MMC
2005 10
MICROMACHINE

MMC Activities

The 11th International Micromachine / Nanotech Symposium

The Micromachine Center, in conjunction with METI and NEDO, will hold the 11th International Micromachine/Nanotech Symposium on November 10 (Thursday), 2005, in the Science Hall of the Science Museum in Kitanomaru Park, Tokyo. Under the subtitle "Micromachine Technology: Driving the Creation and Expansion of New Industries," the symposium will feature 12 lectures presented by four invited speakers from overseas and eight from within Japan, all leading experts in the field, in three sessions: "Micromachine Business Frontiers," "Realizing the Potential of Micromachine Applications," and "At the Cutting Edge of Micromachine Technology." Furthermore, as part of Micromachine Center preparations for the establishment next April of a MEMS Association to promote industrial exchange and technological development, the symposium will also feature a special session entitled, "Towards the Expansion of MEMS Industries," that will include a keynote address and panel discussion comprising panelists representing various industries.

The special session, "Towards the Expansion of MEMS Industries," will begin with a keynote address presented by Professor Hiroyuki Fujita of the University of Tokyo entitled "Strategies for Expanding MEMS Industries and Developing New Fields." This will be followed by a panel discussion comprising Professor Fujita as coordinator and 6 panelists representing various industries: Mr. Yoshinori Komiya, Director of the Industrial Machinery Division, Manufacturing Industries Bureau, METI; Mr. Hiroya Taguchi, President of the Japan Society of Mechanical Engineers and Chief Executive Officer of the Life Science Group at Hitachi Ltd.; Mr. Tsuneyuki Miyake, Deputy Editor of Nikkei Microdevices, Nikkei Business Publications Inc.; Prof. Harri Kopola of VTT Electronics; Mr. Haruo Ogawa, Division Manager of the New Business Planning Division at Olympus Co.; and Mr. Hitoshi Ogata, Sr. Executive Office and Vice President of Corporate R&D at Mitsubishi Electric Corp. This panel discussion is expected to provide extremely useful ideas for the expansion of MEMS industries.

Session 1, "Micromachine Business Frontiers," will feature three lectures presented by representatives of leading manufacturers of products in which micromachine technology plays a significant role. One lecture will recount the success story of Analog Devices, manufacturer of such cutting-edge products as ink-jet printers with heads created using micromachine technology whose application is spreading to previously unimagined fields; rapidly advancing mobile telephones that are expected to evolve even more remarkably through the application of MEMS technology; and acceleration sensors necessary for vehicles (overseas speaker). Symposium participants can look forward to lectures that paint a vivid picture of R&D at the forefront of the MEMS industry.

Session 2, "Realizing the Potential of Micromachine Applications," will present five lectures concerning either research on the application of MEMS and/or nanotechnology in fields such as medicine, energy, and space, or highly integrated complex MEMS adaptable to a diverse range of applications. Of particular interest are lectures on the application of MEMS in space research at NASA's Jet Propulsion Laboratory (overseas speaker) and research at the VTT Technical Research Center, which has produced many of Finland's technical innovations, most famously those of Nokia. Micromachine technology is being heralded as a means of answering society's needs and resolving social problems; R&D is being actively pursued in a diversity of fields, and high expectations are held for its future development.

Session 3, "At the Cutting Edge of Micromachine Technology," will feature four lectures concerning nanomaterials, ultraprecision micromachining, nano-metrology, and thin-film material/nanomaterial limitations. Research on materials, processing, measurement, and reliability-related basic technologies are essential to MEMS development; this session provides a sampling of cutting-edge research being steadily pursued at universities and research institutions. It is anticipated that, through research such as this, micromachine technology will achieve the evolution necessary for it to answer diversifying needs, leading to the further expansion of MEMS industries.

The 16th Micromachine Exhibition will also be held at the Science Museum, over the three days from September 9 (Wednesday) to 11 (Friday). The numerous displays will include micromachine-related works created by businesses, universities, and organizations. In order to gain the best possible understanding of micromachine technology, it is recommended that symposium participants also take this opportunity to see actual micromachines in action. Symposium participants will therefore be allowed free and unlimited entry to the micromachine exhibition on presentation of their participation certificate. Furthermore, the interim report for the MemsONE Project will be presented on September 11, the final day of the exhibition, at the Science Museum; symposium and exhibition visitors are warmly invited to attend this meeting also.

