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FIB sample preparation for X-ray microscopy and ROI target cross-sectioning

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X-ray imaging and X-ray computed tomography (XCT) provide non-destructive characterization capabilities on specimens across a range of length scales, observing features with sizes spanning from millimeters over micrometers down to several 10 nanometers. X-ray microscopy - with focusing lenses - and nano X-ray tomography are the techniques of choice for two- or three-dimensional inspection of small sized objects and objects' interiors with a resolution well beyond that of light microscopy. These techniques reveal structural characteristics and flaws, such as cracks and pores, or features with different composition. There is a wide variety of applications in materials science and engineering, life science, geoscience and microelectronics [1].

Laboratory-based X-ray microscopy with focusing lenses – e. g. Fresnel Zone Plates – enables a spatial resolution of about 50 nm. The maximum thickness of the sample depends on the used photon energy and the respective attenuation lengths of the constituent elements and compounds. For example, the sample has to be have a thickness of < 100 μm to be transparent for Cu-Kα radiation (8.05 keV). The preparation of the sample often is usually time-consuming, since it includes several preparation steps, depending on the kind of samples: mechanical preparation (sawing, grinding, polishing), chemical preparation (etching), laser beam ablation and/or Focused Ion Beam (FIB) milling. Since usually large amounts of sample material have to be removed, either plasma FIB or FIB in combination with (prior) laser beam material removal are used. Figure 1 shows an image of a sample with a cross-section of about 50 μm x 50 μm, which was prepared for nano XCT studies.

For the evaluation of metal interconnect structures in 3D IC stacks with Through Silicon Vias (TSVs) and micro bumps, nano XCT is a suitable technique which has the potential to be applied in process development and failure localization. It was shown in particular, that voids in Cu TSV with a size of about 100 nm can be visualized using nano XCT [2]. For a more detailed failure analysis, target FIB cross-sections through the region of interest (ROI) have to be made, and SEM images with nm resolution have to be taken. Figure 2 shows virtual cross-sections through a Cu-TSV based on a (nondestructive) nano XCT study. Voids in the range of 100 nm are clearly visible. After identifying the voids, a more detailed (destructive) SEM/FIB study – see Figure 2 - reveals more (smaller) voids [3]. This subsequent study is necessary to determine the root cause of the void formation.

For the SEM characterization of these cross-sections again often a large amount of material has to be removed. Common options are the use of Plasma-FIB or the combination of laser ablation and FIB [4,5]. It is important to mention that in the latter case the material that has to be removed by FIB milling in the final preparation step depends on the sample composition and on the wavelength of the laser used.

In addition it is to mention that the ROI target preparation at a position (e. g. a defect) of a usually opaque sample, that has been identified using nano XCT, requires a shuttle and navigation solution. Concepts for this navigation and preparation steps will be explained.

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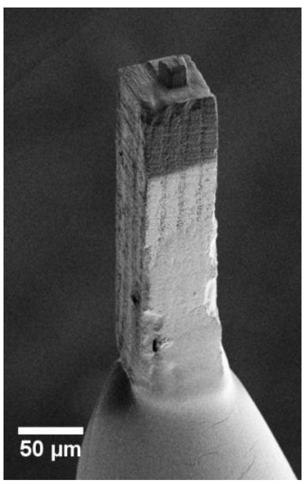

Figure 1. Image of a sample for nano XCT with a cross-section of 50 µm x 50 µm.

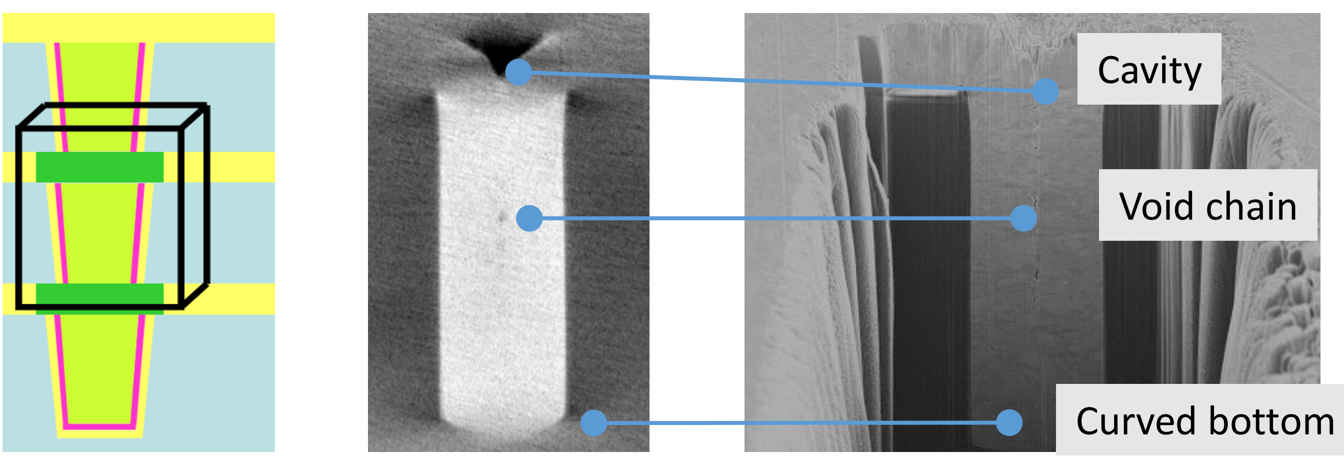

Figure 2. Visualization of filling defects (voids) in the center of a Cu TSV (nano XCT study, virtual horizontal and vertical cross-sections) and SEM image of a FIB cross-section through this void [2,3].