MMC
MICROMACHINE
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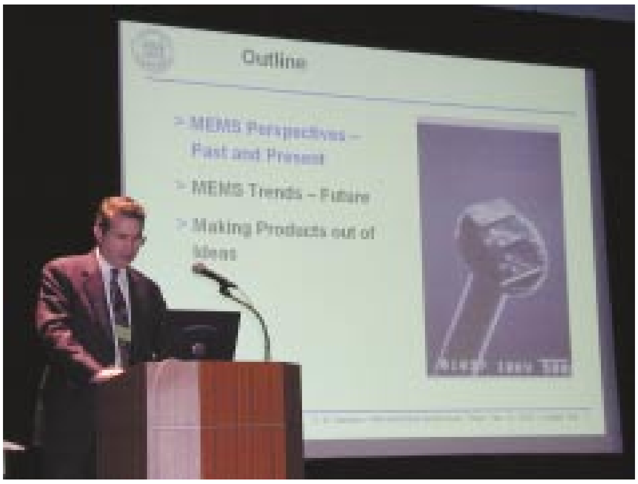
MMC Activities

The 9th International Micromachine / Nanotech Symposium

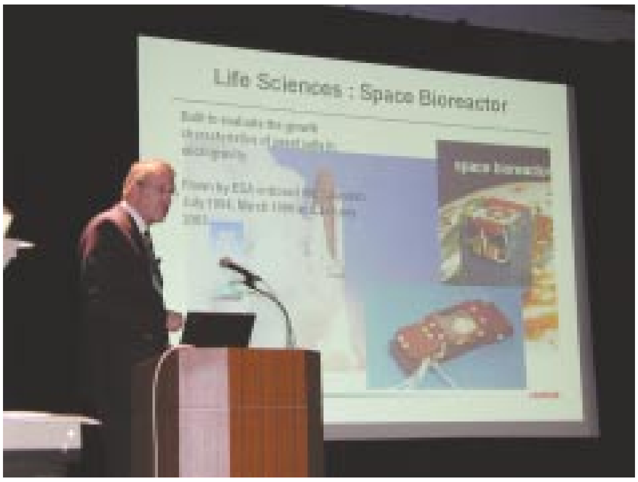
The 9th International Micromachine / Nanotech Symposium, which has the subtitle of "Foundation of Industrial Technology in the 21st Century" was held on November 13, 2003, at the Science Museum in Kitanomaru Park, Tokyo. It was organized by Micromachine Center, and was supported by Ministry of Economy, Trade and Industry (METI) and New Energy Developing Organization (NEDO), and was subsidized by Japan Motorcycle Racing Organization. The lectures and a panel discussion was a resounding success, as attendees participated actively in the panel discussion and lively exchanged opinions with panelists.

Opening Address by Mr. Toshiro Shimoyama

In Session 1, "Opening", an opening address was given by Mr. Toshiro Shimoyama, Chairman of the Micromachine Center, followed by a guest speech by Mr. Sakae Takahashi, Executive Director of NEDO. Mr. Takahashi spoke in particular about the MEMS project begun in Fiscal 2003 as part of the METI program "Focus 21", and expressed his appreciation to the daily contributions of researchers cooperating on NEDO projects and activities of the Micromachine Center.



Special Lecture by Prof. Stephen D. Senturia



Special Lecture by Prof. Nico F. de Rooij

The opening ceremony was followed by two special lectures presented by pioneers in the field of MEMS in the West. The first lecture was presented by Professor Nico F. de Rooij of the University of Neuchatel, Switzerland, on the theme of "MEMS and Opportunities for University / Industry Technology Transfer". The lecture discussed cases of technology transfer to industry in which the University of Neuchatel was involved and the products thus developed. The second was presented by Professor Stephen D. Senturia of the Massachusetts Institute of Technology, U.S.A., on "Turning MEMS Ideas into MEMS Products". The lecture discussed the past and present of MEMS, future trends for MEMS, and points to be considered to commercialize the MEMS ideas.

Session 2, which has the theme of "The Path to New Industries in the 21st Century", featured three lectures; Session 3, which has the theme of "Innovative R&D", featured four lectures; and Session 4, which has the theme of "Strategy for Micro / Nano Technology (Exploring of New MEMS Development)", featured four lectures. In all, thirteen invited speakers, including six from overseas, addressed in the symposium. A panel discussion was made on the theme of "MEMS industrialization" in Session 4. Seven panelists answered to the questions from audience, the lively exchange of Q & A attracted interest of the entire venue.

