Present State of the Micro-Electro-Mechanical Systems (MEMS) Industry and Its Prospects

By Iihama Mika

What are Micro-Electro-Mechanical Systems?

Interest in micro-electro-mechanical systems (MEMS) technology has been on the rise lately in various fields. MEMS generally refers to micro-sized devices fabricated based on integrated circuit (IC) manufacturing technology.

To make our description of MEMS easier to understand, we will use actual examples of commonplace devices. We are all familiar with "switches," which are widely used for purposes such as turning lighting on/off, but they can be made using MEMS technology as well. The basic structure and function of a common light switch and a MEMS switch are the same. Both serve to turn electric current on/off by connecting/disconnecting a lever and a point of contact. However, the critical difference between them is their size. As can be seen in the example of the MEMS switch in Figure 1, the width of the lever (moving part) is 100 microns or less. Considering the fact that the average thickness of a hair is 80 microns, you can probably imagine just how small the switch is. IC manufacturing technology is employed to create such tiny MEMS devices. As most people know, IC manufacturing is fundamentally similar to photo developing technologies. (Fig. 2) A thin film is formed on a silicon substrate, a coat of photosensitive material (photoresist) is applied on top of it, and then a desired circuit pattern is created using a laser over a mask. A developer is used to dissolve and wash away the exposed areas, and then all areas except those covered by the photosensitive material are removed by etching, thereby forming the desired circuit pattern on the silicon substrate.

The difference between how MEMS are manufactured compared to ICs lies in the "positive" use of these processes to create not only two-dimensional structures such as circuits, but also three-dimensional structures (machines). In this respect, MEMS manufacturing technology is an applied form of IC manufacturing technology that achieves MEMS-specific technical advances such as highly precise three-dimensionality (depth gauge), but it is also suited to high-precision mass production (low-cost production), a feature of IC manufacturing technology.

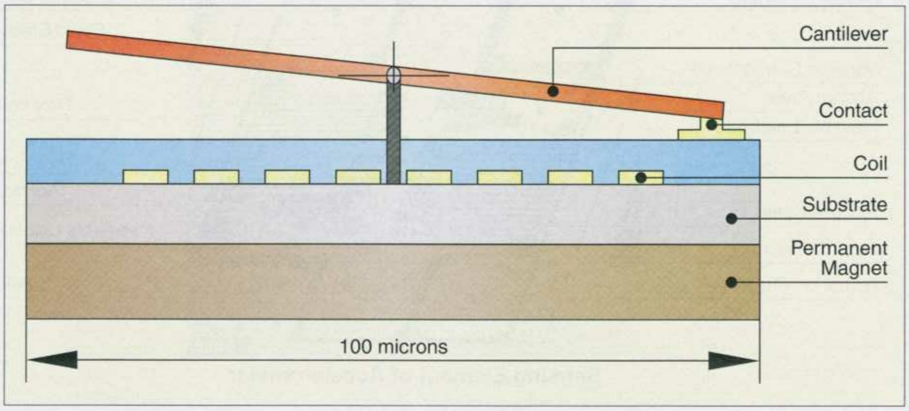
Both overseas and Japanese companies are actively conducting research and development on applying such MEMS switches to element devices for mobile communications such as cell phones by exploiting the micro-miniaturization, high precision and low cost of MEMS.

Current State of the MEMS Industry and Its Future

Where are these tiny, high-performance MEMS actually being used? Although most people do not realize it, MEMS products are already being widely used around us, and their global market is said to exceed ¥500 billion. Typical examples include the acceleration sensors built into automobile air bags (Fig. 3), pressure sensors used to measure blood pressure (Fig. 4) and the sprayers in ink jet printers that spray minute ink droplets from nozzles (Fig. 5). The development and product history of some of these goods spans 10 years or more, and some automotive parts and IT device manufacturers have already established businesses based on them. As mentioned earlier, the features of MEMS technology, which can supply tiny, high-precision products at a low cost, something that is impossible with conventional technology (normal mechanical technology), contribute tremendously to increasing the performance of systems (such as automobiles and printers) that employ such components.

