Analytical Answers

The Information You Need...When You Need It.

Focused Ion Beam (FIB) Milling

The Focused Ion Beam (FIB) technique is analogous to Scanning Electron Microscopy (SEM) in that it scans a focused probe beam, in this case ions rather than electrons, across the surface of interest. This beam can be used to generate high-resolution images of the sample or to mill into the sample to expose the internal structure. This combination of high-resolution imaging to locate features of interest followed by precise site-specific milling provides an invaluable tool for sample preparation and analysis, providing rapid cross-sectional analysis of features that would be difficult or impossible to otherwise prepare. Because of this, the FIB instrument is often used as a sample preparation tool for more complete characterization using Electron Microscopy.

How it Works:

A beam of finely focused gallium ions is accelerated and impacted on the sample surface. The interaction of this energetic beam with sample produces secondary electrons and sputtered ionized and neutral atoms. Images can be produced by scanning the beam across the surface and detecting the secondary electrons or ions as a function of position, in a fashion identical to that used in Scanning Electron Microscopy. In addition to topographic images with high depth of field, FIB images can also show contrast associated with different crystal orientations in polycrystalline materials. An example of this, termed channeling contrast, is shown in Figure 1.

Relatively low ion beam currents are used for imaging to minimize sample damage. Higher ion currents result in more rapid sputtering of the sample and are used to mill into the surface to expose the cross-sectional structure. In this milling mode, we use the ion beam to cut trenches or craters into the sample, to give precise, smooth cuts for subsequent imaging analysis, either directly in the FIB instrument or after transferring to a Scanning Electron Microscope. An example of a typical milled area is shown in Figure 2. The use of an in-situ mechanical manipulator also provides the capability of producing and extracting ultra-thin electron transparent sections (Figure 3), which can then be analyzed using Scanning Transmission Electron Microscopy for ultra-high resolution analytical microscopy. The combination of FIB and SEM/STEM is particularly powerful for characterizing the morphology and composition of layered structures and buried defects.

The FIB instrument also is equipped with gas injection systems, which provide the capability for enhancing the milling rate through gas-assisted etching, or alternatively, to deposit material on the sample thru ion beam induced metal deposition. Metal deposition is commonly employed to deposit a protective coating on the surface prior to ion milling to preserve surface structure.

FIB applications include:

Materials Evaluation

- Process Development
- Protective Coatings
- Inclusions
- Gran size distributions
- Layered structures
- X-sections of hard to polish materials
- Micromachining

Failure Analysis

- Precise sit-specific cross-sections
- Delamination
- ESD damage
- Sub-surface contamination/defects

Quality Control

- Layer thickness
- Etch profiles
- Step coverage and conformality

Data Presentation:

FIB images are displayed on the instrument control computer monitor in real time. Digital images are captured and saved and associated software can be used for making various dimensional measurements.

Sample Constraints:

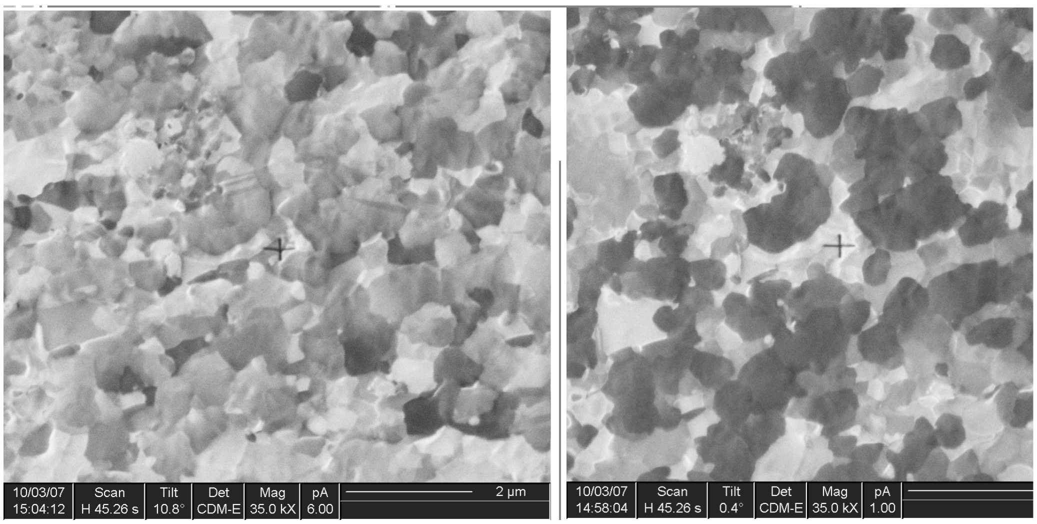
The chamber can accommodate a sample approximately 3 inches in diameter. The maximum height of a sample is on the order of 1 inch. Typical samples we mill are usually no bigger than a few centimeters in diameter.

As in all vacuum techniques, samples must be vacuum compatible (< 1e-4 torr) and in addition must be stable under ion bombardment.