Of the 218 registered participants, about 83% were industry-related persons who are mostly researchers and the managers, 8% belonged to public agencies such as the National Institute of Advanced Industrial Science and Technology (AIST), 7% were from universities, and 2% were from other professions. This analysis shows that this symposium especially attracts industrial researchers for their R & D. In total, participants numbered 297, including registered participants, invited guests, members of the press and others. With the venue very vibrant from beginning to the end, the symposium was a great success. Micromachine Center would like to express deepest thanks to all participants and everyone to cooperate us.

The next symposium, The 10th International Micromachine / Nanotech Symposium, will be held on November 11 (Thu), 2004, at the same Science Museum in Kitanomaru Park, Tokyo, which is located near the Imperial Palace, in conjunction with The 15th Micromachine Exhibition.

Panel Discussion

The 14th Micromachine Exhibition: "Micromachine 2003"

The 14th Micromachine Exhibition, "Micromachine 2003," was held in conjunction with The 9th International Micromachine/Nanotech Symposium at the Science Museum in Kitanomaru Park, Tokyo, for 3 days from November 12 to 14, 2003.

In addition to the Micromachine Center and 14 of it's supporting member organizations, generous cooperation in the arrangement of exhibitions was also provided by private businesses, universities, and independent public organizations. A total of 238 displays (323 booths) were exhibited by representatives of various businesses, academic groups, universities, and research organizations. The theme for this year's exhibition was "Limitless Business Fields Opened up by Micro/Nano Technology: International Exhibition on Micro-Ultraprecision/Microfabrication, MEMS, Nanotechnology, and Biotechnology". France's National Center for Scientific Research *(Centre National de la Recherche Scientifique)* and seven other organizations from abroad also presented exhibits.

In accordance with the increased number of exhibitors, the Micromachine 2003 exhibition occupied, for the first time, the entire first floor hall space and a part of the lounge of the Science Museum.

Furthermore, a total of 77 businesses and academic groups took part in the exhibition, including 2 companies participating for the first time, and a wide range of new technologies and products in the fields of nano-technology and micromachines were presented.

Thanks in part to the exhibition being held in conjunction with the 9th International Micromachine /Nanotech Symposium, a record attendance of 8,793 people was achieved over the three days of the event. Researchers, engineers, and administrators from the frontlines of various technological fields accounted for a large number of these attendees, and through the exchange of ideas and sharing of research information with colleagues from other fields, the exhibition provided an ideal opportunity for discussion of the possibilities for new technologies and to resolve a wide range of developmental issues.

The main products displayed at the exhibition included micromachines, their associated components and application systems, MEMS-related systems, nano-technologies and materials, technologies related to micro-ultraprecision fabrication and production, equipment, biotechnology and medical systems, evaluation and measurement devices, and software. In this regard, Micromachine 2003 was ideally suited to researchers, engineers, designers, manufacturers, and managers from fields such as mechanisms and precision machinery; electrical devices and electronics, medicine; information technology; automobiles and transportation; biology, physics, and chemistry; architecture; metallurgy; space aviation; and shipping and oceanography.

Furthermore, the exhibition provided an excellent opportunity for the promotion of technologies, devices, and products by businesses in the field of micromachine research and development; for the presentation of the results of research projects by universities and other research organizations, and for the announcement of products and technologies by other newly participating businesses. On its opening day, the exhibition was visited by Mr. Yoshifumi Fujita, Director of the Industrial Machinery Division of METI's Manufacturing Industries Bureau, who spoke at the reception that was held following the exhibition.

Micromachine 2004 will be held from November 10 (Wednesday) to 12 (Friday), 2004 at the Science Museum, Kitanomaru Park, Tokyo.

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The exhibition hall, packed with attendees

Attendees at the post-exhibition reception

International Electrotechnical Commission
IEC/TC47 Delft Conference Report

Description of conference

The TC47/WG4 meeting was held in the city of Delft in the Netherlands on October 28, 2003.

Three proposals for international standardization

Three representatives from Japan attended the IEC/TC47 (International Electrotechnical Commission Technical Committee Meeting No. 47) held in Delft in the Netherlands on October 28, 2003. In addition to participating in discussions concerning proposals for international standardization currently being put forth by Japan-standards for the terminology to be used for micromachines and MEMS, tensile testing methods for thin film materials, a proposal for international standardization developed from the results of the R&D for Standards Project conducted from 1999 until 2001, and standard specimens for testing-a report was also delivered on plans for fatigue testing of thin film materials to be performed as part of the energy usage management system standardization research survey begun this year, and a request was made for international cooperation in this regard. It was reported that these are the only three proposals being put forth at the present time by Japan in the field of nanotechnology materials.

