Fabrication of Air Channels for Microelectromechanical and Microelectronic Applications

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The formation of embedded air-gaps or air-channels in a thin dielectric film has numerous potential applications in microelectronics, microelectromechanical systems (MEMS), and microfluidics. A new method for fabricating these embedded air-gaps involves the patterning and encapsulation of thermally decomposable sacrificial polymers. The sacrificial polymer film is applied to the substrate, then patterned photochemically or by conventional lithography and plasma etching techniques (see Figure 1). Following encapsulation of the patterned sacrificial polymer with dielectric, the composite structure is then raised to the decomposition temperature of the sacrificial polymer. The sacrificial polymer decomposes into volatile products which permeate through the encapsulating material, leaving behind minimal solid residue.

Polynorbornenes and polycarbonates have been investigated as polymeric sacrificial materials. Air-gaps have been formed in a variety of encapsulating materials, including silicon dioxide, silicon nitride, polyimide, epoxy, and other polymers. A typical air channel structure fabricated using polynorbornene as a sacrificial polymer and silicon dioxide as the encapsulating material is shown in Figure 2. Various issues have been investigated, including material requirements, feasible air-channel sizes and shapes, optimum processing conditions, and decomposition properties.

A number of applications for this new methodology for the formation of air channels have been investigated, including applications in microelectronic, optoelectronic and MEMs packaging. The air channel forms a low dielectric constant/low refractive index environment for embedding optical waveguides or metal interconnects. For example, a copper/air-gap interconnection structure has been demonstrated using a sacrificial polymer and silicone dioxide in a damascene process (Figure 3). The incorporation of air channels between metal conductors reduces the intralevel dielectric constant significantly, thereby reducing the RC delays and cross-talk. Similarly, embedding optical waveguides within air-gap regions (Figure 4) allows for smaller waveguide pitch and reduced bending loss along small radii optical bends, as the refractive index contrast between the core and cladding regions is maximized.

Compliant interconnection schemes are required to meet increasing density demands on chip-to-module integration. To meet this challenge, a new interconnection technology has been proposed, based on the fabrication of flexible metal leads on top of a compliant air channel. The combination of an in-plane flexible metal interconnect with an out-of-plane compliant air channel creates an interconnection structure that is capable of moving in all three directions.

Sacrificial polynorbornenes and polycarbonates also have been examined for use in the fabrication and packaging of MEMs devices. A trench-refill process has been demonstrated allowing for post-DRIE surface micromachining by formation of planar silicon dioxide membranes encapsulating etched silicon cavities. In addition, air channels fabricated with polycarbonate as the sacrificial material have been explored for the packaging of microactuators.

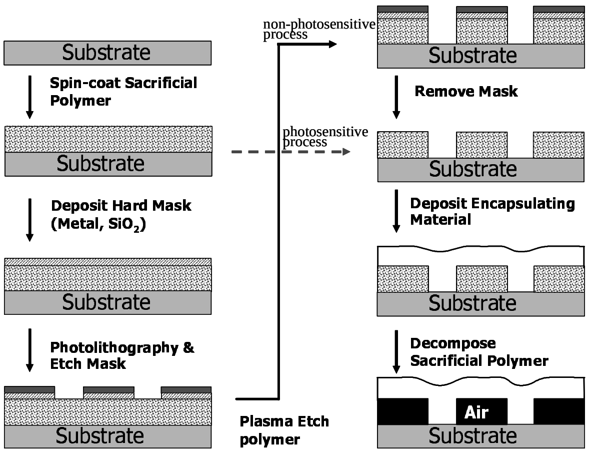

Figure 1. Process for the fabrication of air channels using a sacrificial polymer placeholder

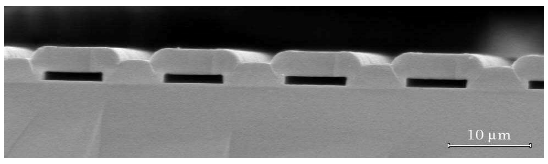

Figure 2. Typical air channel structures fabricated in silicon dioxide

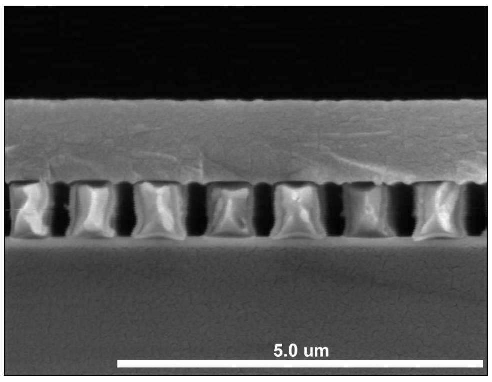

Figure 3. 0.25 micon air channels fabricated between copper lines using polynorbornene as the sacrificial material and overcoated with silicon dioxide

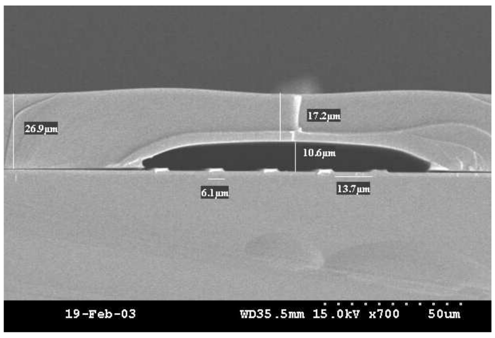

Figure 4. Air cladding for optical interconnects