Chapter 6.
ELEMENTS OF GRAIN BOUNDARIES

Elements of Grain Boundaries

Dislocation model of a small-angle boundary

The five degrees of freedom of a grain boundary

The stress field of a grain boundary

Grain-Boundary Energy

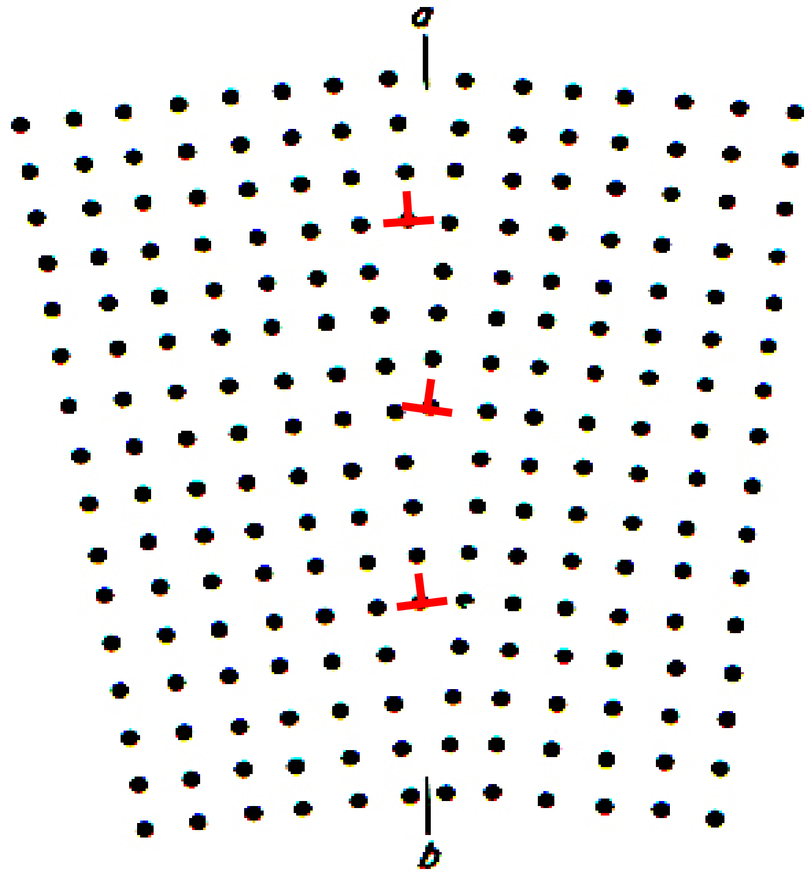
Low-energy dislocation structures, LEDS

Dynamic recovery

Surface tension of the grain boundary

Boundary between crystal of different phases

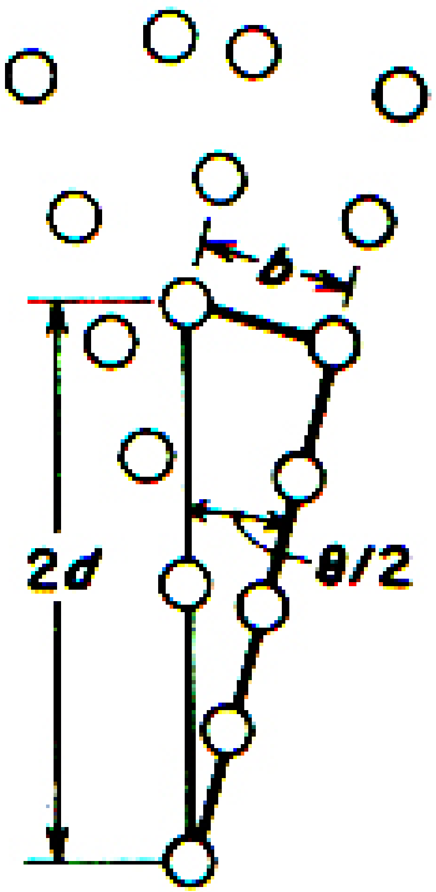
Dislocation model of a small-angle boundary



(A)

Fig. 6.2 (A) Dislocation model of a small-angle grain boundary.

