MEMS PACKAGING UPDATE

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INTRODUCTION

Microelectromechanical Systems (MEMS) are “alive” and well in 2005 with a growing market now in the billions of dollars. Motion sensors, today’s fastest growing commercial segment, continue to see frequent new product launches by both established and new suppliers. While simpler ink jet chips have more share because they are disposable (part of the ink jet cartridge), this is a limited market. Inertial sensors, however, continue to find new applications on a regular basis. While air bag systems are still the main market for sensors, there are many newer applications like disk drive free fall detectors and innovative consumer applications.

The most popular MEMS fabrication process is surface machining where sacrificial materials, like SiO_2, are selectively formed and then etched away to leave 3D structures typically made of silicon. This process is also compatible with CMOS and allows “intelligence” to be built into the MEMS chip. MEMS inertial devices have moving parts and this equates to special handling and packaging challenges. MEMS parts can be sensitive to mechanical shock, especially in unpackaged form and are especially vulnerable to particulate contamination like residue from wafer sawing. The mechanical motion zone of a MEMS chip must be protected during singulation with a temporary mask or by wafer-level packaging techniques. However, the most significant packaging challenge is to provide environmental protection that does not restrict chip-level motion. Electronic devices are readily overmolded and the encapsulant can contact the active side of the chip. But direct contact of the MEMS surface with molding compound or other encapsulant would “freeze” the moving parts. MEMS-specific designs offer the best solutions to these special needs.

MEMS PACKAGE REQUIREMENTS

The hermeticity debate continues; do we really need a full-hermetic package for inertial devices like accelerometers and gyroscopes? We should consider that many other types of MEMS products are not packaged in hermetic enclosures because they require access to the outside world as with ink jet chips and fluidic MEMS products. But inertial sensors are somewhat unique and only need electrical I/Os. At this junction, however, inertial devices are being hermetically enclosed with cavity designs so that mechanical action is allowed. Therefore, the first MEMS package requirement is free space typically achieved with cavity style packaging. Some devices also require internal atmosphere control since moisture and particle contamination can be damaging. Getters (trap moisture and particles), lubricants, or anti-stiction agents may also be added to the package to prevent wear, degradation, or stiction. Stiction, a combination of sticking and friction, occurs when smooth, planar surfaces make contact and become permanently locked together by short-range atom forces. Since MEMS devices are so small, these moving parts have a very high area-to-mass ration making stiction likely. More complex MEMS devices, such as gas and fluid analyzers, require selective access to the environment.

COMMERCIAL PACKAGE DESIGNS

MEMS inertial sensors are one of the oldest classes of product and one of the most active areas; production should exceed 600 million devices for 2005. Analog Devices, Inc., Cambridge, MA, did much of the pioneering work in this field and enjoys a leadership position in the accelerometer area. ADI reached a milestone earlier this year when they shipped their 200-millionth inertial sensor. But there is substantial competition. Freescale also has a long history in motion sensors and has recently launched 3-axis motion sensor products. OKI, MemSense, Hitachi, Kionix and STMicroelectronics have, or will soon offer 3-axis accelerometers. While such devices are useful for automotive, other applications include cell phone pedometers, game sensors/controllers, and a variety of sports products. MEMS can already help improve your golf game or fly casting skills.

Most inertial devices are packaged in small QFN format. The smallest package is 5mm x 5mm x 1.2mm offered by Kionix, but competitors have designs that are only slightly larger. Figure 1 shows several QFN MEMS packages. Most use ceramic hermetic packages, at least for now. The simple QFN has reduced the cost over earlier ceramic cavity style packages that had accounted for more than half of the total component cost. But even the newer ceramic QFNs are not the lowest cost packages. The general electronics market enjoys very low cost plastic packaging that can be as low as $0.05 per assembled package for low I/O QFNs and this is almost an order of magnitude lower than MEMS ceramic QFNs.

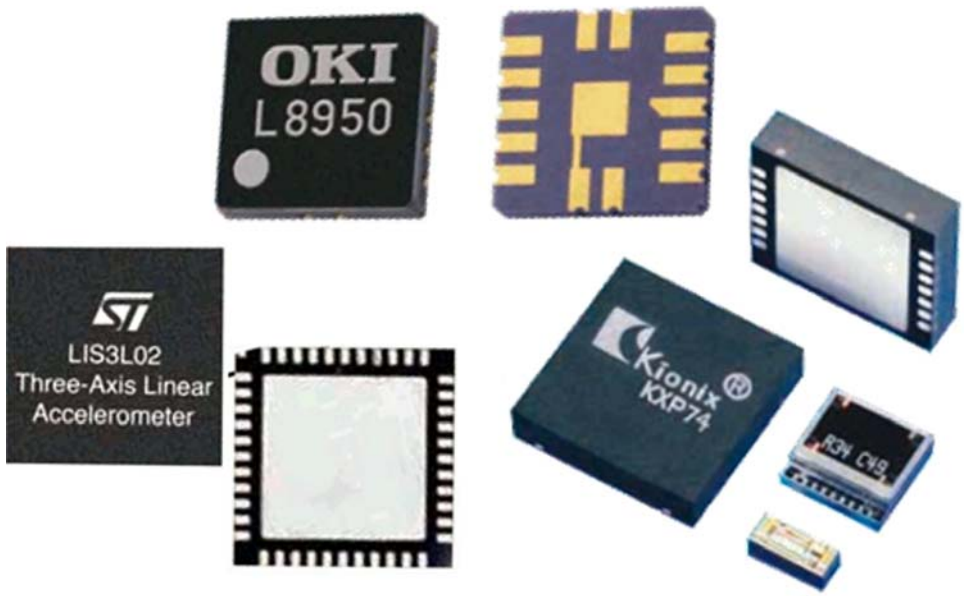


Figure 1 – Packaged MEMS Accelerometers
(SOURCES: ST-Microelectronics, OKI Electric Industry, Kionix)

