Reconstructing Focused Ion Beam Profile by Iterative Simulation Methodology

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Understanding nanoscale details of Focused Ion Beam (FIB) sputtering, Gas-Assisted Etching (GAE), and beam-induced deposition is critical for applications ranging from nano-patterning thin films to prototyping integrated circuits. Dimensions of features targeted by FIB sputtering approaching the physical diameters of focused ion beams and thickness of material layers becoming comparable with depth of ion implantation dictate the need for better understanding of FIB-to-material interaction within the ion beam profile [1].

Recently developed profile reconstruction methodology [2] relies on analysis of multiple TEM micrographs of lattice damage to deduce the primary ion beam current density profile. While providing accurate results, this approach requires preparation of multiple HR-TEM samples and is therefore difficult to apply for routine characterization. We propose a simplified, simulation-based methodology for reconstructing the FIB profile from sputtering and implantation information available from single TEM micrographs (Fig. 1) of lines etched by FIB in fused silica. For first-approximation reconstruction of the ion beam profile we assumed the effective beam diameter to be equivalent to the largest width of ion beam damage visible on bright-field TEM image. A bi-Gaussian beam profile model was assumed for simulations of implantation and sputtering, and linear dependency of sputtered depth on the ion dose was assumed for sputtering simulations.

MATLAB scripts were developed and integrated with SRIM Supporting Software Module (SSSM) and Transport of Ions in Matter (TRIM) packages to concurrently simulate implantation and low-aspect-ratio sputtering. The simulated implantation and etching profiles were visualized for comparison with experimental data (Fig. 2), and ion beam parameters resulting in simulated profiles with the closest match to experiment were assumed to describe the primary ion beam. The resulting reconstructed beam profile was applied to analysis of data from a single line etching and deposition experiment [3] to gain insight into details of gas-assisted etching and beam-induced deposition within the single beam profile.

[1] Jacques Gierak, Nanofabrication 1 (2014) p. 35 – 52.
[2] Shida Tan *et al*, JVST B 30(6) (2012) p. 06F606.
[3] V. Ray et al, Microsc. Microanal. 21 (Suppl 3) (2015) No. 0920

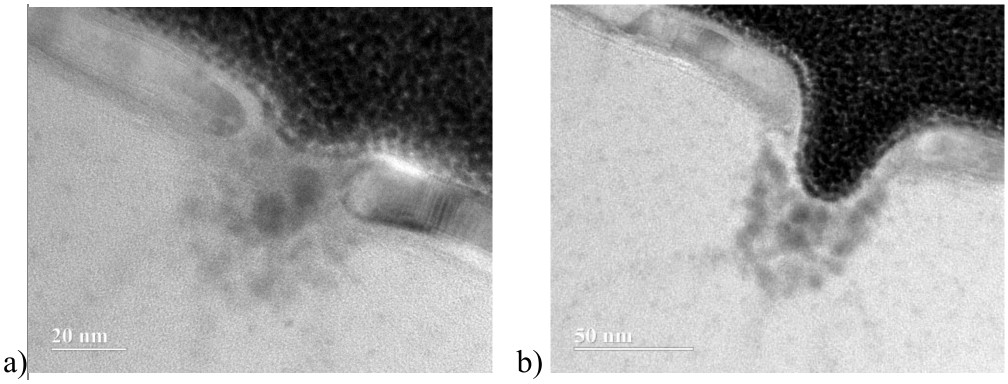

Figure 1) Profiles of physical sputtering with a) 1 pA and b) 7.7 pA, 30kV Ga^+ FIB. The variable density Ga implantation layer is clearly visible in both images. The sample is coated by a ~24nm thick layer of vacuum-evaporated aluminum to eliminate charging.

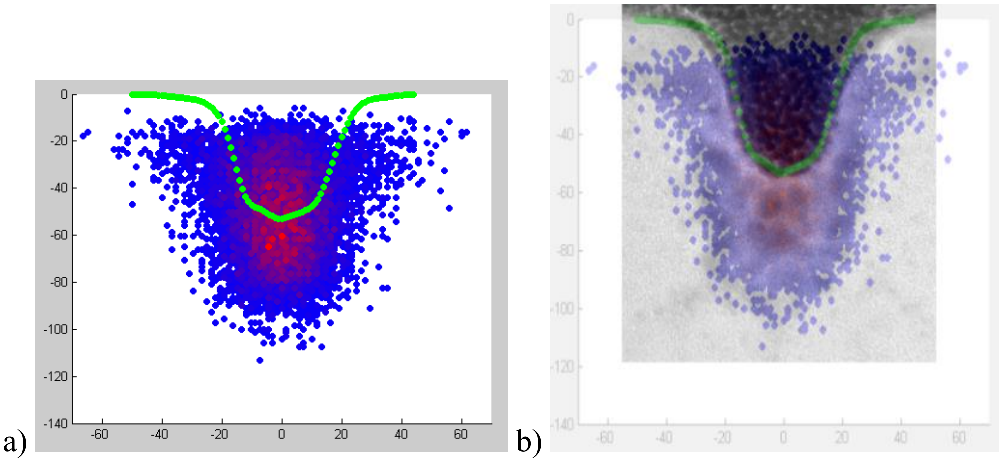

Figure 2) a) Simulated implantation and sputtering profile, b) overlaid with corresponding matched-to- scale TEM micrograph

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