Needs analysis for skills in MEMS
CIME-Nanotech

New challenges in MEMs design – Data collected from John McEleney (Chief Executive Officer , SolidWorks Corp.)

The introduction of MEMS-specific capabilities in mainstream design tools is paving the way to greater use of microtechnology. These tools will help companies facing miniaturization challenges break new ground; innovate products, devices and micromanufacturing technologies; and broaden the use of MEMS for a variety of applications.

Much of the groundbreaking work in this emerging field took place in the semiconductor industry, where the drive to produce silicon ICs steered R&D into the creation of manufacturing processes that yield features and components one can barely see with the naked eye. Although ICs were only the initial focus for the development of microdesign methodologies, manufacturers are leveraging these technologies to develop and produce MEMS and miniaturized mechanical devices to satisfy market demand for miniaturization.

Until the last few years, MEMS and micromechanical design and production were more often research-oriented activities that took place in university labs than commercially viable manufacturing enterprises. The design and manufacturing tools used for MEMS and micromechanical design were highly specialized, and few engineers knew how to accomplish microdesign without developing manufacturing techniques and enabling technologies as part of the design process. Much of this work was done using 2D layouts to represent configurations of the separate layers of silicon that are deposited sequentially to create a conventional MEMS component.

However, the availability of MEMS-specific design functionality in mainstream CAD tools is driving the cost-effective development of MEMS and miniaturized mechanical devices for commercial products.

Potential applications for MEMS are wide ranging. Any miniaturized electrical system that requires a mechanical component is a candidate, including inertial sensors, switches and relays, resonators and mechanical filters, microcapacitors, inductors and probes, as well as inclinometers, valves, DNA sequencers and chemical- and biological-agent sensors.

Whatever the application, the driving force behind micromechanical system development is size and weight. Unlike ICs, which focus on passing electrical current through extremely small circuits, MEMS components all have some mechanical element and most have at least one movable part. While depositing several thin layers of silicon and etching material away to create layer configurations works well for manufacturing ICs and some MEMS devices, new manufacturing processes are emerging that give designers more options for optimizing the mechanical aspects of MEMS.

For years, the primary material available to MEMS designers was silicon and the only manufacturing processes available emanated from the semiconductor industry. These processes generally required highly specialized tools, limited designs to the use of four or five layers of silicon of specific thicknesses, and were time-consuming and costly for creating MEMS components. But as more and more manufacturers turn to MEMS and microdesign to meet demands for miniaturization, new automated processes have been developed that focus on the mechanical aspects of MEMS design.

One company, Microfabrica Inc., has developed a proprietary micromanufacturing technology called EFAB that leverages 3D CAD data. EFAB technology is similar to silicon deposition—the process is based on selective electrolytic deposition of metal onto a substrate—but is more robust, automated and flexible. EFAB allows engineers to design arbitrary, complex 3D geometries based on electroplatable materials such as nickel, silver, copper, gold and platinum, instead of silicon, in tens to hundreds of layers that can range in thickness from 2-10µm.

The ability to create arbitrary geometries rather than those utilized by the IC industry opens a whole new world of possibilities to MEMS designers. Take the mechanical helical spring, for example. This is one of the most efficient designs and most useful devices for controlling force and displacement ever developed. It is difficult, however, to produce an effective helical spring based on four or five layers of silicon. Thus, you cannot take advantage of one of the most proven mechanical designs at the miniature level using traditional silicon-based micromanufacturing. Microfabrica, however, is working to eliminate these types of limitations for mechanical engineers doing microdesign.

One development that helps facilitate the widespread use of MEMS and microdesign techniques is the inclusion of MEMS-specific functionality in a mainstream 3D CAD application. The ability to use a familiar tool and design environment for designs ranging from MEMS and microdevices to larger assemblies and components eliminates the time, effort and cost involved with learning specialized tools.

