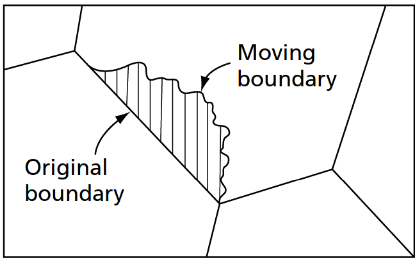

FIG. 8.42 Schematic representation of strain-induced boundary migration. In this case, the boundary moves away from its center of curvature, which is in the opposite direction to the movement in surface-tension-induced boundary migration. (After Beck, P. A., and Sperry, P. R., *Jour. Appl. Phys*, **21** 150 [1950].)

PROBLEMS

8.1 In Sec. 8.1, it was stated that a high-purity Cu specimen, after 30 percent deformation at room temperature, was found to have a recoverable strain energy of about 25 J/g-mol. The Burgers vector for Cu is 0.256 nm and the shear modulus about 5.46×10^{10} Pa. Determine the dislocation density of an array of uniformly distributed alternating right- and left-hand screw dislocations in the Cu that might possess this amount of strain energy.

8.2 (a) Using the 283 K data, given in Sec. 8.5 for the Drouard, Washburn and Parker zinc single crystal, determine the value of A in the rate equation, Eq. 8.2.

(b) Next determine the temperature at which the crystal should recover one-fourth of its yield point in 5 seconds and $b = 3.0$ nm.

8.3 A simple equation can be easily derived that relates the density of the excess edge dislocations in a bent crystal to the radius of curvature of the bent region. This expression is simply $r = 1/\beta b$, where r is the radius of curvature, β the excess edge density, and b the Burgers vector. Compute the local radius in a region where β is 10^{12} m/m^3.

8.4 A well known equation, which treats a crystal as an isotropic elastic solid, was developed in the early days of dislocation theory to predict the surface energy of a low-angle tilt boundary. Basically it assumes that the strain field of an individual edge dislocation is neutralized by the fields of the dislocations above and below it, in the boundary, and at a distance from the boundary equal to approximately one-half the spacing between the dislocations in the boundary. The derivation of this equation is given in most texts on dislocations. The equation is

$$\Gamma = \frac{\mu b}{4\pi(1 - \upsilon)}\alpha(A - \ln\alpha)$$

where Γ is the surface energy, b the Burgers vector, μ the shear modulus, α the angle of tilt of the boundary in radians, A a constant representing the core energy of the dislocation, and υ is Poisson's ratio.

(a) Write a computer program that will determine Γ as a function of the angle of tilt α. Use this program to determine the variation of Γ with α from 0.0001 to 1.047 rad. in 60 steps. Assume $\mu = 8.6 \times 10^{10}$ Pa, $b = 0.25$ nm, $A = 0.5$, and $\upsilon = 0.33$.

(b) Determine the maximum value of the surface energy and divide each value of Γ by the maximum value to obtain a set of relative values of the surface energy. Plot these values as a function of α in degrees and compare the curve that is obtained with Fig. 6.8.

8.5 One of the phenomena during the latter stages of recovery is the coalescence of tilt boundaries into a single tilt boundary with a larger tilt angle. This is accompanied by a loss of surface energy. Compute the fractional loss of surface energy when two tilt boundaries with tilt angles of 0.5° combine to form a 1.0° tilt boundary. (Use the parameters of Prob. 8.4.)

8.6 An investigation of the recovery of a zinc single crystal gave the following data:

Temp., K	Time to Recover 50% of the Yield Point, Hr
283	0.007
273	0.022
263	0.079
253	0.306
243	1.326
233	6.521

(a) Plot these data in the form $\ln(1/\tau)$ vs. $1/T$, where τ is the 50% recovery time and T is the absolute temperature. From the slope of the curve that is obtained determine the activation energy, Q, for the recovery of the yield point. (See Eq. 8.2.)

(b) Determine the corresponding value of the preexponential constant, A, of this equation.

8.7 With the aid of the equation developed in Prob. 8.6, determine the time to recover 50% of the yield stress of the deformed zinc crystal at 213 K and 300 K.

8.8 The data in Fig. 8.15 of Decker and Harker corresponding to the complete recrystallization of pure copper are:

Temp., K	Recrystallization Time, 10^3 S
316	2,300
361	33
375	10
385	7
392	4
408	1.5

(a) Use the above data to determine the activation energy Q and the preexponential constant A in the rate equation for recrystallization, Eq. 8.5.

(b) Determine the recrystallization temperature for the copper; i.e., the temperature corresponding to complete recrystallization in 1 hour.

(c) How long would it take to completely recrystallize the copper at room temperature, 300 K?

8.9 (a) The surface energy of a film of soap and water is about 3×10^{-2} J/m^2. Compute the increase in the pressure on the inside of a soap bubble with a diameter of 6 cm.

(b) In some studies designed to investigate the effect of very rapid cooling on the freezing point of metals, droplets of a liquid metal have been rapidly cooled. The diameter of these droplets were of the order of 50 μm. Consider the case of liquid gold droplets of this diameter with a surface energy of 13.2×10^{-2} J/m^2 and compute the increase in the internal pressure for this case.

8.10 (a) The goal is to write a computer program for the grain-growth law, Eq. 8.13, using data from Fig. 8.32. Express Q in J/mol, R in J/mol-K, and leave D^2 and D_0^2 in units of 10^{-6} cm^2 and the time t in minutes so that the data of Fig. 8.32 can be reproduced. The first step is to determine the value of K_0. To do this, solve for K_0, letting $t = 90$, $T = 973$, $D_0^2 = 2$, and $D^2 = 63$.

(b) Next insert the value of K_0 found above into Eq. 8.13 and write a program that allows the value of the temperature, T, to be substituted into the equation and also contains a (FOR—NEXT) LOOP that varies the time, t, from 0 to 120 min. in steps of 30 min. The purpose is to obtain four values of D^2 at any arbitrary temperature. Check your program against the 973 K (700°C) data in Fig. 8.30 and then use it to determine a set of D^2 values for 1000 K. Note, take $D_0 = 2$.

8.11 If a silver specimen is annealed for a long time under conditions favoring the development of grooves along the lines where internal grain boundaries intersect the outer surface of the sample, a groove angle of 139.5° occurs. If the grain boundary energy for silver is 0.790 J/m^2, what is the energy of the solid-vapor surface?

8.12 Determine, to a first approximation, the limiting grain size in a 2 cm-thick plate of a metal containing a 1 percent volume fraction of a stable spherical precipitate whose average diameter is 600 nm.

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