MMC

MICROMACHINE

2002 10



## MMC Activities

# The 8th International Micromachine / Nanotech Symposium

The 8th International Micromachine/Nanotech Symposium will be held on November 14 (Thursday), 2002, at the Science Museum in Kitanomaru Park, Tokyo, and is being organized by the Micromachine Center.

This is the 8th symposium since the 1st International Micromachine Symposium was held in 1995 supported by METI and NEDO, the symposium aims at establishment and dissemination of micromachine technology, as well as enlightment of micromachine technology. Last year, in the 7th International Micromachine symposium, we presented summary of the fruits of "Micromachine technology development PJT" which took the global initiative in the 10 year PJT of "Industrial Science and Technology Frontier Program" so called (ISTF). From this 8th symposium, we expand the scope from Micromachine technology to nano-technology and applied the sub-theme as "Micro systems implicated nano technology make the Foundation of Industrial Technology in the 21st Century". Therefore we named this symposium The 8th International Micromachine/Nanotech Symposium.

Recently the fruits of research in nanotechnology have been remarkable, however to utilize the nano-scale technology for human size, it is required to develop the new tech which seamlessly links nano-scale and human-size to implicate such as optics and biotechnology into the micro systems. The 8th International Micromachine/Nanotech Symposium focuses on R & D in the new domain of "micro/nano fusion that will enable the realization of novel functions and capacity.

This symposium has been planned by the organizing committee (chairman: Professor Naomasa Nakajima, The University of the Air), and by the program committee (chairman: Professor Hiroyuki Fujita, The University of Tokyo). Through these committees, the frame of program were made and the guest speakers were nominated. Furthermore, to fill up the content of the symposium and international points of view, an advisory board has been organized by nine European and American chief delegates of the 8th world Micromachine summit and we invited five foreign speakers.

The program consists of five sessions, and fourteen speakers including nine Japanese and five foreigners give lectures. In Session 1, "Opening," a guest speech will be given by the Director-General of the Manufacturing Industries Bureau of METI, then Professor Isao Shimoyama, The University of Tokyo presents special lecture entitled "Strategy towards Fusion of Nano and Micro Systems. This lecture will provide participants valuable information about technological strategies and future directions on "micro/nano fusion domain."

In Session 2, "The Path to New Industries in the 21st Century," will feature the following five lectures.

1. International Standardization of MEMS
2. Standardization of Tensile Testing Methods for Thin Film Materials - Round Robin Testing of Thin Film Specimen -
3. MEMS in China, Especially in Shanghai Area
4. MMC's Initiatives towards Foundry Service Network
5. The Sensibility of Scaling Recognition

In the third lecture, Prof. Yilong Hao of Peking University talks the MEMS industry in China, which has been making significant progress in the Shanghai area.

The fifth lecture, "The Sensibility of Scaling Recognition" in Micro/Nano machine design" will be presented by Prof. Kazuo Kawasaki of Nagoya City University Medical School, who has been honored with several good design awards in the field of industrial design, both in Japan, and foreign countries such as U.S.A., France and Germany.

For Session 3, "Innovative R & D," we prepares four lectures to introduce the latest innovative R & D, from which significant future evolutions are anticipated.

1. Creation of Biochips Aiming at Highly Medical Treatment
2. Micro-fluidics for Pre-process of Dioxin Measurement
3. Advanced MEMS Research in US
4. Nanoscale Light Manipulation

The fourth lecture, "Nanoscale Light Manipulation," will be presented by Prof. Laurens Kuipers of the University of Twente MESA + Research Institute, the Netherlands, who researches on advanced photonics structures. Based on his research on how to make the low dimensional photonic crystal and optical phenomena of the crystal, Prof. Kuipers aims at developing new devices for optical communications and high-speed computers.

In Session 4, "National Strategy for Micro/nano Fusion

Domain," prepares following four lectures.

1. Strategy to Enhance the Application of Micro@nano-Technology in France
2. Practice Collaboration between Industry and Academia in Micro/nano System Technology
3. Bio Nano Technology in the 21st Century: CELLOMIX
4. National Strategy on NEMS/MEMS in France

In the first lecture, "Strategy to Enhance the Application of Micro@nano-Technology in France," Dr. Dirk Beernaert of EURIMUS (Eureka Industrial Initiative for Microsystem's Users), will talk the aspects of Integrated Project for the EU 6th Framework Programme such as the project's objectives and policies, and its development of MEMS products.