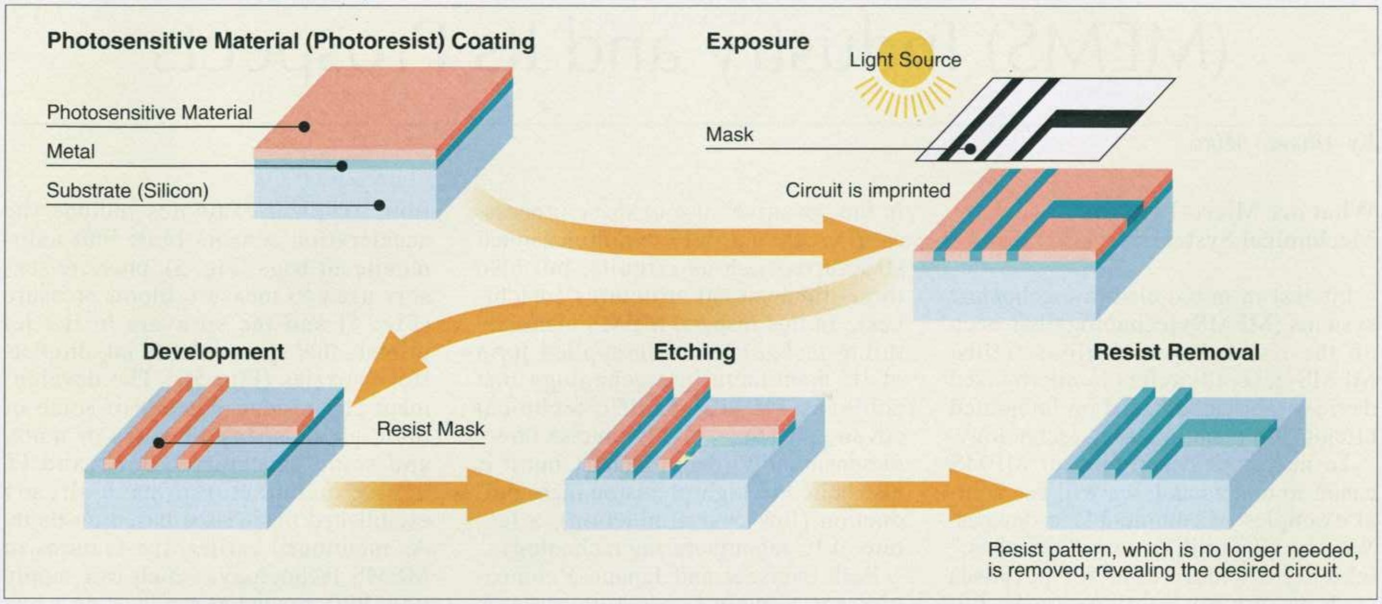
The applications of MEMS are further expanding by making the maximum use of such features. This is expected not only to dramatically improve device performance in a wide range of fields, but also potentially to become a key technology for completely new products and services. The MEMS switches introduced in the