Discussion of individual proposals

A discussion was held on comments submitted by Korea and China concerning the proposal for micromachine and MEMS terminology submitted by the Micromachine Center in July of 2002 now at the stage of a committee draft and it was decided that the terms would be prepared as a committee draft for vote. However it was requested that clarification be made of the scheduling of maintenance before a final draft for vote be written.

As for the two proposals concerning thin film materials tensile testing, these proposals had already been presented in July earlier this year, and while they had only been adopted as new proposals as of October 10, although there were questions raised by British and American representatives about the English phrasing, in recognition of the fact that such questions were unrelated to the essence of the proposals, the representatives said that they would accept the proposals. Since this eliminated the basic problems, approval was given to proceed on to the next step of developing a committee draft and it was decided that Japan would submit a draft in March 2004. Both proposals thereby advanced a single step further towards approval.

Holding of a new WG meeting

The Korean delegation proposed that a WG meeting be held in June 2004 in Geneva or Phoenix to discuss the creation of generic specifications for MEMS. The stated purpose of this meeting would be to start to establish a position for lists of technical terms, tensile testing methods, fatigue testing methods, and other MEMS standards to be developed in the future. The Japanese delegation expressed its agreement with this proposal and it was decided that the WG meeting would be held.

Persons in attendance

The persons who attended the meeting are as listed below:

R. Turner *(Convenor,UK KBCI)*
Kuniki Owada
(International Standardization Engineering Laboratory)
Akira Umeda
(Japan, National Institute of Advanced Industrial Science and Technology)
M. Konno *(Japan, Micromachine Center)*
Sekwang Park
(Korea, Kyungpook National University)
Sang-Geun Lee
(Korea, Agency for Technology and Standards)
Bo Cui
(China, Heibei Semiconductor Research Institute)
Miao Lu
(China, Heibei Semiconductor Research Institute)

Recent MEMS Trends in the U.S.

Microelectromechanical Systems (MEMS) is a technological concept that originated in the U.S. in the late 1980s. MEMS function to form electromechanical devices by integrating the functions of actuators and other mechanical elements with circuitry on wafers using microfabrication. Following subsidies provided by the National Science Foundation (NSF) to support MEMS, the Defense Advanced Research Project Agency (DARPA) began a full-scale MEMS program with an annual budget of $40-50 million.

We interviewed academic and industrial experts to understand the current state of MEMS in the U.S. as part of a survey commissioned by the Japan Industrial Policy Research Institute. Contacts are listed below.

Prof. Wen Ko, Case Western Reserve University

Has been studying pressure sensors since the 1960s and is now conducting training on MEMS in China.

Dr. Clement, Managing Director, MEMS Industry Group

Serves as the day-to-day manager of MIG operations and activities.

Dr. Gabriel, Akustica, former Prof. of Carnegie Mellon University

Served as Director in the initial DARPA MEMS Program and contributed to establishing the existing MEMS research system.

Dr. Bob Rao, Technology and Manufacturing Group, Intel Corporate

Actively involved in research on microsystems and nanotechnology

Prof. Tang, UC Irvine, former MEMS Director of DARPA

Former MEMS Director at DARPA and is now launching MEMS research at UC Irvine.

MEMS research and infrastructure in the U.S. have been developed under the sponsorship of DARPA. DARPA's goals in supporting MEMS R&D are to determine potential applications of MEMS technology in national defense, as well as commercial applications. Accordingly, DARPA has continuously funded MEMS projects anticipated to spark developments in microfabrication technology, changing the focus of the research topics to meet the needs of the times. In the initial stages of the MEMS Program, DARPA aimed at enhancing overall MEMS technology and subsequently focused on applied research in the fields of optics and biotechnology. At present, the agency has shifted its research thrust to biotechnology and wireless technology from optical switches, which it had supported during the "IT bubble era."

In order to ensure that research findings lead to commercialized products, DARPA has recently sought to include private companies in the program. In addition, the agency undergoes strict evaluations at the completion of each 18-month phase in a total of three phases.

