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INVESTIGATION OF SINGLE ARM SOURCE CONTROLLED PLASTIC FLOW IN FCC MICROPILLAR BY DISCRETE DISLOCATION DYNAMIC AND THEORETICAL ANALYSIS

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ABSTRACT

For submicron single crystals, the plastic behaviors are widely observed to be controlled by ‘dislocation source’, which differ significantly from macroscopic plastic flow. In this paper, single arm source (SAS) controlled plastic flow in the micropillars with diameter ranging from 200nm to 800nm is extensively investigated by a statistically based theoretical model and three dimensional discrete dislocation dynamic (3D DDD) method. First, by 3D DDD simulations of micropillar compression test, some specific features of submicron plastic flow are obtained: (i) Intermittent strain burst is directly controlled by the operation and shutdown of SAS; (ii) Strain hardening is virtually absent due to continuous operation of stable SAS and weak dislocation interactions; (iii) The initially high dislocation density finally reaches a stable value after a sharp decrease. And meanwhile, it is found that stable SAS length also reaches a constant value which only depends on the pillar diameter. Then by modifying the conventional dislocation density evolution equation and strain hardening model to consider the SAS operation mechanism, a theoretical model is developed to quantitatively describe the submicron plastic behavior. Here the evolution of SAS length is decided by a statistical model. Once the pillar diameter and initial dislocation density are given, the stress-strain curve, dislocation density, SAS length, and the stable flow stress can all be predicted by this theoretical model and match well with the experimental data and 3D DDD simulation results.