On the central role of local orientation distributions in deformation microstructures

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Abstract

It is well known that complex lattice orientation fields develop in polycrystalline materials subjected to large plastic deformation, as a result of mechanical heterogeneities. These heterogeneities arise both at crystal scale, from grain interaction, and at substructure scale, from dislocation interaction. Eventually, the orientation fields resulting from deformation control microstructure evolution during subsequent annealing. In this work, the central role of local orientations distributions is emphasized from the results of three "grain-tracking" studies carried out over the past decade, either in laboratory or at synchrotron, and associated to crystal plasticity simulations. In the experiments, the evolution of individual grains in 3D polycrystals is tracked during deformation or subsequent annealing, which provides detailed information on their evolution and the correlation to the grain attributes. Simulation is considered for comparison, but also to enrich the datasets with data that are experimentally inaccessible, such as plastic slips, local stresses, etc. "Orientation distributions" refer to orientation fields freed of their spatial information, which are analysed either over whole grains or more locally within grains, at substructure scale. It is first shown that the anisotropy properties of orientation distributions provide important information on the local deformation mechanisms, but also on the characteristics of the underlying substructures. The anisotropy properties are related to the slip activity at relatively small strain, and is then controlled by the global reorientation velocity field. The average stress of the grain is shown to play an important role on their development, while the stress distribution has a relatively smaller influence. When considered locally, the anisotropy properties of the orientation distributions are strongly correlated with the characteristics of substructures, especially to the presence (and sharpness) of bands. It is finally shown how the anisotropy properties of the orientation distributions control recrystallization nucleation and can be used as a quantitative nucleation criterion.

Keywords: microtextures, deformation and recrystallization, orientation distributions, experiment simulation and modelling, stress perturbation modelling

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