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Ga^+ FIB Milling and Measurement of FIB Damage in Sapphire

Brandon Van Leer[1], Huikai Cheng[1], Jessica Riesterer[1]

[1] FEI Company, 5350 NW Dawson Creek Drive, Hillsboro, OR 97124 USA

Single crystal Al_2O_3 (sapphire) is an important material for LED, optical and RFIC manufacturing because of its durability, thermal insulation, chemical inertness and light transmission [1]. Site-specific S/TEM sample preparation for LED specimens require the use of a FIB or DualBeam to characterize active areas for defects and process characterization. Minimizing surface damage during FIB specimen preparation is an important factor for high quality analytical results, especially in the case of TEM lamella. It has been shown in previous experimental studies that the milling process of high energy Ga^+ FIB columns can impart enough surface damage in Si to impede quantitative high resolution S/TEM imaging and low energy Ga^+ FIB can produce samples with the lowest FIB damage [2]. In this paper, we discuss improving S/TEM lamellae quality of sapphire utilizing low energy FIB polishing.

Cross-sections of a blanket Al_2O_3 with surface orientation of [0001] wafer were prepared using a Helios NanoLab 660 DualBeam™. Cross-sections were polished with energies of 30, 5, and 2 keV using incident angles of 88.5°, 87°, 87° respectively. Each cross-section was protected with electron beam induced deposition (EBID) of Carbon. Conventional in-situ liftout TEM samples of the milled cross-sections were prepared using an EasyLift™ nanomanipulator. FIB damage was analyzed by HRTEM on a Titan ChemiSTEM™ TEM operating at 200 keV. Figs. 1a, 1b and 1c show HRTEM images of the FIB sidewall damage from Ga^+ FIB milling with 30 keV, 5 keV and 2 keV, respectively. As expected, as the FIB energy is decreased, sidewall FIB damage also decreases. Unexpectedly, the experimental results deviate from SRIM calculations and predictions from fundamental ion-solid interactions by as much as 50%[3]. Figs 2a, 2b and 2c show the predicted ion trajectories for Ga^+ into Al_2O_3. Table 1 provides a summary if FIB damage into the sapphire induced by Ga^+ ions.

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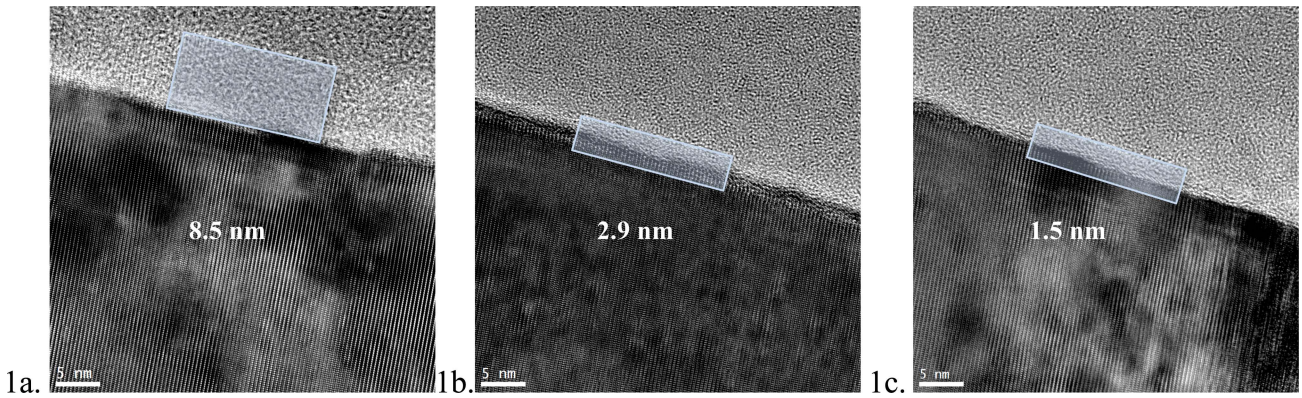
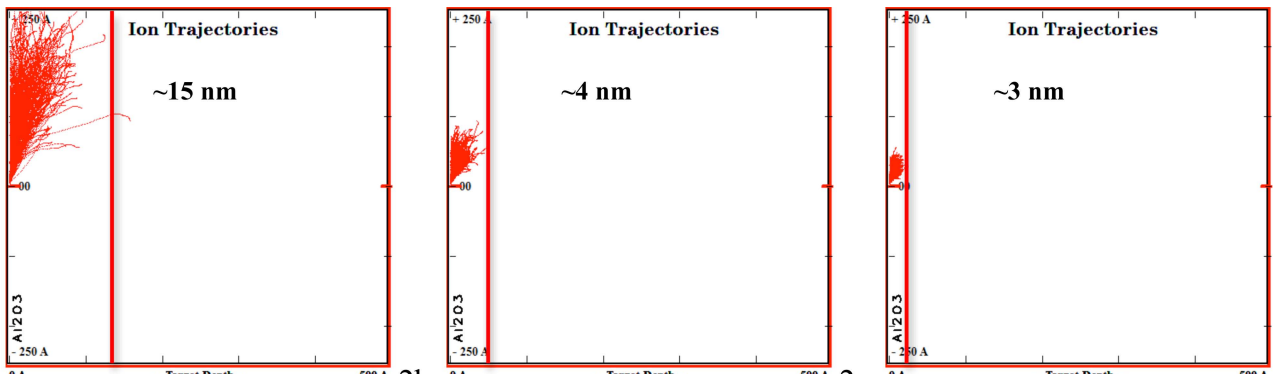


1a. 1b. 1c.

Figure 1. HRTEM images of sidewall Ga^+ FIB damage in Al_2O_3 from a Ga^+ FIB with a) 30 keV, b) 5 keV, and c) 2 keV accelerating voltages.



2a. 2b. 2c.

Figure 2. Ion trajectories of Ga^+ ions into Al_2O_3 with a) 30 keV, b) 5 keV and c) 2 keV accelerating voltages.

	Beam Energy (keV)		
Ion Species	**2**	**5**	**30**
Ga	~ 1.5 nm	~ 2.9 nm	~ 8.5 nm

Table 1. Summary table of FIB damage layer (nm) in Al_2O_3 after Ga^+ milling with 30, 5 and 2 keV.

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