Group Position Paper: MEMS Packaging and Reliability

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Overview: MEMS packaging can be defined as all the activities or concerns after device fabrication. They include post-processing release, package/substrate fabrication, assembly, testing and reliability. In each packaging step, there are associated design and manufacturing issues. Reliability is in fact one of the performance measures that are strongly affected by the package as well as the device. However, it is usually considered as one of the packaging activities/concerns because the packaging rather than fabrication manufacturers usually conduct environmental protection process, burn-in and accelerated tests.

Packaging (including reliability) has been and continues to be a major challenge. Packaging cost is about 50 to 90% of the total cost of the MEMS product. Though the electronics manufacturing industry has a robust and viable infrastructure, direct application of electronics packaging techniques to most MEMS parts is not feasible because of the complexities of their operational structure and domain. For example, packaging should allow some moving parts to interact with other components through optical, electrical, thermal, mechanical or chemical interfaces. As a result, many MEMS packaging problems are new to most of electronic packaging engineers. Here are a few examples:

- Vacuum packaging might be needed when viscous damping is important.
- Die-attachment might affect the pressure measured through thermal stresses.
- Thermal strains might affect the performance of piezoresistive or membrane devices.
- Moisture could cause stiction problems.
- There are no effective thermal paths for thin micro-mirrors for heat transfer.
- There are no accelerated tests since most of failure mechanisms for the moving parts are unknown.

At the present time, custom packaging solutions have been developed for specific products. Such a solution procedure has a potential of stalling the rapid growth of MEMS applications. MEMS packaging (including reliability) is a well-known potential "show stopper."

Challenges:

Standardization: MEMS has a large number of diverse applications. Here is a list of a few emerging applications: microfluidics related to bio-medical applications, data storage, microsurgical instruments, RF communication, optical communication and interconnects, energy storage, and display. It is impossible to develop a standard package for such diverse applications. However, for each application category, it is essential to determine a standard package and its roadmap. Here is an example list of major requirements for a potential standard package for optical MEMS :

- low cost and automated assembly

- hermetic packaging techniques (weld, o-rings, Teflon gaskets, etc.)
- "quasi-hermetic" packaging solutions (adhesives, gaskets, combinations, etc.)
- wafer level packaging of optical MEMS
- die singulation and separation techniques (fast anisotropic particle free etching)
- silicon through vias, wafer bonding to glass (anodic bonding, etc.)
- MEMS reliability models
- stiction and lubrication strategies for micro-structures
- low surface energy thin films
- mechanical wear and creep of micro-structures
- die attach optical alignment capability (x, y, and z control – parallelism)
- high quality optical interface (windows – particle, defect, blemish free)
- particle control within MEMS packages (particle getters ("storage")
- packaging mini-environments (mini-clean areas)

During the workshop, we may develop a similar list for all other major MEMS applications.

Reliability: There are two major issues related to MEMS reliability. One is the reliability assurance by testing existing structures and the other is by processes/materials development. For the reliability test, MEMS technologies are new, and thereby introduce many new failure mechanisms that are poorly understood. There are no known accelerated tests for almost all the emerging MEMS applications. For the processes/materials development, non-hermetic environment and the control of friction and stiction are critical considerations. One of the main applications of the nano-technologies is to develop new processes/materials for reliable MEMS. During the workshop, we may list major failure modes demanding novel tests or solutions.

Modeling: Package is usually an integral part of the device. Both device and package have to be designed at the same time. In order to have a one-pass design, physical and semi-empirical models have to be developed. With the diverse applications, a MEMS CAD tool might need to cover every engineering discipline: electrical, thermal, mechanical, optical, electromagnetic wave, and chemical. How to integrate all the existing tools with innovative interface solutions will be challenging. In addition, how to design MEMS for reliability will be as important as the aforementioned tests and new processes/materials. During the workshop, we may list the available design tools and determine new tools and new interface requirements.

Novel Packaging Technologies: MEMS packaging possesses new problems, and of course, we need to develop new technologies to solve the problems. For example, a new soldering technology has been developed for RF and optical MEMS. Packaging technologies, e.g. co-fired ceramics, have been applied to "fabricate" MEMS devices. Many new packaging technologies have been developed for bio-MEMS. It is important to "guess" the novel technologies to simulate innovations. During the workshop, we may list novel packaging technologies already developed and to be developed.

Role of NSF: Packaging has been and continues to be the major challenge in every system integrating optical, microwave, digital and microelectromechanical components. It is time for NSF to establish a home program for packaging and reliability. The program will develop long-term systematical research activities to be carried out by centers, multiple-investigators and

single-investigators. More importantly, this program will define not only the top priority topics to be addressed but how the collaborations are to be coordinated.