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Focused Ne^+ Ion Beams for Final Polishing of TEM Lamella Prepared Through Ga-FIB Systems

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TEM specimen preparation using in-situ and ex-situ liftout techniques on Ga^+ ion beam based FIB systems has long been realized and become a very important routine in semiconductor industry as well as other material research laboratories [1]. However, more and more data have shown that Ga-FIB processed TEM samples not only contain structural damages due to high energy Ga^+ ion bombarding but chemical contamination caused by Ga^+ ion implantation as well [2]. To reduce structural damage, recent efforts have been made by using low energy Ga^+ ion beam (down to <1 keV) for lamellae final polishing. This low energy Ga^+ ion beam polishing has shown significant reduction in the amorphized layer on lamellae surfaces. Other techniques (for instance, low energy Ar^+ beam polishing, the NanoMill system) have also been applied after routine TEM sample preparation in order to reduce both structural damage and Ga^+ ion contamination.

The gas field ion source (GFIS) based helium ion microscopy has been received a lot attention since the first commercially available Orion system was introduced to the market. Initial applications were focused on imaging. Later, more and more work was conducted for materials processing and fabrication. TEM sample polishing using He^+ ion beam has also been investigated by several research groups [3, 4]. The limited preliminary results with He^+ polishing indicated no obvious benefit in reducing amorphous layers on TEM lamellae. However all the work was done with 30+ keV He^+ beams.

With the development of the second generation GFIS technology, neon ion beam was made commercially available on the Orion NanoFab systems. Ne^+ ion has an atomic mass around 20 much heavier than He^+ (4) and way lighter than Ga^+ (69.7). The sputtering rate of Ne^+ is moderate when milling materials. This is an ion species that is inert, leaving no residues in material after processing (no contamination) and can still introduce significant sputtering to be used for materials processing, but not as damaging as Ga^+ ion does. Recent work in nano fabrications with Ne^+ beams has shown great value of this newly available focused ion beam in processing materials in sub-micron to nano scales.

To investigate the benefit of Ne^+ beam in polishing TEM liftout samples, we designed a mechanism to realize TEM sample preparation on an Orion NanoFab multibeam focused ion microscope. With a micromanipulator and a GIS installed onto a NanoFab system that contains two columns, Ga^+ column and He^+/Ne^+ column (He^+/Ne^+ beams are switchable). A Fin FET DRAM chip was used for TEM sample preparation and then TEM imaging.

As in routine liftout TEM sample preparation, we deposited a Pt layer for sample protection and used Ga^+ ion beam for major cutting. A lamella was lifted out and welded onto an Omni grid. He^+ ion beam was used for imaging purposes in order to monitor the process. After welding the bulk lamella to the Omni grid, initial polishing was still conducted using 30 keV Ga^+ beam for speed. After reducing the lamella thickness to about 600 nm, Ne^+ beam milling takes over. At beginning of this study, only 25 keV Ne^+ beam was used for polishing. Figure 1 shows a thin window (about 50 nm) that was prepared on the lamella liftout from the Fin FET chip, and Figure 2 shows a bright field TEM image taken from the thin window area. Since we just began this study, our plan is to investigate the effect of Ne^+ beam energy and incident angle on the quality of TEM sample including benefit in reducing structural damaging and chemical contamination. Compared to the conventional Ga^+ column, the performance of the GFIS column for He^+/Ne^+ beams is superior, especially at low energy range, meaning that making precise cut and polishing at micron and submicron range using low energy beams become much easier. We will also explore this direction in this study.

References:

[1] F.A. Stevie, C.B. Vartuli, L.A. Giannuzzi, et al, Surface Interface Analysis, **31** (2001), 345-351.
[2] Joachim Mayer, Lucille Giannuzzi, Takeo Kamino, Joseph Michael, MRS Bulletin, **32** (2007), 400-407.
[3] Daniel Fox, et al., Beilstein J. Nanotechnol. **3** (2012), 579–585.
[4] L. Giannuzzi, et al., AVS 58th International Symposium (2011), Nashville.

Figure 1. A Fin FET DRAM liftout TEM lamella sample, a small window thinned with Ne^+ beam.

Figure 2. A bright field TEM image from the thin window area.

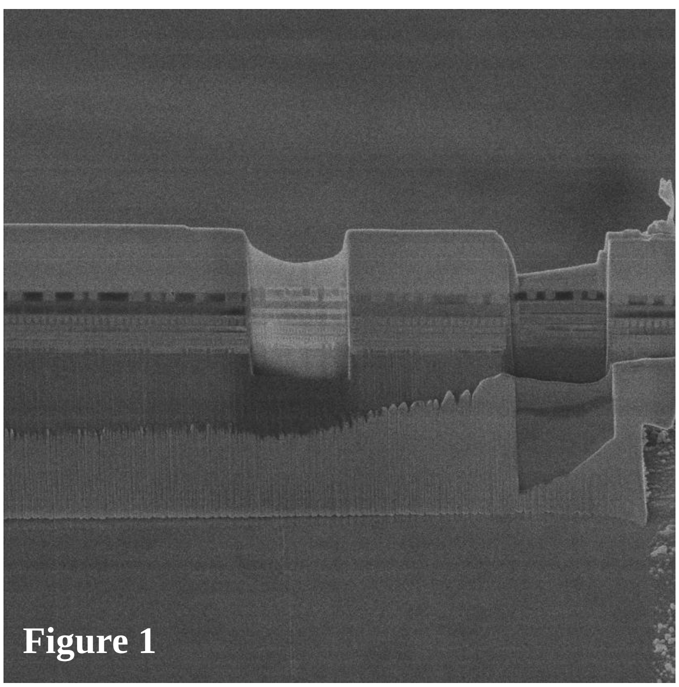
Figure 1

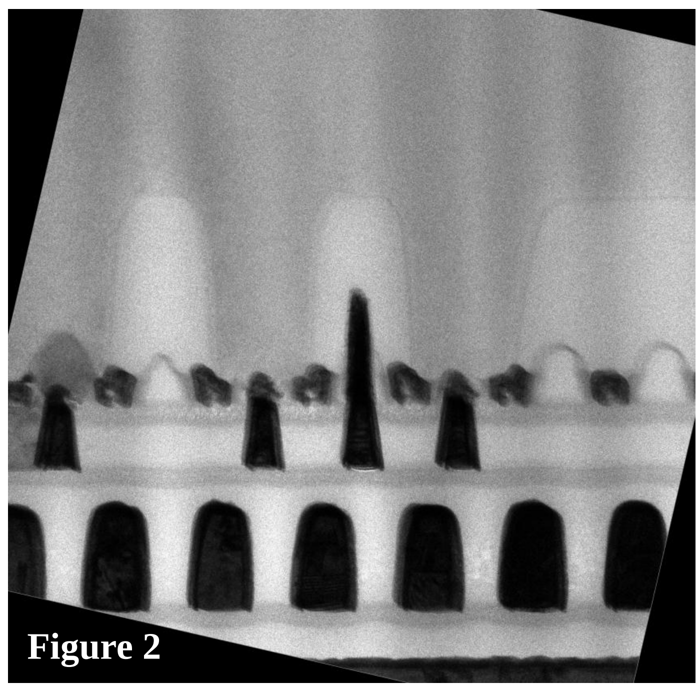
Figure 2

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