SHOCK13-2013-000123

Abstract for an Invited Paper
for the SHOCK13 Meeting of
the American Physical Society

On the homogenous nucleation and propagation of dislocations under shock compression

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In strong shock regimes, homogenous nucleation of dislocation loops is believed to be the dominant mechanism of plastic deformation. We compare threshold stress for homogenous nucleation calculated by continuum elasticity and standards nucleation theory with multiscale dislocation dynamics plasticity (MDDP) predictions for copper single crystals. Several MDDP homogenous nucleation simulations are then carried out to investigate the state of stress and strain behind the wave front. The results show that the stress filed exhibits an elastic overshoot followed by rapid relaxation such that the1D state of strain is transformed into a 3D state of strain due to plastic flow. Based on MDDP results, we develop models for dislocation density evolution, saturated dislocation density, and stress relaxation time at different pressures. Moreover, an extension of high strain rate Orowan equation that accounts for homogenous nucleation is derived. The dependence of strain rate on the peak pressure shows good agreement with Swegle-Grady scaling law.

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