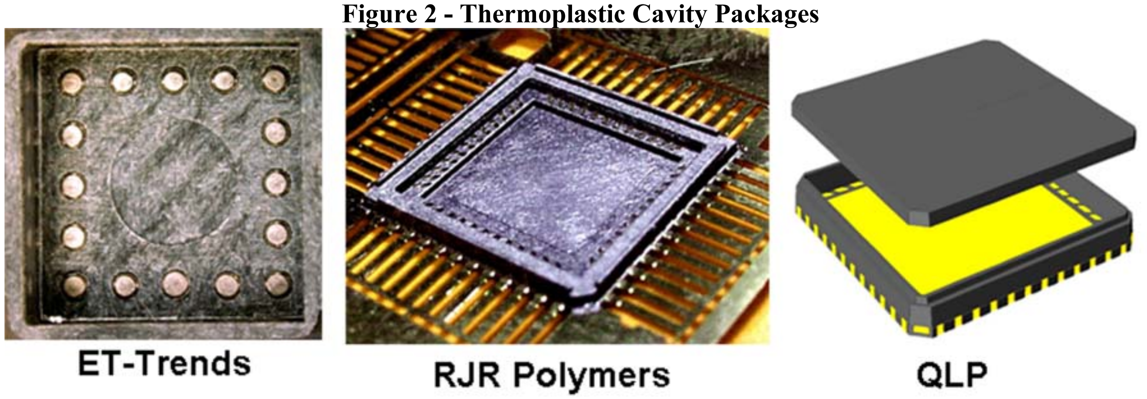
MATERIALS; PLASTIC VS. CERAMIC

Electronics has benefited from low cost plastic non-hermetic packaging materials during the past 50 years. Simple epoxy overmolding adds very little cost, especially today, with area, or flood molding techniques that produce hundreds of packages per cycle. The main cost for plastic packaging has been attributed to the platform, or chip carrier, however. The QFN has reduced cost by simplifying the platform and eliminating secondary operations like solder ball attachment making this the lowest cost design in production. Aware of the cost benefits of plastics, the MEMS industry has been seeking ways to adapt cost-reducing plastics. Since a cavity is required, at least around the mechanical zone, two basic strategies are available.

Although epoxy cavity packages are feasible, transfer molding is not the perfect process here. However, injection molding, a much more common plastic shaping process outside of the package industry, is ideal for producing 3D shapes including cavities. Injection molding uses thermoplastic resins instead of thermosets and that can be a benefit. There are several commercial high temperature (>300^{o}C stability) thermoplastics that have better properties than epoxies, especially regarding low moisture absorption. What's more, materials like Liquid Crystal Polymer (LCP) pass flammability specs without adding flame retardants. Bromine flame retardants are coming under regulatory attack and may be banned, so intrinsic flame retardancy is a big plus for packaging materials. Even better, thermoplastics are "no waste" materials since they can be remelted and reused. This also means that thermoplastic electronics could be recycled just like many other thermoplastic products.

Analog Devices, Inc. has been exploring plastic cavity packages for their MEMS gyroscope family. However, ADI first caps the MEMS device at wafer-level so that the motion zone is hermetically enclosed. Now, the device is protected from both particulate contamination and moisture. The bonded silicon caps are specially singulated so that they are smaller than the chip allowing bonding pad access. The capped MEMS device can now be handled more like an ordinary electronic chip. While some parts can be overmolded with epoxy, chips that are more mechanically sensitive are placed inside injection molded cavity packages. Overmolding adds stress due to shrinkage that detunes the MEMS sensor making it undesirable for some products. Once the capped device is attached and wire bonded to the cavity package, a lid is sealed using dispensed adhesive. The capping adds cost, but solves pre-package problems such as contamination from sawing. However, many MEMS devices cannot be capped and these are candidates for injection-molded plastic cavity packages that are now available. These thermoplastic packages have better barrier performance than non-hermetic epoxies but do not achieve full hermeticity; the term Near-Hermetic Package (NHP) seems appropriate. Figure 2 shows low-cost thermoplastic cavity packages.

Figure 2 - Thermoplastic Cavity Packages



(SOURCE: ET-Trends LLC, RJR Polymers, Inc., Quantum Leap Packaging)

FUTURE

MEMS will continue to grow at a steady, sustainable rate that will drive low cost packaging innovation. Plastic packaging is certainly in the future but ceramic dominates for now. MEMS packaging technology, because of its high versatility, will also provide the foundation for Nanoelectronics devices that could emerge within the next five years. A paradigm shift is likely within a decade. [1].

Reference

[1] Gilleo, K., ***MEMS/MOEM Packaging: Concepts, designs, materials and processes***, McGraw-Hill, New York, NY June 2005.