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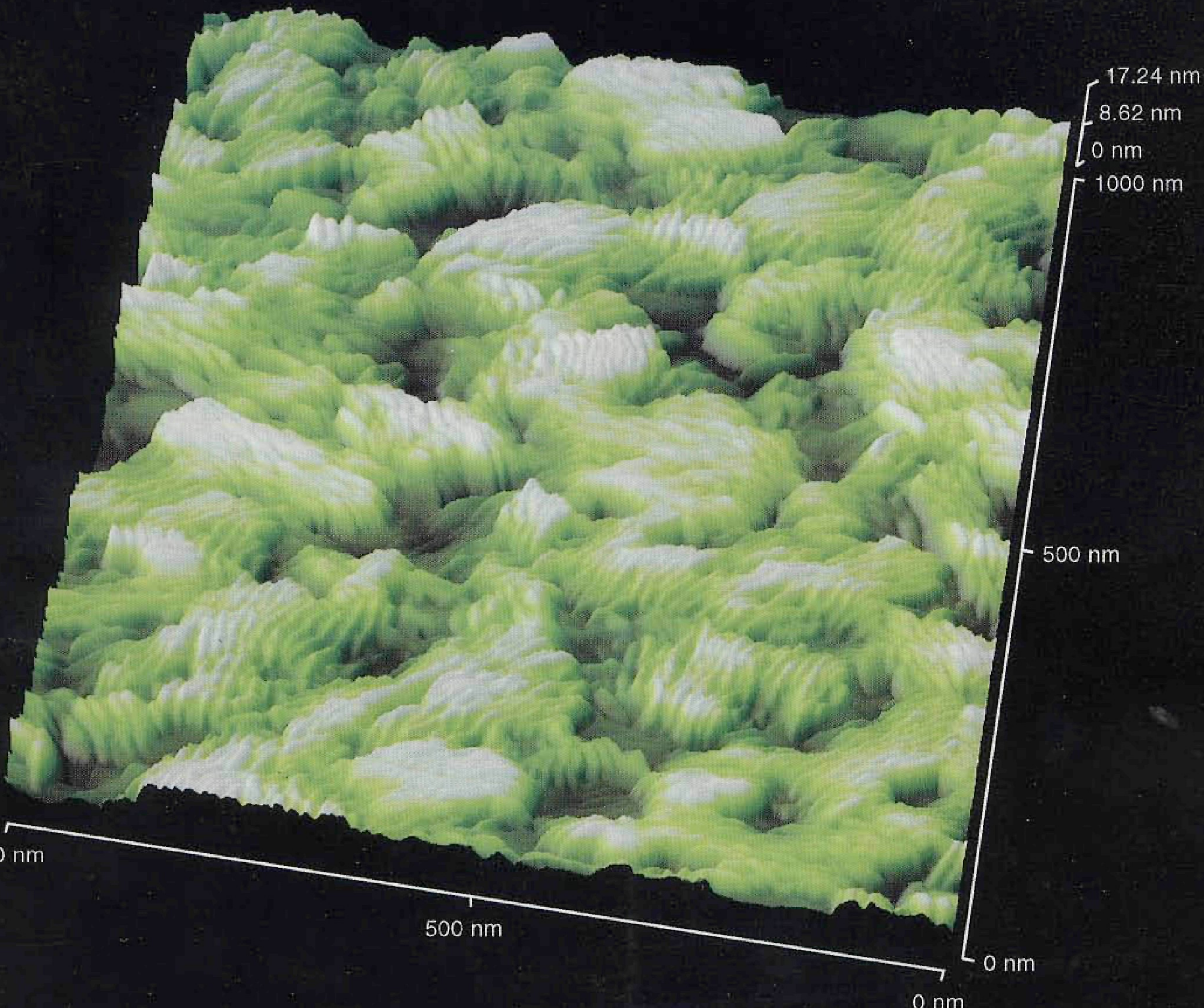
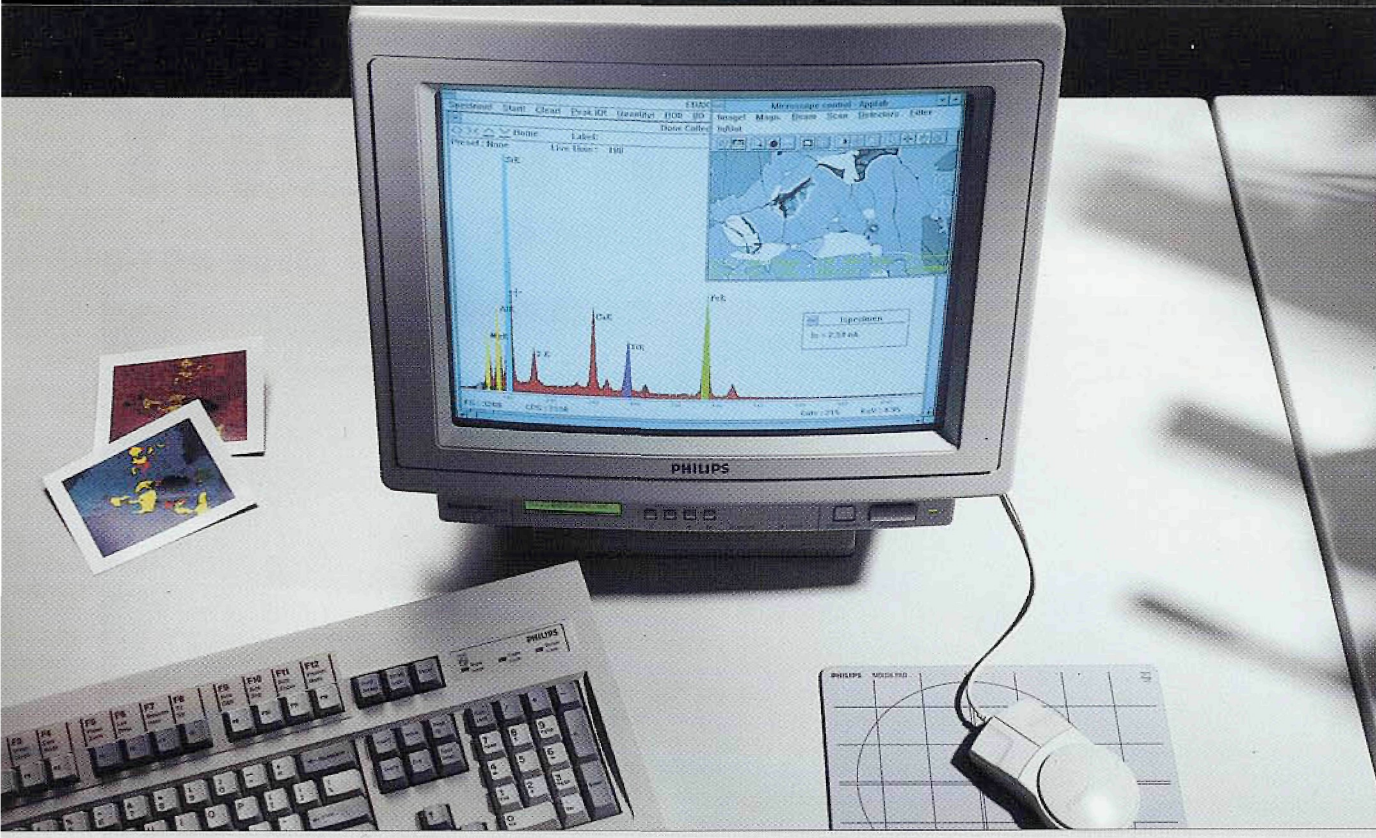