The fourth lecture, "National Strategy on NEMS/MEMS in France," will be presented by Dr. Constant Axelrad, a Scientific Advisor at CEA-LETI in Grenoble, France, and actively involved with France's Micro/nanotechnology Innovation Center and NEXUS. As the title suggests, Dr. Axelrad's lecture will look at French approaches and strategies in the fusion of micromachine technology and nanotechnology.

The 13th Micromachine Exhibition will be held on the ground floor of the Science Museum from November 13 (Wednesday) to November 15 (Friday), 2002 and will feature a diversity of products by micromachine-related industries, universities and institutions. We believe that this micromachine exhibition and the symposium will provide a good opportunity for participants to obtain a clear and comprehensive image on what are cutting-edge micromachine technologies, and we recommend all participants to visit the events to enable you to see actual micromachines in action. Symposium participants can be permitted free admission to the micromachine exhibition by simply showing their participation cards.

The deadline for applications to attend the symposium is October 31, 2002. but if seats are available, applications will be accepted on the day of the symposium.

## ✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻ PROGRAM (Tentative) ✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻✻

**As of October 11, 2002**

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|---|---|---|
| 9:00 – | Registration | |
| **Session 1 : Opening** | | **Chairman : Mr. T. HIRANO** |
| 9:30 – 9:35 | Opening Remarks | Mr. Toshiro SHIMOYAMA, Chairman, Micromachine Center |
| 9:35 – 9:40 | Guest Speech | Director-General,Manufacturing Industries Bureau, METI |
| 9:40 – 10:20 | Special Guest Speech: Strategy towards Fusion of Nano and Micro Systems | Prof. Isao SHIMOYAMA, The University of Tokyo |
| **Session 2 : The Path to New Industries in the 21st Century** | | **Chairman : Prof. H..FUJITA** |
| 10:20 – 10:45 | International Standardization of MEMS | Dr. Kuniki OHWADA, International Standardization Engineering Laboratory |
| 10:45 – 11:10 | Standardization of Tensile Testing Method for Thin Film Material - Round Robin Test of Thin Film Specimen - | Toshiyuki TSUCHIYA, Toyota Central R&D LABS INC |
| 11:10 – 11:35 | MEMS in China, Especially in Shanghai Area | Prof. Yilong HAO, Peking University |
| 11:35 – 12:00 | MMC's Initiative towards Foundry Service Network | Mr. Takashi MIHARA, Foundry Service Industry Committee |
| 12:00 – 13:00 | ✻✻✻✻✻✻✻✻ Lunch ✻✻✻✻✻✻✻✻ | |
| 13:00 – 13:30 | The Sensibility of Scaling Recognition | Prof. Kazuo KAWASAKI, Nagoya City University Medical School |
| **Session 3 : Innovative R & D** | | **Chairman : Prof. K. .IKUTA** |
| 13:30 – 14:00 | Creation of Biochips Aiming at Highly Medical Treatment | Prof. Yasuhiro HORIIKE, The University of Tokyo |
| 14:00 – 14:30 | Micro-fluidics for pre-process of Dioxin Measurement | Dr. Ryo MIYAKE, Hitachi Ltd. |
| 14:30 – 15:00 | Top Down and Bottom Up Approaches to Bio Nano Technology | Dr. Jennifer Gaudioso, Sandia National Laboratory |
| 15:00 – 15:30 | Nanoscale Light Manipulation | Prof. Laurens KUIPERS, University of Twente |
| 15:30 – 16:00 | ✻✻✻✻✻✻✻✻ Break ✻✻✻✻✻✻✻✻ | |
| **Session 4 : National Strategy for Micro/Nano Fusion domain** | | **Chairman : Prof. I. SHIIMOYAMA** |
| 16:00 – 16:30 | Strategy to enhance the application of micro @ nano-technology in France | Dr. Dirk BEERNAERT, European Commission |
| 16:30 – 17:00 | Practice Collaboration between Industry and Academia in Micro-Nano System Technology | Prof. Susumu SUGIYAMA, Ritsumeikan University |
| 17:00 – 17:30 | Bio Nano Technology in 21st Century, CELLOMIX | Prof. Teruo OKANO, Tokyo Women's Medical University |
| 17:30 – 18:00 | National Strategy on NEMS/MEMS in France | Dr. Constant AXELRAD, CEA-LETI |
| **Session 5 : Closing** | | |
| 18:00 – 18:10 | Closing speech | Mr. Takayuki HIRANO, Executive Director, Micromachine Center |