The typical sequence for designing a MEMS device is to begin with a model of the component created out of multiple semiconductor layers. Designers then produce photomasks, 2D layouts for each layer that match each specific cross-section configuration, to drive manufacturing.

A significant challenge in MEMS design arises in working with photomasks for several cross-sections of a solid model at the micron and submicron level for a device that will be packaged in a much larger assembly. Without MEMS-specific CAD functionality, designers must move back and forth in their CAD systems between different dimensional scales, from microns to millimeters to meters. They are unable to truly visualize the complete assembly and cannot take advantage of basic solid modeling features such as parametric associative design.

Fortunately, 3D solid modeling systems with the ability to operate on this scale simplify the complexity of the process by providing capabilities that specifically address MEMS design functions. For example, some mainstream 3D CAD software packages enable a broad geometric range, which allows designers to work on the same assembly at the micron level all the way up to many meters. Engineers can simply zoom into the MEMS detail and zoom out to the larger assembly, providing full 3D visualization of both the MEMS component and its packaging. The software also automatically cross-sections the MEMS component and creates fully associative photomasks for each layer, eliminating the time and effort involved in manually creating each 2D layout.

As the design is modified and refined, changes propagate to all associated design documents, including components, assemblies, detail and photomask drawings. Submicron feature definition, collision/interference detection of components and the creation of feature patterns and patterns of patterns are capabilities that are also useful for MEMS design.

MEMs applications opportunities – Data collected from iSuppli technologies

According to iSuppli, Microelectromechanical Systems (MEMS) are making major inroads in the consumer- and mobile-electronics worlds. As a result, shipments of MEMS for consumer and mobile electronics is expected to grow from $1.1 billion (2006) to $2.6 billion (2012). STMicroelectronics ranked first in the global consumer/mobile MEMS market in 2008. Texas Instruments, which was first, now ranks second. In 2008, STMicroelectronics more than doubled its revenue from accelerometers, gyroscopes and pressure sensors for consumer and mobile applications, exceeding $200 million in 2008. Other MEMS suppliers include Epson Toyocom, which experienced an 75% increase in MEMS sales due to its new-generation gyroscope for gaming and navigation applications. Bosch Sensortec's revenue exploded by 167.3% in 2008, driven by strong sales in mobile handsets. Kionix, whose sales grew by 29.9% in 2008, has now expanded to 120 employees. Finally, start-up Invensense only began shipping its MEMS products in 2007 and already exceeded $40 million in revenue in 2008.

Microelectromechanical Systems

Consumer Electronics Devices Shipment revenue for MEMS in consumer electronics devices will increase to $1.1 billion in 2012, up from $699.9 million in 2006. Products in this segment consist of game controllers, digital still cameras, camcorders, MP3 players, personal navigation devices, remote controllers, rear-projection televisions, mini stand alone projectors, sports equipment, white goods, toys, headsets, and USB sticks.

Mobile Handsets iSuppli predicts mobile handsets will remain the market's main driver until 2012, not only for accelerometers but also for other devices like Radio Frequency (RF) MEMS filters, actuators for zoom and autofocus, radio frequency MEMS switches, pressure sensors, gyroscopes, and pico projectors. Global revenue from shipments of all types of MEMS for mobile handsets and smart phones will increase to $1.3 billion by the end of 2012, rising at a Compound Annual Growth Rate (CAGR) of 34.4% from $296.8 million in 2007.

Notebooks Looking at another type of popular product, notebook PCs, MEMS accelerometers are increasingly being employed to detect freefall and quickly park the heads of the Hard Disk Drive (HDD) to protect it from damage. Until this year, such systems mainly were used in professional notebooks. However, the system is being employed in consumer systems starting in 2009. iSuppli predicts the market for notebook PC MEMS — also including microphones and pressure sensors — will rise to $185.9 million in 2012, up from $37.6 million in 2006.

