DISCRETE DISLOCATION-BASED CRYSTAL PLASTICITY AT SUBMICRON SCALE

Zhuo Zhuang, Zhanli Liu and Yinan Cui

AML. School of Aerospace Engineering, Tsinghua University, Beijing 100084, China, zhuangz@tsinghua.edu.cn

Focus Material: Metals

Focus of the Presentation: *(i) Physics-based multi-scale model development;*

Abstract

Crystal plasticity at micron-nano scales involves many interesting issues. Some results are obtained for uniaxial compression experiments conducted on FCC single crystal micro-pillars, e.g. size effect and strain burst, etc. In the experiments, the mobile dislocations may escape from the free surface leading to the state of dislocation starved whereby an increase applied stress is necessary to nucleate or activate new dislocation sources. By performing in-situ TEM, the dislocation motion affected the material properties is observed. However, the atypical plastic behavior at submicron scales cannot be effectively investigated by either traditional crystal plastic theory or molecule dynamics simulation. The surfaces are transmissible and loading gradients are absent. Therefore, the strain gradient theory could not well explain these new mechanical behaviors. This in turn has led to develop new analytic and numerical models. Accordingly, a three dimensional discrete-continuous crystal plastic model is developed, which is coupling the discrete dislocation dynamics with finite element method [1]. Three kinds of plastic deformation mechanisms for the single crystal pillar are investigated: (1) Single arm dislocation source controlled plastic flow; (2) Confined plasticity in coated pillars [2]; (3) Dislocation starvation under low amplitude cyclic loadings. The predicted results agree well with the experimental data.

References

[1] Cui Y.N., Liu Z.L. and Zhuang Z., 2015, “Theoretical and numerical investigation on confined plasticity in coated pillars at microscale. *J. Mech. Phys. Solids*, 76, 127-143

[2] Wang Z.J., Li Q.J., Cui Y.N., Liu Z.L., Ma E., Li J., Sun J., Zhuang Z., Dao M., Shan Z.W., Suresh S., 2015, “Cyclic deformation leads to defect healing and strengthening of small-volume metal single crystals”. *PNAS*, 10/14/1518200112