Micro Electromechanical Systems Move Toward Standardization

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Introduction

Microelectromechanical systems (MEMS) offer the handheld and consumer electronics industry great hope for enhanced functionality[1]. MEMS based accelerometers, microphones, pressure sensors, antennas, RF switches[2] and embedded memory chips, are being integrated with Integrated Chip (IC) products and leading to new applications. Yet to reach the end-user, MEMS technology must become commercialized enough to offer cost-effective volume production. Like most industries this only occurs when some level of standardization is present.

A key to MEMS industry growth is the emergence of standardized material characterizations. The presence of reliable material properties, processing effects and variables during design and manufacturing will determine how and when MEMS are volume-production ready.

Standardization Motivation

Radio Frequency (RF) MEMS represent a growing segment of micro system component design and implementation. RF communications can benefit from the multi functional qualities of MEMS. In fact, micromachined film bulk acoustic resonators (FBARs) are already carried in 20 mobile handset platforms for 2-way voice and data traffic[3]. They are also developed for switching applications such as Transmit/Receive Duplexers (TDD), band/mode selection, time-delay for phased-array, antenna diversity or reconfigurable antennas. A variety of RF-MEMS switches have been developed and are being implemented. MEMS varactors are often used for VCO tuning, variable matching or variable delay line applications. MEMS also provide low loss inductors or filters for band-select filters, IF channel filters, RF filter banks, VCO stabilization or image rejection.

Yet the rapid growth of the MEMS industry has been impeded by a general lack of reliable material properties, understanding of processing effects on materials, and process variables. It is often stated that there is no standard process in MEMS. Due to the fact that MEMS offer many more degrees of design freedom than ICs and because approximately 90% of available MEMS products are produced in captive fabs, it is possible that there will never be a MEMS "standard process" in the IC sense. What can and should be standardized, however, are methods of characterizing a process and its associated material properties. Standardization of Materials Characterization will enhance accuracy and efficiency of Design and Simulation tasks (or phases) by offering a higher rate of first pass success. Currently, RF MEMS designers are able to develop custom devices using parameterized element model (MEMS specific) libraries available via MEMS specific software design tools. This provides behavioral model building blocks for each design, but does not provide an "off-the-shelf" device design. The idea is to grow the RF MEMS manufacturing infrastructure to accommodate and streamline design, which can be translated into fabrication techniques and ultimately faster, cheaper and smaller RF products.

For fabrication, the MEMS industry must provide comparison and qualification of foundries to enable second sourcing and interchangeability of manufacturing sources. As new devices are developed in the lab, the MEMS industry would benefit greatly from introducing and evaluating new process technologies to MEMS as well as providing technology transfer from the lab to prototyping fab and eventually high volume fabs. Standardization may also be achieved by adding consistency between measurement techniques. The industry must also investigate MEMS reliability issues such as yield, fatigue, creep, charging and contact physics. The MEMS Industry Group (MIG), a non-profit industry organization has recently released a MEMS reliability study that indicates that 90 percent of MEMS providers surveyed stated that customers demand reliability demonstrations. To help achieve these goals, MIG has embarked on a MEMS reliability initiative that includes a web-based reliability database, sponsored expert courses and collaboration with standards organizations. MIG is also working toward changing attitudes regarding MEMS, a key contributing factor toward standardizing any technology by developing a MEMS reliability communications campaign[4].
MIG is encouraging designers to once again view MEMS technology as an enabling technology for a wide variety of applications. The European Commission supports investigation of MEMS reliability through the 6th Framework Program, where such issues are addressed in Network-of-Excellence collaboration projects such as PATENT-DfM and AMICOM[5].

With these issues in mind, any standardization effort must involve identification and selection of relevant material properties, identification of conditions, both processing and ambient, that affect material properties, and specification methods of metrology (measurement).

MEMS Standardization Vision

In three to seven years, a mature MEMS industry is possible, although several factors must come to fruition. First the industry must further split specialization of roles for independent foundries, process equipment suppliers, test equipment suppliers, software, design houses and test houses. Second, there needs to be enhanced communication between process engineers and designers. In this case standardized data on MEMS materials and processes can be shared through design kits. Design kits allow a fab to set fabrication standards which may be used as rules during the entire design flow. Likewise the MEMS industry must extend process control through the use of Standard Test Methods and Statistical Analysis.

Standardization Goals

One goal is to develop standard MEMS testing method(s), including property extractions, for individual primary and reliability parameters. These test methods must then be accepted and promoted through industry organizations such as National Institute of Standard and Technology (NIST) or the American Society of Test and Materials (ASTM) and their overseas equivalents. It is helpful that leading MEMS design software providers are teaming up with standards organizations to develop a Test Structure Methodology for a limited number of parameters. It has already been implemented in a number of fabs and has set the stage for test structure expansion in order to be adopted by more fabs. In order for a Test Structure Methodology to work, it must also be adopted in independent foundries and captive fabs, test equipment and hardware suppliers and design and simulation software platforms and design houses.

Implementation and Conclusion

MEMS technology has strong ties to semiconductor processes and Electronic Design Automation (EDA) tools, such that there is a strong effort to integrate MEMS technology with IC development. This is especially true in RF MEMS design. By developing our own MEMS industry material property methodology, we may borrow much of the processing methodology from the IC world. Design and simulation tools are already at a highly sophisticated level and are prepared for this challenge. In order to expedite MEMS standardization, the industry must design test structures that measure specific material properties and processing effects, derive models in suitable formats, adapt the structures to specific process flows, develop test methods for test equipment and arrange these elements in widely distributed standards. The proof of design and reliability will come as more and more wireless product designers incorporate RF MEMS within their designs and demand reliability and fabrication standards. The benefit will be both to wireless product designers in high-quality, cost-effective components and affordable functionality to the end-user.

References:

1. Richard Nass, MEMS are finding homes in unexpected places, Portable Design, August 2003
2. RF MEMS family switches offered for mobile systems integrations, Portable Design, June 2001

3. MEMS Industry Group, “MIG Industry Report: Focus on Reliability”, pg. 3 April 2004
4. MEMS Industry Group, “MIG Industry Report: Focus on Reliability”, pp. 8-9, April 2004
5. http://www.cordis.lu/fp6/projects.htm