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Deformation Twinning through Ideal Nanoshear Events near Crack Tips in Deformed Nanomaterials

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Extended Abstract

The outstanding mechanical properties of nanocrystalline materials represent the subject of intensive studies motivated by their high technological potential. Plastic deformation processes and their micromechanisms in nanocrystalline materials and ceramics in many aspects are different from those in their conventional coarse-grained counterparts. High applied stresses often initiate operation of specific modes of plastic deformation in mechanically loaded nanomaterials. One such mechanism is the experimentally observed emission of partial Shockley dislocations by grain boundaries followed by the formation of stacking faults and deformation twins in nanocrystalline metals. However, it is hardly possible for a partial dislocation to pre-exist at a grain boundary on every slip plane to form a single twin. Recently, formation of nanoscale twins in crack-free solids at high stresses has been described as a process being realized through either consequent (Ovid'ko, Sheinerman, 2011) or simultaneously (Ovid'ko, 2011) occurring ideal nanoshear events and serving as an effective alternative to conventional twin formation mechanism in nanocrystalline materials. However, it was shown that deformation twinning through ideal shear events can occur at only high stresses that can not be reached in defect-free nanomaterials. In this context, it is interesting to understand and describe formation of nanoscale deformation twins through ideal shear events in areas near crack tips, where high local stresses operate in nanocrystalline materials.

With in our model, the deformation twin near the crack tip is generated and evolves through the events of ideal nanoscale shear consequently occurring on parallel glide planes. In terms of dislocations, the twin formation process is represented as consequent generation of N dislocation dipoles on parallel glide planes. Generation of each dislocation dipole is realized through both growth of the magnitude of the Burgers vectors of its dislocations from 0 to the magnitude of the Shockley partial and corresponding evolution of generalized stacking faults located between immobile dislocations composing the dipole.

Our calculations have shown that the nanotwin growth through ideal nanoshear events is an energetically favorable process (initiated by high local stresses in the vicinities of crack tips) in nanocrystalline Ni in wide ranges of parameters characterizing its mechanical load and internal structures. Also, it has been demonstrated within our theoretical model that the nanoscale twin formation releases in part local stresses near crack tips and thus hampers crack growth in pre-cracked nanocrystalline solids.

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