# The 2nd Workshop on Standardization for Micromachines / MST / MEMS in Tokyo

In addition to performing advanced research, Micromachine Center is working to achieve international standardization. So far the Micromachine Center has been studied in two areas: One is to establish unified technical terminology able to commonly use among various fields, because the micromachine is multidisciplinary system. And the other is "Standardization of measurement and evaluation methods of Micromachine" to compare the functions of newly developed micro-devices. Micromachine Center summarized these studies in technical reports. And the Center aims to propose these reports as international standard to international organization as contributions from Japan to the world. For achieving these and the international harmonization, Micromachine Center established on-line International Standardization Forum that exchanges opinions over the inter-net and is operating since 1998. The Forum occasionally hold face-to-face meeting such as the 2nd Workshop on Standardization held recently in Tokyo.

The 2nd Workshop on Standardization for Micromachine / MST / MEMS was held at Tokyo Metropolitan Small Business Promotion Agency on July 23, 2002, with Hisayoshi Sato, Professor of Chuo University, serving as chairperson.

The 2nd Workshop was scheduled to be held in Washington D.C. in October 2001, according to the agreement at the 1st Workshop on Standardization held in London in March 2001. However, this Workshop was postponed due to the terrorist attacks that occurred in New York and Washington D.C. on September 11, just prior to this date. It was decided that the 2nd Workshop on Standardization would be held in Tokyo in conjunction with presentations regarding RRT (Round Robin Test) on thin film specimens, which is planning to propose to international organization as world standards by Micromachine Center. Thirteen people, including four from overseas, joined in this workshop.

During the morning session, the workshop reviewed activities following the 1st Workshop, including standardization activities in the U.S., Germany, and Japan, and discussed future activities leading up to the 3rd Workshop. Dr. Kuniki Owada, joined as a special participant in this workshop, reported that a technical report issued by the Micromachine Center in 1998 called "Technical Terms in Micromachine Technology" (220 words) had been proposed to the IEC/TC47. Serving as a member of the IEC/TC47/WG4, Dr. Owada had worked on this proposal under commission by the Japanese Industrial Standards Committee. Takashima, Associate professor of Tokyo Institute of Technology, presented the development of a fatigue testing machine and results of fatigue tests conducted on cantilever type specimens. The Micromachine Center has proposed this machine to the METI as an item for standardization to follow the thin film tensile tests.

In the afternoon session they had presentations and discussions on RRT performed under the NEDO project called "standardization of evaluation method of properties for micromachine materials" which developed original testing machines for thin film materials and standard specimen of these materials ended in March last year.

A total of twenty-four people participated, including above workshop members and representatives from three universities, three makers, and the National Institute of AIST (Advanced Industrial Science and Technology) who involved in RRT, as well as the Japanese Standards Association, which is preparing international standardization of RRT. The participants agreed to support activities related to IEC terminology and to support such projects as world RRT proposed by U.S. delegate on thin film residual stress tests. They concluded to hold the 3rd Workshop on Standardization at NIST in Washington, U.S.A. in March 2003.

**The 2nd Workshop on Standardization for Micromachine/MST/MEMS**

# Submitting MMC Technical Reports on Terminology to the IEC

While the Micromachine Center was carrying out R&D on Micromachine Technology under METI's Industrial Science and Technology Frontier Program over a ten-year period, it also stressed the standardization of terminology and measurement evaluation, even at the research stage. Accordingly, the Center organized working groups for measurement evaluation and terminology under the Committee on Micromachine Standardization (chairman: Hisayoshi Sato, Professor of Chuo University) and conducted studies on these topics. The results were compiled in technical reports that have been published. For terminology, definitions were confirmed in English and Japanese for 220 terms. The Micromachine Center led discussions on this glossary at an online International Standardization Forum, while publishing the glossary on its home page and collecting comments regarding its contents.

