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マイクロマシン
MICROMACHINE

MMC Activities

The 8th International Micromachine / Nanotech Symposium

The 8th International Micromachine / Nanotech Symposium was held at the Science Museum in Kitanomaru Park, Tokyo, on November 14, 2002. The symposium program began with an opening address by Mr. Toshiro Shimoyama, Chairman of the Micromachine Center, followed by a guest speech by Mr. Masakazu Toyoda, Director-General of the Manufacturing Industries Bureau, METI. In his address, Mr. Toyoda not only spoke about the importance of MEMS technology, which integrates nanotechnology, to Japanese industry, but also expressed words of encouragement regarding promotional activities of the Micromachine Center.

The symposium was very successful, with the venue packed to almost full capacity. In total, participants numbered 311, including 227 registered participants, presenters, members of the press and others.

A special lecture presented by Professor Isao Shimoyama of the University of Tokyo, "Strategy towards Fusion of Nano and Micro Systems," attracted the greatest attention within the industries. Painting an image of the future of Micromachine and MEMS using the slogan "Nano on Micro," Professor Shimoyama stated that, in particular, the development and industrialization of devices with high added value and into which nano materials or technologies have been actively incorporated are vitally important for Japan's future.

Other presentations included "The Path to New Industries in the 21st Century," "Innovative R&D," and "National Strategy for Micro/Nano Fusion Domain." In all, a total of thirteen invited speakers, including four from overseas, addressed the symposium.

Of the registered participants, 82% were industry-related researchers or management persons, 12% belonged to public agencies such as the National Institute of Advanced Industrial Science and Technology (AIST), 5% from universities, and 1% were from other professions. This breakdown is especially indicative of the high interest in this symposium shown by researchers in the industries.

The next symposium, The 9th International Micromachine / Nanotech Symposium, is planned for November 13, 2003 (Thursday).

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No.42

Strategy towards Fusion of Nano and Micro Systems

Isao Shimoyama,
Professor,
Department of Mechano-informatics,
Graduate School of Information Science and Technology,
The University of Tokyo

As I was introduced, my name is Isao Shimoyama. Allow me to explain how I came to be speaking at this symposium today on a "Strategy towards Fusion of Nano and Micro Systems." The Micromachine Center gave me an assignment to consider the state of Micromachine, or MEMS, five or ten years from now. For this reason, I was allowed to participate in various committees at the Micromachine Center. Based on my findings, I would like to relate to you what course I believe Micromachine, or MEMS, will take in the medium- to long-range future.

Although the English title for my discourse is "Strategy towards Fusion of Nano and Micro Systems," I will reveal the conclusion of my study first by saying that R&D in the field of Micromachine, or MEMS, will shift decidedly toward devices replete with functions in the fields of nanotechnology and nanomaterials. From this viewpoint, the key phrase of my speech will be "nano on micro," as I would like to talk to you about how the products of nano materials and technology will be provided on microsystems.

Features of Micromachine and Industrialization

To define Micromachine and their potential industries from the unrestrained standpoint of the university, the first thing we observe is that the elements of Micromachine are extremely small, allowing for the manufacturing of dense and highly integrated devices. For example, it is possible to manufacture machines from elements strung one-dimensionally in a long line, as in the example of an endoscope. By densely integrating elements two-dimensionally, it is possible to develop thin, lightweight televisions like wallpaper, for example, or extremely thin displays used in cell phones and the like. And while it may be possible to manufacture Micromachine that can be used in specific medical environments, it is also conceivable that there would be a large market for industries providing extremely small, lightweight, and thin devices. Another great feature of Micromachine, or MEMS, is their capacity to contain a driving unit, unlike IC or VLSI technologies. Based on the strict definition of movement, even an immobile solid object has within it molecules and atoms that are moving, and numerous functions are being emerged through this movement. The fact that there is intrinsically a high probability of movement is extremely advantageous, particularly in the small nanoworld. Therefore, it is sufficiently conceivable that Micromachine can be industrialized as next-generation devices, using their advantageous shapes and functions, and not simply as an extension of ICs and VLSI.