DARPA also funds research conducted by startup companies until they can find venture capital and other financial sources. The funding has proved effective in luring serious investors. As the MEMS infrastructure is still in its growing stage, DARPA supported a foundry service based on standardized multiuser MEMS processes (MUMPs) that enable us to fabricate different types of devices on a single wafer. After the MEMS infrastructure was fully developed, the foundry was transferred to a private company. The MEMS Exchange, currently in operation, is a network of fabrication facilities at universities designed to aid universities and small to medium-size companies. By linking the facilities at these universities, the project is beneficial for universities that conduct only small-scale MEMS research.

With the support of DARPA and other organizations, startup companies have started to commercialize the results of research conducted by universities. Some professors and university researchers who pioneered the field of MEMS are taking two-year long sabbaticals to launch their own venture companies, where their achievements are put into practical use. Dr. Gabriel, former professor of Carnegie Mellon University, created an innovative method for developing MEMS-based speaker and microphone chips. About two years ago, he founded a fabless company named Akustica with some twenty employees and is currently involved in operations, while on sabbatical from CMU. Akustica is expected to break even by 2005. Since startup companies like Akustica rely on investments from venture capital and individual investors, their success depends both on the technology to be commercialized and their fund-raising ability.

California is a center for hi-tech companies, such as those located in Silicon Valley, and academic research. The state has many prestigious universities, such as the University of California, Berkeley, but since their campuses have reached a saturation point for research facilities, additional facilities and faculties for advanced research are being constructed in Irvine, located 40 mile south of Los Angeles. Many biotechnology companies and other ventures are flocking to Irvine because of the venture capital available and are working closely with UC Irvine in biotechnology research. Irvine is already beginning to take the form of a "Bio Valley."

Normally new companies look outside the company for technological seeds to develop MEMS products, but U.S. companies establish relationships, in the form of joint research and the dispatch of in-house researchers, with universities that have accumulated technological expertise through advanced research. Intel Corporation, for example, has begun conducting biotechnological research in cooperation with universities.

According to comments we received, it is extremely important for startup fabless companies to find foundry services that can maintain repeatability in product quality and performance.

A widely used technology, MEMS is being incorporated into various devices developed with CMOS, SiC and other materials. As measuring technology is becoming vital to the application of MEMS, the MEMS Industry Group (MIG) is holding workshops to address this issue.

The U.S. MEMS community has been shifting to application-oriented research, while firms offering integrated services have also expressed an interest in MEMS technology. Advanced research covers the potential uses of not only silicon but also new innovative materials for MEMS device. Many experts have indicated that commercialization of MEMS technology must include an improvement in reliability and reduction in costs, particularly packaging costs.

Micro Device Center
Yamatake Corporation

Shunichiro Awa
Director, Micro Device Center

1. Challenge of Micromachine Technology

We have been developing business operations with the aim of improving the energy and resource efficiency in buildings, plants, and factories under the visionary slogan "Providing Greater Comfort for People and the Earth." To achieve our business goals, sensing and control technologies are essential. Hence, we have placed emphasis on microelectromechanical systems (MEMS) for developing miniature, high-performance sensors and actuators to be installed on the ends of measuring devices in the field.

We first tackled micromachine technology with the inauguration of our corporate research center in the middle of 1980. Since then, we have established a business partnership with Honeywell Inc. (U.S., now Honeywell International Inc) for the purpose of researching and commercializing micromachine technology. Today, we are taking on both R&D and fabrication of microdevices, from sensor elements to packages, and are functioning as an organization capable of making microdevices for in-house use available commercially through divisions products. Since it requires much time and effort to discover new products and businesses with marketability, a separate organization has been created in the Research & Development Headquarters to perform exploratory seeds development function.

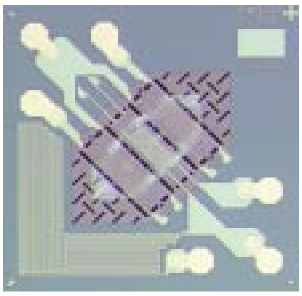
2. Development of Micromachine Technology

Here, we will introduce some of the microdevices we have successfully developed and commercialized.

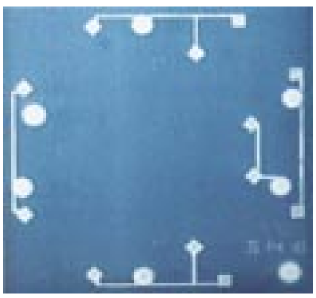
1) Humidity sensors

Humidity sensors are next in importance after temperature sensors in terms of controlling the air condition in a building. A stable humidity-sensitive polymer film was developed through joint research with universities conducted over several years, enabling us to develop advanced humidity sensors. Evaluations conducted by an independent Swiss institute revealed that our product is superior to other major humidity sensors in the world in dew point stability and chlorine resistance. Accordingly, Yamatake humidity sensors are being widely employed, primarily in air conditioning systems for buildings, while increasingly attracting the attention of both national and international users.