Elements of Grain Boundaries



(B)

(B) The geometrical relationship between θ ,the angle of tilt, and d , the spacing between the dislocations.

$$\sin\frac{\theta}{2} = \frac{b}{2d}$$

$$\frac{\theta}{2} = \frac{b}{2d}$$

$$\therefore \theta = \frac{b}{d}$$

Elements of Grain Boundaries

The five degrees of freedom of a grain boundary

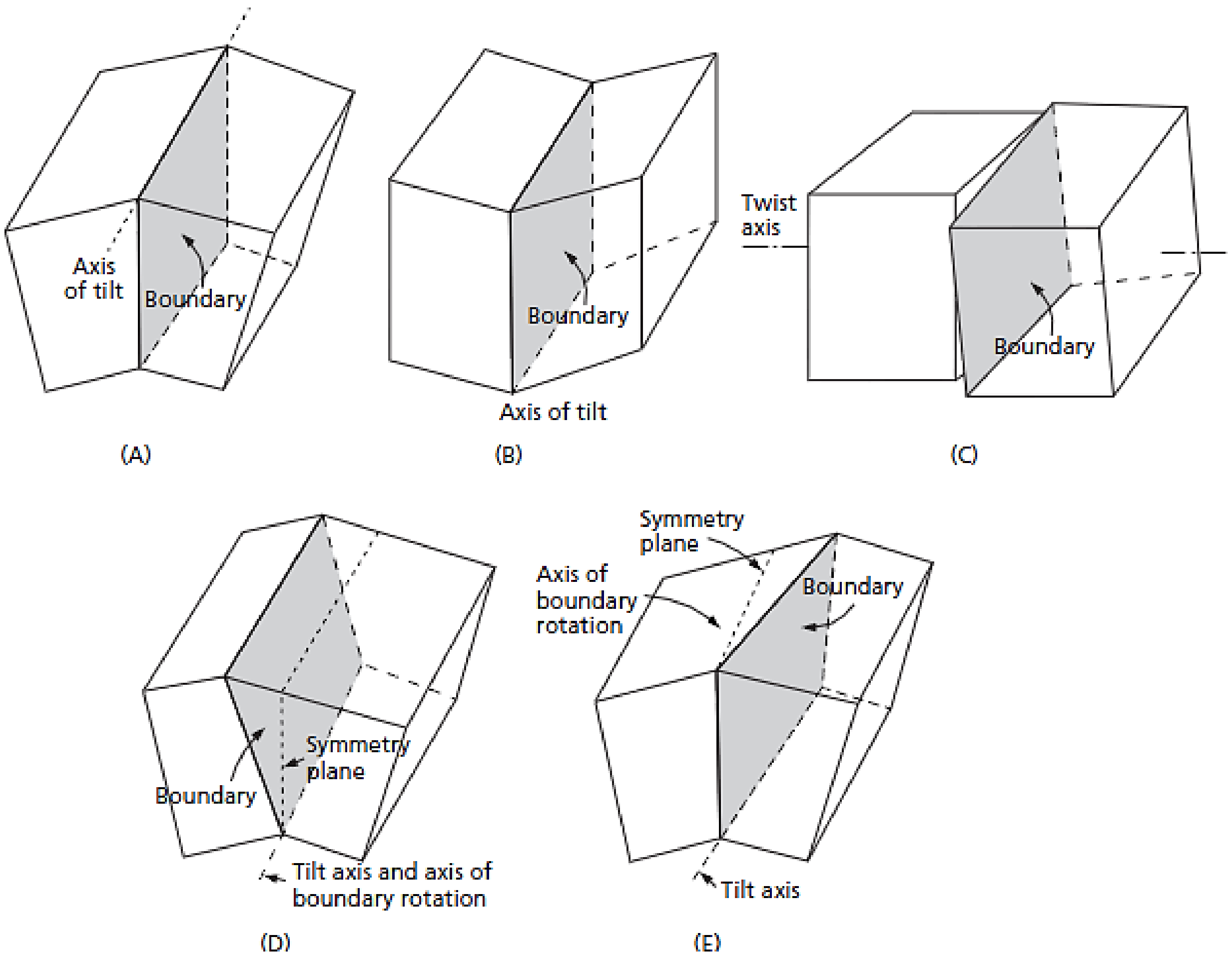


Fig. 6.5 The five degrees of freedom of a grain boundary.