Participation in the symposium, exhibition, and report presentation is sure to stir the imagination and suggest ideas instrumental to future research and business. We therefore look forward to welcoming a large number of participants to each of these events.

The 11th International Micromachine / Nanotech Symposium

- Micromachine Technology is Pulling the Creation and Development of New Industries -

November 10, 2005, The Science Museum, Tokyo

Opening		Chairman: Keiichi Aoyagi (MMC)
9:15 – 9:20	Opening Remarks	Tamotsu Nomakuchi (Micromachine Center)
9:20 – 9:25	Guest Speech	Yoshinori Komiya (Industrial Machinery Division, Manufacturing Industries Bureau, METI)
Special Session	**Towards Development of New MEMS Industries**	
9:25 – 9:40	Strategies for Further Development of MEMS Industries and Emerging Applications	Hiroyuki Fujita (The University of Tokyo)
9:40 – 11:00	Panel Discussion Towards Development of New MEMS Industries	Coordinator: Hiroyuki Fujita (The University of Tokyo) Panelist: Hitoshi Ogata (Mitsubishi Electric Corp.), Haruo Ogawa (Olympus Corp.), Yoshinori Komiya (METI), Hiroya Taguchi (The Japan Society of Mechanical Engineers), Tsuneyuki Miyake (Nikkei Business Publications, Inc.), Harri Kopola (VTT Electronics)

Session 1	The Forefront of the Micromachine Business	Chairman: Isao Shimoyama (The University of Tokyo)
11:00 – 11:25	The Inkjet Printer and Its Industrial Application	Mitsuro Atobe (Seiko Epson Corp.)
11:25 – 11:50	Trends in Mobile Phones and RF-MEMS Applications	Kunihiko Nakamura (Matsushita Electric Industrial Co., Ltd.)
11:50 – 12:20	Acceleration Sensors	Bob Sulouff (Analog Devices Inc.)

12:20 – 13:20 Lunch

Session 2	Micromachine Applications Expected to Flower	Chairman: Kazuhiro Hane (Tohoku University)
13:20 – 13:45	Biomedical Application of BioMEMS and Nanotechnology	Yoshinobu Baba (Nagoya University)
13:45 – 14:15	Optical Applications - Potential and Challenge for MEMS -	Harri Kopola (VTT Electronics)
14:15 – 14:40	Development of Integrated Micro Reactors with Reformers for Small Fuel Cells	Osamu Nakamura (Casio Computer Co., Ltd.)
14:40 – 15:10	MEMS and Nanotechnology for Space Applications	Thomas George (ViaLogy Corporation)
15:10 – 15:35	Fine MEMS	Isao Shimoyama (The University of Tokyo)

15:35 – 15:50 Break

Session 3	The Leading Edge of Micromachine Technology	Chairman: Ryutaro Maeda (AIST)
15:50 – 16:15	MEMS-related Nanomaterials	Gen Hashiguchi (Kagawa University)
16:15 – 16:40	Ultraprecision Micromachining and Its Application	Yoshimi Takeuchi (Osaka University)
16:40 – 17:05	Nanometrolog - Subnanometer-scale Dimensional Measurement Using Atomic Force Microscopy -	Satoshi Gonda (Advanced Semiconductor Research Center, AIST)
17:05 – 17:35	Understanding the Limitations of Structural Films and Nanomaterials	Christopher Muhlstein (The Pennsylvania State University)

Closing		
17:35 – 17:40	Closing Remarks	Keiichi Aoyagi (MMC)

MEMS Foundry Service at Matsushita Electric Works

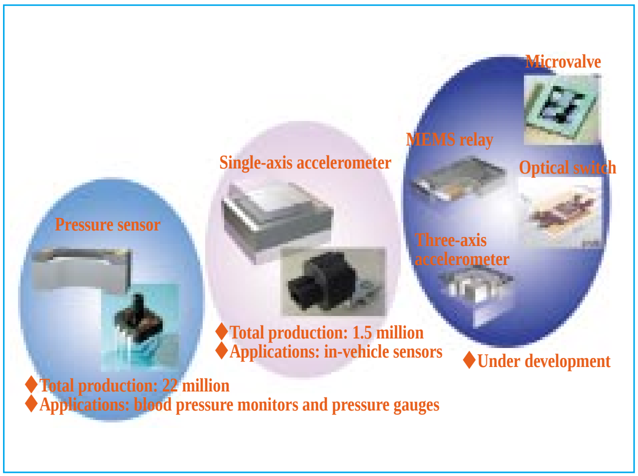
Kazushi Tomii, Group Leader of Prototype Fabrication
Advanced MEMS Development Center
Matsushita Electric Works, Ltd.

