Advanced analysis of 3D EBSD data obtained from FIB-EBSD tomography

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The combination of serial sectioning with a focused ion beam (FIB) and EBSD-based orientation microscopy in a combined FIB-SEM constitutes, for certain applications, an ideal technique for 3D microstructure characterization. The FIB sectioning delivers accurately spaced serial sections while EBSD-based orientation mapping delivers quantitative materials characterization ideally suited for microstructure reconstruction. The spatial 3D EBSD data are measured as unconnected volume pixels (“voxels”). In order to group these voxels into crystallites the measured sections have to be aligned such that subsequent sections fit together in an optimum manner. Alignment of complete sections is accomplished using cross-correlation techniques. Additionally, we have implemented a simple Monte-Carlo Potts-model algorithm which effectively cleans up the microstructure while conserving most of the sub-structure inside of the grains. Voxel-based description of microstructures can be used for characterization of stereological data, as grain size and shape, volume fraction of different phases etc., see an example in figure 1. Note, however, that many of these data can also be obtained from 2-dimensional measurements using stereological correlations. More complicated parameters like gradients of crystal rotations can be used to obtain a measure for the density of geometrically necessary dislocations in the sense of Nye ([1],[2]), for example.

3D EBSD data open the unique possibility to describe the 5-parameter crystallographic nature of interfaces consisting of the misorientation across the boundary (3 parameters) and the crystallographic orientation of one of the interface normals (2 parameters), see e.g. [3]. For boundary reconstruction we have employed the Marching Tetrahedra algorithm [4] which solves a number of problems involved in the originally proposed Marching Cube algorithm [5]. The as-meshed surface structure is subsequently smoothed using a strategy [6] which is inspired by computer models for grain growth simulation as implemented in a vertex model by Barrales [7].

The described algorithms have been employed for the analysis of selected grain boundaries in an Fe 28% Ni alloy. The microstructure of this material consists almost entirely of lenticular martensite, Fig. 2a. Three adjoining grains are isolated from the microstructure, Fig. 2b. The boundary character is described by plotting, in one pole figure, the rotation axis and the position of the grain boundary normal, figs. 2c and d. The boundary character is tilt when boundary normal and rotation axis are perpendicular and twist when they are parallel. It is interesting to note that in the present microstructure grain boundaries with a [110] 55° misorientation are all twist boundaries, fig. 2 (c) while boundaries with a [323] 53° misorientation almost all have tilt character, fig 2 (d).

References

**Fig 1 (above):** Voxel-based 3D microstructure display of a deformed low-alloyed TRIP steel. (a) Inverse pole figure (IPF) plot. (b) One of the grains in (a) created by grain reconstruction.

**Fig. 2:** Microstructure of an Fe-28% Ni alloy. (a) The full block of material displayed as IPF map. (b) Three martensite plates taken from (a). (c), (d) Twist-tilt pole figures of the interfaces between 2 grains, respectively, from fig. (b)