Characterization of low-k to extreme low-k SiCOH dielectrics

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Carbon doped oxide dielectrics comprised of Si, C, O, and H (SiCOH) have been prepared by plasma enhanced chemical vapor deposition (PECVD) using tetramethylcyclotetrasiloxane (TMCTS) as the precursor. With this precursor, films with a dielectric constant (k) as low as 2.8 have been obtained. Thermally unstable CHx fractions can be incorporated in the SiCOH matrix by adding an organic precursor to the gas feed of the PECVD reactor and these fractions can be removed by thermally annealing the deposited films. The removal of the organic fractions from the films can create porosity, if the film does not collapse, and thus further reduce the dielectric constant. By proper choice of the organic precursor and adjustment of the deposition and annealing conditions the dielectric constant of PECVD SiCOH has been reduced to extreme low-k values below 2.1.

The extreme low-k films have a porosity of about 30size below 2.5 nm. The entire range of SiCOH films, with k=2.8 – 2.0, is characterized by low leakage currents of about 10-10 A/cm2 at 1MV/cm and relatively low coefficients of thermal expansion of about 12x10-6/oK. The hardness and modulus of the SiCOH films decrease with decreasing dielectric constant, yet have values similar to bulk polymeric materials of significantly higher dielectric constants.

The films have been characterized by FTIR and the deconvolution of the SiOx absorption band has been used to evaluate the structure of the films of different dielectric constants. Rutherford backscattering (RBS) combined with forward recoil elastic scattering (FRES) has been used to determine the composition of the SiCOH films. The results have shown that the reduction of the dielectric constant is caused mainly by an increase in the porosity of the films, with very little changes in the composition of the film skeleton.

The properties of the SiCOH films makes them suitable for integration as the interconnect dielectric in ULSI devices and the range of dielectric constants makes the films potentially useful for several generations of ULSI chips.