1. Outline

Since 1981, Matsushita Electric Works (MEW) has developed and accumulated knowledge in technologies involving semiconductor devices, such as relay devices, for in-house applications. From the mid-1990s, the company began developing MEMS devices in earnest, including pressure sensors and accelerometers, and later put its in-house facilities to use by launching the MEMS foundry service in 2002. MEW offers a wide range of services from wafer processing, using bulk micromachining techniques (a micromachining technology for producing complex 3D structures through Deep-RIE on silicon substrates and wafer bonding) accumulated through in-house development of MEMS products, to packaging. Through its rich experience in mass-producing MEMS sensors, the company can provide total solutions from prototyping to mass-production.

2. MEMS Technology at Matsushita Electric Works

For many years now, MEW has developed and commercialized various MEMS products with a focus on bulk micromachined MEMS sensors. Applying anisotropic etching of silicon, developed through processing semiconductor relays, MEW has used piezoresistive pressure sensors in such consumer products as blood pressure monitors, and has employed single-axis accelerometers of the same piezoresistive type for automotive uses. To date, the company has also developed three-axis accelerometers, and actuators used for MEMS optical switches, MEMS relays, and microvalves.



MEMS development at Matsushita Electric Works

Owing to this development, MEW developed a vertical silicon etching technique using Deep RIE for forming through-holes and micropatterns in wafers and achieving high aspect ratios, and silicon-on-insulator (SOI) bulk micromachining techniques for performing precision processing on a submicron order using SOI wafers formed by wafer bonding. These technologies enable the fabrication of smaller devices with higher performance.

3. Features of the Foundry Service

MEW's foundry service performs a wide range of services from single-wafer processes to device fabrication and packaging. In addition to the technologies described above, the foundry can produce various 3D structures by combining nanopatterning with a semiconductor stepper, glass substrates processing, and bonding steps. MEW also possesses a packaging technology fostered through the development of various in-house devices and can offer services applying a micropackaging technology using molded interconnect devices (MID; a technology to manufacture 3D electric circuits directly on injection molded boards).

MEW possesses fabrication and quality assurance knowledge founded on a wealth of experience from development to mass-production of in-house products. Based on this know-how, the foundry offers services from design and small-quantity prototype fabrication to design studies for mass-production and actual mass-production.

MEW can perform services from development and prototype production to small-quantity production on its 4-inch line at the Advanced MEMS Development Center, located at the Kadoma headquarters in Osaka, and possesses a 6-inch line for mass-production at its Ise Plant in Mie Prefecture.

4. Conclusion

In addition to using its MEMS processing technologies developed and accumulated thus far for in-house products, MEW also hopes to accelerate the practical use and applications of MEMS by extensively providing these technologies to users trying to develop MEMS businesses.

Through assistance from NEDO, MEW is participating in the MEMS Project, a three-year endeavor that began in 2003, developing new MEMS processing technologies. The company aims to further develop and expand its foundry services in the future.

Mechanical Simulator and Process Analysis Tools

Mizuho Information & Research Institute, Inc. Micro-Electro-Mechanical Systems, Science and Technology
Yasuroh Iriye, Associate General Manager;
Atsushi Sato, Senior Consultant; and
Takuya Iwasaki, Ph.D., Chief Consultant

In the previous issue of the MICROMACHINE magazine (May 2005 issue), Hiroyuki Fujita, the project leader of MemsONE, summarized the entire MemsONE project. In this issue, we will introduce the mechanical simulator and process analysis tools led by the Mizuho Information & Research Institute.

As shown in Fig. 1, the mechanical simulator and process analysis tools are provided in the MemsONE system as basic analytical functions that can be used through a software framework in the form of a GUI and can be linked with the material and process database, for example. The software framework for the MemsONE system comes with CAD and visualization functions so that coherent mechanical analysis and process analysis can be performed through this system alone.

