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ΠΕΡΙΛΗΨΗ

Despite continuous experimental interest and theoretical efforts, the mechanisms which govern various spatio-temporal dislocation patterning phenomena during the plastic deformation of metals remain obscure to a large extent. The controversy starts with the general theoretical framework to be adopted for analytically describing dislocation patterning, specifically, the question about the nature of the “driving force” (in the thermodynamic sense) inducing those crystal plasticity phenomena. The present paper aims at setting out a basic theoretical framework for the description of dislocation patterning that is in accordance with the notion of self-organization in non-linear dynamic systems. Analytical dislocation dynamics modelling approaches have to cope with the long-range nature of dislocation interactions. These interactions are the reason why various characteristic length scales may not clearly separate, as to allow the application of simple coarse graining procedures in going from the microscopic to the macroscopic scale. Proceeding on a statistical picture of collective dislocation fluctuations at the mesoscopic scale, a stochastic dislocation dynamics approach is developed which emphasizes the importance of the strain-rate sensitivity of the flow stress in mediating the effective range of dislocation interactions. Applications of the stochastic dislocation dynamics show that fluctuations can induce (i) mesoscopic patterning in space by dynamically stabilizing non-uniform dislocation distributions during monotonic multiple-slip deformation (self-similar dislocation cell structures) or cyclic single-slip deformation (quasi-periodic dislocation wall structures), and (ii) macroscopic plastic strain localization in space and time that is associated with plastic instability of the strain-rate softening type (Portevin-LeChatelier effect).

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