Application of the new CrossBeam® Technology to extend Accuracy in Site Specific Cross Sectioning and TEM Sample Preparation

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Introduction

The use of the focused ion beam (FIB) systems has increased to a high level in recent years [1]. The imaging, milling, and deposition capabilities of the FIB make it the ideal instrument for e.g., site-specific failure analysis, specimen preparation and nano-machining. Ion channelling contrast allows for selective imaging of polycrystalline and poly-phase microstructures. In addition, the FIB and CrossBeam® instruments are unique stand-alone analytical tools. Their vast capabilities have enabled numerous applications into the semiconductor and materials analysis fields.

System Layout

Through the combination of the outstanding imaging capabilities of the Gemini field emission SEM with one of the most sophisticated FIB columns (the Canion 31) into one integrated instrument the new LEO 1500XB Series CrossBeam® workstations open up a new dimension in the field of nano-technology, semiconductor and materials science applications.

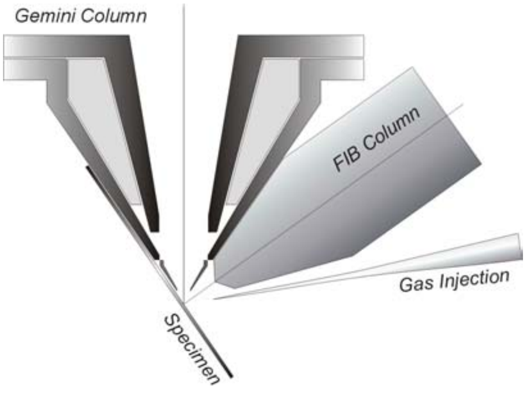

Fig. 1: Schematic layout of the LEO 1500XB with Gemini lens, FIB column and gas injection.

Together with a versatile gas injection system for metal and insulator deposition and for enhanced and selective etching the CrossBeam® workstation is a very powerful analytical and imaging tool for a wide range applications.

SEM Cross sections

Cross sectioning in a standard FIB workstation is basically a blind process. The sample surface is imaged with the FIB before cutting to determine the area of interest. Afterwards the sample is milled and polished with a predefined milling pattern. Without the possibility of monitoring the milling process directly the area of interest can easily be destroyed.

The unique capability of CrossBeam® tools to image the sample in real time at high resolution during the ion milling process gives the operator a direct interactive control to the ion milling process. This results in an extended accuracy on site specific cross sections. The milling and polishing process can be directly imaged and stopped exactly at the detail of interest (FIG.2).

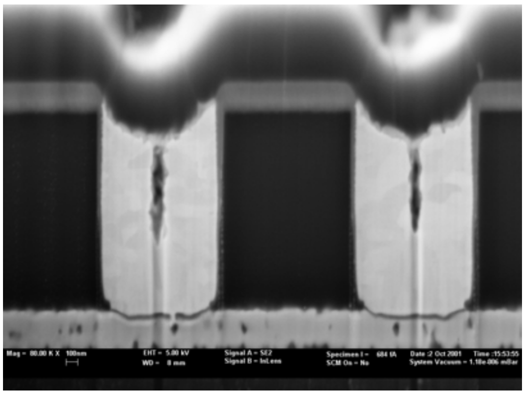

FIG. 2: Cross section through tungsten plugs in a semiconductor device. The milling process was stopped exactly in the centre of the plugs.

Especially in the case of TEM sample preparation the danger of destroying the fine lamella is reduced to a minimum.

Another advantage of the CrossBeam® technology is the time saving cut and see operation: The sample is imaged during or immediately after the polishing. This results in extremely short inspection times for each cross section.

TEM Sample Preparation

Several TEM sample preparation techniques using FIB, such as pre-thinning (FIG. 3) and lift-out techniques (FIG. 4, 5) have been published [2-3]. The FIB lift-out technique allows thin membranes to be extracted from bulk material, which saves a lot of sample pre-thinning time and is very successful in the preparation of site specific cross sections and planar samples. However TEM sample preparation can be automated by using scripts and macros the best accuracy is achieved if the milling is done manually with direct SEM observation. (Keep in mind that an automated process is a blind process). In a first step the sample is milled and polished from the front side under continuous SEM control until the detail of interest is visible. In the second step the sample is rotated by 180° and the backside of the sample is milled and polished under continuous SEM control until the desired thickness is achieved (FIG. 3).

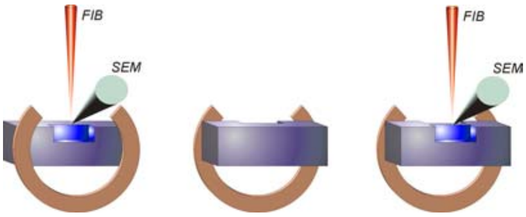

FIG. 3: Steps for a pre thinned TEM sample preparation using the CrossBeam® technology. In step 1 the sample is milled and polished from the first side under continuous SEM control. In the second step the sample is rotated by 180° and the backside of the sample is milled and polished under continuous SEM control until the desired thickness is achieved.

By imaging the TEM sample in the SEM the danger of destroying the TEM lamella due to drift etc. is minimized. Another opportunity of the direct SEM imaging is a very straight control of the specimen thickness and electron transparency during the ion milling process.

The best result concerning time and accuracy is achieved if different samples are pre-thinned automatically overnight to a thickness of about 1µm and then polished manually under high resolution SEM observation.

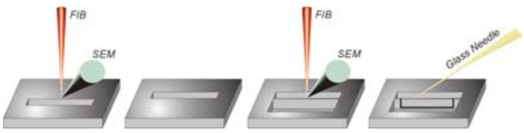

FIG. 4: TEM lift out sample preparation using the CrossBeam® technology After the final polish the lamella is cut out of the substrate by three cuts and is transferred to a TEM grid by use of a micromanipulator and a glass needle.

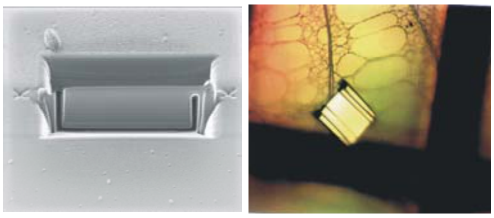

FIG. 5: TEM lift out sample after milling and polishing (left), and after the transfer to a TEM Grid (right).

References

[1] J. Orloff, Rev. Sci. Instr. 64, 1993, p. 1150 ff

[2] L. R. Herlinger, S. Chevacharoenkul, D. C. Erwin, ISTFA 1996, p415

[3] R. Rai, S. Subramanian, S. Rose, J. Conner, P. Schani, J. Moss, ISTFA 2000, p415