The mechanical simulator is a set of programs for studying and evaluating the mechanical properties of MEMS devices and can be used in specification studies during the initial design stage. The simulator may also be used for final performance evaluations once the shape of the device has been determined. The mechanical simulator includes the following functions.

- **Stress-strain analysis**
  Can predict structural behavior, such as vibrations, deformation, and stress characteristics
- **Electromagnetic field analysis**
  Can evaluate Lorentz force and distributions of electric potential, electric current, and magnetic fields in devices employing electromagnetic drive systems
- **Piezoelectric analysis**
  Can predict structural behavior in devices having piezoelectric material
- **Thermal analysis**
  Can analyze changes in the temperature distribution in structures over time and thermal deformation in such changes
- **Effect analysis of ambient gases**
  Can find the damping rate of a MEMS structures that oscillates rapidly in gases
- **Coupling analysis**
  Can perform coupled analysis of the aforementioned functions in the mechanical simulator and can comprehensively verify and evaluate structural stress-strain, electrostatic fields, magnetic fields, piezoelectric and other drive mechanisms, and moving mechanisms in such MEMS as electromagnetic actuators, electrostatic actuators, and thermal actuators

The process analysis tools are used to create device structures, as well as to study mask layout and process flow design. Three-dimensional device structures developed with this tool can be imported into the mechanical simulator described above. The process analysis tools include the following functions.

- **Anisotropic wet etching**
  Provides a simulator to analyze anisotropic wet etching processes in order to predict transient changes in the 3D etching profile
- **Dry etching**
  Can confirm the etching shape produced through a dry etching process
- **Thin film deposition**
  Creates a 3D structure by emulating a physical or chemical vapor process according to a geometric method
- **Multiprocessing**
  Provides a function for creating 3D structures according to an emulator using a geometric method, and enables the thermal history and other data described in the 3D structural data and the process recipe to be used in the mechanical simulator

It is our hope that many people engaged in the design and development of MEMS devices will make use of these tools, and that the tools will contribute to the development of MEMS industry in Japan.

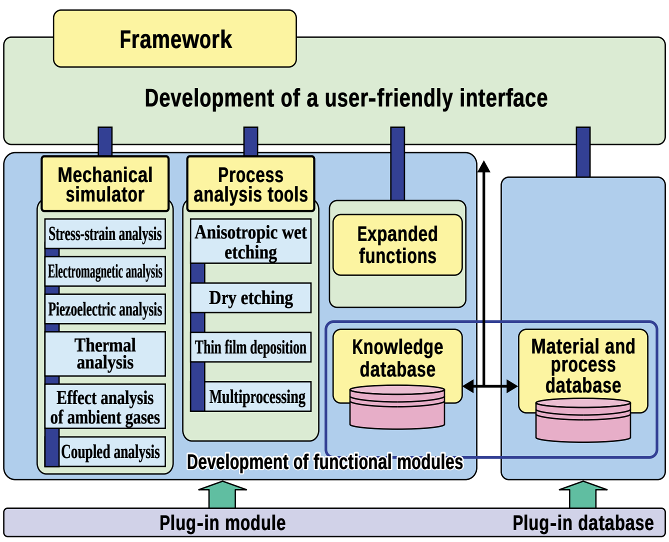


Fig. 1 Configuration of the MemsONE system

Column

MEMS Design and Analysis Support System Development (MemsONE) Project

Hidetoshi Kotera, Professor, Department of Mechanical Engineering, Graduate School of Engineering, Kyoto University

Steps in manufacturing include planning, functional design, basic design, trial production, functional testing, design for mass-production, and trial mass production. For manufacturing in the 21st century, computer-aided engineering (CAE) can be effective in each step of manufacturing to reduce the amount of trial production and to perform functional evaluations in advance for more suitably examining structures, principles, mechanisms, and materials.

Used, in many fields, CAE enables the researcher to virtually manufacture prototypes on a computer and to perform experiments to comprehend functions and phenomena of the object to be created. In MEMS R&D, the structure of the object is very small, making it difficult to grasp phenomena of the object through detailed measurements. Further, testing prototypes requires as much time and expense as normal equipment development. In this sense, CAE can be an effective tool.

