Gas Assisted Focused Electron Beam Induced Etching of Alumina

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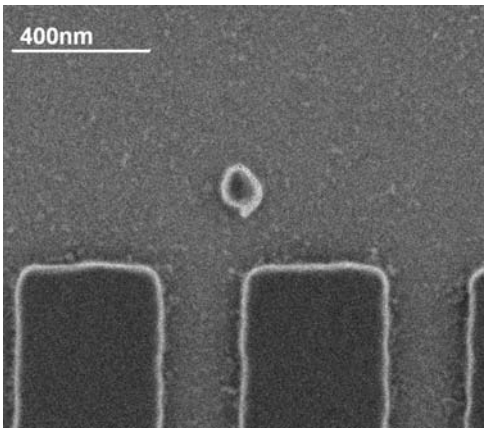
This study investigates Focused Electron Beam Induced Etching (FEBIE) for removal of foreign particles on patterned EUV masks. As potential contaminants, particles of Aluminum oxide (alumina, Al_2O_3) and hydrocarbons (including PMMA and polystyrene) have been successfully removed, leaving the underlying layers undamaged. The particles were applied onto a EUV mask, consisting of a multilayer Bragg mirror capped with a thin Ru layer and a structured TaBN/TaBON absorber film. Plasma cleaning and activation of the surface was performed prior to drop coating with particles to avoid coagulation. For the results shown in the figures, ~100 nm alumina nano-particles and ~180nm polystyrene nano-particles were applied from an aqueous suspension.

Etch gases, such as Cl_2, XeF_2, and H_2O, have been previously used for beam-induced EUV mask repair [1]. Similar repair techniques have also been used on 193 nm phase-shift masks and quartz binary masks [2], as well as for local photoresist patterning [3].

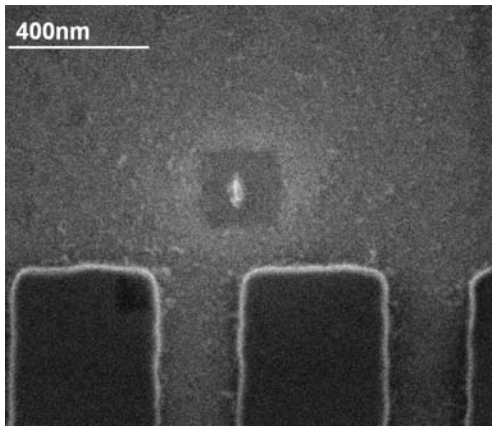
The alumina particles could be etched using a novel halogen-containing etch chemistry (see figures 1A and 1B). Neither the Ruthenium nor the absorber was significantly etched during the process, in spite of a square area scanned by the focused electron beam larger than the particle.
The novel gas also etched hydrocarbon particles successfully, although more slowly, and still without damage to the surrounding EUV mask structures (see figs. 2A & 2B). Further studies are under way to increase insight into the etching mechanisms.

1 T. Liang *et al.*, J. Vac. Sci. Technol. B 23(6), 2005
2 K. Edinger *et al.*, J. Vac. Sci. Technol. B 22(6), 2004
3 K.T. Kohlmann-von Platen *et al.*, J. Vac. Sci. Technol. B 14(6), 1996

Figure 1: SEM images of an Al_2O_3 particle on Ruthenium (EUV Mask) with TaBON lines.

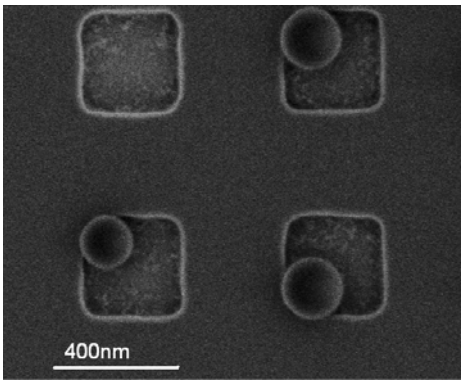


A) Prior to the etching experiment.

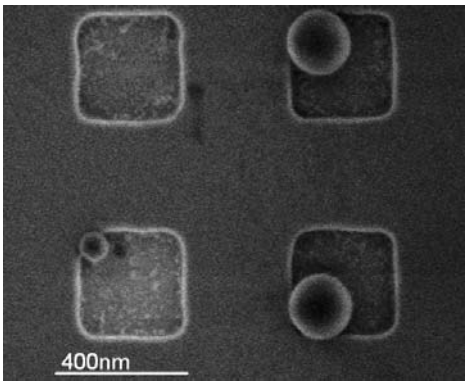


B) After the etching experiment with the novel halogen-containing assist gas (process duration ca. 30 min.).

Figure 2: SEM images of polystyrene particles on Ruthenium inside structured square holes in TaBON. Images show the change in one of these particles after an etching experiment using the novel halogen containing gas.



A) Prior to etching experiment.



B) SEM image after the etching experiment.