MEMS

A quick look at a breakthrough technology

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As an emerging technology, MEMs has been a hot topic at various conferences over the past decade or so. The MEMS acronym stands for Micro-Electro-Mechanical Systems. These devices and systmes range in size from a few microns to a few millimeters. The field is called by a wide variety of names by different people,e.g. Micro-Electro-Mechanical Systems (MEMS), Micromechanics, Micro System Technology (MST) and Nano technology. This field, which encompasses all aspects of science and technology, is involved with things on a smaller scale. Things behave substantially differently in the micro domain. Forces related to volume, like weight and inertia, tend to decrease in significance. Forces related to surface area, such as friction and electrostatics, tend to become large. And forces like surface tension that depend upon an edge become enormous.

MEMS may also be regarded as the integration of microelectronics and micromechanics, and sometimes micro-optics and micromagnetics. It combines conventional semiconductor electronics with beams, gears, levers, switches, sensors, accelerometers, diaphragms, and heat controllers, all of them microscopic in size. MEMS technologies make devices ranging in size from a dozen millimeters to a dozen microns. For example, MEMS technology has enabled electrically-driven motors smaller than the diameter of a human hair (about 80 (m) to be realized. Thus, MEMS technology lets scientists and engineers build things that have been impossible or prohibitively expensive with other technologies.

Fabrication process

MEMS is a manufacturing technology; that is a new way of making complex electromechanical systems. It uses batch fabrication techniques—similar to the way integrated circuits (ICs) are made—and makes the electromechanical elements along with electronics.

This new manufacturing technology has several distinct advantages. First, MEMS is an extremely diverse technology that potentially could significantly impact every category of commercial and military products. Second, it blurs the distinction between complex mechanical systems and integrated circuit electronics.

While some Asian approaches may be different, the US approach to MEMS fabrication involves the repetitive process of designing, fabrication, packaging and testing, as shown in Fig. 1.

(1) Design: There are software packages available for the design and simulation of MEMS devices.

(2) Fabrication: While the electronics are fabricated using integrated circuit (IC) process sequences, the micromechanical components are fabricated using compatible "micromachining" processes. The MEMS materials are typically restricted to those used in the IC process. MEMS promise to revolutionize nearly every product category by bringing together silicon-based microelectronics with micromachining technology. This makes possible the realization of complete systems-on-a-chip.

(3) Packaging: MEMS packaging is an application-specific task. It accounts for the largest fraction of the cost of the MEMS device. Packaging should avoid transferring mechanical strain, heat, pressure, etc. to the device in the package. MEMS introduce new interfaces, processes and materials foreign to the IC packaging industry.

(4) Testing: The testing of MEMS devices is more complex than that of ICs because of the integrated electronic and mechanical character of MEMS.

Since MEMS devices are manufactured using batch fabrication techniques, similar to ICs, unprecedented levels of functionality, reliability and

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sophistication can be placed on a small silicon chip at a relatively low cost.

Applications

MEMS technology has emerged as very useful in telecommunications with major applications particularly in optical switching. Applications are in the large terabit network switches and other equipment used in metropolitan and wide-area networks. In such systems, the efficiency of keeping the optical signals as light provides significant performance gains and better overall cost savings. Satellite and spacecraft also benefit from MEMS technology. For example, the picosats weigh less than 280 grams each and comprise little more than a small radio. Such MEMS-based satellites with negligible mass, size and power consumption can easily be piggybacked onto conventional satellites or launched using small launch vehicles.

Another area for using MEMS technology is transportation, in particular, making mechanical parts for the automotive industry. Motors, pivots, linkages, sensors, microswitches and other mechanical devices can be made to fit inside this circle O. These devices are also inexpensive. For example, using silicon surface micromachining, a gear captivated on a pivot can be made for less than one cent (U.S.). Micromechanical parts tend to be rugged, respond rapidly, use little power, occupy a small volume, and are often much less expensive than conventional macro parts. For example, MEMS sensors measure pressure, strain, acceleration, temperature, fluid flow and more.

