Characterization of Low Dielectric Constant Film Etching
In High Density Halogen Plasmas

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Abstract

Microchip fabrication facilities are exploring low dielectric constant materials (low-k) as replacement materials for SiO_2 as the insulating material between metal interconnects. Etching of three low-k dielectric films is examined in this work: Benzocyclobutene (BCB), Black Diamond and Coral. The goals of the project are to explore the etching mechanisms of the films in halogen plasmas, to measure the selectivities with respect to other films, and to evaluate the feasibility of integration of the dielectrics into a copper damascene process. By using plasma diagnostics and plasma beams, four specific areas of focus are explored: the specifics coming down to the wafer, the surface composition, the net reaction rate on the surface (etching rate), and the species leaving the surface.

For BCB, the etching rates in $F_2 + O_2$ and $Cl_2 + O_2$ plasmas are quite high with excellent selectivity over oxide and nitride. BCB films are not isotropically etched by Cl atoms or O atoms. BCB etching yields in plasmas measured with a plasma beam/QCM system suggest that the neutral fluxes and surface chemistry control the etching rates under these conditions. Using XPS, it was determined that oxygen plasmas preferentially remove the carbon content of BCB, leaving behind a silicon oxide surface, whereas chlorine plasmas preferentially remove the silicon, leaving behind a carbon surface. Fluorine-oxygen plasmas etch BCB through a fluorocarbon film layer, the thickness of which increases with increasing fluorine concentration in the plasma.

Black Diamond and Coral organosilicate glasses (OSG's) are not spontaneously etched at an appreciable rate by halogen molecules or by Cl and Br atoms. Atomic fluorine etches the OSG's spontaneously, causing isotropic etching and difficulties with profile control. F, Cl, and Br atoms remove carbon rapidly from the films, showing the SiO_2 matrix limits the etching rate. Under typical processing conditions in a high density plasma, the OSG surfaces are saturated by halogen atoms and the ion flux limits the etching rate. Coral filims are strongly depleted of carbon during halogen plasma etching. Oxygen atoms extract nearly all of the carbon and nitrogen from OSG's, leaving a stoichiometric SiO_2 layer.