Dislocation patterns

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In the long march that leads from the elastic and core properties of individual dislocations to the mechanical response of real materials, one finds collective dislocation processes. In spite of many efforts, the spontaneous formation of dislocation patterns under stress has not yet been convincingly modeled. A short historical sketch shows how the physical content of successive models evolved through the importation of new concepts borrowed from thermodynamics, the dynamics of non linear dissipative systems, statistical mechanics and the continuum theory of dislocations.

Among the various types of patterns found in deformed single crystals, the dislocation cell structures that emerge during unidirectional deformation in stage III have attracted most of the attention. Because of their almost periodic ladder structure, the persistent slip bands formed in fcc metals during cyclic deformation under low plastic strain amplitudes also drew some attention. Although a few confusions are sometimes found in the current literature, the basic dislocation mechanisms that lead to these two types of patterns are now better understood. In the context of modeling, two of their properties are worth being mentioned. When there is no lattice resistance dislocation microstructures follow two scaling laws, which are experimentally well documented. One of them, the dislocation strengthening relation is understood and reasonably well modeled, whereas the physical origin of the second one, the similitude relation, still remains unclear. The state of the art in the simulation of dislocation cell structures will be illustrated by a few examples. Simulating other types of microstructures, in particular the ones obtained at very large strains, still remains a challenge.

The seminal article by M. Carmen-Miguel *et al.* [1] on dislocation avalanches uncovered a new vision of the elementary event that leads to macroscopic plastic flow. This suggests basing the next generation of models for dislocation patterning on the spatio-temporal evolution of the dislocation density stored by avalanches.

[1] M.-Carmen-Miguel *et al.*, Nature, **410**, 667 (2001).