Low energy dislocation structures due to unidirectional deformation at low temperatures -

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The line energy of dislocations is \( Gb^2f(v)/4\pi \) \( 1n(R/b) \) with \( R \) range of the dislocation stress field from the axis. This equation implies that quasi-uniform distributions are unstable relative to dislocation clusters in which neighboring dislocations mutually screen their stress fields, correspondingly leaving the major fraction of the volume free of dislocations. The value of \( R \) decreases in the following order: pile-ups to dipolar mats, Taylor lattices, tilt and dipolar walls to dislocation cell structures. This is the same order in which dislocation structures tend to develop with increasing dislocation density and hence increased dislocation interactions, leading to the corresponding energy decrease per unit length of dislocation line. Taking into consideration also the longer-range "termination stresses" of finite dislocation boundaries, and minimizing the total energy, explains the size dependence of cells on stress as well as the occasionally observed pattern of rectangular cells with alternating left-right rotation about a common axis. Energy minimization further explains the transition from stage I to II in f.c.c. metals. The following topics which are at the present frontier of research are considered in this paper: (i) the sum of the energy stored in the dislocation line energy and the longer-range stresses is significantly smaller than some recently reported experimental values; (ii) subdivision of cells is discussed on the basis of observations in rolled aluminum showing a "hierarchical" cell structure; (iii) suggestions are made to account for microband formation on the basis of energy minimization. Finally, the relationship between surface markings and the underlying dislocation structure is discussed and related to slip processes taking place during uniaxial deformation.