Multiscale Modeling of Fatigue Crack Initiation and Propagation in Nanocrystalline Metals

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Fatigue-crack growth simulations at the nanoscale are performed using an atomistic/discrete dislocation method at finite temperature. The general mechanisms of the plastic deformation at the crack tip are studied in nickel and copper single crystals. The dimensions of the specimens are in the range of several hundred nanometers, and the fatigue loading is strain controlled under constant and variable amplitude.

From our simulations, the growth rates of nanocracks are found to be comparable to those of microscale cracks, but considerably larger than those of long cracks. In addition, nanoscale cracks are found to grow at stress-intensity-factor ranges well below the commonly accepted values for long crack. This clearly indicates that fatigue damage progression in metals involves multiscale phenomena such as accelerated growth rates for cracks in the nanometer range that cannot be neglected in the failure mechanism. The effects of temperature and loading rate on the crack growth behavior are also investigated.