# FIB-Tomography and 3D Image Analysis for Quantitative Characterization of Microstructures

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The properties of many modern materials are strongly influenced not only by their chemistry, but also by their microstructure. As these microstructures often consist of complex constituents, determination of the real 3D shape becomes increasingly important. In the past and even today, many problems have been solved using 2D image analysis and stereology. In case of anisotropic microstructures with only convex constituents, stereology still provides suited methods for determination of real 3D shape out of 2D images. As soon as the constituents of the microstructure become non-convex and are not uniformly distributed, stereology fails and tomographic studies have to be done [1].

In the recent years, a great variety of different tomographic methods has been developed. These are mainly characterized by the achievable resolution, the size of the region of interest that can be imaged and how contrast is developed. One often used tomographic method is X-ray tomography, which is a nondestructive method using x-ray transmission images. Resolution is in the range of 1µm and 0.5µm in case of synchrotron radiation, which is sometimes not sufficient. In electron tomography, using a transmission electron microscope, a resolution of a few nanometers is achievable, but the imaged volume is limited to thin foils or sharp needles in the range of 100nm, which doesn't provide statistical results. Atom Probe Tomography even reaches atomic resolution and chemical quantification, but samples have to be very small as well.

In the case of many microstructures, FIB-Tomography is well suited, because resolution of a few nanometers is achievable but on the other hand, larger volumes up to $(100\mu m)^3$ can be studied as well. FIB tomography is a serial section technique (Figure 1) [2], where the region of interest is consecutively sliced with a focused ion beam and imaged with a scanning electron microscope [3]. For this, all contrasts known from conventional scanning electron microscopy may be used. Usually images are taken in secondary electron or backscattered electron contrast, but with new generation instruments even EDS [4] and EBSD [5] mappings are possible within a tomography for chemical and orientation or phase contrast. With this, FIB tomography becomes a powerful tool, suited for a great range of microstructures.

For quantitative description and understanding of these microstructures, conventional methods from 2D image analysis have to be adapted to three dimensions. With suited software packages (e.g. MAVI, "Modular algorithms for volume images", Fraunhofer ITWM, Kaiserslautern) the basic parameters of the microstructure and particle based parameters like size distribution and shape can be determined in 3D. With this, differences and changes in microstructures can be quantified [6].

Imaging and quantitative analysis of microstructures can provide information about formation and processing of microstructures. On the other hand, resulting properties are of interest. For calculation of effective properties, FEM simulations can be performed. Using a suited software (e.g. GeoDict, Fraunhofer ITWM Kaiserslautern) real tomographic data may

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be used instead of simplified models. So differences in effective properties, caused by different microstructures, can be described quantitatively [7].

For 3D analysis, the suited tomographic method is of great importance and FIB tomography proves to provide high resolution images of relatively big volumes. With help of modern software, microstructures can be described quantitatively an effective properties can be simulated out of real tomographic data. This leads to a better understanding of formation of microstructures and allows the connection to the materials properties.

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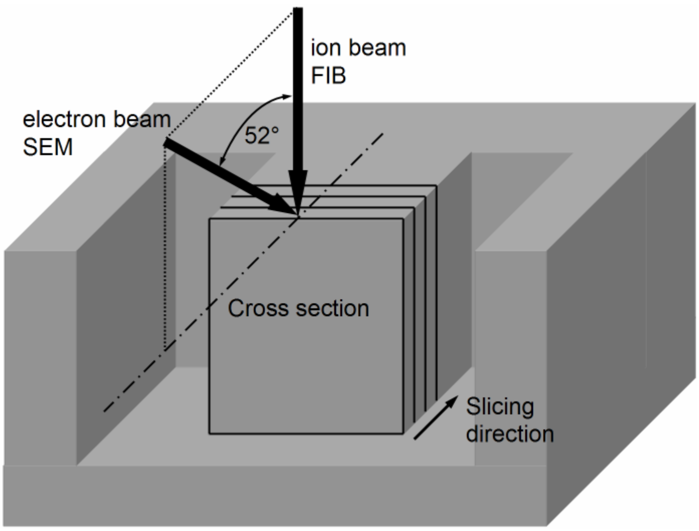


**Figure 1.** FIB tomography: the region of interest is consecutively sliced with a focused ion beam and imaged with a scanning electron microscope. All contrast from SEM may be used.


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