After it was determined that nearly all opinions had been collected, the Center received approval from the WG for terminology to submit the glossary formally to the IEC. The Center also formally submitted the glossary to the IEC/TC47/WG4 after receiving approval from a domestic committee (JEITA) on TC47 (semiconductor devices).

The copy below shows a letter from the IEC notifying all countries on July 5 of Japan's proposal regarding terminology and definitions. As shown by the notifications, P- members are urged to vote by October 4 on whether or not to adopt this proposal. If the proposal is adopted at this time, then the issue will be offered up for a discussion on international standards. However, the proposal has many hurdles to overcome before it can finally be standardized.

Through these achievements, however, the standardization activities of the Center have entered an international phase, thereby achieving one milestone. In keeping with this, tensile testing methods for thin films conducted under commission of NEDO have entered a stage this fiscal year in which a standardization proposal will be created with the support of the Japanese Standards Association.

The following is the list of the committee members (at the time of the committee activities) who contributed to developing the terminology.

Chairman Nobuyuki Moronuki (Tokyo Metropolitan University Graduate School)

Members Nobuyuki Kabei (Saitama Cardiovascular and Respiratory Center)
Masaaki Ikeda (OMRON CORP.)
Koichi Suzumori (TOSHIBA CORP.)
Hiromu Narumiya (MITSUBISHI ELECRIC CORP.)
Takefumi Kabashima (YASKAWA ELECTRIC CORPORATION)

**47/1644/NP**

**NEW WORK ITEM PROPOSAL**

| | |
|---|---|
| Proposer: Japan | Date of proposal: 2002-07 |
| TC/SC: 47 | Secretariat: Korea |
| Date of circulation: 2002-07-05 | Closing date for voting: 2002-10-04 |

Classification according to IEC Directives Supplement, Table 1
A3

A proposal for a new work item within the scope of an existing technical committee or subcommittee shall be submitted to the Central Office. The proposal will be distributed to the P-members of the technical committee or subcommittee for voting, and to the O-members for information. The proposer may be a National Committee of the IEC, the secretariat itself, another technical committee or subcommittee, an organization in liaison, the Standardization Management Board or one of the advisory committees, or the General Secretary. Guidelines for proposing and justifying a new work item are given in ISO/IEC Directives, Part 1, Annex C (see extract overleaf). **This form is not to be used for amendments or revisions to existing publications.**

**The proposal** (to be completed by the proposer)

**Title of proposal**

IEC 60747 : Semiconductor devices — Part XX-1 : Micro electromechanical devices — Terms and definitions

☒ Standard ☐ Technical Specification

**Scope** (as defined in ISO/IEC Directives, Part2, 6.2.1)

To provide terms and definitions of microelectronic mechanical devices.

**Purpose and justification**, including the market relevance and relationship to Safety(Guide 104), EMC(Guide 107), Environmental aspects(Guide 109) and Quality assurance(Guide 102).(attach a separate page as annex, if necessary)

In the field of micro electro-mechanical devices, many technology areas are included such as, electronics, mechanical engineering, chemistry and biology. it is desirable to construct glossary for micro electromechanical devices for convenience of end-users of the devices.

# IWMF 2002 Held in the U.S.A.

The 3rd International Workshop on Microfactories (IWMF) was held at the University of Minnesota, Minneapolis, through the joint sponsorship of Carnegie Mellon University and the University of Minnesota, for three days, September 16 through 18, 2002,.

The former Mechanical Engineering Laboratory of the Agency of Industrial Science and Technology took the initiative to hold the 1st IWMF in December 1998. In October 2000, the 2nd IWMF was held in Switzerland.

The program at this year's workshop included the following sessions: (1) System Architectures for Microfactories, (2) Micro Assembly Systems, (3) Micro Assembly Techniques, (4) Micro Fabrication, (5) Micro Fluidic Systems, (6) Micro Actuation and Sensing, and (7) Toward Nanofactories.

The breakdown in number of presentations given per region had America with 8, Europe 9, Japan 5, and other regions 2. Fifteen presentations were given in the poster session.