As a practical constraint based simply on achievable milling rates, FIB cross- sections are limited in their physical dimension. Typical cross-sections are < 100um in length and several microns in depth.

Figures:

Figure 1: FIB secondary electron images of a copper surface showing channeling contrast produced by different orientations of the various grains to the incoming ion beam. Images are the same field of view, but the image on right was taken after the sample was tilted 10 degrees. This tilt changes the crystal orientations to the beam and produces a dramatic change in the image.



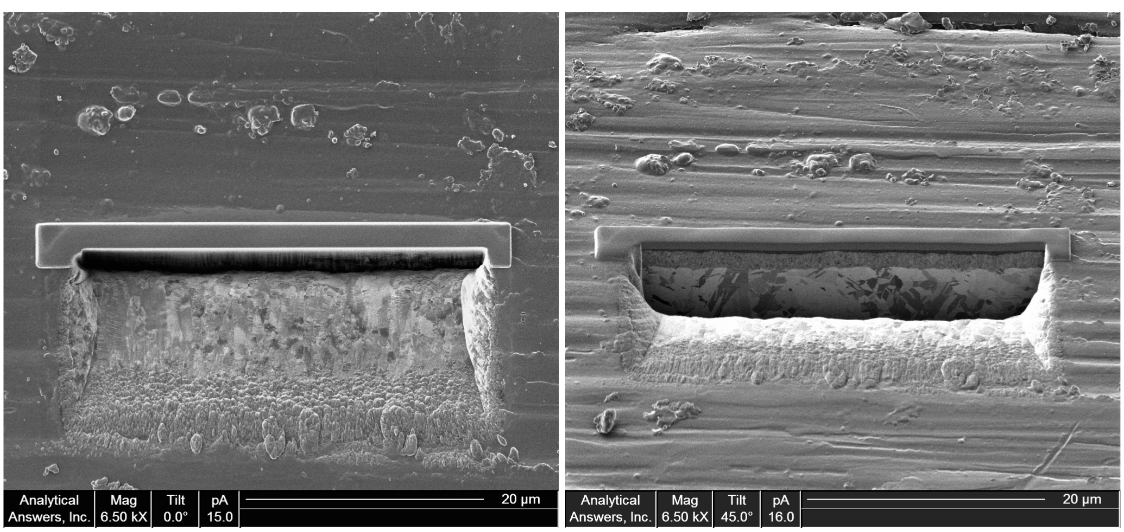


Figure 2: FIB milled cross-section on a printed circuit board edge connector. Left image is taken after milling and shows the milled area as well as the protective metal strap deposited using the ion beam. Right image is after tilting the sample 45 degrees to expose the cross-section face. Metal layers in the connector show channeling contrast.

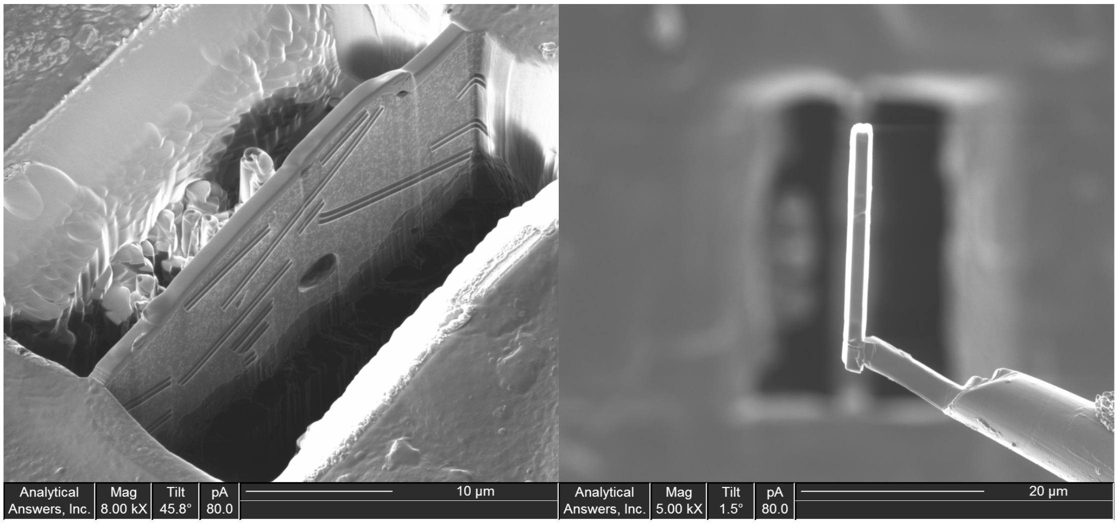


Figure 3: Thin section FIB sample prep for Scanning Transmission Electron Microscopy (STEM). Sample is milled from both sides to form a thin section containing the area of interest (Left). Using an in-situ manipulator, the section is removed from the sample (Right) and will be mounted to STEM sample holder for final thinning.