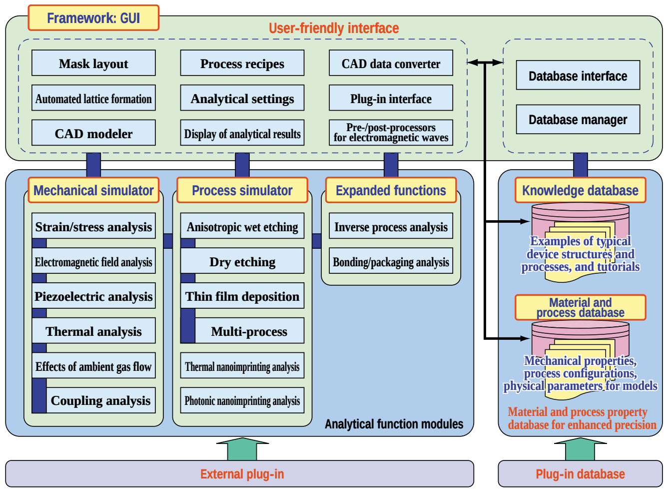
There are four fields within CAE, (1) computer-aided design (CAD), (2) computer-aided analysis (CAA), (3) computer-aided testing (CAT), and (4) computer-aided machining or manufacturing (CAM). CAD and CAA are the most important functions in research and development. Most researchers and engineers in MEMS R&D employ one of many general-purpose or proprietary CAE systems. Unfortunately, commercial CAE systems are terribly expensive and are prohibitive to beginners because of their extensive functions. The design and development of any equipment requires knowledge and experience in the materials, mechanisms, and structural processes involved. Even if one is versed in the usage of CAE systems, it is difficult to determine which materials to select and which mechanisms to use, as well as how to evaluate a device that has been manufactured virtually on a computer. Hence, a support environment is vital when using this system. In the case of MEMS, the properties of the finished materials and structures differ according to the equipment and conditions involved in production. Therefore, even if the device can be virtually manufactured on a computer, much time is still required for specifying conditions for actually manufacturing the device.

With this background, the objective of the MemsONE Project is to provide a CAE system that is readily available and easy to use for engineers and researchers aspiring to develop MEMS devices.

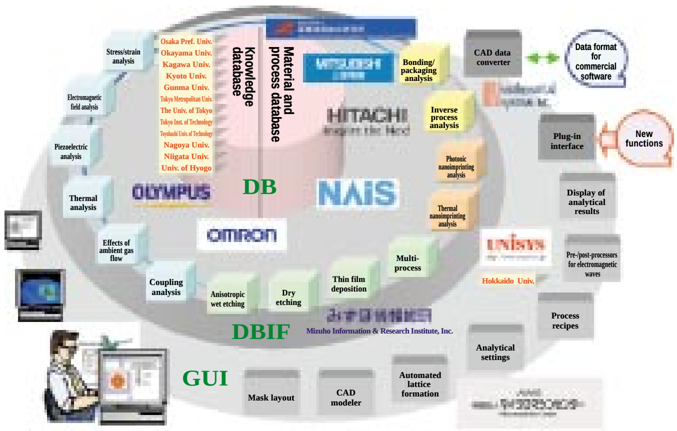
In the spring of 2007, the MemsONE system will be released in Japan free of charge. In addition to a CAD system for designing MEMS devices and various CAA systems for understanding such phenomena as how a virtually developed device will function, the MemsONE system has a knowledge database containing contributions from many experts in MEMS and a database of materials used in MEMS. The system has been designed so that first-time users and engineers with relatively little experience can design MEMS devices with less anxiety. The material database includes sample measurements of material properties obtained by domestic MEMS foundries during trial manufacturing. Results obtained by the user when designing MEMS devices on the computer can be used for trial manufacturing at a foundry service. (Note: material properties can change due to various factors and cannot be guaranteed.) The MemsONE system also incorporates an emulation program for calculating possible mask shapes once the final formation is entered, as well as a mask layout editor and functions for simulating such processes as etching and thermal and photonic nanoimprinting.

The MemsONE Project for developing this system has been subsidized by NEDO, enabling specialists from about ten companies and fourteen universities to participate in the development between 2004 and 2006. We sincerely hope that you will follow the progress of the MemsONE Project and obtain the MemsONE system for your own use in the spring of 2007.

