Hot Filament Chemical Vapor Deposition of Polyoxymethylene as a Sacrificial Layer for Fabricating Air Gaps

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In the rapid evolution towards electronic devices with smaller feature sizes and faster speed, the factor limiting overall performance is no longer gate delay, but the Resistance-Capacitance (RC) delays due to interconnects, which are the electrical connections between wires on different layers within the chip. In an attempt to alleviate this problem, novel materials of low dielectric constant (k) have been introduced to replace traditional silicon dioxide (k = 4.0). Air is a "material" with the lowest known dielectric constant (k = 1.0). Air gaps can be formed by the removal of a sacrificial layer deposited in an earlier processing step. The properties of the sacrificial layer material must satisfy the following criteria: ease of synthesis and integration, short time and low temperature of decomposition, removal in the absence of oxygen, negligible residue left behind after decomposition.

Hot Filament Chemical Vapor Deposition (HFCVD) of polyoxymethylene (CH_2O) n, has great potential be used as sacrificial layer. This polymer was chosen because of the ease of decomposition via an unzipping mechanism in the absence of oxygen to form its monomer formaldehyde (CH_2O) gas at less than 300°C, leaving behind negligible residue. Here, the HFCVD process is also demonstrated as a novel method for making the thin sacrificial layers of polyoxymethylene (POM). POM is manufactured commercially in bulk via liquid phase processes. In the HFCVD process, an array of heated wires causes decomposition of the incoming precursor gas into lower molecular weight species which then react on a cooled substrate placed below the wires. The precursor gas is trioxane, a six-membered ring trimer of formaldehyde, which decomposes cleanly into three molecules of formaldehyde with no side reactions.

A new method for synthesizing polyoxymethylene (POM) film at high deposition rates was achieved via Hot Filament Chemical Vapor Deposition (HFCVD). Nuclear Magnetic Resonance (NMR) shows that the structure of the polymer is linear, rather than cross-linked (which plasma enhanced CVD would have produced). The linear structure is responsible for its ease of decomposition at less than 300°C and leaving behind negligible residue. Thus, the HFCVD POM film is a novel sacrificial layer for fabricating air gaps, offering the advantages of shorter removal time, decreased heat load and ease of process integration over conventional methods and materials. An air gap fabricated using an HFCVD POM layer is shown in Figure 40.

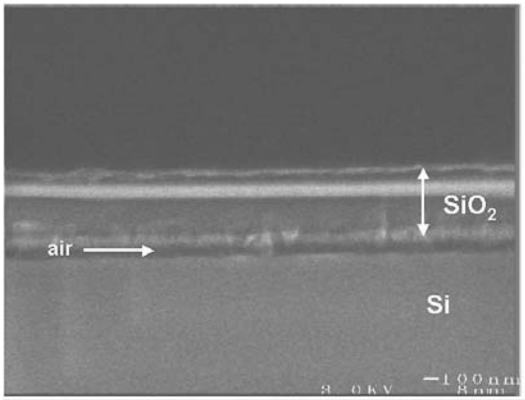

Fig. 40: Cross-sectional Scanning Electron Micrograph showing a 100 nm thick air layer in between a bulk silicon substrate (bottom) and silicon dioxide CVD layer (top). The air structure was created by the decomposition of a HFCVD POM sacrificial layer.