Ex-Situ "Auto Lift" Technique for TEM Sample Preparation

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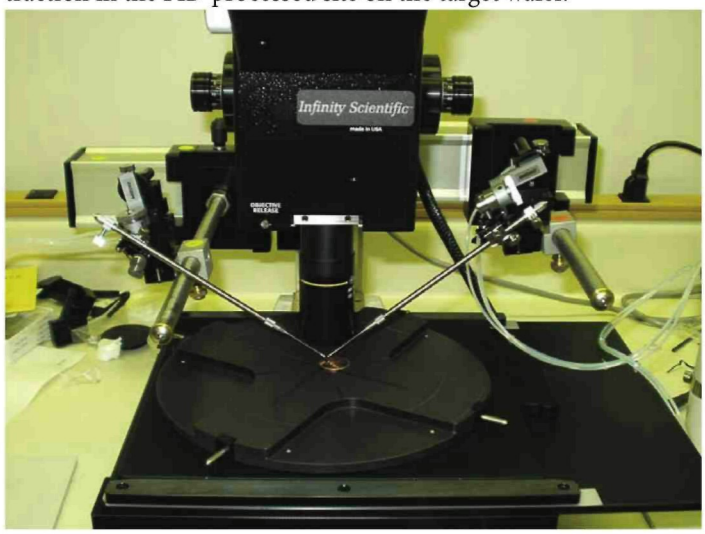
"The most advantageous feature of the ex-situ lift out method is throughput."(1)

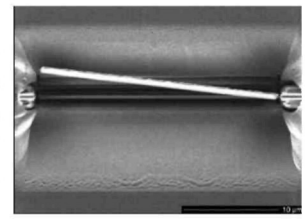
A great deal of emphasis is placed on "throughput" in the microprocessor industry. Wafer sizes are getting larger and the costs of building them have increased astronomically. The transmission electron microscope (TEM) has become the essential tool for examining current microprocessor products. The TEM can only be effective if it has properly prepared specimens to put into it. In order to achieve the highest specimen preparation spatial resolution, the microprocessor industry has turned to focused ion beam (FIB) tools, either single or dual column, for TEM specimen preparation in applications ranging from process control to failure analysis, and on to semiconductor device metrology. With the use of these tools, the birth of the ex-situ lift out (EXLO) FIB specimen preparation method became an important technique for delivering thin, site-specific specimens to a TEM grid, and ultimately to the TEM for analysis. As the quotation says the rapid EXLO method is the most advantageous for its throughput.

In addition to throughput advantages, the EXLO technique is done outside the FIB. It is a stand-alone tool set that is generally situated near the FIB. A single EXLO set-up can service several FIB tools and increases throughput, and saves expensive FIB time, by taking the specimen retrieval and grid mounting operation out of the FIB tool and performing it "ex-situ."

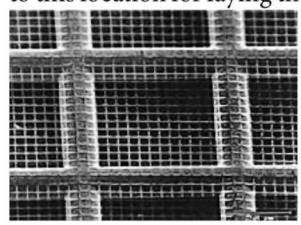
In this article we discuss how we have increased the EXLO method throughput significantly via the automation of our stages and the use of a programmable nanomanipulator that controls the thin glass tips that retrieve the thin membranes by electrostatic attraction in the FIB-processed site on the target wafer.



Some FIB tools are able to accommodate an entire wafer and creating a number of TEM membranes ready to be picked up and mounted on grids. In some cases this FIB multiple specimen preparation capability can be performed using automation packages that come with the FIB. Once the thinning is done and the membranes are cut free (See inset on right, below), the wafer can be removed from the FIB and placed on the EXLO system stage. The programmable EXLO stage can traverse about on the wafer and pick up the thin samples. This in itself speeds the process up considerably. Remember "time is money" and looking for the prepared sites can be tedious and time consuming. Using the automated nanomanipulator, the EXLO glass tip can be put into lift-out position over the prepared specimen without the intervention of an operator.



Once the tip has traversed to the prepared site and is in the "ready position," the sample can be lifted out and placed on a TEM grid. The motorized stages have a special location where the TEM grids are placed ready to receive the specimen. The nanomanipultor glass tip, carrying the specimen, can be programmed to move to this location for laying the specimen on the pre-positioned grid.



The grid position location can be rotated to give the operator the ability to place several samples on one grid. This saves time and allows for TEM inspection of several samples in one TEM session. The TEM grids used are a 400 mesh carbon or formvar coated grids. The new Quantifoil grids (See adjacent inset) do not have a carbon or formvar film over the grid holes. The samples are suspended over the small grid holes, which is more desirable for getting maximum image resolution in the TEM.

Key elements of the EXLO system include an automated microscope with an extra long working distance (19mm) and an auto zoom feature that extends the magnification range from 75x to 3200x, the precision motorized stage with a software controlled interface, and the auto-nanomanipulator.

In conclusion the new "Auto Lift" EXLO method increases throughput significantly compared to in-situ units. There is simply no faster method than the "Auto Lift." In many cases, the target wafer is minimally disturbed and may often be put back into the production facility for further processing. ■

Reference:

(1) L.A. Giannuzzi et al., "FIB Lift-Out Specimen Preparation Techniques", in Introduction to Focused Ion Beams: Instrumentation, Theory, Techniques, and Practice, L.A. Giannuzzi, F.A. Stevie (eds), Sprintger-Verlag New York, 201 (2004).