Computer-Controlled Polishing System For Preparing Multiple Pre-FIB TEM Specimens

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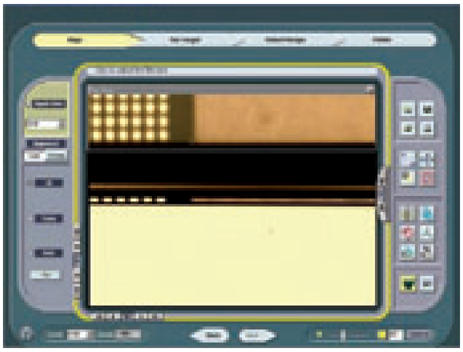
Introduction

Semiconductor manufacturers are increasingly turning to Transmission Electron Microscopes (TEMs) to monitor product yield and process control, analyze defects, and investigate interface layer morphology. To prepare TEM specimens, Focused Ion Beam (FIB) technology is an invaluable tool, yielding a standard milled TEM lamella approximately 15 µm wide, 5 µm deep and ~100 nm thick. Several techniques have been developed to extract these tiny objects from a large wafer and view it in the TEM. These techniques, including *ex-situ* lift-out, H-bar, and *in-situ* lift-out, have different advantages and disadvantages, but all require painstaking preparation of one specimen at a time.

The technique described here, developed by Micron Technology and Gatan, Inc., uses the Gatan's Centar system to improve the throughput of specimen preparation. Using the Centar's computer-controlled polishing process, *in-situ* microscope, CCD camera, advanced image processing and 3D exact angle control, preparation of multiple TEM specimens 12µm thick, ready for final thinning in a FIB, is possible with the time per specimen reduced to roughly 10 minutes for batches of up to 12 specimens.

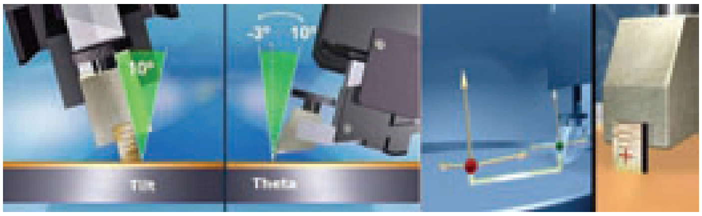


The Centar Specimen Preparation System

The Centar is a computer-controlled polishing platform that integrates microscope, CCD camera and image processing to fully automate specimen preparation, specifically, cross-section (SEM, SCM) and thinning in plan view or cross-section (TEM/STEM) applications.

It has no limitations with regard to material type, structure, shape or minimum size (for example, it can process, as is, specimens as small as 1mm × 1mm). All polishing parameters and the system's components are computer controlled. Users set parameters and recipes using a graphical user interface that allows fine adjustment and very accurate repeatability. Any number of preparation recipes can be created and saved in the recipe bank, allowing multiple users to perform the same process with highly repeatable results, regardless of experience or expertise.

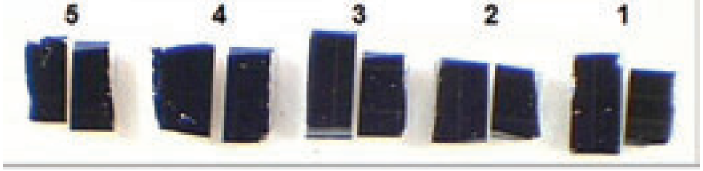
An *in-situ* optical microscope coupled with a CCD camera eliminates the need for the traditional routine of moving between polisher and microscope multiple times. It also eliminates inaccuracies caused by realignment, re-focusing, and re-searching for the preparation target. Images are taken automatically and in addition, the operator can choose to capture any image, at any magnification, at any point in the process. Images can be captured in top view or cross-section, saved, printed, and shared. Angular alignment (z direction) accurate to 0.01 degrees is possible using automated theta and tilt controls. Spatial, x-y alignment, is accomplished using a top-down view and is independent of actual shape or desired specimen placement inaccuracies, allowing polishing parallel or perpendicular to the geometry defined on the semiconductor surface or at any arbitrary angle desired on the surface. Bevel or double bevel polishing techniques may be employed, extending the polishing capabilities further when processing Polyamide, Cu metallurgy, low-K insulators, resist coated specimens, or any package device, among others.



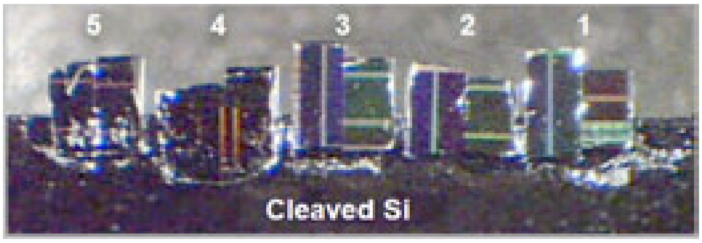
Integrated encoders (the PolishEye system) monitor the polishing process in real time, without the need for an image. This helps make the process more secure and avoids overpolishing, even when polishing rates change because of edge-size, material, or old and new consumable abrasive polishing films. The sophisticated SMPT image processing system offers high accuracy, up to 100 nm. When the user selects a target, the system automatically saves the target image, selects and saves a reference image, and measures the distance from the target to the edge. These parameters allow the system to monitor the process and perform ongoing comparisons to confirm when polishing is complete.