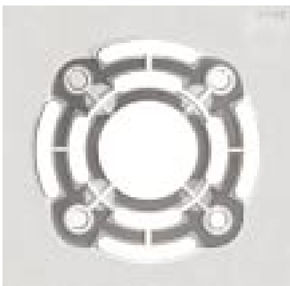
Humidity sensing elements



Microflow sensing elements



Piezo-resistive pressure sensing elements



Sapphire pressure sensing elements

2) Microflow Sensors

We began full-scale development of thermal flow sensors in the late 1980's, with the aim of applying this knowledge to gas flow measurement. In 1994 we succeeded in mass-producing microflow sensors with 1.7 millimeters square chip. The sensor possesses outstanding features, such as a high sensitivity capable of measuring a flow rate of 1 cm/sec or less. We improved the performance and functionality of the sensor through the production of numerous prototypes and repeated field tests. In addition, we collected and evaluated sensors that had been installed in the field for more than ten years. Then proved the long term reliability of our products. Using this microflow sensor, we have developed a high-speed, high-accuracy flow measurement technology for a wide range of applications, from ultra low flow rates to high flow rates. In addition, many results have been obtained by applying this microflow sensor to studies of flows on wall surfaces.

3) Pressure Sensors

The most basic targets of industrial measurements are flow rate and pressure. A pressure sensor measures not only pressure, but also flow rate calculated based on the pressure differential across the diaphragm, or orifice, formed in the piping. The pressure sensor is the oldest MEMS sensor that has been widely used in industrial applications. Yamatake has also conducted intensive research and development since the inauguration of the corporate research center and the Micro Device Center. We successfully developed pressure sensors utilizing piezoresistive pressure sensing elements and marketed them as the world's smallest microprocessor-based pressure sensors. Our primary pressure sensors have high accuracy and high-temperature stability.

In order to meet the demands for pressure measurements under high-temperature and corrosive environments, we developed the Sapphire capacitive sensor that can offer excellent resistance to heat and corrosion. The sensor element is produced from 100% sapphire and can directly measure temperatures of several hundreds of degrees, as well as pressures on corrosive media. Since the development phase, the sensor has received high praise from customers in the fine chemical and semiconductor industries. We hope to accelerate commercialization of this sensor.

3. Future Challenges

As described above, humidity, flow rate, and pressure are basic targets of sensing in the field of measurement and control. We continue to conduct research and development to meet the needs of our customers. In addition, we will employ a comprehensive technology accumulated through the development of in-house microdevices to take a further step toward developing and producing commercial devices for outside customers.

ULVAC, Inc.

Hiroyuki Yamakawa,
Managing Director and General Manager of the Tsukuba Institute for Super Materials

1. The Challenge of MEMS

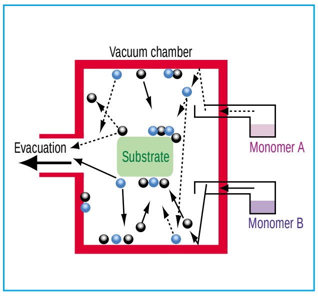
ULVAC has been supplying advanced vacuum technology products, such as semiconductor production equipment, flat panel displays and other production equipment based on myriad technical development in the core of vacuum technologies Some ULVAC Group companies have been involved in such advanced materials as ultrafine particles, and surface analysis equipment. In addition, ULVAC plans to enter new fields, including biotechnology, fine mechatronics, and fine chemicals. We have added to our equipment lineup with the SME-200 sputtering device for forming high-dielectric films and SAW device electrodes, the CME-200 CVD device for forming silicon oxide films and nitride films, and the NLD-6000, which demonstrates its efficiency in the deep etching of quartz.

2. Launching a MEMS Foundry Service

ULVAC develops distinctive semiconductor wafer processing technologies, including deposition of high-dielectric films, magnetic films, and other functional materials that are difficult to form with conventional equipment, as well as deep etching of quartz, and dry etching of materials that could not be etched until now due to low vapor pressure. The vapor deposition polymerization method developed by ULVAC can add a water-shedding quality, hydrophilicity, biocompatibility, antifungal properties and other properties to various types of samples. It also provides excellent step coverage enabling the formation of a uniform polymerization film over the details of a fine processing shape. Using these technologies, ULVAC has undertaken some processings of brought -in materials for deposition and etching onto customer's wafers.

