Quantification and Segmentation of Electron Tomography Data– Exemplified at $ErSi_2$ Nanocrystals in SiC

J. Leschner, J. Biskupek, A. Chuvilin and U. Kaiser

Central Facility of Electron Microscopy, Group of Materials Science, Albert-Einstein-Allee 11, 89069 Ulm, Germany

Jens.Leschner@Uni-Ulm.de
Keywords: electron tomography, nanocrystals in SiC, quantification, segmentation

Small transition metal crystals embedded in a semiconducting matrix are nanostructured systems with potential applications in nanotechnology. As their size distribution plays a key role for the detailed understanding of the device properties, the precise three-dimensional quantification is a must. However, the quantification process of the observed three-dimensional object is still under big discussion [1], due to subjective (manual) segmentation and desired ease of data-processing. However, before application related questions can be addressed, the nanocrystal formation as well as basic questions in the field of quantification have to be answered and robustly solved.

In the past we studied the nanocrystal formation process of hill-like shaped $ErSi_2$ nanocrystals formed after high dose Er ion implantation in 4H-SiC by HAADF-STEM imaging and spectroscopy and we suggested that the nanocrystals start to form at matrix defects, rather than to grow spontaneously [2,3]. However, the crystal shape within the volume could not be derived from two-dimensional imaging, but by HAADF-STEM tomography only. Using iterative reconstruction techniques, it was possible to visualize not only facets of the nanoparticles (Figure 1), but also Er decorated voids and channels filled with Er atoms [4,5].

As a next step the obtained data has to be quantified: facets, nanocrystal size and distribution with respect to implantation depth. The crucial point is to guarantee that the visualized object is in one-to-one correspondence to the original object. In order to decouple the quantified results from the adjustments during reconstruction and – as the method of choice – segmentation by thresholding, the contribution to the object contrast has to be investigated and an objective measure for thresholding has to be derived. Different imaging modes and the influence of the reconstruction algorithm as well as its parameters have been already discussed for a specific case of material and home-made reconstruction algorithm [6], but a quantitative way for easy segmentation is still not established.

In this work we evaluate how to perform robust segmentation for our material system and reconstruction algorithm (SIRT, FEI Inspect3D®) in order to implement it into an objective segmentation algorithm. Therefore, we model phantoms of the nanocrystals, reconstruct them and evaluate the influence of the developed algorithm. Afterwards we derive the quantified values from the experimental nanocrystals with higher reliability (Figure 2).

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7. This work has been supported by the German Research Foundation (DFG) – project KA1295/7-1.

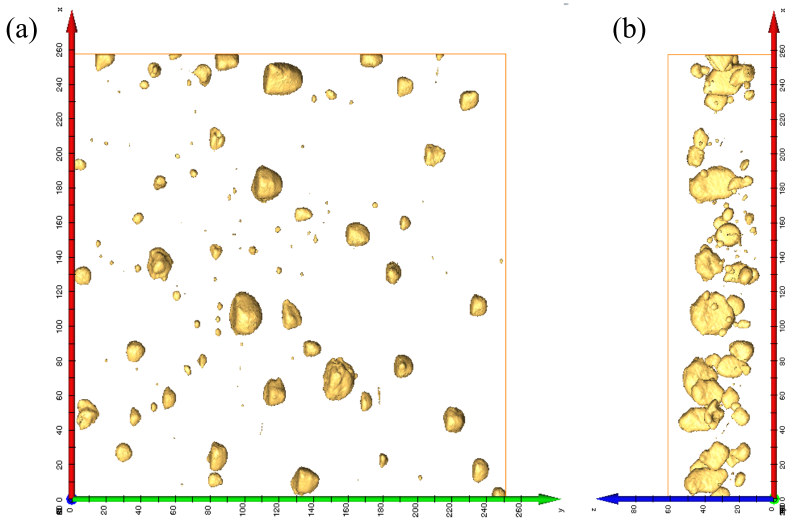

Figure 1. Reconstructed volume of $ErSi_2$ nanocrystals embedded in a crystalline SiC matrix (scale is nm): (a) three-dimensional view of the hill-like shaped particles in the xy-plane, and (b) along the implantation direction [11-20] (xz-plane) showing facets

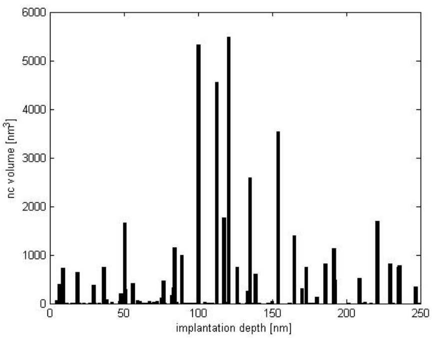

Figure 2. Quantification of the nanocrystals according to size and distribution w.r.t. (relative) implantation depth: small nanocrystals can be found at the surface and deep within the sample, whereas big grown particles are found dominantly in the middle