Figure 1 Magnetic MEMS Switch



Source: EDN Japan, http://www.ednjapan.com/ednj/2002/200205/feature-b0205.htm

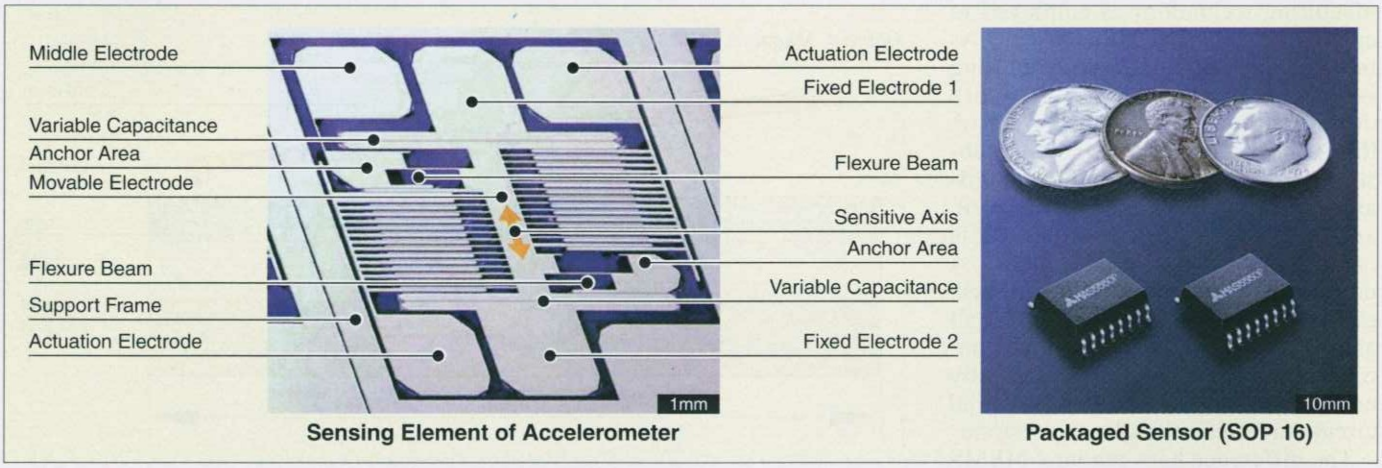
Figure 2 Overview of MEMS Manufacturing Process



Source: Dainippon Screen MEG, Co., http://www.screen.co.jp/eed/lsi/lsi_nyumon/4_01.html

previous section are a typical example of this sort of new MEMS, and as already mentioned, leading Japanese and overseas companies are competing with each other to incorporate them into cell phones and other devices. Cell phone multifunctionality is expanding each year, but there continues to be a strong demand for compact and low-cost handsets. In addition, the semiconductor switches used in current cell phones have, in principle, difficulty in supporting further increases in the radio wave frequencies that are used for cell phones, and it is said that they are reaching their limit in performance (for example, proper switch "off" performance) and power loss. MEMS switches are considered to be an improvement over conventional semiconductor switches in terms of performance because they turn on/off by means of an extremely easy mechanical structure. They are also seen as having great potential as components for cell phones, which particularly demand reduced power consumption, with the additional benefits of being tiny and inexpensive. There are more than a few issues that must be resolved, such as mechanical-specific durability, but full-fledged practical application is expected somewhere around 2005. MEMS technology is also expected to be applied to other cell phone-related

Figure 3 Acceleration Sensors Built into Automobile Air Bags

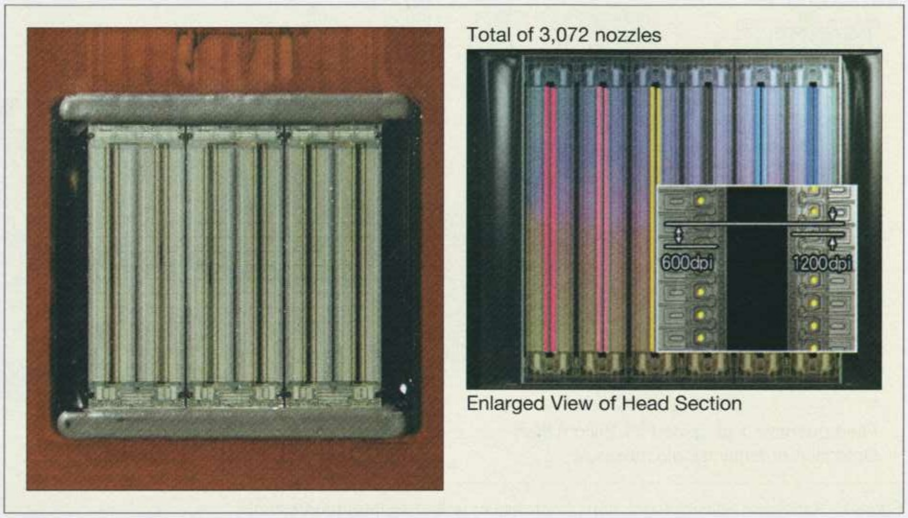


Source: *MITSUBISHI DENKI GIHO*, 1999, Vol.73, No.8

Figure 4
Pressure Sensor for Blood Pressure Meters

Source: OMRON Corporation

Figure 5
Ink Jet Printer Head (Sprayer Section)