Anticipated Manufacturing Technologies and Materials

While it may be far in the future, I believe it is an important issue in manufacturing technology to discuss how we can put functions emerging on nanoscale to practical use. Further, it will be extremely important to develop new nanomaterials, and manufacturing technologies for mass-producing these nanomaterials at a low cost, since we have not yet been able to industrialize nano emerging functions that were first emergence on a nanoscale. In a sense, taking advantage of such as self-assembly phenomena on nanoscale and to obtain nanomaterials or nano emerging functions is what we call a bottom up approach. In contrast, Micromachine technology is an example of a top down approach used to process such as surfacing and removing by micro-machining methods that enabled microfabrication, assembly, and systems, as represented by lithography. These types of processes have raised the potential of manufacturing technology through innovation. Microfabrication systemization is another anticipated manufacturing technology for achieving 3-dimensional high-density integration, multiple functions, and fabrication of not only silicon, but also ceramics, polymers, and other materials together. High-speed analysis and sensing technologies in microarea have begun to be developed in microchemical processes and the field of μ-TAS. These technologies will be used to create a society and a lifestyle with satisfaction in which we can feel growth and development. When considering these from the binding of information, we can anticipate ubiquitous environments in which anyone, anywhere, at anytime can access data or another person with ease; and an environment in which an individual like me, only here and now, can obtain an order-made product or a regional service;

and a safe and secure living environment in which our privacy is protected when accessing a network. These are the goals of a vision to provide satisfying lifestyles to users. I have provided this scenario to show that the use of these technologies can elevate Japan to the top level internationally.

Innovation

Innovation required to achieve this goal includes progress in wearable, mobile, and interfacing technologies. For example, we are able to produce super-small batteries and low-power CPUs, or are becoming capable of producing them. We have developed, or will soon develop, sensors that appeal to the five senses, including hearing, sight, smell, and touch, or that correspond to stimuli of the senses, as well as devices that present and display these senses. Using Micromachine technology, we can develop light, thin devices. We can develop flexible devices using organic materials. Other innovations are devices that can display 3D images that are made from the above technologies to be light, thin, and flexible enough to fold up and put in your pocket. Also, optical communications or sensors placed on networks are appearing as innovations in the wearable, mobile, and interfacing fields.

Robots as an Example Achievement

When we see these from the viewpoints of robots, it has applications in such areas as healthcare, welfare, information, everyday living, safety and security. There are surgical robots in medical care. In welfare, we have nursing robots and attendant robots. In the field of information, there are human-like robots, robots with no strength but serving as an interface. There are robots that help with various household chores and, at night, can feasibly serve as night watchmen. If we broke down these robots into desired element technologies, we would have such abilities as taking diagnoses and giving medical care at the invasion stage of disease, reading vital signs, sensing and displaying the five senses, and performing wireless communications or telemetry. We would also like the robots to have a soft quality, an actuator, and a battery that can be powered externally, as well as reliability and adaptability to society. Breaking down manufacturing technologies into the key technologies, naturally one large key or breakthrough is MEMS, or what we are calling Micromachine technology. Using technologies to fuse these with nanoarea, we have been able to emerge new functions in nanoarea and have developed devices that can use soft, thin, and narrow curved surfaces, as well as small devices that are dense and highly integrated.

Policies and Markets

Markets for these technologies include devices, networks, learning and education, and security. Industries include semiconductors, system LSI, sensors, micro-fabrication, Micromachine, communications, content services, and fuel cells. With that in mind, what policies should we consider for these technologies? Since it is quite difficult to produce products simply by using of emerging nanofunctions and nanomaterials, it is necessary to promote manufacturing technologies in the micro-nano fusion domain or research on the fusion of systemization technologies and to establish a measurement evaluation technology. We must develop a foundation for the technology transfer from universities and development of these technologies in industries, R&D systems at National Institute of Advanced Industrial Science and Technologies, and R&D typified by foundries that use these facilities. We must create an infrastructure that can reduce barriers as much as possible, enabling anybody with an idea to participate in this industry or its research and development. I would like to ask government to fill up a mechanism or infrastructure at the national level for developing creative products through the active cooperation of industries in applying fundamental base technologies.

Conclusion

A recent newspaper article commented that Japan's manufacturing technologies have still globally competitive. In general, businesses are not healthy and tend to look toward short-term profits, as in how something will be profitable a half-year or a year from now. However, an issue being discussed at the universities is that we must strengthen our competitiveness while we are still strong. If we do not conduct R&D for the mid-term and long-term while outlining dreams that are feasible now, I ask you what will we do when Japan's strong manufacturing technologies die out? How will Japan survive in the future? The focus of our R&D should be on technologies vital for strengthening Japan, including micro-nano manipulation of 3-dimensional MEMS/NEMS, design simulation, and MEMS and NEMS created from multiple materials. Finally, I am often told that infrastructure as well as cooperation between industry and academia and the fostering of human resources is extremely vital. While cooperation between industry and academia creates an atmosphere in which universities are required to execute everything up to product development, the most important mission for universities is to educate-and to develop seeds. Through the combination of healthy industries and university initiative, I hope we can generate a great surge in the field. As we progress into the 21st century, Japan must continue to take action and earn respect in order to occupy a prestigious position in the world. For this reason, I conclude that there is no more time for debate.

