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In-Plasma Photo-Assisted Etching[1]

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A methodology to precisely control the ion energy distribution (IED) on a substrate allowed the study of silicon etching as a function of ion energy at near-threshold energies. Surprisingly, a substantial etching rate was observed, independent of ion energy, when the ion energy was below the ion-assisted etching threshold ($\sim$ 16 eV for etching silicon with chlorine plasma). Careful experiments led to the conclusion that this "sub-threshold" etching was due to photons, predominately at wavelengths <1700 Å. Among the plasmas investigated, photo-assisted etching (PAE) was lowest in Br_2/Ar gas mixtures and highest in HBr/Cl_2/Ar. Above threshold etching rates scaled with the square root of ion energy. PAE rates scaled with the product of surface halogen coverage (measured by X-ray photoelectron spectroscopy) and Ar emission intensity (7504 Å). Scanning electron and atomic force microscopy (SEM and AFM) revealed that photo-etched surfaces were very rough, quite likely due to the inability of the photo-assisted process to remove contaminants from the surface. In-plasma PAE may be be a complicating factor for processes that require low ion energies, such as atomic layer etching. On the other hand PAE could produce sub-10 nm high aspect ratio (6:1) features by highly selective plasma etching to transfer nascent nanopatterns in silicon.

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