The stress field of a grain boundary

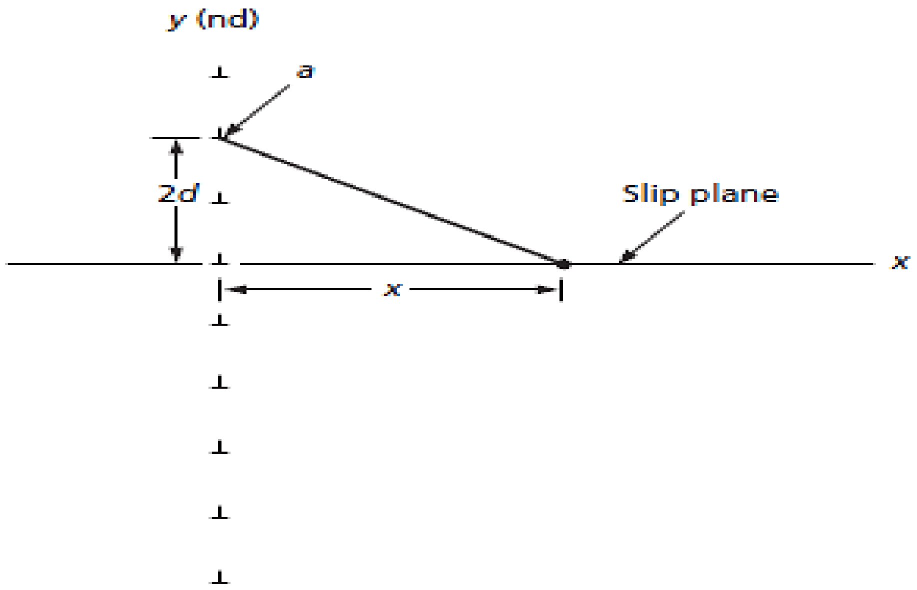


Fig.6.6 A diagram defining the parameters used in computing the stress due to a simple tilt boundary

$$\tau_{xy} = \frac{\mu b}{2\pi(1-\upsilon)} \cdot \frac{x(x^2 - y^2)}{(x^2 + y^2)^2}$$

$$\tau_{xy} = \frac{\mu b}{2\pi(1-\upsilon)} \cdot \frac{x[x^2 - (2d)^2]}{[x^2 + (2d)^2]^2}$$

$$\tau_{xy} = \frac{\mu b}{2\pi(1-\upsilon)} \sum_{n=-\infty}^{n=+\infty} \frac{x[x^2 - (nd)^2]}{[x^2 + (nd)^2]^2}$$

$$\tau_{xy} = \frac{2\pi\mu b x}{2(1-\upsilon)d^2} \exp(-\frac{2\pi x}{d}) \cos(\frac{2\pi x}{d})$$

Elements of Grain Boundaries

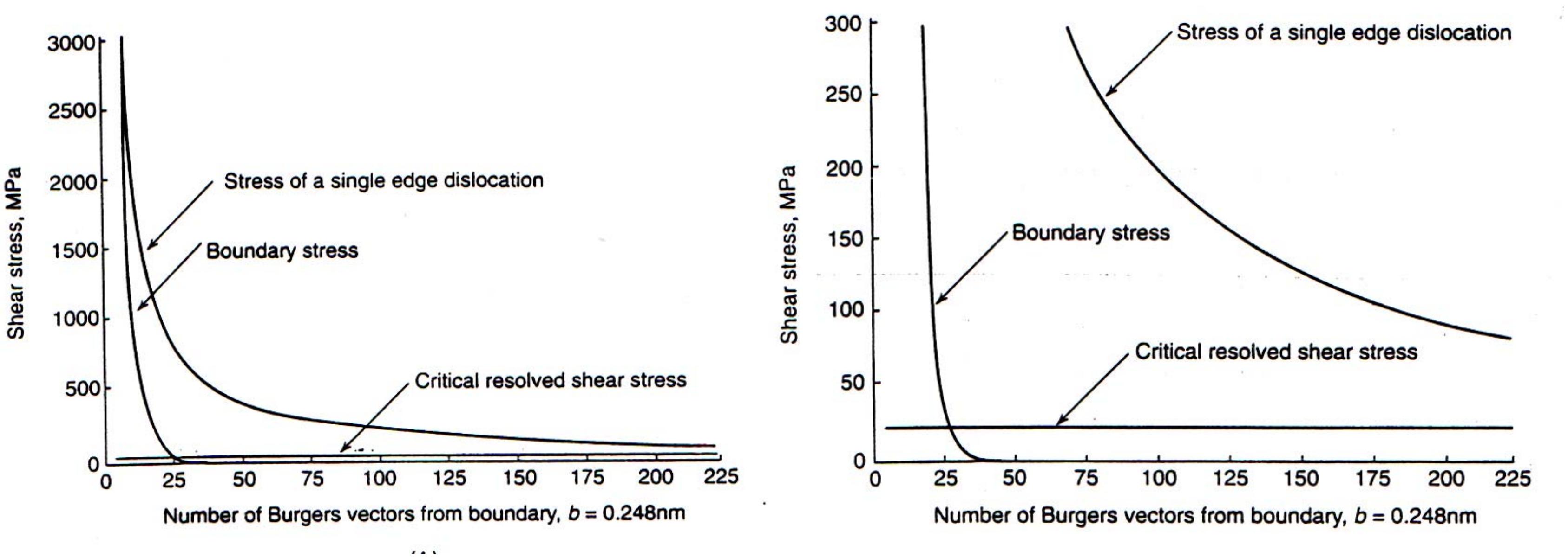


Fig. 6.7 (A) The stress, τ_{xy}, due to a tilt boundary and due to a single-edge dislocation as function of the distance measured in Burger vectors. (B) Same as in (A) but at an expended stress d=22b.

