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Dislocation Avalanches, Mean Free Path and Patterning[1]

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Dislocations are the defects that carry plastic flow in crystalline materials. At the defect scale, plastic deformation occurs by dislocation avalanches, which are characterized by scale-free behavior within a bounded domain of amplitudes or energies. The probability distribution functions of these avalanches, their processes of initiation and termination and their contribution to dislocation storage during plastic flow are investigated using dislocation dynamics (DD) simulations. The model material is a copper single crystal strained along three high symmetry orientations. The distributions of avalanche amplitudes exhibit, for all orientations, a scaling exponent of 1.6, similar to what is reported in the literature. However, the average value of strain burst amplitudes, taken in the recorded domain of amplitudes, is found to be orientation-dependent. In parallel, a continuum model based on the notion of dislocation mean free path, which predicts the mechanical response of f.c.c. single crystals, was established with the help of DD simulations. It appears that both intermittent and continuum behavior exhibit the same orientation dependencies. Furthermore, for the three tested orientations, the ratio of the continuum mean free path to the average characteristic length traveled by dislocations during avalanches is a constant. This constant ratio simply results from an implicit coarse-graining procedure that is performed upon measuring different types of quantities in the simulated results. As a consequence, it appears that avalanche behavior can effectively be incorporated into continuum models for crystal plasticity. The present results are discussed with respect to the available experimental literature on the deformation of f.c.c. crystals. Finally, the formation of dislocation patterns, that is the self-organization properties of dislocations under strain, is tentatively discussed in terms of the properties of dislocation avalanches.

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