The Japan side featured a presentation by Takayuki Hirano, Executive Director of the Micromachine Center, entitled "Micromachine Technology Trends in Microfactories," which covered the results of METI's Industrial Science and Technology Frontier (ISTF) Program, the fusing of micromachines with nanotechnology, and the like. In addition, the National Institute of Advanced Industrial Science and Technology presented several research findings.

Here, we will summarize some of the more memorable parts of the presentations.

The Fraunhofer-Institute for Manufacturing Engineering and Automation, (IPA Department for New Applications) announced research findings on a "mini-factory," similar to the micro-factory concept developed in the ISTF Program. The mini-factory is configured of handling modules arranged around a conveying plate. For conveying, a two-dimensional planar motor with a wire is used for power supply. However, the positioning precision is ± 20 $\mu$m, which is equivalent to that in the micro-factory of the ISTF Program using a stopper, and a precision of 200 nm is achieved when using a magnetic sensor. Each module is provided with a controller using distributed JAVA, which is advantageous for its suitability in an Internet environment through the use of Ethernet. Designing tools have been developed for designing the system. Research is currently being conducted on a system using a micro fluidic injection module. There is a plan to develop a system for assembling laser diodes of different specifications by 2004.

As a new venture, France's Laboratoire d'Automatique de Besançon is researching a proposed concept on plug-and-play devices called microrobots on chip. While the research is aimed at developing an inexpensive high-resolution device that is compact and can be used immediately, research to date has focused on mounting a two degrees-of-freedom gripper on a SmartCard Reader and verifying its functions. The laboratory is also studying a linking construction for accurately positioning an end effector. Manipulation by sensors is apparently not performed in order to protect the object being manipulated.

At this workshop, there were a lot of presentations on measurement and evaluation technology in particular, such as a study on capturing the shape of objects based on CAD data and methods for taking wide images using multiple cameras.

The 4th IWMF has been scheduled for Shanghai in September 2004.

# TOYOTA CENTRAL R&D LABS., INC.

**Norikatsu Ishikawa**
**Director**

Toyota Central R&D Labs., Inc., in cooperation with the Toyota Group and research organizations throughout the world, carries out extensive research on automobile-related technologies, electronics, information and communications, functional materials, biotechnology, and environmental technology.

Since its founding in 1960, Toyota Central R&D Labs., Inc. has made many contributions to the micromachine field, developing the world's first strain gauge that incorporates the piezoresistive effect of silicon and conducting research on such silicon micromachining processes as silicon anistropic etching and anodic bonding technologies to aid in the practical utilization of pressure sensors and accelerometers developed by Toyota Group companies. In recent years, we have conducted research on a wide range of device, circuit, design, process, and evaluation technologies focusing on surface micromachining and silicon integrated sensors.

In process technologies, research on surface micromachining for the fabrication of microstructures using polysilicon, $SiO_2$ thin films and SOI wafers have been conducted, which includes vapor etching of sacrificial layers, surface coating and machining for sticking prevention, fabrication formation of thin film multilayer structures, and thin film vacuum encapsulation . Fig. 1 is a vibrating gyroscope (angular rate sensor) formed of three layers of polysilicon thin films produced using the above technologies. This 2-$\mu$m thick thin film structure is supported on four beams over a vertical gap of 2$\mu$m, as if floating in space. By inserting this type of sensor structure in a micro-chamber having the same thin film structure, we produced a on-chip vacuum-sealed angular rate sensor. This is the world's first sensor that allows us to verify operations for detecting angular rate .

In evaluation techniques, we have focused on evaluating the mechanical properties of thin film materials. We are developing such equipment as a device for measuring the Young's modulus and internal stress of a thin film membrane based on its pressure-deflection curve and a thin film tensile tester (Fig. 2) with an electrostatic chucking system for evaluating micro-sized specimens. We are also studying property evaluations necessary for designing and evaluating the reliability of micromachine devices. Using these technologies, we participated in a NEDO project called "the standardization of evaluation method of material properties for micromachines" implemented by the Micromachine Center through the last fiscal year.

In the future, we would like to expand our applications based on surface micromachining technologies to encompass micromachine devices incorporating not only sensors, but also actuators and the like.

