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New FIB Fold-Out Method for TEM Cross-Section Sample Preparation

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Sample preparation is an important part of obtaining information from transmission electron microscopes (TEM). Conventional preparation is time consuming therefore other methods have been developed to increase sample output. The focused ion beam (FIB) lift-out technique has become popular due to its site-specific preparation but it requires the use of a nano-manipulator and very sharp probes. To reduce the amount of required equipment, the FIB fold-out method has been developed which does not require curing, TEM grids, fine polishing or nano-manipulators with probes, yet still permits site-specific analysis for a few hours work.

In this study, a wafer's area of interest (AOI) was centered under a disk cutter with a diameter of 3mm. It was then placed on a mechanical polishing holder oriented so that the sample's edge would be polished at an angle, with the device side protruding farther than the backside. The sample was then polished until the edge was a few microns away from the AOI, checked by an optical microscope. The sample was then removed and then polished on its backside to achieve a thickness of 150µm, allowing the wafer to be directly placed in the TEM holder. These steps are illustrated in Fig. 1.

The sample was then placed in the FIB, oriented so that the beam was normal to the wafer's surface. The AOI was found and a platinum protective layer was deposited over the intended target. A deep trench was then ion milled into the sample, leaving the AOI as a tab connected to the substrate by one side. At this point, the sample was taken out of the FIB and reoriented so that the beam was parallel to its surface. The AOI was found again and a line was milled across the tab, which causes the AOI to tilt away from the surface [1]. When the tilt brought the AOI close to the beam, another line was milled further away to bring the AOI parallel to the surface of the sample. Fig. 2 shows a sequence of the rising tab and images displaying their durability. A final thinning was then carried out to make the specimen e-beam transparent. The final product is shown in Fig. 3.

The FIB fold-out preparation method avoids the need for equipment such as the nano-manipulator to create clean, fast, and site-specific samples in a few hours. The full potential of this method can be exploited if devices to be compared are lined up on a wafer. The mechanical polish could then be applied along that line to expose each device to the ion beam, allowing the creation of a series of fold-outs from these devices. Thus, with one TEM sample, comparisons of life-tests or fabrication recipes can be examined and analyzed in a short period of time [2].

References
[1] N. Wang, Microscopy Today, 13 (5), (2005), 38
[2] We acknowledge financial supports by KETI through the international collaboration program of CORSAR (funded by MOCIE).

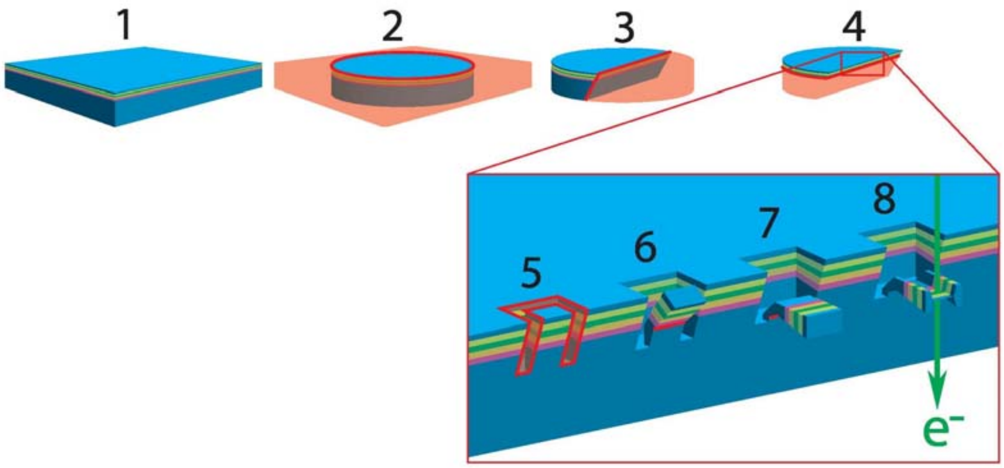

FIG. 1. Illustration of the fold-out method steps: 1. Find area of interest, 2. Cut disk out of wafer, 3. Polish edge of wafer with slight angle, 4. Polish backside of wafer, 5. Ion beam etch sample to create tab, 6. Ion mill line to fold tab, 7. Ion mill a second line to bring tab parallel to wafer surface, 8. Final thinning and imaging in TEM.

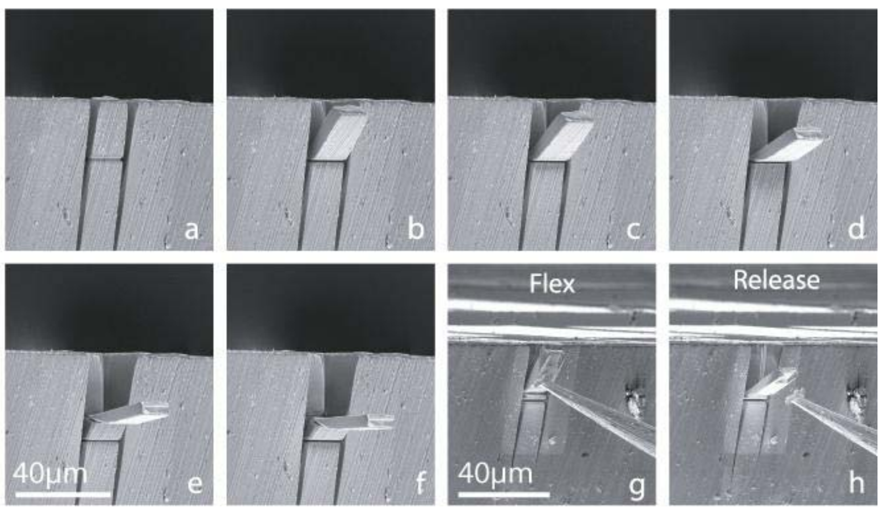

FIG. 2. Sequence of scanning electron microscope images showing the rising tab (a-f) and images of a nano-probe showing the durability of the resilient tab (g, h).

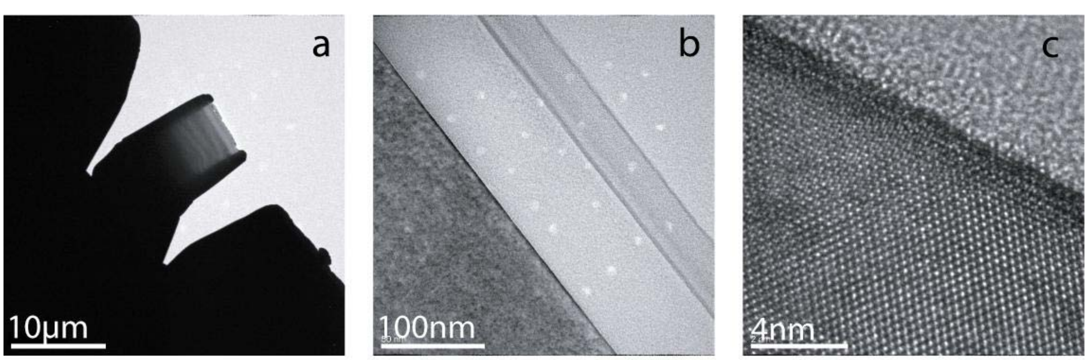

FIG. 3. TEM images of the FIB fold-out sample (a) after final ion beam thinning, (b) in cross-section view revealing the film structure and (c) HRTEM of the substrate showing the interface between the single crystal Si and oxide layer.