The 13th Micromachine Exhibition: "Micromachine 2002"

The 13th Micromachine Exhibition, "Micromachine 2002," was held in conjunction with The 8th International Micromachine/Nanotech Symposium at the Science Museum in Kitanomaru Park, Tokyo, for 3 days from November 13 to 15, 2002.

In addition to the Micromachine Center and 11 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 187 displays were exhibited by representatives of various businesses, academic groups, universities, and research organizations. The theme for this year's exhibition was this event centered on realizing an international exhibition focusing on super-accuracy, nano-fabrication, and nano-technology that will open up new frontiers in size reduction and precision. France's National Center for Scientific Research (*Centre National de la Recherche Scientifique*) and five other organizations from abroad also presented exhibits.

In accordance with the increased number of exhibitors, the Micromachine 2002 exhibition occupied, for the first time, the entire first floor hall space of the Science Museum.

Furthermore, a total of 72 businesses and academic groups took part in the exhibition as newcomers, 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 8th International Micromachine / Nanotech Symposium, a record attendance of 8,424 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; biotechnology and medical systems; technologies, equipment, and materials associated with precision fabrication and production; evaluation and measurement devices; software; and nano-technologies. In this regard, Micromachine 2002 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 2003 will be held from November 12 (Wednesday) to 14 (Friday), 2003 at the Science Museum, Kitanomaru Park, Tokyo.

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The exhibition hall, packed with attendees.

Attendees at the post-exhibition reception

μTAS 2002

μTAS2002 (The 6th Micro Total Analysis Systems 2002 Symposium) was held at Nara New Public Hall in Nara, Japan, from November 3 to 7, 2002.

Fig. 1 Nara New Public Hall

This was the sixth holding of the international conference, which began in 1994 as a small-scale workshop held in Enschende, Netherlands. Initially the conference was held in alternate years, but after the year 2000 the conference was switched to an annual format in order to accommodate the increase in participants. The number of participants at μTAS 2002 exceeded 700.

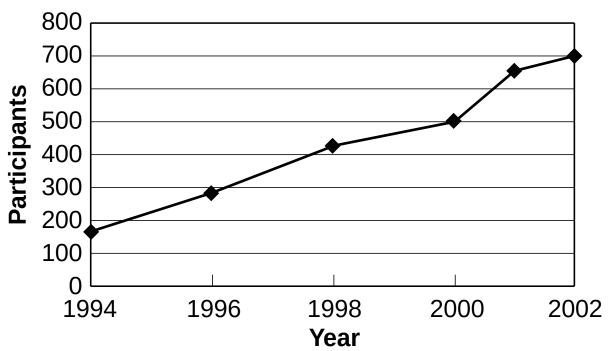


Fig. 2 Trends in participation

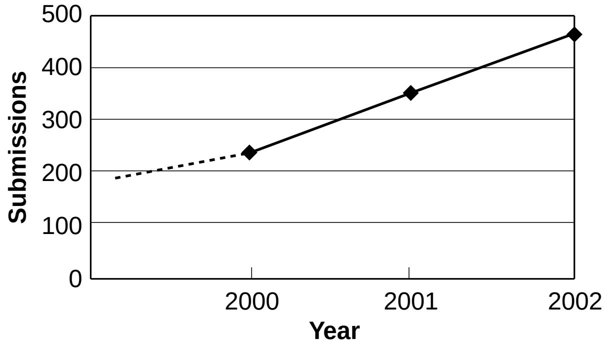


Fig. 3 Trends in abstract submissions

Since an increase in the number of abstract submissions accompanied this increase in participation, speeches were held in parallel sessions, using the same format employed in the previous year. As a result of the increase in poster presentations, 66 oral presentations and 257 poster presentations were selected from among 460 submissions, equivalent to an approximate 70% acceptance ratio. Since μTAS is limited in its fields and has a higher acceptance ratio than that for MEMS, transducers, and the like, the international conference is thought to be an excellent opportunity to learn about the latest trends in the field. However, while the conference provides many advantages, such as the possibility to hear explanations of poster exhibits firsthand from the researchers, this conferences was mildly disappointing in that the posters had to be replaced daily due to the limited exhibition space and visitors could not view posters at after hours, as is possible overseas when the conferences are held at hotels, for example.