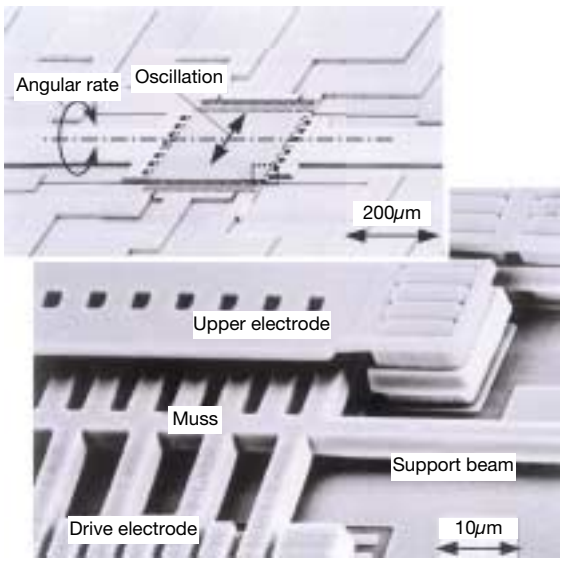


**Fig. 1 Polysilicon vibrating gyroscope**

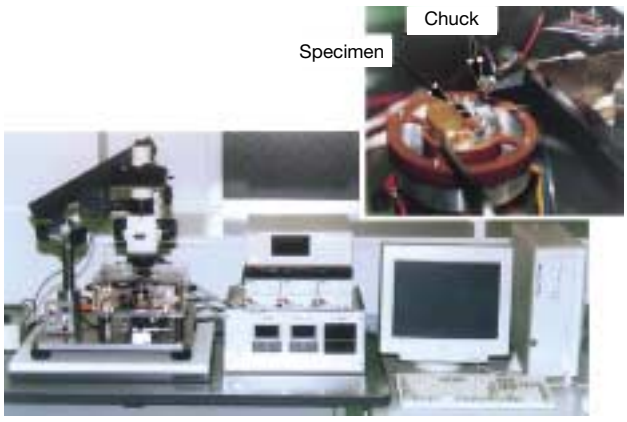


**Fig. 2 Thin film tensile tester with electrostatic chucking system**

# NAGANO KEIKI CO., LTD.

**Shigeru Miyashita**
**President**

## 1. The Challenge of Micromachine Technology

Pressure measurements designed to meet the needs of various industries are important basic technologies in any age. Nagano Keiki became involved in this technology as a general manufacturer of pressure measurement and control equipment by developing pressure sensors using micromachine technology.

## 2. Development of Micromachine Technology

To date, Nagano Keiki has developed high-temperature semiconductor pressure sensors using epitaxial aluminum deposition through a commission by the Japan Science and Technology Corporation, integrated capacitance type pressure sensors through joint research with Tohoku University, and a high-precision wet etching technology.

There are currently two types of pressure sensors manufactured with our micromachining technology: a capacitive type and a SOI (silicon on insulator) strain gauge type.

Nagano Keiki mass-produces a series of highly sensitive, highly durable pressure capacitive sensors ranging from the micro-pressure of 25 Pa. In addition to satisfying customer demands for sensors, we produce other products that make use of high-sensitivity and high-durability features, such as differential pressure detecting leakage testers and medical equipment that detects the behavior of infants and issues an alert for abnormal breathing and the like.

Compared to diffusion type sensors, sensors using an SOI strain gauge are superior in heat resistance and with stand voltage and demonstrate high reliability in severe environments.

## 3. Future Challenges

We have recently begun developing sensors for microspaces designed to measure the physical properties (pressure, temperature, etc.) of micro chemical plants formed on a glass substrate and analyzing devices that fit in the palm of one's hand called $\mu$-TAS (micro-Total Analysis System).

In addition to improved sensitivity and precision, there will be future demand to further reduce the size and cost of sensors with increased performance. We would like to increase the scope of nano and micromachine technologies and aim toward creating durable products.


