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FIB-assisted TEM Sample Preparation Refinement Using TRIM Simulations

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Focused ion beam (FIB) assisted TEM sample preparation uses an ion beam to precisely remove material in order to create electron transparent specimen. This technique enables the preparation of lamellae containing small targeted features, and can conveniently be used for specimen preparation from an expansive list of bulk materials [1]. The drawback for using high energy ion bombardment for TEM specimen creation is that it inevitably results in damage and other artifacts to the prepared TEM sample [1] [2], which can diminish the quality of the TEM image [2] thereby making image interpretation and analysis challenging.

For the semiconductor industry, FIB-assisted TEM sample preparation poses increasing challenges as transistor size continues to decrease according to Moore's law. With the technology node dwindling from tens of microns in the 1960's to tens of nanometers by 2010 and beyond [3], there is an increasing emphasis on preparing thinner specimen, faster, and with minimal damage and artifacts. Hence, the optimal set of FIB parameters (i.e. energy and angle of incidence) are needed to prepare high quality ultra-thin TEM samples.

FIB conditions which allow for the creation of high quality sub 25nm lamellae were identified using the Transport of Ions in Matter (TRIM) computer program [4], which is based on a Monte Carlo code that simulates ion-solid interactions [5]. Ion damage depth and curtaining effects from dissimilar milling rates were evaluated using TRIM outputs: mean projected range, Rp, and sputter yield, SY, respectively. Computer simulations were verified with cross-sectional TEM samples prepared with various FIB conditions.

References:

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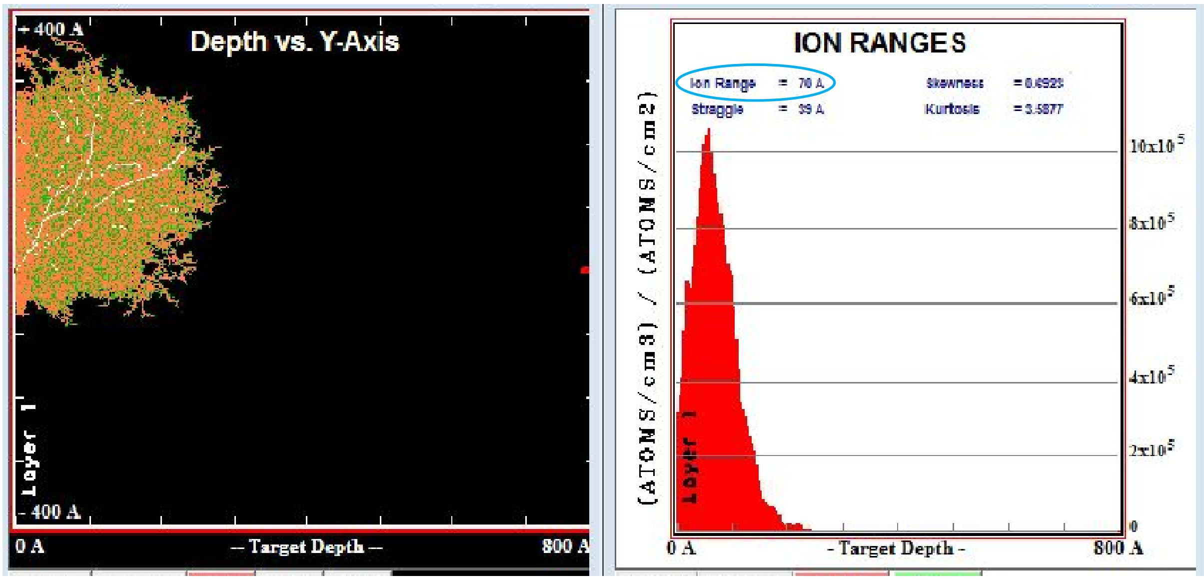

Figure 1. Damage Depth Evaluation. TRIM simulaiton for a Ga ion beam bombarding a silicon (Si) target at 10keV with an ion angle of incidence of 60 degrees with respect to the target surface normal. The plots shown are: (1) the Ion Collision Plot (left) which depicts the individual ion paths projected onto the x-y plane of the target, and (2) the Ion Distribution Plot (right) which plots ion concentration information as a functon of depth into the solid. The statistical distribution of ions in an amorphous solid is shown to be gaussian in nature with the peak concentration occuring at the mean projected range, Rp. In crystalline materials however, the presence of channeling can result in deviations from gaussian profile; channeling results in deeper penetration of ions into the solid than predicted for amorphous solids [6].

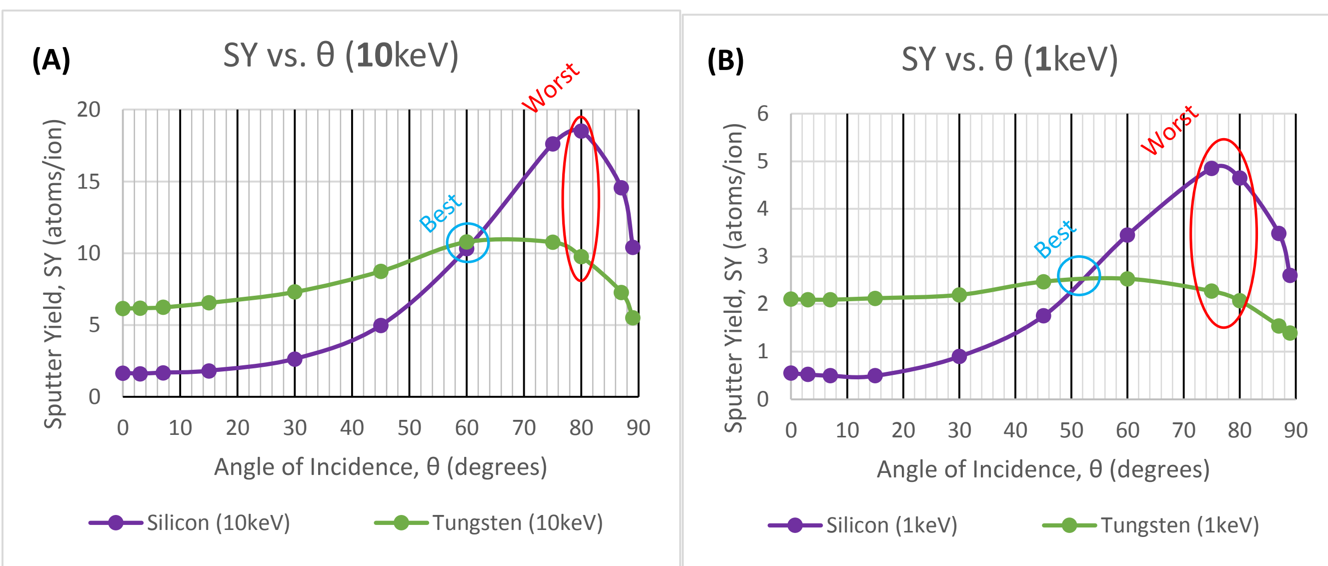

Figure 2. Curtaining Effect Evaluation. Sputter Yield, SY, versus Ion Angle of Incidence, θ (Ga ion beam) with respect to the surface normal of selected target materials at **(A)** 10keV and **(B)** 1keV. Numerical data plotted was obtained from TRIM.