The percentages of presentations broken down by region were 40% from the U.S., 24% from Europe, and 36% from Asia. This distribution was more balanced than the previous year, when North America accounted for approximately half of the presentations, due to the effects of the simultaneous terrorist attacks.

In the early 90s, the application of a sensing technology using capillary electrophoretic separation and fluorescent light in on-chip DNA analysis set the stage for developments that put μTAS research in the spotlight. As with last year, there was an astounding number of presentations on DNA, proteins, cells, and other matter that originates in organisms. Further, presentations emphasizing applications of MEMS devices were more numerous than those on devices themselves, such as micropumps.

These trends showed an increase in studies on performance enhancements in more practical areas of DNA analysis and an increase in cases using actual samples rather than reference materials and alternate materials. The study trends also revealed a shift from DNA and proteins to cells. One presentation commented on the production of chips used for hemanalysis that are developed from layers of plastic molded components. There appears to be a lot of activity in the formation of nanostructures through a combination of disposable chips and surface modification, polymer materials and their processing techniques, and device development.

Next year the conference site will shift back to America. μTAS 2003 is scheduled to be held in Squaw Valley, California, from October 5 to 9, 2003.

Oki Electric Industry Co., Ltd.

Fumio Ichikawa
General Manager of the VLSI Research Center

1. The Challenge of Micromachine Technology

Oki Electric first became involved in micromachine/MEMS-related technology in the 70s by developing an anisotropic etching technique for silicon that was applied to the production of high-voltage thyristor switches used in electronic exchanges. First, KOH is used to etch about 50 microns from the surface of a silicon wafer, forming a V-shaped channel. After oxidizing the surface of the wafer, the channel is implanted with polysilicon. The silicon substrate on the bottom of the wafer is polished, ultimately forming a high-voltage device on a silicon island surrounded by an oxide layer. The technology was developed by Nippon Telegraph and Telephone Public Corporation (present-day NTT). Oki Electric also participated as a member of a fact-finding committee (chairman: Prof. Kyoichi Ikeda, Department of Mechanical Systems Engineering, Faculty of Technology, Tokyo University of Agriculture and Technology) concerned with the concept of a foundry network system for micro and nano production technologies and has actively worked toward achieving practical MEMS devices.

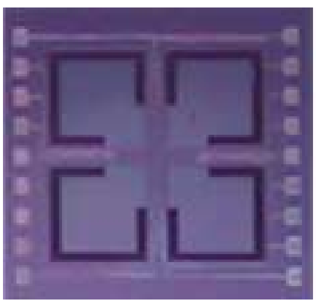
2. Development of Micromachine Technology

(1) Accelerometer

Oki Electric is developing small, high-performance 3-axis accelerometers for use in portable devices, in-vehicle units, games, industrial equipment, security equipment, and the like.

(2) RF-MEMS/W-CSP

Using a photolithography rerouting technique, we are developing and mass-producing wafer level CSP (W-CSP), which are extremely thin, light-weight, and compact packages ideal for mobile devices and have outer dimensions equivalent to the size of the semiconductor chip. Oki Electric is developing a next-generation rerouting technology for forming Hi-Q passive devices (e.g. inductors and capacitors) on the surface of semiconductor chips by decreasing the size and increasing the layers. In this way, passive devices that to date have been provided externally can be built into high value-added semiconductor packages (next-generation W-CSP).



Three-axis accelerometer

RF-MEMS/W-CSP

(3) Optical Interconnections

Electric wiring on printed circuit boards cannot keep pace with the decrease in size of LSI wiring and the improvements in clock speed, resulting in a problem known as an I/O bottleneck that limits the performance of the overall system. Optical interconnections are attracting attention as a technology for solving this problem. At Oki Electric, we are studying optical chip interconnections using free space based on the understanding that the ability to increase channel density, enabling light to cross without interference, can be used to achieve multichannel interconnections over short distances.

3. Future Challenges

In addition to our silicon processing technologies fostered through many years of LSI production, Oki Electric works closely with its customers to provide a micromachine/MEMS foundry service based on process control and quality control technologies that have been shaped by strict market quality requirements. Oki Electric is flexible in supporting various types of services, from undertaking part of the client's processes to undertaking the entire process and design, including joint projects with alliance partners.

