BRIDGING LENGTH-SCALE IN CONTINUUM DISLOCATION THEORY

K.C. Le, D. Kochmann and P. Sembiring
Lehrstuhl für Allgemeine Mechanik, Ruhr-Universität Bochum,
D-44780 Bochum, Germany

Within the framework of continuum dislocation theory the plane-strain constrained shear of a single and bicrystal strip is analyzed. For the single crystal strip we consider the single and double slip systems oriented at different angles to the direction of shear. For bicrystal strip the main assumption is that each crystal layer has only one active slip system. These slip systems are oriented differently with respect to the direction of shear. We also assume that both crystal layers are elastically isotropic and have the same elastic moduli. At the grain boundary the displacements and the tractions must be continuous. Besides, the dislocations cannot penetrate the grain boundary. The problem is to determine the displacements and the plastic distortion as functions of the given overall shear strain.

Our aim is twofold. First, we are going to find the solution in closed analytical form for the single crystal with one active slip system and with symmetric double slip systems, and for the bicrystal in the symmetric case (twins). If the dissipation can be neglected, then dislocations appear to minimize the total energy of crystal. Due to the specific form of the energy of dislocation network which is proportional to the dislocation density for small densities, we show that there is an energetic threshold for the dislocation nucleation. If the shear strain exceeds this threshold, geometrically necessary dislocations appear and pile up near the grain and phase boundaries leading to the material hardening. From the obtained solution we can compute the contribution of the geometrically necessary dislocations to the energy of grain and phase boundaries. If, in contrary, the dissipation due to the resistance to the dislocation motion is essential, the energy minimization should be replaced by the flow rule. The solution exhibits the dissipative threshold for dislocation nucleation, the Bauschinger translational work hardening, and the size effect. Our second aim is to develop the numerical procedure for the solution of this problem in the case where the active slip systems are not symmetric. The agreement between the numerical and analytical solution for the special case of symmetry will justify the correctness of developed numerical procedure.