MEMs market trends – Survey collected from NEDO (New Energy and Industrial Technology Development Organization)

Objective of the Survey

The objective of the survey was to gather the latest market data in order to analyze the current scale and industrial structure of the MEMS-related market and to forecast future trends, as well as to provide basic data required for conducting a rolling review on a strategic map of MEMS technology.

Method of the Survey

To calculate the size of the MEMS-related market, we defined two indexes: MEMS contribution and MEMS value ratio. Some components included in existing products or equipment can be replaced with MEMS technology as a result of numerous factors including technological innovation, improvements in performance, and manufacturing costs. The MEMS contribution is calculated by estimating the portion that can be replaced with MEMS technology in products or equipment that may incorporate MEMS. The MEMS value ratio is the part of the estimated portion actually employing MEMS technology that accounts for the value of the estimated portion.
<MEMS market scale> = <Production volume> x <percentage of MEMS contribution> x <MEMS value ratio>
The future market of MEMS was predicted for 2010 and 2015 with consideration for the market growth of products and an increase in MEMS applications.

MEMS Market Scale

The domestic MEMS market share for 2005 was about 440 billion yen. We predict this share will increase to 1.17 trillion yen in 2010 and 2.4 trillion yen in 2015. When viewing the market share for MEMS-related products by industry, the automotive and telecommunications fields occupy 71% of the overall market. These two fields are expected to account for 70% of the overall market in 2010 and drop to 67% in 2015. However, the market share of other industries is expected to gradually increase, with particularly remarkable expansion in the fields of amusement (game machines), precision instruments, and medical and welfare equipment.
Viewing the market scale by type of MEMS device, MEMS sensors accounted for just over 57% of the approximately 440 billion yen market in 2005. This
share is expected to gradually decrease to 55% in 2010 and just over 51% in 2015, while the market share of optical MEMS, RF-MEMS, microfluidics, and chemical and biological MEMS is expected to show some, albeit gradual, increases annually.
Hence, the current MEMS market is led by the automotive and telecommunications fields, with a focus on MEMS sensors. While this trend is expected to continue, it is thought that market expansion will be linked to the fusion of optical MEMS, RF-MEMS, microfluidics, chemical and biological MEMS, and the like with optical technologies, and efforts to incorporate new key technologies, such as integrated micro-nano manufacturing technologies uniting nano and biological processes.

MEMS Industrial Structure in Japan

In order to see the total picture of MEMS-related industries, we distributed a questionnaire to MEMS-related companies and used the responses on this questionnaire together with the results of the MEMS market survey to analyze the domestic MEMS industrial structure. While nearly 80% of all companies surveyed working on MEMS projects that are currently or are expected to be promising enterprises, just over 50% of these companies indicated that the MEMS-related projects accounted for less than 2% of their overall business, and

nearly 90% of the companies surveyed indicated that the MEMS-related projects accounted for less than 10% of their business. Although these results imply that the current percentage of MEMS-related business conducted at MEMS-related companies is low, the responses show that expectations for MEMS are high and suggest a trend of companies actively expanding their MEMS business.
Further, MEMS device manufacturers are currently exhibiting a trend toward expanding their business into MEMS sensors, which currently carry great importance in the MEMS market, and optical MEMS and RF-MEMS, for which the market is expected to expand in the near future. However, future surveys are expected to show an interest in expanding into µTAS-related devices such as microfluidics and chemical and biological MEMS.
Further, while a majority of the companies still have too few personnel involved in MEMS projects and research and development on MEMS and currently invest less than 5% of their MEMS-related sales in research and development, a majority of the companies indicated that training personnel in MEMS and reinforcing collaboration between industry and academia are solutions to the problem.

Conclusion

From this survey, it is clear that MEMS-related industries view MEMS devices as the core of Japan’s future principal manufacturing industry and wish to expand into this field, although the actual scale and growth of this expansion is uncertain. Hence, while the market share for MEMS has been slow to rise, the acceleration in development in MEMS technology gives us great hope that the results of this development will be reflected in the market, leading to rapid market growth.