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A continuum framework for dislocation structure, energy and dynamics of dislocation arrays and low angle grain boundaries

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We present a continuum framework for dislocation structure, energy and dynamics of dislocation arrays and low angle grain boundaries which may be nonplanar and nonequilibrium. In our continuum framework, we define a dislocation density potential function on the dislocation array surface or grain boundary to describe the orientation dependent continuous distribution of dislocation in a very simple and accurate way. The continuum formulations of energy and dynamics include the long-range interaction of constituent dislocations, local line tension effect of dislocations and the cooperative motion of dislocations, which are derived from the discrete dislocation model. The continuum framework recovers the classical Read-Shockley energy formula when the long-range elastic fields are canceled out. Applications of our continuum framework in this paper are focused on dislocation structures on static low angle grain boundaries or misfitting interfaces that may be nonplanar. We present two methods within our continuum framework for that purpose: the continuum version of the Frank's formula and the energy minimization method. Applications are given for dislocation structures on planar low angle grain boundaries, perturbed low angle tilt boundaries, and interfaces with misfitting spherical inclusions.

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