The Centar system is capable of both general and site-specific TEM preparation in cross-section or plan-view, as well as site-specific cross-sectioning for SEM analysis with ~0.1 µm accuracy and high surface quality.

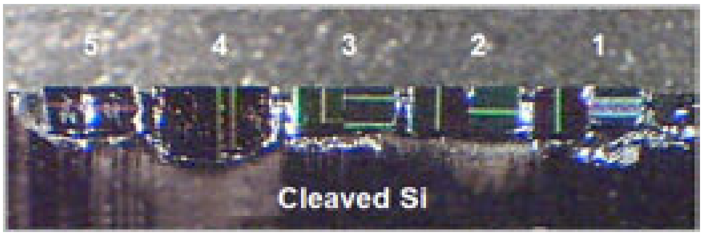
Batch Specimen Preparation



Specimens are cleaved from the wafer to approximately 2 mm wide.

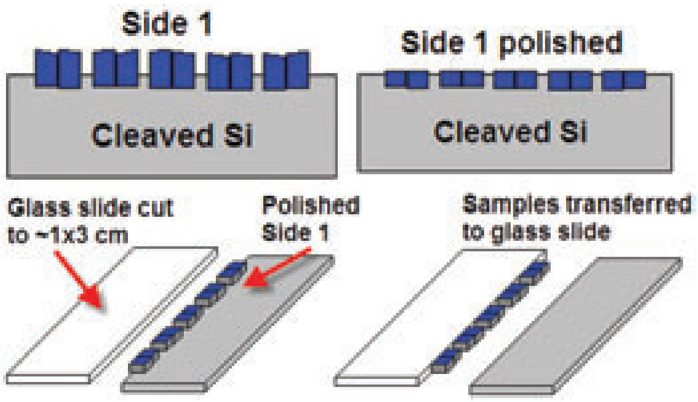


The specimens are affixed in pairs and mounted using hot wax to a cleaved rectangular Si carrier bar.

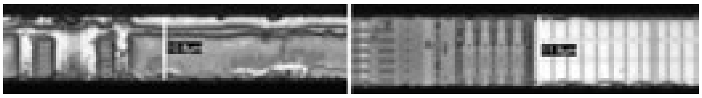


Using the Centar's 3D EAC™ (Exact Angle Control), the Si carrier is aligned and side 1 of all the specimens is polished to the same plane.

The row of specimens is then super-glued to a glass slide. After the glue has cured, the Si carrier is removed by melting the wax away. This transfers the specimens to the glass slide. Shown schematically below



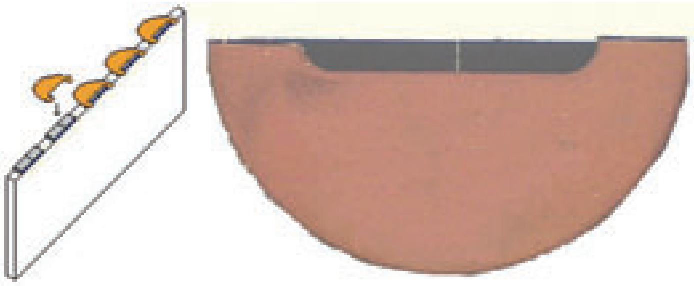
The Centar then aligns the batch of specimens according to Side 1 and polishes Side 2 using edge to edge algorithms and image processing. Polishing stops when the desired thickness is reached, in this case ~12 µm thick. Although tilt control with the Centar is very accurate, there is still a small variation in specimen thickness from one end to the other, usually <4 µm, which will have no negative impact on a pre-FIB specimen except perhaps a slightly longer FIB milling time on thicker specimens.



Left end of specimen row, 3000x *Right end of specimen row, 3000x*

Conclusions

Compared with other methods of TEM specimen preparation for pre-FIB applications, the technique described in this article yields high quality polished specimens in much less time. The Centar provides a highly automated interface that frees the operator to multi-task while preparing multiple specimens.



After polishing Side 2, half grids are glued to each pair of specimens with M-Bond. After the M-Bond is cured, specimens are soaked in acetone to dissolve the glue and float the specimens off the glass slide, left and close-up view of two specimens in half grid carrier.

Considerations

The primary purpose of this technique is for preparing a batch of non-site-specific pre-FIB specimens. It can also be used for site-specific specimens, where Side 1 is prepared either by cleaving or grinding (although this will risk the alignment). The only specimen limitation is cleavability, however, this can be accommodated by using an inexpensive diamond saw to cut specimens down to size. Specimens must be able to withstand immersion in water and acetone and heat up to ~150° C. ■

Specimen Preparation Throughput

Typical elapsed time for each step in specimen preparation:

Step	Process	Minutes
1	Cleaving specimens from wafer and mounting on Si carrier	10
2	Initializing Centar parameters (tilt, theta, target, recipe)	5
3	Polishing up to 12 specimens, Side 1	10
4	Transferring specimens to glass slide carrier	15
5	Initializing Centar parameters (tilt, theta, target, recipe)	5
6	Polishing up to 12 specimens, Side 2, to ~12µm thickness	25
7	Attaching grids to specimens with M-Bond and curing	20
8	Dissolving glue with acetone	10
	Total minutes to prepare up to 12 specimens	100