Beam study of plasma-surface kinetics and simulation of feature profile evolution in Cl_2 and HBr etching of polysilicon

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Etching yields of silicon in pure Cl_2, HBr and mixture of Cl_2+HBr high density plasmas have been measured as a function of ion bombardment energy, ion bombardment angle, and plasma composition. Ion beam was extracted from an inductive coupled plasma source and biased (20-200eV) and reactive neutral species was also created from this plasma source. The low energy ion beam and neutral were utilized to simulate a high-density plasma environment. These kinetic measurements facilitate the formulation of surface kinetic models in a Monte Carlo based profile simulator, and enable predictive simulations of feature profiles evolutions.

For all plasma chemistries, the etching yield increases approximately with the square root of ion energy. Pure Cl_2 and pure HBr plasmas have very similar etching yields. The dependence of the etching yield on ion bombardment angle is significantly different for Cl_2 and HBr plasmas. The etching yield in Cl_2 plasmas decreases rapidly for ion angles above 60^o (measured from the surface normal), which results in significant ion scattering from the sidewalls, and may cause the sidewall bowing and microtrenching seen when patterning polysilicon with Cl_2 plasmas. The etching yield in HBr plasmas decreases more gradually with the ion angle, resulting in less ion reflection from the feature sidewalls and may explain the much less pronounced sidewall bowing and microtrenching typically seen when patterning polysilicon with HBr plasmas.

A Monte Carlo based profile simulator was constructed to simulate feature profile evolution during plasma etching processes. The etching yield models implemented were formulated from our beam scattering studies in which dominant reaction mechanisms such as surface adsorption under ion bombardment, surface re-emission, and ion reflection were accounted. The etching artifacts were explained using the profile evolution simulator. The microtrenching was associated with two mechanisms – ion scattering from tapered sidewalls and the focusing of directional ions by bowed sidewalls onto the feature bottom. The absence of tapered sidewalls initially and the relatively straight sidewall profiles developed during the etching explained the non-occurrence of microtrenches when using HBr.

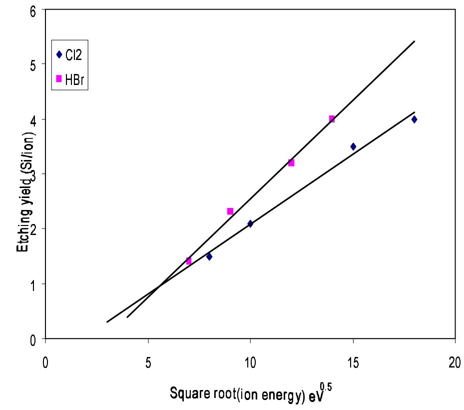

Figure 1. Si etching yield as a function of ion bombardment energy

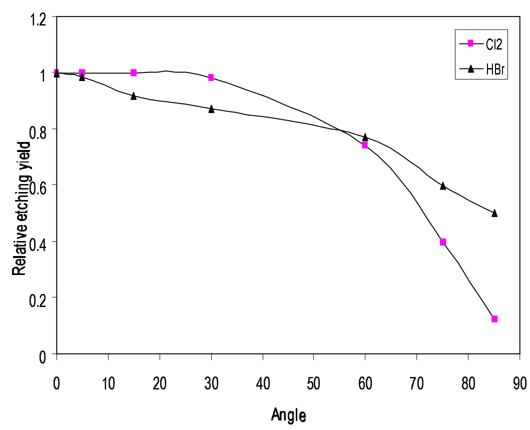

Figure 2. Si etching yield as a function of ion bombardment angle

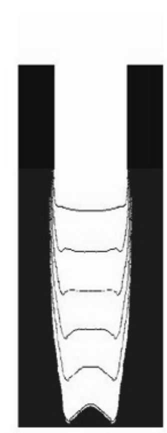

Figure 3. Profile evolution with Cl_2 etching by the Monte Carlo simulation