microPREP™ PRO - Workflow for High-Throughput TEM Sample Preparation

Introduction

Current and future semiconductor technologies, particularly in transistor manufacturing processes, require stringent process control with nanometer or even sub-nanometer resolution. As a result, transmission electron microscopy (TEM) has become an indispensable tool for IC metrology and failure analysis. Since the insights gained from TEM analysis is closely linked to the quality of the samples under investigation, sample preparation is of utmost importance to the overall semiconductor fabrication process.

Motivation

To enable TEM at the highest possible level, samples should ideally be ultra-thin, mechanically stable, and free of artifacts. In the case of IC metrology, the TEM sample should also be fabricated with high throughput and low cost of ownership. Currently, obtaining high-quality TEM samples requires expensive high-end tools such as focused ion beam (FIB) workstations, which have to be operated by experienced users as part of a closely intermeshed workflow.

Mechanical saw dicing of samples has been well established in IC metrology for decades, and mechanical saw dicing of structures for bulk thinning, followed by FIB for final thinning to electron transparency, is still the standard process for sample preparation used in fabs around the world. However, this process is extremely slow for preparing complex structures, such as H-bar cross-sectional specimens. In this case, a significant amount of FIB capacity is wasted in excavating several hundred microns worth of material from the bulk sample in order to create an H-bar structure that is approximately 80-100 µm wide.

Laser-Based Approach to High-Throughput Sample Preparation

microPREP™ PRO was developed jointly by 3D-Micromac and Fraunhofer IMWS to improve and accelerate TEM sample preparation in IC metrology as well as material sciences, with ablation rates up to 10,000x greater compared to FIB. In addition to having a dedicated workflow for bulk samples or in-plane geometries, microPREP offers a unique technology for preparation of site-specific H-bars (XL-Chunks™) having lengths ranging from several hundred microns up to 3 mm. Using the novel piezo-driven stage in microPREP, fully automated sample preparation at multiple positions is feasible. On each sample chunk, single or multiple regions of interest can be thinned to thicknesses of less than 15 µm (Fig. 1 and 2) using ultra-short laser pulses, which leave laser-affected zones of typically less than 1 µm.

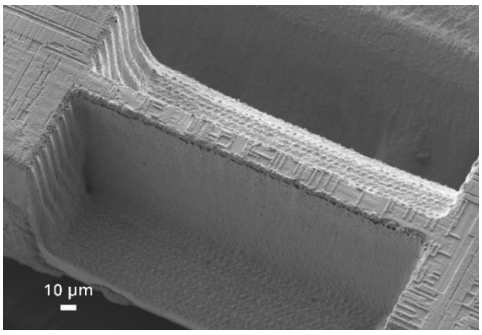

Fig. 1: SEM micrograph of the thinned area of an XL-Chunk prepared from an IC sample

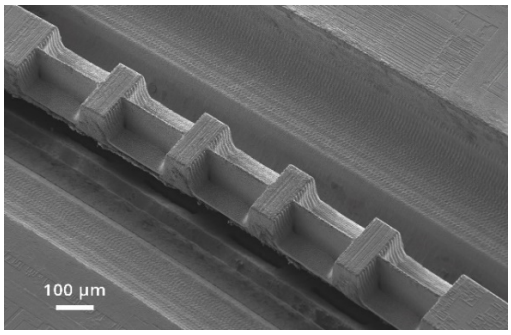

Fig. 2: SEM micrograph of an XL-Chunk prepared from an IC sample that has been thinned at multiple positions

In contrast to mechanical sawing, which can burst or tear the fragile H-bar structure, microPREP is minimally invasive since it can prepare H-bar structure samples at arbitrary positions or orientations from the raw material without any restrictions. Each XL-Chunk is securely kept in place by supporting structures (Fig. 3) until it is extracted from the sample surface using tweezers and glued onto a standard copper half-ring.

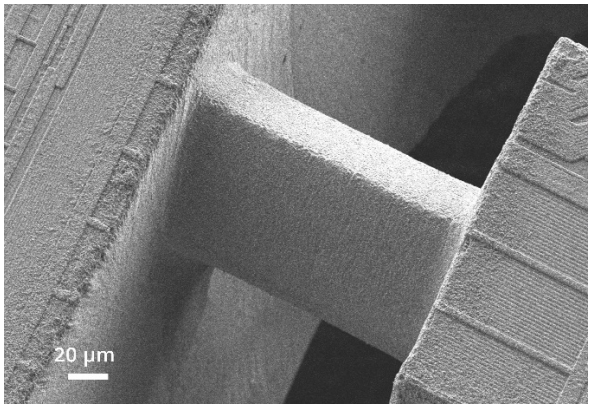

Fig.3: SEM micrograph of the supporting structure of an XL-Chunk

In addition to enabling the preparation of samples with a wide range of geometries and shapes, microPREP leaves ultra-clean sample surfaces after laser micromachining, which is key for ensuring curtaining-free FIB post processing and, thus, the final quality of the sample. In fact, the user can choose between using temporary protective layers to protect the surface from debris or unique in-situ-cleaning utilizing a CO_2 snow jet integrated into the microPREP tool.

Conclusion

microPREP offers fast and reliable TEM-sample preparation for process development, process control, as well as failure analysis. Its inherently high compatibility to well-established workflows in IC metrology leads to a significant reduction of FIB capacity and thus shorter time to sample, making microPREP a valuable tool for semiconductor manufacturing.

For more information, visit https://3d-micromac.com/laser-micromachining/products/microprep/.

Contact:

3D-Micromac AG

Technologie-Campus 8
09126 Chemnitz, Germany

Phone: +49 371 40043-0
E-Mail: sales@3d-micromac.com
Website: www.3d-micromac.com