Enhanced Removal of Material by FIB Etching at Glancing Angle of Incidence in Cross-Sectioning Application

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Advances in Focused Ion Beam (FIB) instrumentation and control software have transformed preparation of electron microscopy samples by Focused Ion Beam (FIB) [1] into a routine procedure, however FIB cross-sectioning remains a time-consuming process.

Dependence of etching yield on the angle of on beam incidence is known [2] and differences of etching in up-slope vs. down-slope directions were explored [3], however FIB etching at glancing-angle [4] has not yet become commonplace in practical applications.

We evaluated FIB etching with multiple-raster and single-raster scanning at glancing angle of ion beam incidence. While etching with multiple-raster scanning was not sensitive to direction of raster (*Fig. 1*), with single-raster scanning etching in down-slope direction was inhibited (*Fig. 2*), whereas up-slope direction etching by single raster scanning appeared strongly enhanced.

Cross-sectional cut (*Fig. 3*) produced by multiple etches with single-raster scanning in up-slope direction at varied angles of ion beam incidence demonstrates potential application of FIB etching at glancing angle of incidence for cross-sectioning and TEM sample preparation.

[1] R. Langford and A. Petford-Long "Preparation of transmission electron microscopy cross-section specimens using focused ion beam milling" J. Vac. Sci. Technol. A 19, 2186 (2001)
[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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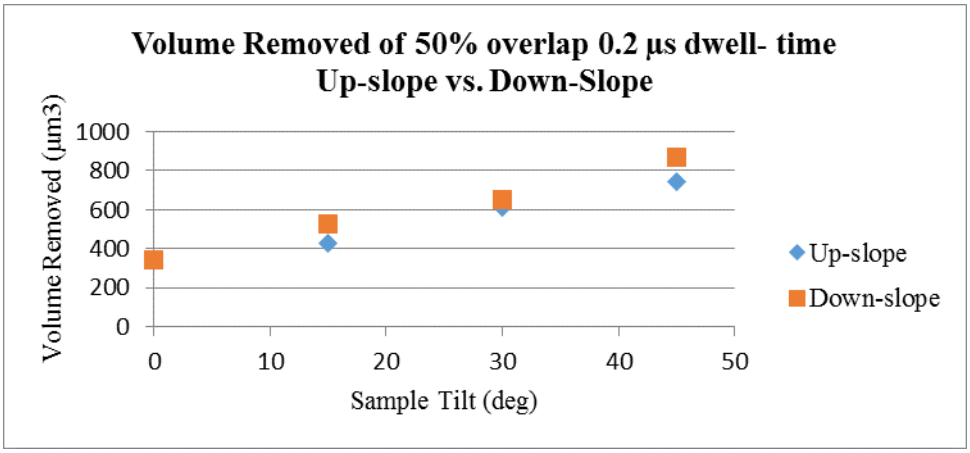

Figure 1: Volume of material removed by same-dose etching with multiple-raster scanning as function of direction of the raster and angle of ion beam incidence.

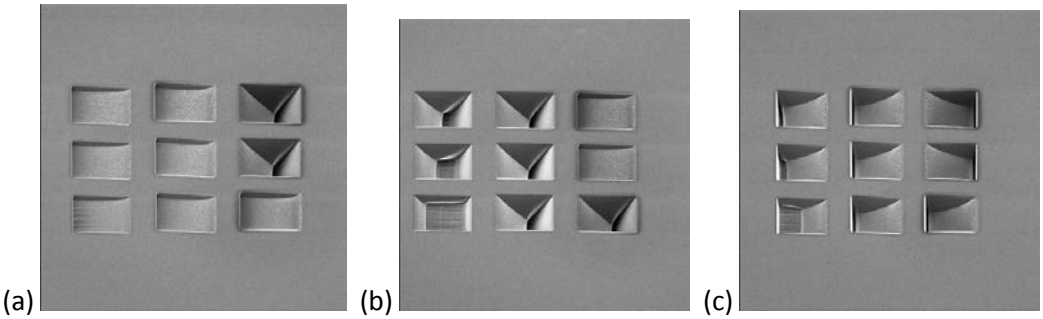

Figure 2: Enhancement and suppression of etching at 60 degrees angle of ion beam incidence by single-raster strategy as function of direction. All parameters are same, except of (a) 7 boxes were etched down-slope and 2 up-slope, vs. reversed direction (b) where 7 boxes were etched up-slope and 2 down-slope; (c) no tilt.

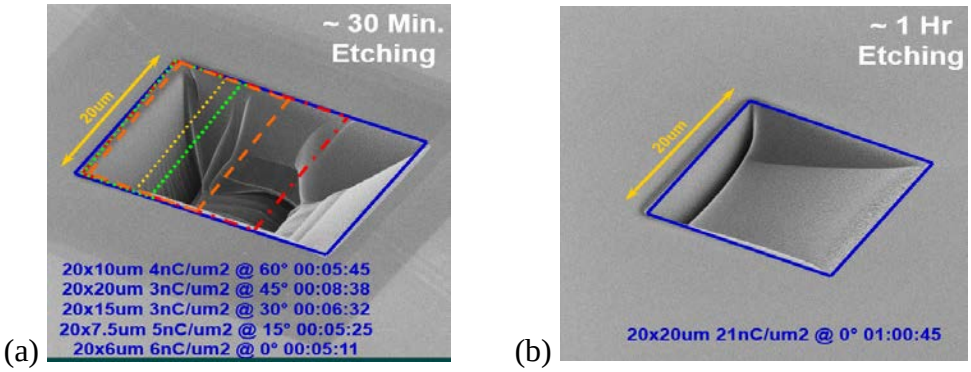

Figure 3: Enhanced cross-section by multiple single-raster up-slope cuts at varied angles of ion beam incidence (a) was superior in depth, time, and volume of removed material, as compared to single-raster cut (b) with same total ion dose at normal angle of incidence.