Nikon Corporation

Yosuke Takahashi
President of Core Technology Center

1. The Challenge of Micromachine Technology

Nikon has been engaged in technical development related to micromachines for a relatively long time, including working in cooperation with the Yoshida Nano-Mechanism Project in 1986 to develop a probe for a special scanning tunneling microscope. Nikon has also developed its own micromachine devices, including the following:

- Probe for a scanning probe microscope
- 3-dimensional accelerometer
- Microgripper
- Microknife
- Non-cooled infrared image sensor

2. Development of Micromachine Technology

Here, we will introduce some representative devices and related technologies developed by Nikon thus far.

To begin with, we will introduce a microgripper for manipulating small objects under a microscope as an example of bulk micromachining (Fig. 1). Thin film fingers having a thickness of 0.7μm and a length of 600μm are controlled under a microscope using a master-slave system. With this microgripper, it was possible to manipulate eggs and protozoa between 20 and 100 microns in size using a gripping force of about 10 nN. The gripper was also used to construct a system capable of performing in-situ measurements to determine the hardness of microobjects. Through this development, we established basic processing technologies and evaluation technologies regarding self-supporting thin films. This microgripper can be considered a special micromachine for its capacity to operate in a solution.

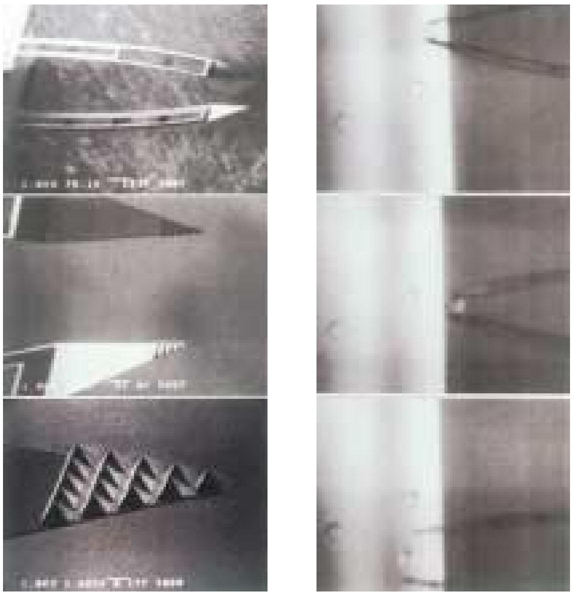


Fig. 1 External view and operations of the microgripper

Next, we will introduce a non-cooled infrared sensor as an example of surface micromachining (Fig. 2).

Infrared light received from the back of a substrate is converted into heat, causing the bimorph unit to deform, which in turn tilts the mirrors integrated in the bimorph unit. The slopes of the integrated mirrors enable thermal images to be obtained by a 2-dimensional CCD that detects all visible light. Recent devices have been successful in obtaining accurate thermal images without requiring special temperature control by canceling deformation caused by temperature changes in the outside air. Basic properties of the infrared sensor include a pixel size of 55μm, a resolution of 160x120 pixels, and a sensitivity of 2.8 mV/K.

3. Future Challenges

Nikon hopes to continue developing useful micromachines for data communications and biotechnology, while utilizing aspects of its technologies such as the ability to drive devices in liquid and high-rise MEMS structures.

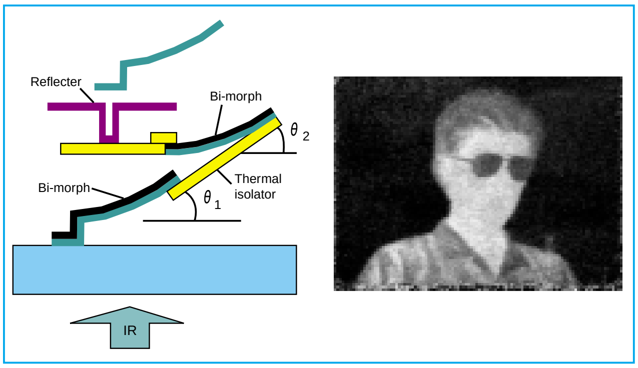


Fig. 2 Cross-sectional view of the non-cooled infrared sensor and a generated image

Worldwide R&D

Laboratory of Advanced Science and Technology for Industry

Tadashi Hattori, Professor, Himeji Institute of Technology

1. Introduction

Various research departments have been gradually added at the Laboratory of Advanced Science and Technology for Industry at Himeji Institute of Technology after construction of the laboratory in April 1994. Currently advanced research is being conducted under five standard departments and one special department for visiting researchers. The Department of Micro Systems came to be in February 2000 after I joined the university. Along with other staff in the department, including associate professor Yuichi Utsumi and research associate Harutaka Mekaru, I am currently conducting research on microsystems through active use of the synchrotron radiation facility New SUBARU built in the laboratory.

