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Xe^+ FIB Milling and Measurement of Amorphous Silicon Damage

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Minimizing surface damage during FIB specimen preparation is an important factor for high quality analytical results, especially in the case of TEM membrane and EBSD sample preparation. For conventional Ga^+ FIB milling, techniques using reduced accelerating voltages for final polishing to minimize sample damage are commonly used [1]. With newer ion species available for FIB milling, namely Xe^+, the ion-solid interaction will be slightly different from Ga+, but the same low ion energy strategies can be applied for minimizing ion milling damage.

Previous studies on single crystal silicon with a conventional Ga^+ FIB show ~22 nm amorphous sidewall damage when milled with an energy of 30 keV and less sidewall damage with lower energies . On the same substrate, modeling indicates that milling with heavier ions will produce less sidewall damage than with a lighter ion of the same energy [2]. Hence, less sidewall damage should be achievable when FIB milling with Xe^+ (54) in comparison to Ga^+ (31). In this study, the sidewall amorphization damage on single crystal silicon after Xe^+ FIB milling and also Ga+ FIB milling has been measured for comparison.

Cross-sections of a blanket silicon wafer were prepared using both a Vion™ Plasma FIB (Xe^+) and a Helios DualBeam at 30 keV. Specimens were polished with energies of 5, and 2 keV using incident angles of 88°, 86°, 84° respectively. After sputter coating the surface with iridium as an initial protection layer, conventional in-situ liftout TEM samples of the milled cross-sections were prepared using a Helios NanoLab™ 450HP DualBeam equipped with an EasyLift™ nanomanipulator. Amorphous silicon damage was analyzed by HRTEM on a Tecnai Osiris™ TEM operating at 200 keV.

Figs. 1a, 1b and 1c show HRTEM images of the amorphous sidewall damage from Ga+ FIB milling with 30 keV, 5 keV and 2 keV, respectively. Figs. 2a, 2b and 2c show HRTEM images of the amorphous sidewall damage from Xe+ FIB milling with 30 keV, 5 keV and 2 keV, respectively. As expected, the experimental results follow SRIM calculations and predictions from fundamental ion-solid interactions [3]. The Xe+ sidewall amorphous damage decreases dramatically as a function of energy and is smaller than 30 keV Ga+ FIB results by as much as ~ 40%.

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[3] Intro. to Focused Ion Beams, eds. L.A. Giannuzzi and F.A. Stevie, Springer, 2005.

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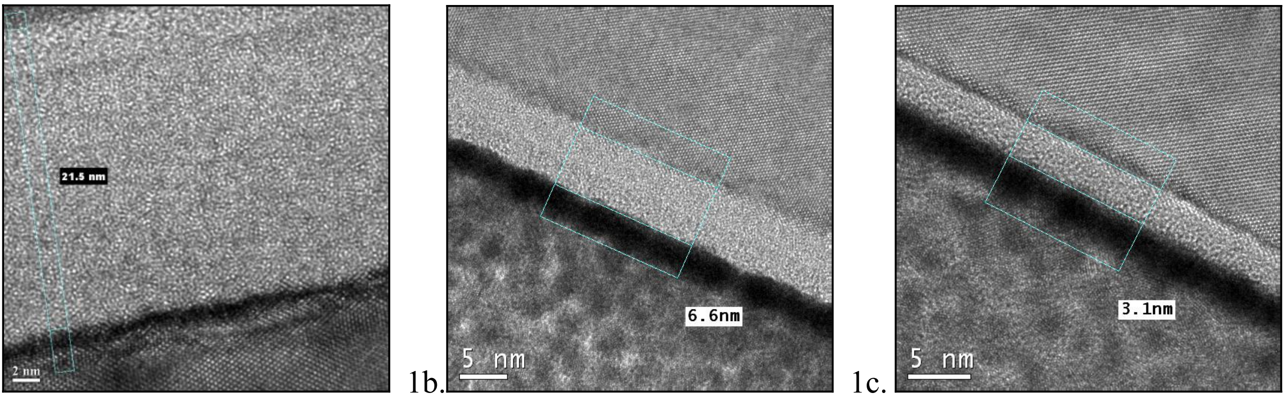
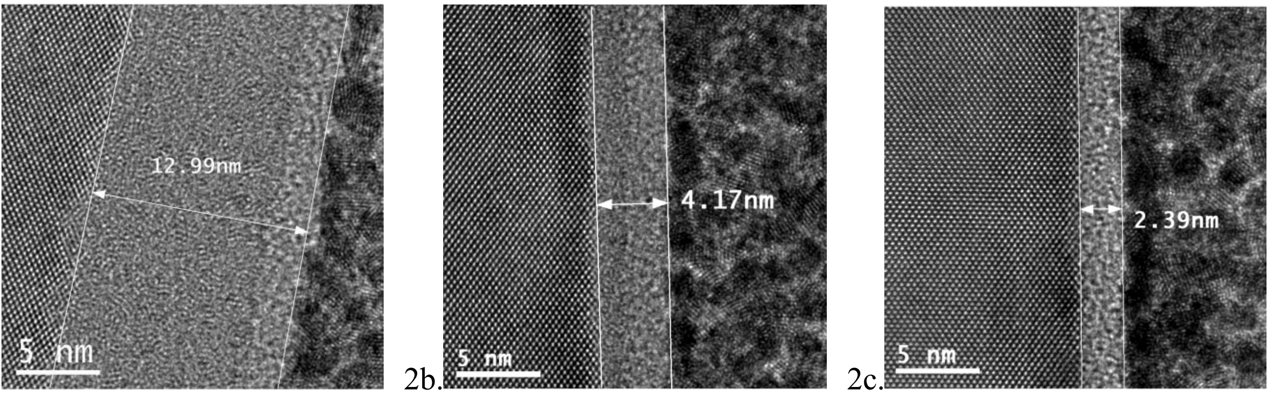


1a. 1b. 1c.

Figure 1. HRTEM images of sidewall amorphization damage in Si from a Ga^+ FIB with a) 30 keV, b) 5 keV, and c) 2 keV accelerating voltages.



2a. 2b. 2c.

Figure 2. HRTEM images of sidewall amorphization damage in Si from a Xe^+ FIB with a) 30, b) 5, and c) 2 keV.

Damage Layer Thickness for Xe^+ and Ga^+ FIB Milling (nm)			
	Beam Energy (keV)		
Ion Species	**2**	**5**	**30**
Ga	~ 3 nm	~ 7	~ 22
Xe	~ 2	~ 4	~ 13
% Difference	20	35	41

Table 1. Summary table of sidewall amorphization damage layer thickness in Si after Xe^+ and Ga^+ milling with 30, 5 and 2 keV.

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