General Concept of MemsONE System



Research and Development Members and Implementation Structure



COMS 2005, Germany, August 21-25, 2005

The international conference COMS 2005 was held at Baden-Baden, a world-famous and stylish hot springs resort in Germany's Black Forest, for discussing issues regarding the vitalization of the micro and nano technology (MNT) industry. The conference is held for industrial and government representatives involved in the MEMS industry primarily in Europe and North America as an opportunity to raise and discuss issues related to this industry. The conference is held in major cities, alternating between the two continents. This year marked the tenth COMS conference. Recently, representatives in the industry have recognized the importance of Asia as a source of information and have advocated holding a conference in the Asia-Oceania region. There now appear to be plans for holding the conference in Australia in 2007 (next year the conference will be held in St. Petersburg, Florida.).

This year's conference had 270 some people in attendance and more than 140 presentations, producing lively discussions with more than half of the participants reporting. Incidentally, the first conference held in 1984 was very small, with only 80 some participants. However, the number of participants has increased steadily every year, particularly in North America where last year's conference received an attendance of 340. Attendance at conferences held in Europe, on the other hand, tends to be only slight more than two-thirds that in North America, indicating that the field has a stronger hold in North America.

The breakdown of participants in this year's conference held in Baden-Baden was 65% Europeans, 25% North Americans, and 10% Asians. The vitalization of industry in Europe was a major topic of discussion.

The conference opened with a greeting from Dr. Sigrun Lang, the mayor of Baden-Baden. She related how the city had a rich history in which it prospered as a high-class resort for kings, emperors, and noblemen and has long been a behind-the-scenes political arena. She expressed her hope that COMS 2005 would serve as a venue for new and important discussions, as when Charles de Gaulle held his private meetings there.

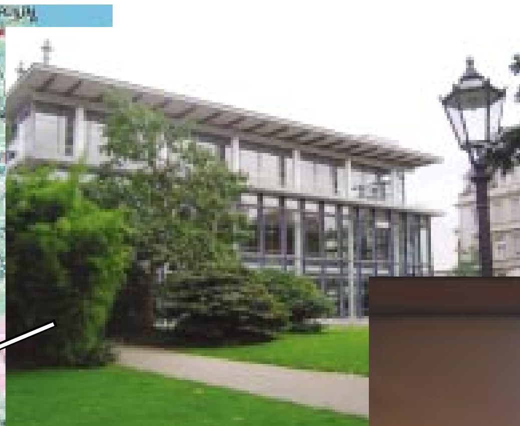
Later, Dr. Wolfgang Stöffler of the BMBF-Federal Ministry of Education and Research in Germany proclaimed that the German government has invested much in micro and nano technology and has great expectations for the field. As Dr. Stöffler had to attend to other business matters, his deputy Carsten Diehl reported on how the MNT industry had achieved recognition as an important industry in Germany by reaching a market share of 4.2 billion euros in 2003 by itself, creating 49 thousand jobs and as many as 680 thousand jobs when including related industries. He indicated that the industry from innovation to the development of industrial technology was receiving resolute support.

Themes in the keynote session and plenary session included successful case studies on issues facing the micro nano industry, citing Bosch as one successful enterprise. Other presenters talked about the MNT businesses in Germany, Holland, and Switzerland, while others emphasized that a national system for providing support to MNT in the nation or region had been strengthened, or advocated the nurturing of entrepreneurs and the like. While I was impressed with how the Europeans countries were actively engaged in the MNT industry nationwide, there were remarks that the EU procedures for MNT programs were complex and inflexible, providing little actual help for industrialization and being particularly ineffective for small businesses.

Overall, the presentations appeared to be stressing the need for cooperation among industry, government, and academia, intensifying activities to support entrepreneurs and a broad range of businesses, and advocating the need to establish a commercialization center by promoting its usefulness.

In connection with this, it was also striking to see how European countries work actively to industrialize MNT in their local industries. Steady activities to commercialize micromechanical parts, traditionally thought to be far removed from MEMS industrialization, have been nurtured through sound national support. One example can be seen in Switzerland in the supply of parts to watch-related industries. This year's conference included a tour of Forschungszentrum Karlsruhe, a research institute under the German government. On the expansive grounds of the institute, the birthplace of the LIGA technology, work is carried out on parts industrialization and on producing machines and heat exchanger parts through a unique method of micromachining metal and ceramic materials. These approaches toward parts other than semiconductors could serve as a reference for future undertakings in micromachines.

