THE MOBILITY OF EDGE DISLOCATIONS IN PURE COPPER SINGLE CRYSTALS*

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The velocity of selectively introduced edge dislocations in 99.999 percent pure copper crystals has been measured as a function of stress at temperatures from 66°K to 373°K by means of the torsion technique developed by Pope, Vreeland, and Wood (1967). The range of resolved shear stress was 0 to 15 megadynes/cm^2 for seven temperatures (66°K, 74°K, 83°K, 123°K, 173°K, 296°K, 373°K).

The path of motion of individually displaced dislocations was traced from Berg-Barrett x-ray micrographs, while the etch pit technique was used to indicate the crossing of forest dislocations. The test crystals were free from substructure, with a grown-in dislocation density between 10^3 and 10^4 cm/cm^3. The dislocations were between 0.01 and 0.02 cm in length and displacements varied between 0 and 0.1 cm, so that in the extreme case the intersection of forest dislocations was reduced to zero.

The dislocation motion is characterized by two distinct features; (a) relatively high velocity at low stress (maximum velocities of 9000 cm/sec were realized at low temperatures), and (b) increasing velocity with decreasing temperature at constant stress. For temperatures at 123°K and above, dislocation velocity is proportional to the resolved shear stress. However, at lower temperatures the experimental data indicates that the mobility exponent is slightly greater than 1.

In the temperature range 123°K to 373°K, it is possible to write

$$B(T)v = \tau b$$

where v is the dislocation velocity, τ is the resolved shear stress, b is the dislocation Burgers vector, and B is the damping coefficient at temperature T. At lower temperatures B is a function of T and v, and we use here its value at a velocity of 2000 cm/sec. The experimental values of B are found in Figure 1.

The experimental results are consistent with an interpretation on the basis of phonon drag. While the various theories provide the correct order of magnitude of the damping coefficient, the complete temperature dependence of B could not be closely approximated by the

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predictions of one or a combination of mechanisms. The high-temperature behavior of the damping coefficient is in accord with the phonon viscosity concept developed by Mason (1960 and later papers), although the experimental value of B decreases more rapidly at lower temperatures.

The viscosity mechanism, as it applies to dislocations moving on the 111 planes of fcc crystals, is examined in some detail. Explicit formulas for increases in the elastic stiffnesses are derived and we show that the temperature dependence of B deviates from Mason's analysis when lattice anisotropy is considered. Employing a criterion for the inner cut-off radius similar to that proposed by Suzuki, Ikushima, and Aoki (1964), and using the dislocation relaxation times for copper, we find a velocity-dependent damping coefficient at low temperatures.

References

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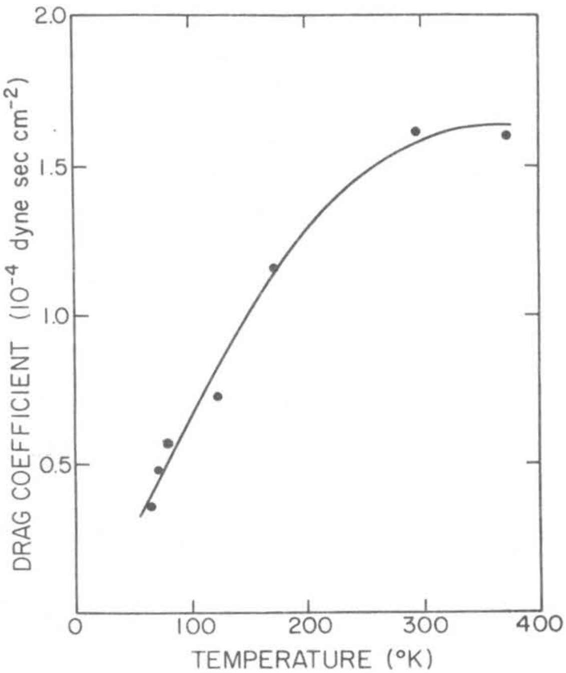

Figure 1. Experimentally determined dislocation drag coefficient as a function of temperature.