Analysis of plasma-surface interactions during plasma etching by in-situ diagnostics of reactants and reaction products

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The incoming ions and neutrals onto substrate surfaces govern the etching characteristics achieved; moreover, the product species, desorbed from the substrate being etched, also play an important role in processing. This paper presents a mechanistic study of plasma etching processes, using in-situ plasma and surface diagnostics of reactants and reaction products, to gain a better understanding of competitive mechanisms that occur during etching. Experiments were performed primarily in an inductively coupled plasma reactor, with emphasis being placed on Si etching with Cl$_2$/O$_2$ chemistries and on HfO$_2$ etching with BCl$_3$/Cl$_2$/O$_2$ chemistries. Optical emission spectroscopy, laser-induced fluorescence spectroscopy, and quadrupole mass spectrometry were employed to observe reactant and product species in the gas phase. Fourier transform infrared absorption spectroscopy was also employed, to observe triatomic and larger molecules of reactants and reaction products in the gas phase and on surfaces; in practice, the gas-phase species was observed by transmission absorption spectroscopy, and the product species such as SiCl$_x$ and HfCl$_x$ on the surface by reflection absorption spectroscopy. The mechanisms responsible for selective etching of Si over SiO$_2$ and of HfO$_2$ over Si are discussed based on these observations.

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