Ion-radical synergy in HfO_2 etching studied in a beam experiment

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To get a fundamental understanding of the etching process of HfO_2, we studied the etching of atomic layer deposited (ALD) HfO_2 films on crystalline silicon (*c*-Si) substrates under well-defined conditions in a multiple-beam experiment.[1,2,3] The experiment consists of a thermal XeF_2 beam and a low energy (2-1000 eV) Ar^+ beam. The HfO_2 etch rate is determined by real time ellipsometry and mass spectrometry as a function of ion-to-radical flux ratios and ion energy. Physical etching proves to be the main etching mechanism for HfO_2 in the XeF_2/Ar^+ chemistry. The F-radical does not etch HfO_2 spontaneously. However, the Ar^+ ion etch rate can be increased by at least a factor of two in an F-chemistry, clearly indicating a synergetic effect between the ions and radials. The etch yield for both the sputtering and the radical enhanced ion etching proves to follow the well-known $EY \propto \sqrt{E}-\sqrt{E_{th}}$ dependence.[4] Currently, we are applying the interface-sensitive nonlinear optical technique of second-harmonic generation (SHG) to the HfO_2 etching process. SHG is known to probe defects such as strained Si-Si and Si dangling bonds at the *c*-Si interface, while the method is also sensitive to built-in charge. We monitor the second-harmonic signal, which derives from the buried *c*-Si/HfO_2 interface, *in situ*. The observations and implications will be discussed.

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