2. New SUBARU Synchrotron Radiation Facility at Himeji Institute of Technology

The synchrotron radiation facility New SUBARU was put in-service in January 2000. The facility, which is the third largest of its kind in Japan, is primarily intended to help establish a new industrial technology foundation through advanced research focusing on optics and development in cooperation with businesses. Financially supported by the local government of Hyogo Prefecture, New SUBARU is housed within the same complex as SPring-8, the world's brightest synchrotron radiation facility. But while the two facilities have an impact on each another, New SUBARU is a unique facility both domestically and overseas for the fields of soft X-rays and vacuum ultraviolet light sources in the strong emphasis it places on industrial use.

Already seven beam lines are currently in use. Fig. 1 shows the overall layout of the facilities. The storage ring has a circumference of 119 meters, a beam energy of 1.5 GeV, and a stored current of 500 mA. Beam line 11 (BL11) is dedicated to microsystem processing and is used to perform deep X-ray lithography in the LIGA process.

3. Department of Micro Systems

Studies on the LIGA process are conducted at nearly every research institute having a radiation facility. However, few links have been made to industrial applications as of yet, even though such research has been conducted for more than twenty years. Recent trends in research on LIGA processes can probably be classified under the following three categories.

(1) Studies on producing structures with a high-aspect ratio (height/width) using high-energy soft X-rays
(2) Studies on producing 3D structures
(3) Advanced and practical studies on electroforming and molding processes important in post-lithography manufacturing

America and Europe in particular emphasize (1) above because a high aspect ratio increases the specific surface area of the structure, providing various advances in functionality. However, (2) and (3) are more important for making realistic advances in industrial applications. In effect, we are striving to create 3D microstructures of desired shapes using LIGA, which can only create simple, cookie-cutter shapes, while reducing production costs and expanding material selections. Through our effective policy designed to establish all processes, from developing an X-ray mask to mass-production of molds, we have succeeded in developing optical switches for broadband applications, optical devices for terminals, chips for bioanalysis, and essential components for various microsystems. While there are still a mountain of issues to overcome before we can achieve our goal of being the first to produce microfunctional structures having a dynamic range from nanometers to microns, we are moving forward one day at a time toward establishing a single base in Japan for radiation manufacturing.

If you are fortunate to have the time and means to take a trip, please visit us at the West Harima Science Garden City. Take a break from your everyday activities and tour the New SUBARU and SPring-8 facilities.

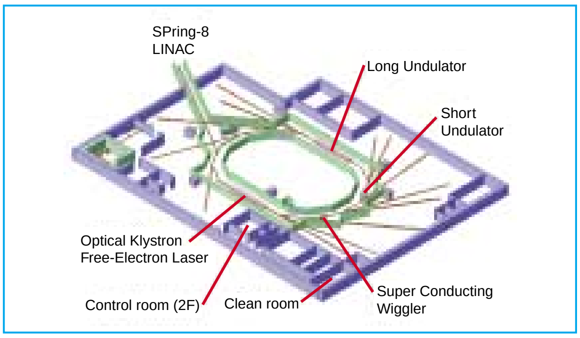


Fig. 1 The synchrotron radiation facility New SUBARU

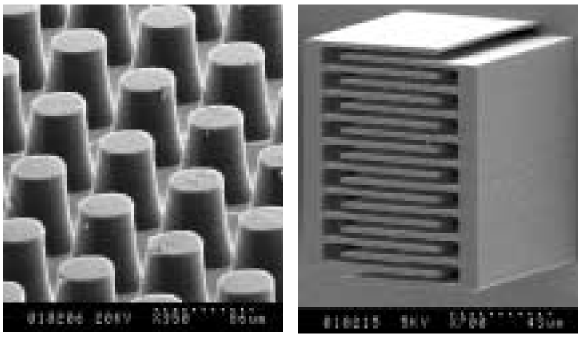


Fig. 2 PMMA exposure pattern

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