Innovative Imprint Lithography for Chip-to-Chip Connections

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Abstract:

Transmission lines on printed circuit boards are currently fabricated with copper and an insulating glass dielectric, but this structure is not viable for high frequencies, long transmission lengths or high density. To reduce power loss, increase signal propagation and minimize noise, an innovative structure has been fabricated with an encapsulated air dielectric and copper shielding. This structure was fabricated with only one alignment step through the use of imprint lithography, chemical-mechanical polishing, and a sacrificial polymer. Production of these coaxial transmission lines could enable high frequency chip-to-chip communication with low power loss and low manufacturing cost.

Introduction:

Routing high frequency signals off-chip is a challenging task with current transmission line technology. Since loss in the dielectric scales linearly with frequency and loss in the conductor scales with the square root of frequency, at operating frequencies above 10 Ghz, the loss in the dielectric becomes the dominant loss contribution [1]. The power dissipated limits the maximum distance the signal can be routed at the necessary signal to noise ratio. Furthermore, crosstalk limits the proximity of lines to each other.

Imprint lithography's three-dimensional patterning capabilities were used to fabricate the halfcoaxial structure shown in Figure 1. The air dielectric layer can lower power loss from both the conductor and dielectric, allowing signals to be routed over longer lengths with increased signal propagation velocities, and the copper shielding could minimize crosstalk noise and radiation losses [1]. The imprint process minimized registration steps increasing attainable densities, and planarized surfaces improving line definition.

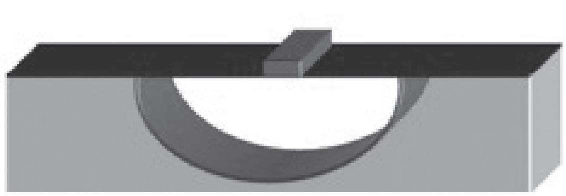

Figure 1: Half-coaxial schematic.

Experimental:

To create the semicircular stamp, tin/lead solder lines were electroplated and then reflowed to achieve the semi-circular geometry. The stamp, coated with Teflon®, was imprinted into a softbaked film of a polynorbornene polymer Avatrel 2000P (Promerus) at 110ºC and 45 bar for 60 seconds. The sample was then blanket exposed to ultra-violet (UV) light and then post-exposure baked. A seed layer of copper was then sputtered and electroplated to 1.5 μm. Chemical-mechanical polishing was used to remove copper from the field, leaving copper solely in the trench. A thick layer of polypropylene carbonate (PPC) was spin-coated on to the imprinted sample and then a Teflon-coated glass slide pressed the sacrificial material into the trench at 60ºC and 45 bar for 180 seconds. A polyhedral oligomeric silsesquioxane (POSS) (Hybrid Plastics Inc.) was spin-coated onto the sample, soft-baked, and blanket exposed to UV light. A seed layer of copper was sputtered and then photo-patterned with NR-9 (Futurexx). After the transmission line was electroplated, the seed layer was wet-etched back and the PPC was slowly decomposed in a nitrogen furnace.

Results and Discussion:

One of the primary objectives for patterning the half-coaxial structure was to minimize expensive or complex processing steps. To achieve this objective, photolithography masking and registration steps were minimized to reduce complexity and cost. The semi-circular geometry was transferred into Avatrel 2000P using only elevated temperature and pressure. The natural relief of the structure allowed the copper shielding in the trench to be patterned using simple chemical-mechanical polishing. Spin coating the sacrificial polymer, PPC, into the trench did not produce a planar sample surface and only partially filled the trench. This challenge was remedied by imprinting the sample with a Teflon-coated blank glass slide and thereby, pushing the polymer into the trench and planarizing the surface.

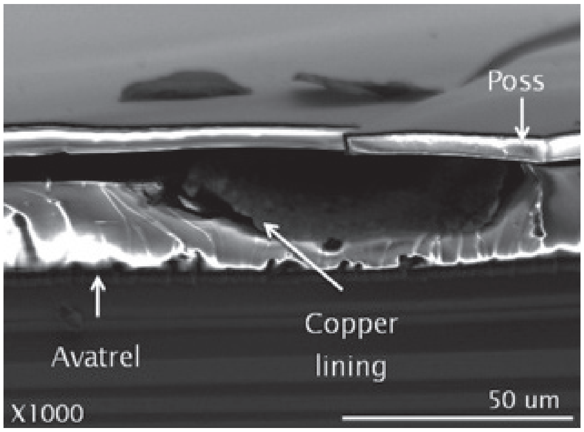

Figure 2: Inlayed air cavity.

The decomposition temperature of PPC on copper is greater than that of PPC on Avatrel 2000P, allowing thermal patterning of the sacrificial material. The primary volatile products of PPC decomposition are acetone and carbon dioxide and can permeate through many dielectrics at the decomposition temperature [2,3]. Decomposing PPC through the POSS overcoat initially resulted in damage to the POSS overcoat as shown in Figure 2. Thermo-gravimetric analysis of PPC allowed an improved decomposition recipe to be created eliminating overcoat damage. Patterning the transmission line was the only alignment recipe needed for the structure and x-ray tomography confirmed that the structure was successfully patterned. However obtaining cross sectional scanning electron microscope images (SEM) required breaking the sample, and the damage in Figures 3 and 4 are due to cross-sectioning.

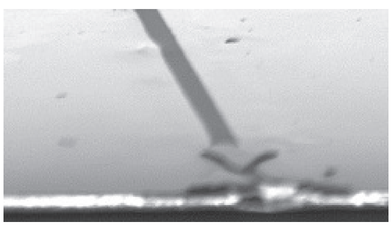

Figure 3: SEM of smooth, planar, POSS overcoat.

Figure 3 shows that the field is planar and that the damage is only in the cleaved area. Figure 4 shows the transmission line extending from the air cavity and the crack in the overcoat is attributed likely due to dicing the sample.

Conclusions:

An ultra-low loss half-coaxial transmission line was fabricated using imprint lithography, chemical-mechanical polishing, and sacrificial polymers. Imprint lithography allowed the fabrication of a complex geometry and also planarized surfaces simplifying the buildup process. The use of chemical-mechanical polishing and sacrificial polymers eliminated costly masking and registration steps. Incorporation of an air insulation layer in the transmission line can lower power loss and increase signal propagation velocities enabling high frequency chip to chip communication.

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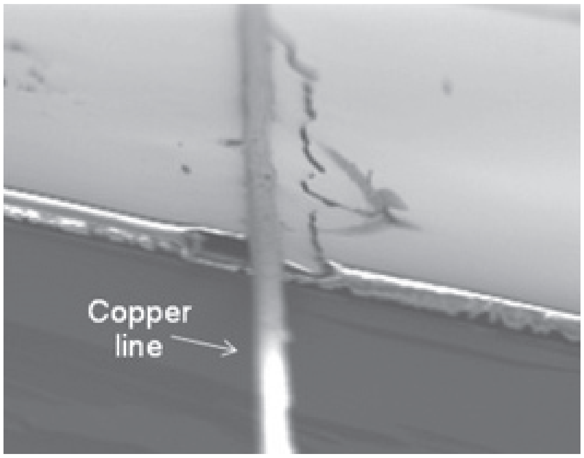

Figure 4: SEM cross-section of half-coaxial transmission line.