In addition to telecommunications and transportation, other areas of MEMS application include microwave/RF switches and relays; printers, where inkjet technology is revolutionizing a booming field; optical systems where new actuated mirror- and lens- systems are being exploited for display; information storage in which much increased density at increased speed and reduced cost; and medical applications where MEMS promise truly revolutionary systems. Yet these examples only scratch the surface of what the future holds.

Future MEMS applications will be dictated by processes that enable greater functionality through higher levels of electronic-mechanical integration and more mechanical components. The variety of available mechanical microdevices and their applications will grow. Many new MEMS applications will emerge, expanding beyond that which is currently identified or known.

Need for MEMS engineers

Traditionally, the training of MEMS engineers and scientists has entailed a graduate education at one of a few research universities. Even then, the student works under the direction of an experienced faculty member to design, fabricate and test a MEMS device. As a result, the graduate education in MEMS technology is very costly and comparatively time-consuming. Consequently, the current output from US universities of technical persons trained in MEMS technology is much smaller than the number required to support the projected growth of MEMS industry. The output of well-trained MEMS engineers and scientists needs to increase.

If your university offers classes in MEMS, take as many of them as possible. Better still, if your university has a laboratory on MEMS, you may consider doing your senior design or your graduate thesis in this area. That should prepare you well enough for the job market.

Conclusion

MEMS technology has already taken root firmly in today's world. It is destined to become a hallmark 21st-century manufacturing technology with numerous and diverse applications. MEMS will have a dramatic impact on everything from aerospace technology to biotechnology. As a breakthrough technology allowing unparalleled synergy between apparently unrelated fields of endeavor such as biology and microelectronics, MEMS is forecasted to have a commercial and defense market growth similar to its parent IC technology.

Read more about it

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About the author

Matthew N. O. Sadiku received his B. Sc. degree in 1978 from Ahmadu Bello University, Zaria, Nigeria and his M.Sc. and Ph.D. degrees from Tennessee Technological University, Cookeville, TN in 1982 and 1984, respectively. He was a professor at Florida Atlantic University, Boca Raton, FL and Temple University, Philadelphia, PA. Since July 2001, he has been a senior scientist with Boeing Satellite Systems in Los Angeles, CA. He is the author of over 100 professional papers and over 20 books. He was the recipient of the 2000 McGraw-Hill/Jacob Millman Award for outstanding contributions in the field of electrical engineering.

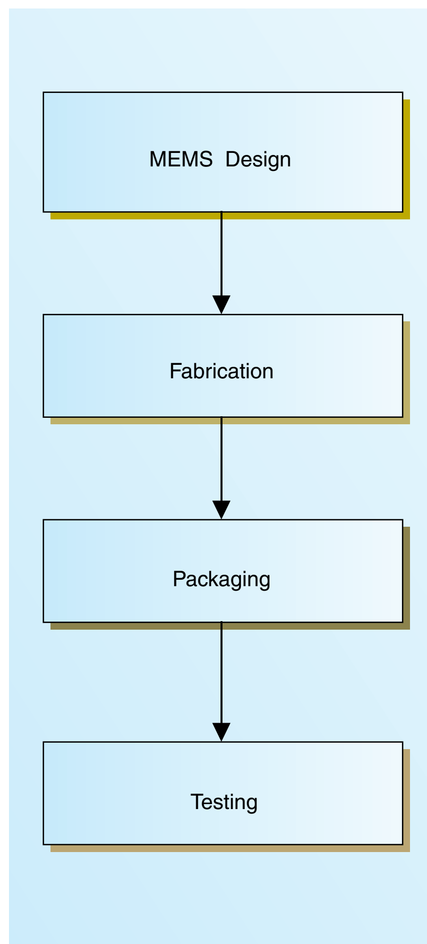

Fig. 1 Flow diagram for the fabrication of MEMS devices