Investigating Focused Ion Beam Processing With Simulations: Etching and Deposition with a Precursor Gas

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We study focused ion beam (FIB) processing using the Monte Carlo based simulation code EnvizION. This code has recently been extended to include both FIB etching with a reactive precursor, as well as ion beam induced deposition. The use of precursor gas for etching can greatly enhance material removal compared with sputtering, allowing for nanoscale valleys to be formed with lower dose and, consequently, with less damage to the bulk material. At the same time, the achievable resolution of the etched valley is impacted by a number of factors, such as the competition between chemical etching and physical sputtering, platform level artifacts, and the impact of valley shape on gas coverage inside of it. EnvizION is a purpose built FIB simulation code, accounting for changes in the substrate configuration due to physical sputtering, as well as the dynamics of the precursor gas, while maintaining sufficient speed to practically simulate ion doses on the order of millions of ions.

We study the etching of SiO_2 using a XeF_2 precursor gas. Etching simulations are validated against experimental data; Figure 1 shows such a comparison for an etched valley, and simulations with varying gas fluxes. Simulations are used to identify how gas flux, beam current distribution, and platform level artifacts combine to determine achievable resolution in the nanoscale valleys. Etching is studied for both Ne^+ and Ga^+ ion beam species, and the effective beam current distribution of each, corresponding to the experimental data, is identified. We additionally study the effect of the competition between etching gas flux and the beam dwell time, and, in order to optimize resolution, we identify an intermediate gas flux for which etching resolution is the lowest. Finally, we demonstrate the IBID portion of the code, by simulating the growth of nanopillars using a $MeCpPtMe_3$ precursor.

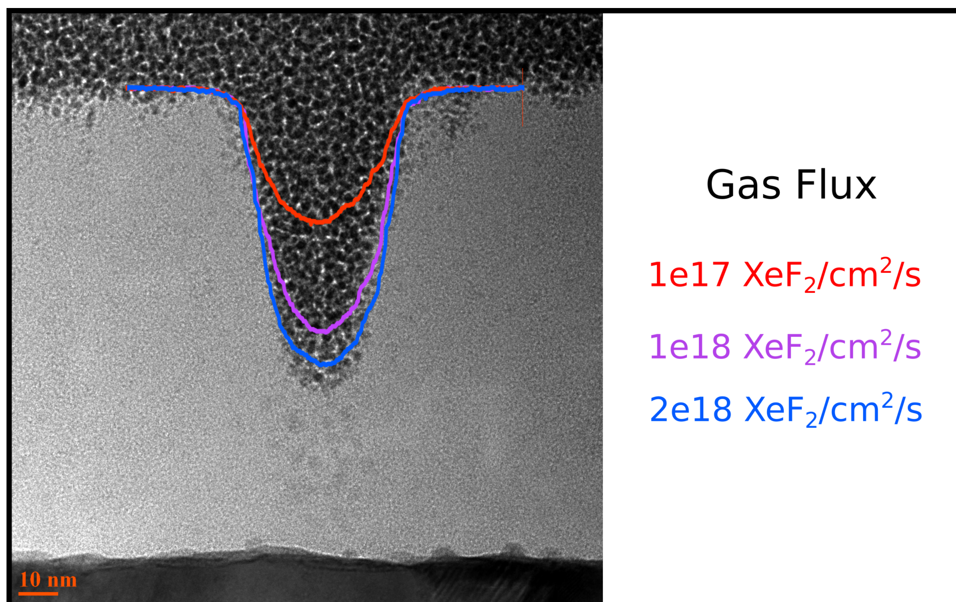

Figure 1: Comparison of a line scan etched by a 30keV Ga^+ beam and a XeF_2 precursor, for experiments, and simulations with various gas fluxes. (1pA current, 0.5μs dwell, 4nm pixel spacing, 4000 lines.)