Titanium-Tungsten Grains


PHILIPS

FIB "Microsurgery" Part 1: A Sample Preparation Tool for the Microscopist

Dave Laken, FEI Company, Hillsboro, Oregon.

For sample preparation, e.g. cross-sectioning and thinning, SEM and TEM microscopists routinely use mechanical techniques (e.g., cleaving, slicing, lapping, polishing, and microtoming) and chemical or broad beam ion thinning. Two problems they run into are (1) locating the site of and cross-sectioning or thinning at the site of extremely small features at specific locations (site specific samples) and (2) dealing with materials and material systems that are altered or destroyed by mechanical sample preparation (material-specific samples). These material systems may contain multiple components with dramatically different characteristics, such as hardness or chemical reactivity.

Many of these limitations can be overcome by using focused ion beam (FIB) micromachining, often referred to as "FIB microsurgery." This technique can locate micron and submicron features and use precisely placed cuts to cross section and thin samples. The FIB ion beam has a sub 10-nanometer diameter and can be placed with better than 0.1-micron accuracy.

FIB has become widely available to the microscopy community through laboratories that offer FIB services on an hourly or per-sample basis. We talked to several contract analytical laboratories using FEI FIB Workstations about these two classes of samples.

Site-specific samples are encountered in TEM sample preparation for the semiconductor industry. The FIB technique's ability to locate submicron features and precisely place line and pattern cuts is very important. This class of samples will be discussed in detail in Part 2 of this article series.

Material-Specific Samples

Preparation of material-specific samples is of growing interest at the laboratories we spoke to. They provided us with a list of examples of materials that are difficult or impossible to prepare using traditional techniques:

- IR detectors with soft, thin indium phosphide layers.
- Gallium arsenide ICs. Gallium arsenide is both brittle and soft.
- Microwave devices containing gold layers. Gold smears using conventional preparation techniques, and selectively etching the gold layer introduces undesirable artifacts.
- ICs with polyimide layers or photoresist (more difficult than gold).
- Fibers being studied to characterize a metallic coating or dye penetration. Microtoming a fiber is likely to destroy it.
- Thin-film print and magnetic media heads with thin layers of soft material.
- Abrasive materials, e.g. diamond particles in a cobalt matrix.
- SOG (spin on glass), a physically weak layer that may delaminate during polishing.
- SOS (silicon on sapphire) because sapphire is very similar to alumina, severely limiting the materials used for polishing.
- A dielectric multi-layer laser mirror containing an array of materials, where one component would be eroded away before the other component becomes sufficiently thin.

FIB milling can prepare these material-specific samples because the focused beam interacts differently with the material than conventional techniques.

A thin fiber can be prepared as the ion beam size is small in relation to the fiber size, and the momentum transfer of the ions is miniscule compared to the action of a microtome. These factors keep the fiber intact without shredding it into many, smaller fibers.

Ions in the beam do not sweep or drag across the sample like in a mechanical grinder. Each ion sputters a vertical section, and new ions sputter the adjacent vertical section. A grinder has the same piece of grit shearing across adjacent sections and can pull layers apart or smear material. There is no shear force in FIB sputtering.

Any technique for sample preparation relies on removing the material at the face of the sample. The removal rate depends strongly on the technique used and on the properties of the material, e.g. hardness or chemical reactivity. For example, sapphire is, in general, removed significantly slower than aluminum. FIB can remove the effects of different erosion rates for different materials by placing the beam only where material is to be removed. All materials are removed in this area and none outside it. Grinding techniques cannot help remove soft material in preference to the harder material around it.

The list of difficult materials was compiled from discussions with people at laboratories offering FIB analytical services and sample preparation. We appreciate their help:

- Jay Glanville, President of F.A.S.T. in San Jose, CA, phone: (408) 398-1372.
- Giorgio Riga, President of Riga Analytical Lab, Inc. in Santa Clara, CA, phone: (408) 496-6944.
- Alan Street, President of Integrated Reliability Services in San Diego, CA, phone: (619) 658-9770.
- David Su, Electron Microscopy Specialist at the Materials Analysis Group in Sunnyvale, CA, phone: (408) 991-4798.
- John Walker, Applications Specialist at FEI-Europe's Laboratory, Cambridge, U.K., phone: 44(0) 1954 250526.
- Scott Wills, President of BEAM-IT in Dallas, TX, phone: (214) 446-9203.
- Tracey Woodward, FIB Applications Engineer at Materials Analytical Services in Raleigh, NC, phone: (919) 829-7041.

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Front Page Image
Titanium-Tungsten Grains

The image on the cover is a 1 μm x 1 μm image of Titanium Tungsten (TiW) film imaged with a Voyager™ AFM from TopoMetrix Corporation. TiW is typically used in semiconductor processing as a barrier film between oxide and metal layers. It improves electromigration properties of metal film. TiW film has very fine surface features and cannot be easily imaged by SEM, while AFM is readily used to characterize it. The sample and image is courtesy of Milind Weling, VLSI Technology, San Jose, CA 95131.

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