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Chip-Level Packaging of MEMS Devices Using Air-Gap Structures

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Recent advances in microelectromechanical systems (MEMS) technology have expanded their possible applications and uses. However, MEMS packaging presents a pivotal challenge to their overall potential. For today's typical MEMS-based products, packaging expenses can be 20% to 40% of the product's total material and assembly cost. [1] While certain MEMS devices require specialized conditions for operation; a cost efficient, IC compatible packaging process would vastly improve cost and application for a large variety of MEMS devices. In this work, a polymer-based Air-gap structure process is being investigated to provide a cost efficient method for lead frame packaging of MEMS devices. [2-4]

The air gap process (Figure 1) uses an overcoat material to cover a sacrificial polymer, polycarbonate (PC), which protects the MEMS device during packaging. Once the overcoat is in place, the sacrificial polymer is thermally decomposed freeing the MEMS structure while the overcoat dielectric provides mechanical and chemical protection from the environment. The decomposition process and the overcoat material have been designed for clean removal of the PC material without damaging the cavity formed during the process. These developments have demonstrated that air-gaps with rigid overcoats can be used to encapsulate MEMS devices in a wafer-level packaging process (Figure 2).

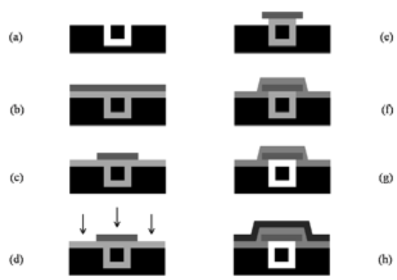

Figure 1. Schematic of the fabrication process for a MEMS package cavity. (a) Fabricated MEMS device (black). (b) Spin-coat PPC (light gray) and POSS (medium gray) layers. (c) Pattern POSS mask. (d, e) Pattern PPC using the POSS mask in RIE. (f) Apply overcoat material. (g) Decompose PPC and cure polymers. (h) Evaporate metal layer (dark gray).

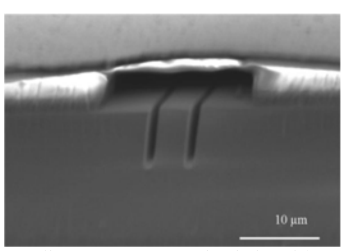

Figure 2. An all-POSS overcoat cavity designed for a resonator. A 1 µm Al layer is on top of the 2 µm POSS overcoat. The trenches in the wafer show where the resonator would be located.

The packaging structures can be designed for a range of MEMS device sizes and operating environments including fluidic, hermetic and vacuum conditions. However, the air-cavity structures need additional rigidity to withstand chip level packaging conditions, which are dependent on cavity size and molding pressure. Current work is focused on implementing a wafer level air-cavity package into a lead frame packaging scheme for MEMS devices. Air-gap structures have been studied with regards to a metal overcoat for increased rigidity. 2-D finite element models using ANSYS were used to understand the experimental results with regards to cavity deformation and provide a basis for designing larger structures. The process has currently been optimized for lead frame packaging resonator cavities of size 70 x 200 µm using an injection molding process (Figure 3).

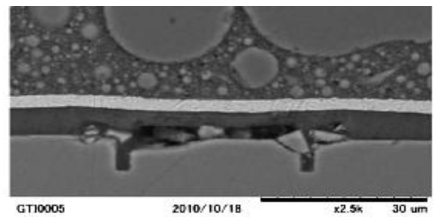

Figure 3. A 70 X 200 µm resonator cavity cross-sectioned after injection molding. The residue in the cavity is due to dicing damage.

A second approach will look at a size independent, semi-hermetic package (no metal). This process will look to combine the thermal steps of the sacrificial release and the molding process in to one step. The sacrificial polymer is designed to decompose under epoxy molding conditions during its 8 hour cure. This design will provide improved mechanical stability by prevention of cavity deformation during decomposition and molding simultaneously.

References:

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