The representative of Micralyne Inc., a Canadian foundry, remarked that there is not likely to emerge another “killer app” for the MEMS industry, and most growth in the industry will come about by the steady production of small volume, high added value products. He emphasized that foundry customers must design their products within the technological capacity of the foundry rather than trying too hard to produce something unusual, undertake due diligence in manufacturing their products, and educate themselves on the framework of commercialization, including new products and required investment. We would be wise to carefully consider this advice in Japan, as well.



Report on the Transducers '05 International Conference in South Korea

The 13th International Conference on Solid-State Sensors, Actuators and Microsystems was held in Seoul, Korea, June 5-9, 2005 at the Convention and Exhibition Center (COEX). The 800 some participants from twenty-seven countries (registered as of May 31) at Transducers '05 was down from the 1,100 some participants at Transducers '03, held two years earlier in Boston, but the lively feel at this year's conference reflected the great expectations that the MEMS field still commands. As the conference was held in neighboring South Korea this year, 201 of the participants came from Japan. This very large number shows the high level of interest Japan holds for MEMS in comparison with the rest of the world.

The majority of presentations at the conference consisted of reports on sensors, actuators, and their materials, production, and assembly that apply technologies across a broad range, including the chemical, physical, mechanical, and electrical fields. The 532 presentations included 3 keynote speakers, 15 guest speakers, 199 oral presenters, and 315 poster presentations, while 50% of the 1,035 submitted papers were accepted (based on a report given during the opening ceremony).

Fig. 1 illustrates the changes over the years and the number of submitted papers and the percentage of papers that were accepted, showing a dramatically increasing trend in the number of submitted papers over the past several years. These figures support the vigorous activity in MEMS R&D in recent years. When examining the number of presentations given by country, Japan had the most with 132, followed in order by the U.S. with 119, South Korea with 79, Germany with 39, and Taiwan with 33. In terms of research institutes, the University of Tokyo gave the most presentations, providing evidence to the spirited efforts put forth by Japan's research institutes.

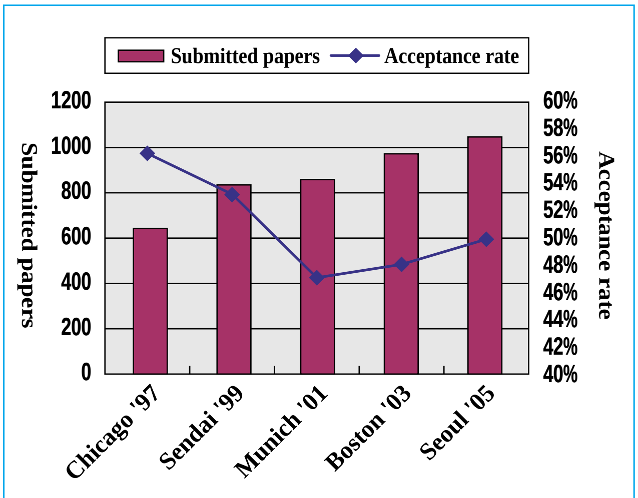


Fig. Changes in the number of submitted papers and their acceptance rate

Except for the keynote speeches given on the opening day, the entire format of the conference consisted of four parallel sessions run simultaneously. Lively discussions were heard in all sessions. The biotechnology-related sessions particularly attracted many listeners in every hall and in some cases were so crowded that not everyone who wanted to could attend.

A session of the conference

Among the keynote speeches given on the first day of the conference, Dr. Kurt E. Petersen of SiTime Corporation in the U.S. talked about the history, present state, and future of MEMS under the theme “A New Age for MEMS.” A memorable part of this lecture was his description of how the well-known Moore's Law predicting the trend of technological advancement in semiconductors could be adapted to MEMS technology.

