)

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