We have received an increasing number of requests from customers to manufacture MEMS devices in addition to these processing services. To meet such demands, we have prepared lithography and other MEMS processing lines and have established an integrated production line from design to dicing and bonding, to say nothing of the deposition and etching processes, in order to launch our MEMS foundry service.

NLD-6000 MEMS dry etcher and processed sample



Our own vapor deposition polymerization technology for forming uniform polymer film over complex substrates

SME-200 PVD device for forming high-dielectric films and MEMS electrodes

CME-200 PE-CVD device for forming SiO_2 and SiNx films

3. Features of the ULVAC Foundry Service

Our foundry service has the following two features:

1. Utilizing ULVAC's distinctive technologies for vapor deposition polymerization, dielectric deposition, and NLD dry etching, we fabricate MEMS devices and manufacture and provide materials. The ULVAC foundry also provides a wide range of materials for purposes other than silicon processing.
2. Utilizing our technologies and know-how to develop equipment and processes as an equipment manufacturer, we provide rapid services for processing that requires new processes and equipment to meet customer demands.

4. Future Challenges

In addition to these technologies, ULVAC has carbon nanotube and ultrafine particle manufacturing technologies and powerful surface analysis tools. Through the integrated application of our technologies, we hope to provide our foundry service, while simultaneously developing MEMS devices and processes.

Worldwide R&D

Intelligent Formative Engineering, Department of Intelligent Mechanical Systems Engineering, Faculty of Engineering, Kagawa University

Gen Hashiguchi, Associate Professor
E-mail: hasiguti@eng.kagawa-u.ac.jp

1. Introduction

The Faculty of Engineering at Kagawa University is relatively new in that the first class enrolled in April 1998. Intelligent Formative Engineering, one research group in the Department of Intelligent Mechanical Systems Engineering, has focused on semiconductor microfabrication technology since its inauguration. We were granted permission to share the clean room in the Future Research Center On To The New Millennium KAGAWA (FROM Kagawa) in October 2000. Since then, we have been intensively studying micromachine technology. Professors Yutaka Mihara, Fumikazu Ohira, and I have been working together to raise funds and operate the clean room. This year we intensified our research activities by adding Research Associate Maho Hosogi to our group.

2. Research Facilities

We received permission to use the facilities at FROM Kagawa, including a Class 1000 clean room having an area of $70m^2$ (see Fig. 1), two laboratories, a conference room, and a sitting room, for a total floor area in the five rooms of $300m^2$. The clean room is equipped with photolithographic devices such as a two-sided mask aligner, draft chambers for treating organic and acid chemical wastes, an RF sputterer, a reactive ion etcher (RIE), and a STS-manufactured inductively-coupled plasma RIE, which we persuaded Kagawa Prefecture to install. Additional measuring equipment includes a measuring microscope and surface profiler. The electric furnace room is equipped with an oxidation furnace having an external combustion tube , a sintering furnace, an annealing furnace, and an SiN low-pressure chemical vapor deposition furnace. Except for an ion implanter , the facilities include all basic equipment required for research on semiconductor microfabrication.

3. Research Themes

The research group of Intelligent Formative Engineering conducts numerous studies with a focus on the following topics.

- Micromolding
- MEMS-based optical communications
- Wearable sensors
- Microdevices for DNA analysis
- Probes for nanofabrication

In addition to conventional electroplating technology, micromolding research covers processing technology using superplastic titanium. MEMS-based optical communication research is the study of phase variable filters and optical switches that can maintain communication lines when electric power is interrupted. Under the theme of wearable sensors, a stethoscopic sensor is being developed for detecting vital signs.

Recently we have also turned our attention to bionanotechnology, working with Tokushima University and the University of Tokyo to establish microdisection for the specific isolation of DNA molecules from solution using a DNA nano pin set (see Fig. 2) and to fabricate prototypes of multi-nanoprobes for AFM field processing.

4. Conclusion

Owing to use of the clean room over the past three years, we have learned basic micromachining processes and production techniques for MEMS devices. We are committed to moving forward with our research in order to prove our competence as a MEMS research laboratory.

Fig. 1 Class 1000 Clean Room ($70m^2$)

Fig. 2 DNA nano pin set, SEM photo of microdissectioned DNA cells (λ-DNA)

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