Surface modification and material degradation of porous low-k and polymer dielectrics

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Decreasing the dimension of integrated circuits requires novel materials with lower permittivity in order to reduce the wiring capacitance. Most of the materials that have been evaluated to date are, to a certain extent, porous. To avoid degradation of their properties and hence an increase in k value, their surface must be sealed to prevent adsorption of moisture and other chemical species from penetrating into the dielectric layer during subsequent processing steps.

In this study, we present ellipsometric porosimetry (EP) [1-2] characterization of three different types of low-k dielectrics: silica-based (microporous), Methylsilsesquioxane-based (mainly mesoporous) materials, and an organic polymer. In an attempt to seal these porous materials, surface treatments were performed involving exposure of the samples to an Oxygen-, Nitrogen-containing plasma, and UV-O_3. Characterization of the porous low-k films was performed using a prototype EP system to evaluate pore size and open porosity. Toluene was used as adsorptive. Changes in optical characteristics (ellipsometric angles, delta and psi) of the film during solvent adsorption/desorption were measured by ellipsometry.

In the case of microporous dielectric, pores at the surface can be sealed under certain conditions of treatment. For mesoporous material, reactive plasma treatment was found to be insufficient in terms of pore sealing, mainly due to the large size of the pores present at the surface. Increasing the plasma power or time results in a decrease in porosity, structure change, and hence degradation of the dielectric. Fig. 1 shows the variation in open porosity for mesoporous low-k before and after O_2-containing plasma treatment. The treatment clearly induces a decrease in porosity by about 10% after 60 s of treatment. For the polymer dielectric, formation of a dense layer on the surface can be achieved. As shown in Fig. 2, the formation of such a layer during UV-O_3 treatment prevents solvent from penetrating and therefore delta and psi remain constant during solvent exposure. Longer treatment time leads to significant loss of thickness, which was found to be even more severe for the porous polymer (Fig. 3). The results obtained from Time-of-Flight Secondary Ion Mass Spectroscopy, Fourier Transform Infrared Spectroscopy, and nanoindentation of modified films will also be discussed.

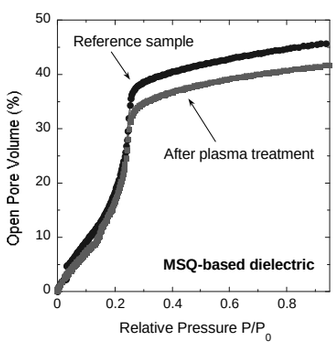

Fig. 1: Change in open porosity of mesoporous dielectric after plasma treatment as determined using ellipsometric porosimetry

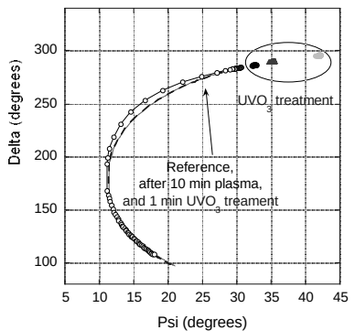

Fig. 2: Change in delta and psi during toluene adsorption of untreated organic polymer and after subjected to different surface treatments

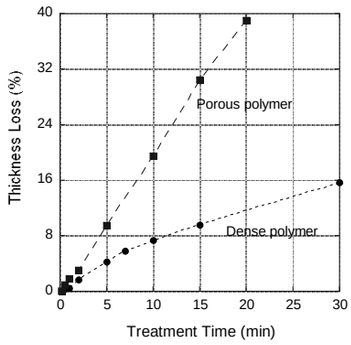

Fig. 3: Thickness loss as a function of treatment time of dense and porous organic polymer subjected to UV_O3 treatment

References

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