

Surface Chemistry Modifications for Improved Electron-Beam Induced Etching (EBIE) Processes

Matthew G. Lassiter¹, Ted Liang², Philip D. Rack¹

¹University of Tennessee, 308 Dougherty Engineering Hall,
Knoxville, Tennessee 37996 USA

²Intel Corporation, 2200 Mission College Blvd., Santa Clara, California 94054 USA

The use of electron beam induced processes for the repair of features on lithography masks has recently been developed as an alternative to focused ion beam (FIB) repair of masks. The electron beam induces the dissociation of a precursor gas to cause a reaction at the surface of the substrate. This reaction either deposits material or causes the etching of the mask material, depending upon the type of precursor used and the substrate material. This work focuses on the latter case of electron beam induced etching (EBIE). The electron beam provides superior spatial resolution than that of the FIB and also minimizes damage to the mask materials because of the relatively small mass of the electron.

Because EBIE is chemical process, the condition of the initial substrate surface (typically from an adventitious carbon layer significantly affects the process) and competitive deposition processes (typically from residual hydrocarbons) affect the EBIE process. Therefore eliminating carbonaceous species on the substrate and the vacuum chamber can significantly improve the overall etch rate and process repeatability. We have explored the effects that an oxygen plasma pre-treatment (XEI Scientific Evactron C) has on the EBIE process. Figure 1 compares two etched TaN features that have and have not been exposed to the oxygen plasma prior to the EBIE. We will compare the surface chemistry of the treated and untreated surface and show how the plasma pre-treatment controls the repair-to-repair repeatability.

Some precursor gas and substrate/film combinations result in spontaneous etching reactions at room temperature. This is an undesirable effect because it compromises the ultimate resolution of the EBIE process and can affect the repaired feature geometry during subsequent edits. TaN is currently being explored as an EUV mask absorber material. In the case of TaN EBIE using a XeF₂ etch precursor, XeF₂ spontaneously etches TaN but does not spontaneously etch TaO_x. In this presentation we will show that an ex-situ active e-beam H₂O passivation of the sidewalls of etched TaN features can prevent further spontaneous etching from occurring (Figure 2). The surface chemistry of the treated and untreated TaN surfaces were characterized by Auger Electron Spectroscopy. The effects of electron beam parameters and passivation process gases were investigated and the results will be compared. Furthermore, we will show how an in-situ passivation process can improve the spatial resolution by inhibiting the spontaneous etch process during the EBIE process. Finally, we will present simulations using our Monte Carlo 3-D electron beam induced processing simulation.

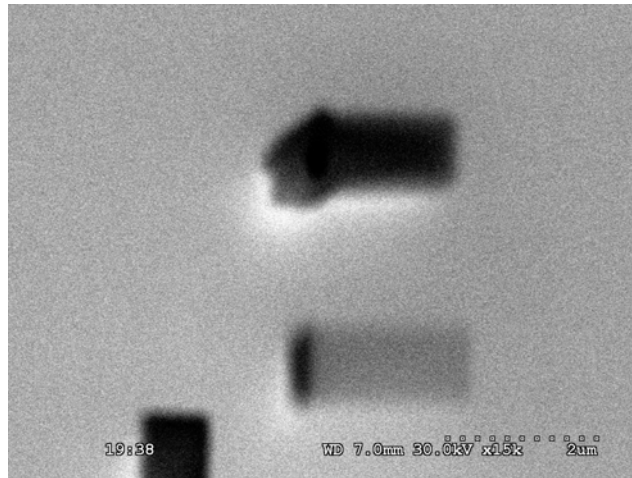


Figure 1: Effect of Surface Treatment: Both sites were etched for equal time under identical EBIE beam and gas conditions. The site on the bottom was etched after no surface treatment. The etch rate is slowed due to carbon contamination on the surface and due to competitive carbon deposition due to carbon contamination everywhere in the SEM chamber. The upper site was etched after cleaning the chamber and sample with an Oxygen plasma system immediately before the EBIE process. The etch rate is greatly improved due to the absence of competitive deposition.

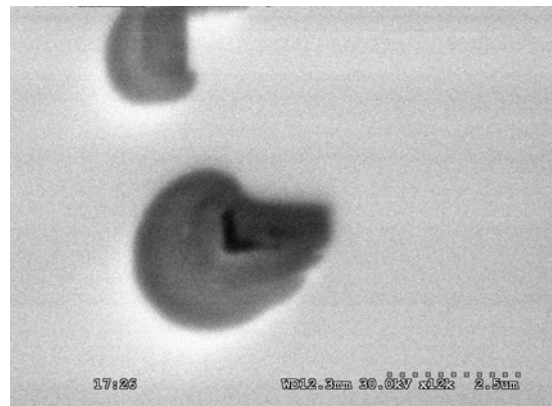
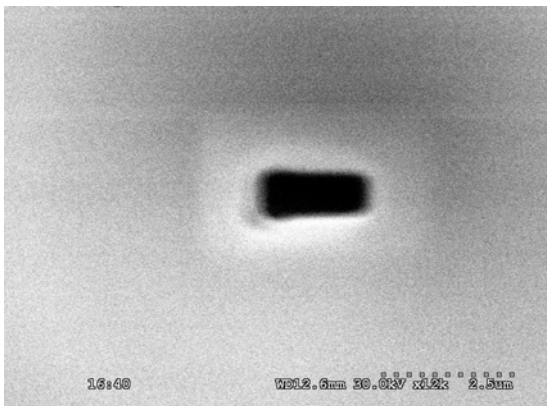


Figure 2: Passivation Process Performance: Both sites were TaN etched using XeF_2 precursor gas and e-beam scanning in box mode. The site on the left was passivated ex-situ in a H_2O environment using a scanning e-beam. The two sites were then exposed to the XeF_2 precursor again, and only periodically imaged by the e-beam. The passivated site exhibits resistance to further spontaneous etching, while the XeF_2 gas easily etches the non-passivated site further. This snapshot is taken after 9 minutes of exposure to 0.1Pa XeF_2 .