**Fig. 1 Applied products**


**Fig. 2 Pressure sensor device**

Worldwide R&D

# Research on Technologies for Utilizing Miniature Device

**Tokio Kitahara**, Professor, Shonan Institute of Technology, Faculty of Engineering

Shonan Institute of Technology is a university with an engineering faculty (five departments) and a graduate school (three specializations) and approximately 2,500 students. I am affiliated with the Mechanical Engineering department and graduate school specialization. My laboratory deals with technologies for utilizing miniature mechanisms, which do not require very large-scale equipment. We conduct research on the element technologies of microfabrication machines, high-speed lathing of microparts, micro generators, and the like. Here, I will describe two of these research projects.

## (1) Direct-driven device with built-in actuator

We are studying direct-driven devices driven by friction. An actuator is integrated in the device for use in microfabrication equipment. We have verified the usefulness of these devices in a microlathe, which we developed earlier, and are currently analyzing the device properties in detail.

Fig. 1 shows the basic structure of the device, wherein two piezoelectric elements intersect a slider. Fig. 2 shows the results of an experiment for finding the relationship between the surface pressure and velocity of the slider, while varying the slider's thrust. From this experiment, we determined that thrust decreases the slider velocity, but a thrust of 10 N or less is possible when the slider surface pressure is approximately 150 kPa.

## (2) High-speed lathing of microparts

When microparts are processed on a normal lathe, the cutting speed decreases, increasing the roughness of the processing surface dramatically. In a lathe experiment using a high-speed small-diameter spindle (manufactured by NSK Ltd.), we proved the effects of increasing the speed of the spindle on improving the lathed surface.

Fig. 3 shows the condition of the surface of brass after lathing the piece to a diameter of 100$\mu$m. Deep striation and the like observed when using a spindle rotational speed of 2 x $10^4$ rpm did not appear when the speed was 16 x $10^4$ rpm.

Fig. 4 shows the relationship between the rotational speed of the spindle and the arithmetic average roughness (Ra) of the lathed surface. A remarkable improvement in surface roughness occurred at a rotational speed of 4 x $10^4$ rpm (a lathing speed of 13 m/min) or greater, while a Ra value of approximately 20 nm was obtained at 16 x $10^4$ rpm. These results indicate that microfabrication devices capable of achieving high spindle speeds are effective in improving the processing surface.

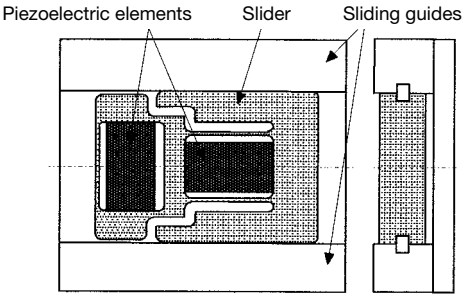


Fig. 1 Construction of a direct-driven device

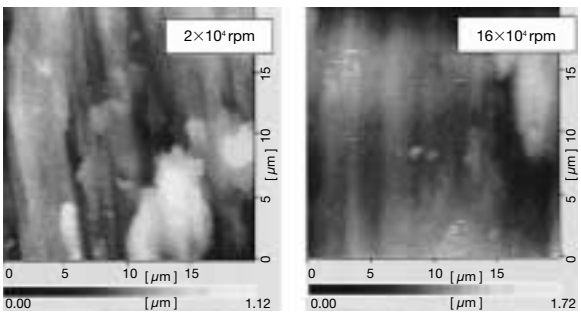


Fig. 3 Topography of the lathed surface

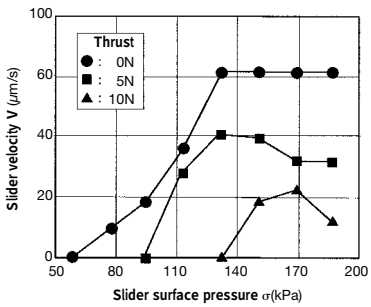


Fig. 2 Properties of the direct-driven device

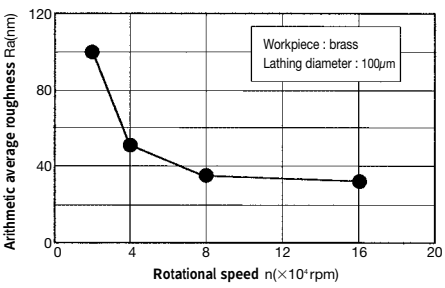


Fig. 4 Characteristics of high-speed lathing



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