Turning to the oral presentations, a report on the integration of LSI and physical sensors, such as pressure sensors and accelerometers, attracted much attention. Although the approaches for such integration differed, one came away with the impression that the fusion of MEMS and LSI is progressing more steadily than before. In the area of materials, it appears that polymers are being incorporated into various biotechnology MEMS. These features were also presented in the previous conference, but it appears that new functionality and performance, as well as practicality, has been derived by skillfully incorporating the characteristics of polymers in MEMS. In terms of manufacturing methods, the DRIE session was reestablished at this conference, and proposals were made for several devices and methods using silicon DRIE, one of the keys to MEMS machining technology. It would appear that a DRIE technology capable of meeting the needs for device processing is nearing completion.

The next international conference, Transducers '07, is scheduled to be held June 10-14, 2007 in Lyon, France.

Members' Profiles

Nano Device and System Research, Inc.

1. Endeavors in MEMS Technology

Nano Device and System Research, Inc. (NanodeS) is a venture company that was founded on April 2, 2001 to develop commercially viable applications for MEMS. We are also planning on trying our hand at nanodevices, which are expected to be a critical technology in the 21st century. Susumu Sugiyama, the CEO of the company, has been conducting close collaborative research with Ritsumeikan University, while holding a concurrent post at the university as a professor specializing in MEMS. Ritsumeikan University possesses a synchrotron for irradiating soft X-rays to perform nanolithography. By making good use of this technology, we can develop devices with nanostructures.

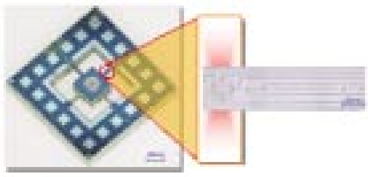
Nano Device and System Research, Inc.
Yoshikazu Tobinaga, COO

2. Existing Technology

MEMS can be broadly categorized as sensors that take in signals from the environment and the like, and actuators for drive systems. Currently, development of sensors has advanced more rapidly, as they can be given functionality with a simple structure. NanodeS has also focused its development on sensors, specifically accelerometers, biosensors, and pressure sensors.

(1) Developing Applications for Existing MEMS

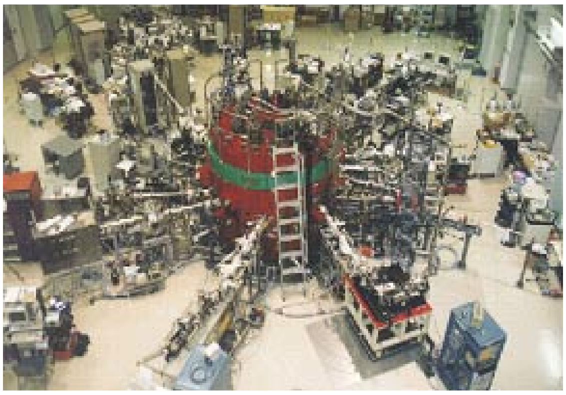
We have primarily been developing applications centered on MEMS researched at Ritsumeikan University. We are now nearing completion of a six-axis accelerometer and are currently seeking a partner for collaborative research aimed at commercializing the accelerometer. A feature of this accelerometer is its ability to perform rotational sensing, making it suitable for use in a fluid sensor or a robot arm that performs complex movements. We are striving to capture the subtle movement of humans.



The 6-axis accelerometer developed at Ritsumeikan University

(2) Developing Nanodevices

Through X-ray lithography performed with a synchrotron, we can achieve nanoprecision machining. With this technology, NanodeS is currently trying to develop a nanogap biosensor. This is a new biochip sensor that captures a single strand of DNA in the nanogap and evaluates its electrical properties when an electrical bias is applied.



The synchrotron at Ritsumeikan University has a peak wavelength of 1.5 nm

3. Future Endeavors

Optical devices are devices that use nanostructures as functions for direct expression. For example, the wavelengths of visible light fall within a range from 800 nm to 400 nm, the former extreme being the color red and the latter corresponding to blue or violet. If we can control the wavelengths at a precision of about 20 nm units, it is likely that we can use the optical properties to implement functions. In a simple example, a 500-nm hole is formed in a plate and a white light is directed on the hole. Since only light having a wavelength smaller than the diameter of the hole can pass through, the hole will appear to be colored. Microstructures are capable of coloring without pigments. In fact the colors on a butterfly's wings appear to form patterns by exactly the same method. Hence, by studying nanostructures that already exist in nature, I believe we can discover still unknown nano phenomena and use that knowledge to develop applications for nanotechnology.

MICROMACHINE No. 53

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