Defects Dynamics Element Models for Nanoindentation: Effect of Indenter Radius, Initial Density and Crystal Orientation on Incipient Plasticity

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A multiscale model which couples dislocation dynamics and finite element method was developed to simulate the mechanical response of FCC Al single crystal under spherical nanoindentation. The multiscale model can capture both motion of individual dislocation segments at small scale and macroscopic constitutive response of material at continuum scale concurrently. The resulting load-displacement curves, stress distribution and dislocation structure were analyzed to provide insights into the mechanism for dislocation plasticity. Dislocation nucleation as shear stress approach theoretical strength and the formation of prismatic loop were observed on initially dislocation-free crystal. Nucleation in the Al (110) crystal requires lower load and shear stress than the Al(010) and Al(111) crystal. Nanoindentation of crystal with existing sources shows decreasing shear stress at incipient plasticity with increasing indenter radii as both dislocation nucleation and activation of a nearby source can serve as the mechanism for plastic deformation. Decreasing initial dislocation density can increase shear stress at the onset of plasticity.