FIB Tomography of an Integrated Circuit

FIB tomography has become an important tool for studying materials at the micro and nano scale. Unlike a single cross-section, FIB tomography gives better understanding of the volume distribution, 3D structure and the relationship between three dimensional objects. TESCAN FIB-SEMs can be equipped with 3D Tomography - an optional software module for automated data acquisition and reconstruction.

Introduction

FIB tomography is a method specific to FIB-SEM systems such as LYRA3 or FERA3. It is based on serial SEM imaging of FIB-prepared cross-sections and subsequent 3D reconstruction and visualization (see Fig. 1). All the necessary steps are fully automated in the new 3D Tomography software module.

Experimental Conditions

For the present example, a piece of an old broken CPU (180 nm technology) was used. The analysis was performed with a LYRA3 XM – a high resolution FIB-SEM system. The TESCAN backscattered electron detector was used for the imaging of slices because it provides material contrast. For the acquisition, the voxel size was set to 55 nm for all Cartesian axes (z size - slice thickness).

3D Tomography Software Module

The 3D Tomography software module is a fully integrated part of the TESCAN control software.

The module consists of the following parts:
- Milling and image acquisition wizard
- Data post-processing
- 3D reconstruction and visualization

Data Acquisition

The Acquisition Wizard guides the operator to set optimal milling and imaging parameters. The region of interest is selected in the FIB window and some parameters related to milling conditions, number of slices and resolution have to be set (Fig. 2).

Fig. 1: Schematics of the FIB tomography technique. The selected volume is sliced into slices of defined thickness by means of a FIB. A SEM image acquisition is performed for each slice.

Fig. 2: Data acquisition wizard: a) Volume selection in the FIB image. b) Control of the process.

Fig. 3: The preparation of a 10 × 10 × 10 μm³ cube for tomography consists of three automated steps. a) A Pt protective layer is deposited upon a surface to prevent surface damage and to provide good contrast for reconstruction. b) Rough milling of the trench to reveal the cube. c) Final polishing of the cross-section.
Automated Ion Milling & Image Acquisition
The first step in the “preparation” consists in creating an optional protective layer, milling a ditch of the given depth and preparing a polished initial cross-section (Fig. 3). The ditch size is set automatically in order to prevent estimated redeposition effects and geometrical shadowing of the cross-section. A protective Pt layer is deposited in some cases, e.g. when a precise surface profile reconstruction is required, and in other cases can be switched off.

The second step starts from the initial cross-section. A sequential process of milling away thin slices of material followed by SEM image acquisition. The tilt correction, image shift and focus are re-adjusted automatically in order to keep the image of the polished surface at the center of the view field. The whole process of data acquisition for a volume of approx. $10 \times 10 \times 10 \, \mu m^3$ can take about 2-3 hours (depending on the selected milling conditions).

Data Post-Processing
The acquired series of images are not always suited for a direct visualization without post-processing. This is why the images can be cropped, realigned and some additional filters can be applied (shading correction, median, etc).

3D Visualization
Various visualization methods are available. The module can load a series of grayscale images or import raw binary data (dimensions, scale and file format are given by the user).

There are several visualization methods:

- **Isosurfaces**
  Multiple isosurfaces of different colors and transparencies can be shown. High-quality images are required for this method (low noise). (Fig. 4)

- **Direct volume rendering**
  In direct volume rendering the color and opacity depends on the brightness value in the image. This algorithm is not so sensitive to noise or gradual changes in brightness as the isosurfaces method. (Fig. 5)

- **Slices**
  Multiple slices can be displayed, either aligned to a major axis or taken at arbitrary angles. A different color map (palette) can be attached to each slice. The slices can be opaque, transparent to a given threshold or their transparency can be defined in the color map. (Fig. 6)