Tech Science Press

ICCES, 2024, vol.31, no.4
DOI: 10.32604/icces.2024.012582

PROCEEDINGS

Nonlocal Crystal Plasticity Modeling of Heterostructured Materials

Jianfeng Zhao[1,*], Xu Zhang[2], Guozheng Kang[2] and Michael Ziaser[3]

[1]School of Materials Science and Engineering, Southwest Jiaotong University, Chengdu, 610031, China

[2]Applied Mechanics and Structure Safety Key Laboratory of Sichuan Province, School of Mechanics and Aerospace Engineering, Southwest Jiaotong University, Chengdu, 610031, China

[3]WW8-Materials Simulation, Department of Materials Science, University of Erlangen-Nuremberg, 90762, Fürth, Germany

[*]Corresponding Author: Jianfeng Zhao. Email: zjfswjtu@126.com

ABSTRACT

A continuum model of dislocation transport incorporating grain boundary transmission was developed within a dislocation-based crystal plasticity framework, which was then adopted to study the deformation mechanisms of gradient-structured material and bimodal-grained material. The nonlocal nature of the model on the slip system level enables the direct investigation of strain gradient effects caused by internal deformation heterogeneities. Furthermore, the interaction between dislocations and grain boundaries leads to the formation of pileups near grain boundaries, which is key to studying the grain size effects in polycrystals. Finite element implementation of the model for polycrystals with different grain sizes captured the grain size effect well. Simulation results of heterostructured materials and their homogeneous counterparts showed that smaller grains lead to higher geometrically necessary dislocation density and enhanced back stress. The soft grains in a bimodal-grained material are strengthened when constrained by hard grains, and the strengthening effect depends on the mechanical properties of the hard grains. These effects are attributed to the severe dislocation pileup and the resulting back stress. This work helps to understand the contributions of deformation mechanisms to the synergetic strength and ductility of heterostructured materials and to guide the microstructure design and optimization for improved strength-ductility combination.

KEYWORDS

Heterostructured materials; crystal plasticity; nonlocal; strengthening mechanisms

Funding Statement: This work was supported by the National Natural Science Foundation of China (Grant Nos. 12202423, 12222209).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.