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3D grain orientation mapping of nanocrystalline materials in the TEM

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Nanocrystalline materials (i.e. polycrystalline aggregates where the individual crystallites/grains or particles have sizes below 100 nm) are formed through various processes ranging from mechanical treatments of bulk materials, to electrodeposition of thin films and coatings to aggregation of nanoparticles. The materials constitute one of the most rapidly growing new classes of materials and exhibit enhanced properties, see e.g. [1,2], ranging from high strength and wear resistance, to unique functional characteristics, which open up a large spectrum of applications e.g. for micro- and nano-electro-mechanical systems (MEMS and NEMS). Consequently, materials models tend to be based only on simple observables such as a 2D crystalline projection or an average grain/particle size. Motivated by this, a new and non-destructive technique called “3D-Orientation Mapping in TEM” (3D-OMiTEM) was developed and it was demonstrated that both orientation and 3D morphology of ~1000 individual nanograins could be measured with spatial and angular resolutions of 1 nm and 1 degree [3]. Notably, the foil may have five or more grains stacked on top of each other in the thickness direction. Technically speaking, 3D-OMiTEM is based on conical-scanning dark-field imaging. By recording images at a series of different beam and sample tilt angles it is possible to reconstruct the complete 3D orientation map of nanograins or nanoparticles. With the availability of 3D-OMiTEM crystallographic orientation relationships, interface curvatures, 3D connectivity between nanograins or nanoparticles as well as evolution of 3D structures e.g. during heat treatments or deformation steps, can be addressed for the first time in nanocrystalline materials. An overview of the methodology and latest results is given.

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