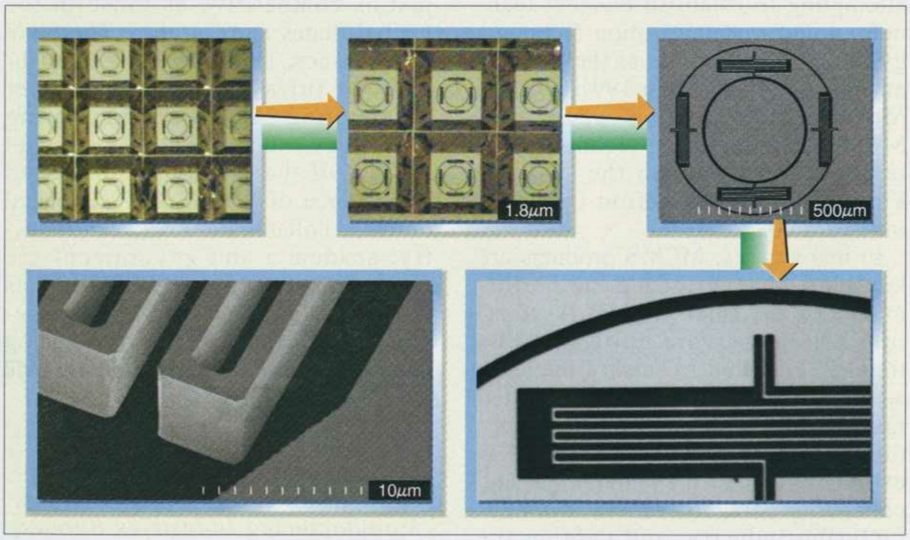
Source: Canon Inc.

Source: Canon-Sales Inc.

components such as filters, resonators and antennas. Research is underway on the future integration of switches and these other components with logic circuits.

Along with radio communication, another promising field for MEMS is optical communication. Research on optical switches is very active (Fig. 6), and various companies from Japan, the United States and Europe have already announced their trial products. Most of them feature an array of tiny mirrors with high-precision angle control, enabling incoming light to be switched to the desired direction.

