Effects of Beam Raster Parameters and Up/Down Slope Direction on Multiple-Raster Etching of Material by Focused Ion Beam at Glancing Angle of Incidence

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It is widely known that the yield of Focused Ion Beam (FIB) etching varies as a function of the angle of the ion beam incidence [1]. A few researchers have evaluated the effects of the varying angle of beam incidence [2] and up-slope vs. down-slope direction of beam deflection [3]. Removing material by FIB at glancing angle of incidence in cross-sectioning and TEM sample preparation applications was recently proposed [4], however it relies on a single-pass type of raster which may or may not be available on a particular FIB system.

We evaluated the effects of multiple-raster etching by 30KV Ga^+ FIB at normal and glancing angles of incidence in up-the-slope and down-the-slope directions by a digital raster with dwell times of 0.2µs and 500µs and pixel overlaps of 0% and 50%, while the sample was tilted to angles of 0, 15, 30, and 45 degrees from the direction orthogonal to the ion beam.

While the effects of up-the-slope vs. down-the-slope direction of raster in conjunction with varying pixel dwell times and overlap parameters appear to be negligible, as shown in *Fig. 1* and *Fig. 2*, we observed consistent difference in volume of the removed material as a function of the angle of incidence. Up to 2.5x larger volume of material removed while the sample was tilted 45 degrees vs. no-tilt conditions.

This result suggests that multiple-raster etching at glancing angle of incidence may also be potentially suitable for bulk material removal.

[1] C.A. Volkert et al., “Focused Ion Beam Microscopy and Micromachining” MRS Bulletin; Volume 32, p. 392, May 2007
[2] Xin Xu at. al., “Focused Ion Beam induced deposition and ion milling as a function of angle of ion incidence” J. Vac. Sci. Technol. B 10, 2675 (1992)
[3] L. Gianuzzi et. al., “Optimization of Nano-Machining with Focused Ion Beams” NSTI-Nanotech Vol. 2, 2005
[4] V. Ray “FIB at Glancing Angle of Incidence” Presentation on FIB User Group at International Symposium for Testing and Failure Analysis ISTFA 2013, http://www.academia.edu/5021132/FIB_at_glancing_angle_of_incidence

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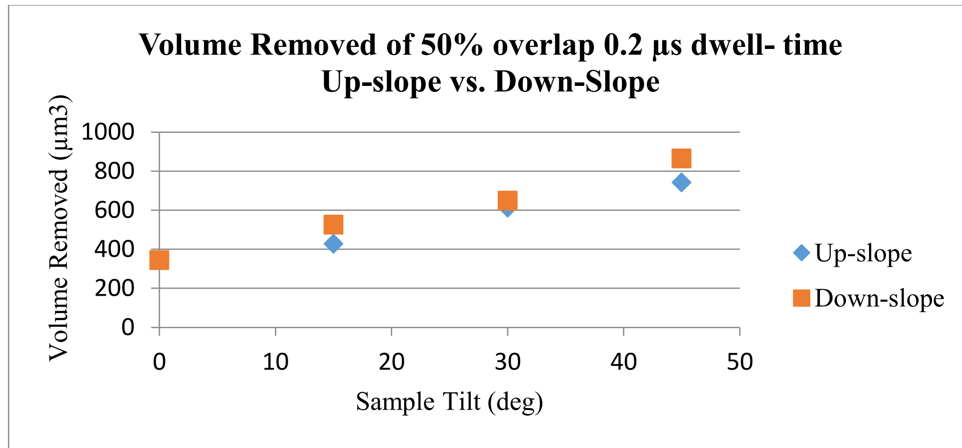

Figure 1: Volume of the material removed as function of direction of the raster and angle of incidence at 50% pixel overlap and 0.2µS pixel dwell time.

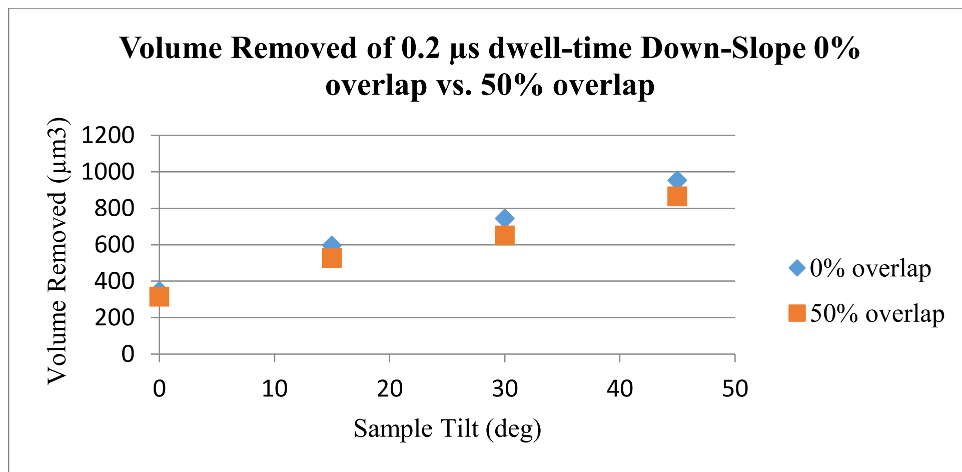

Figure 2: Volume of the material removed as function of pixel overlap and angle of incidence in down-the-slope raster direction and 0.2µSec dwell time.

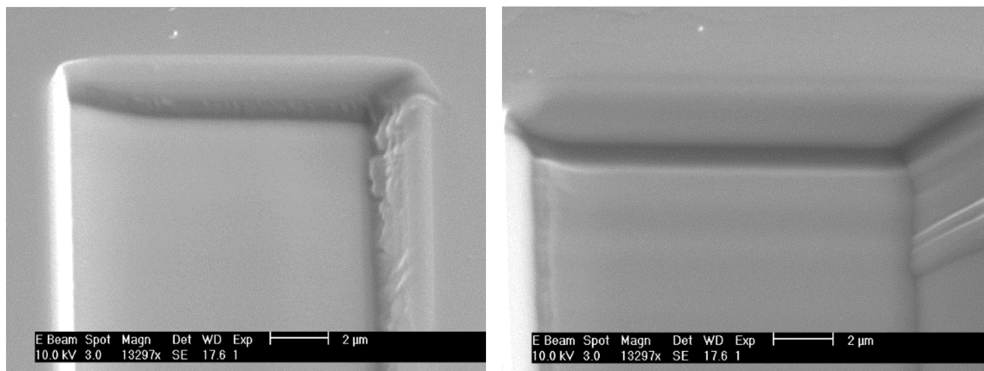

Figure 3: Difference in volume of material removed at normal incidence (left) vs. 45 degrees sample tilt conditions (right). Both were etched by 30KV Ga^+ FIB for 20min. by 2.7nA beam current in down-slope direction of the raster with pixel dwell time of 0.2 µs and 0% overlap.