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DISCRETE DISLOCATION MODELING OF POLYCRYSTAL PLASTICITY

*** A. Needleman[1], E. Van der Giessen[2]**

[1]Division of Engineering, Brown University
182 Hope Street, Providence, RI 02912 USA
needle@brown.edu

[2]University of Groningen, Zernike Institute for Advanced Materials
Nijenborgh 4, 9747 AG, Groningen, The Netherlands
E.van.der.Giessen@rug.nl

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ABSTRACT

The main mechanism of plastic flow in crystalline metals is the collective motion of dislocations. As is now well appreciated, at the micron (and smaller) scale, the discreteness of dislocations leads to observed responses that not only differ quantitatively but sometimes also qualitatively from the predictions of conventional size-independent plasticity theory. The implications of this have been explored for a variety of deformation and fracture processes in single crystals. What has been less explored are the implications for polycrystals where the grain size introduces another length scale. Here, a number of recent discrete dislocation analyses of polycrystalline response [1-6] will be discussed. These are simulations with the dislocations all of edge character and modeled as line singularities in a linear elastic material. Boundary value problems are solved by writing the stress and displacement fields as superpositions of fields due to the discrete dislocations, which are singular inside the body, and image fields that enforce the boundary conditions. This leads to a linear elastic boundary value problem for the smooth image fields that can be solved by standard numerical techniques. Thus, the long range interactions between dislocations are accounted for through the continuum elasticity fields. Short range interactions are accounted for through constitutive rules. The stress-strain response and the dislocation structures that emerge are outcomes of a boundary value problem solution. Grain boundaries are modeled as being impenetrable to dislocations. The implications and limitations of this assumption will be discussed.

Among the issues considered are: (i) the effect of grain boundaries on size effects in thin films; (ii) the transition from a single crystal sector crack tip field to a polycrystal HRR field; (iii) the contrast between the size dependence seen for single crystal pillars with the size independence seen for polycrystalline pillars; (iv) the scaling in indentation with indentation depth and grain size.

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