Figure 6 Optical Switch

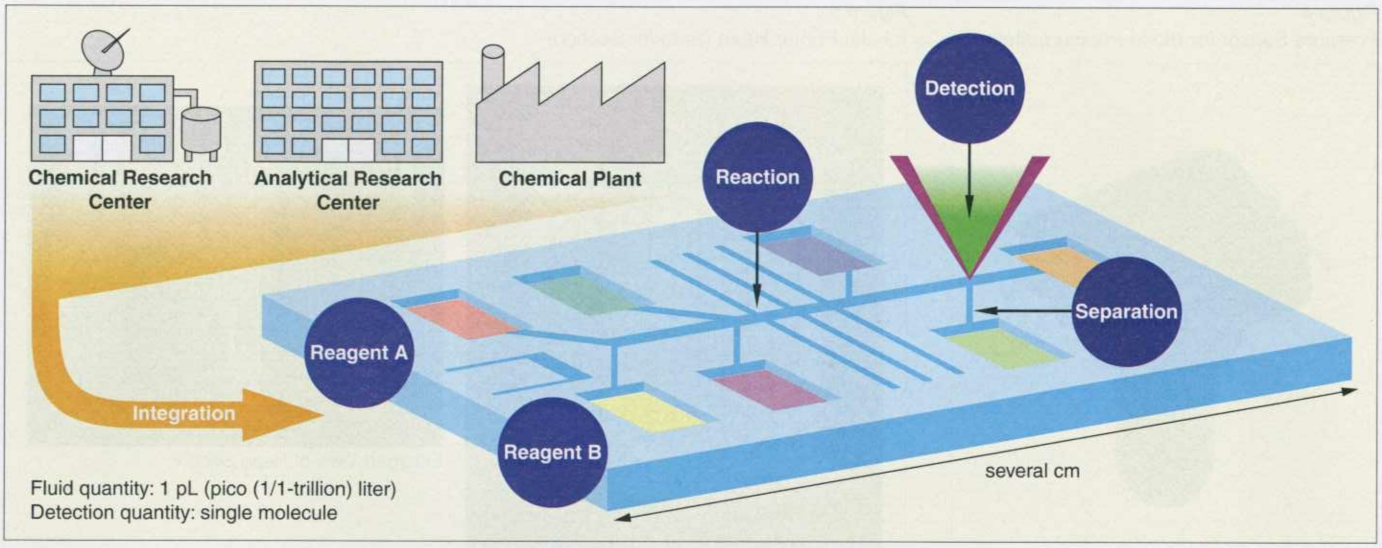


Source: R. Sawada, et al., "Single Crystal 1024ch MEMS Mirror Based on Terraced Electrodes and High-Aspect Ratio Torsion Spring for 3-D Cross-Connect Switch," *Technical Digest of IEEE/LEOS International Optical MEMS Conference* (Aug. 20-23, Lugano, Switzerland), pp.11-12 (2002).

Compared to the photoelectric switches employed in current optical communication systems, optical switches are smaller, less expensive and lower in power consumption. They are even expected to be employed as devices that can implement highly flexible systems. After the IT bubble burst in the United States, research on MEMS optical switches temporarily suffered a downturn, but their practical application is anticipated because they are a vital technology for the mid to long term. Although it may seem strange in many ways at first glance, the new mechanical manufacturing technology known as MEMS is being focused on as one of the crucial technologies supporting the creation of a ubiquitous society that is based on radio and optical communications. The market size for MEMS products employed in these fields is expected to grow at a fevered pitch, with some forecasters predicting sales of more than ¥1 trillion worldwide by 2010.

Expectations for chemical and bio-related MEMS products are also high, although a slight delay is expected compared to products for the communications field. There are various types of and applications for MEMS

Figure 7 Lab-on-a-Chip



Source: Kanagawa Science Park, http://home.ksp.or.jp/kast/res/proj/proj01.html

in these fields, and a great deal of research is currently underway. One particularly promising device is a lab-on-a-chip that handles fluids (Fig. 7). A lab-on-a-chip incorporates microscopic channels, pumps, valves and other such mechanisms on a several-centimeter-square substrate, enabling it to implement compact, high-speed chemical analysis, measurement and production systems utilizing highly efficient chemical reactions at the microscopic level. If this comes into practical use, activities like diagnostics in the medical field such as blood tests, environmental measurement for river water, and even the small-lot production of high-value-added chemical products are expected to be made faster, easier and performable on-site. This will cause revolutionary change toward the current situation of chemical research, bio-analysis, measurement and production, and has the potential to alter the world through the creation of new industries and services.

Japan's MEMS Efforts and Future Issues

In addition to existing businesses centered on such devices as acceleration sensors and pressure sensors as already noted, MEMS are a promising technology for creating new markets in the fields of radio and optical communications, chemistry, and biotechnology. Large numbers of companies are expected to get involved in such MEMS technology, including electrical equipment, precision machinery and telecommunications firms. The Japanese government, too, has been attempting to establish element technology and systematization technology through such efforts as the "Micromachines Project" from 1991 to 2000. Moreover, to further accelerate MEMS manufacturing technology, it is expected to launch the "MEMS Project," a three-year effort that starts in fiscal 2003.

In many cases, MEMS products are key parts that influence the performance of the final product (system) into which they are built, and this trend is expected to further intensify as even more features are integrated into MEMS. Securing the manufacturing technology for such key parts is extremely crucial for maintaining and enhancing competitiveness in manufacturing industry, and gaining the upper hand in MEMS technology is of great importance for the future of Japan's manufacturing-based economy. Japan boasts superior semiconductor manufacturing and mechatronics technology, and is said to have hidden potential for getting ahead of the United States and Europe in MEMS as well by making use of these accumulated technologies. In the automotive field, a current key application area for MEMS, Japanese companies are actually considered to be just as competitive as those in the United States and Europe. There are many issues, including the establishment of infrastructure for further accelerating MEMS manufacturing technology and nurturing industry, but in light of the previously discussed importance of MEMS, efforts based on close collaboration between industry, academia and government are required for securing MEMS markets in the new fields mentioned in the previous section, as well as strengthening competitiveness in existing areas. JJTI

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