Elements of Grain Boundaries

Grain-Boundary Energy

Hirth & Lothe

$$\frac{W}{L} = w_{bd} = \frac{1}{2}\int_{r_0}^{\infty} \tau_{xy} b\,dx \qquad \left(\eta = \frac{\pi x}{d}, \quad \eta_0 = \frac{\pi b}{\alpha d} \right)$$

$$\therefore w_{bd} = \frac{\mu b^2}{4\pi(1-\upsilon)} \int_{\eta_0}^{\infty} \frac{\eta d\eta}{\sinh^2 \eta}$$

1/d : The dislocations per unit area

∴The energy per unit area of the boundary (γ_b) is,

$$\gamma_b = w_{bd} / d = \frac{\mu b^2}{4\pi(1-\upsilon)} [\eta_0 \coth \eta_0 - \ln(2\sinh \eta_0)]$$

We may take $\theta = \frac{b}{d}$ → $\gamma_b = \frac{\mu b}{4\pi(1-\upsilon)} \theta(\ln \alpha / 2\pi - \ln \theta + 1)$

Low-energy dislocation structures, LEDS

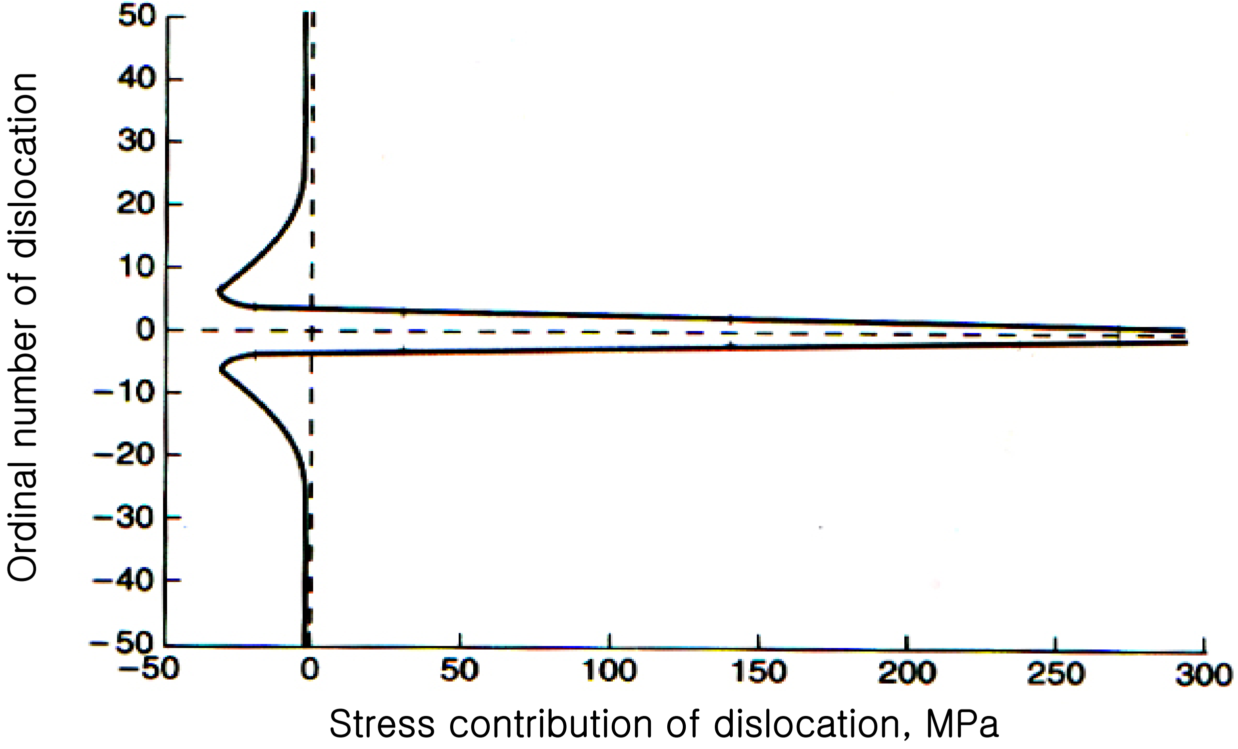


Fig. 6.11 The magnitude of the shear-stress contribution, at point X on the slip plane, of a dislocation in the tilt boundary as a function of its location in the boundary.

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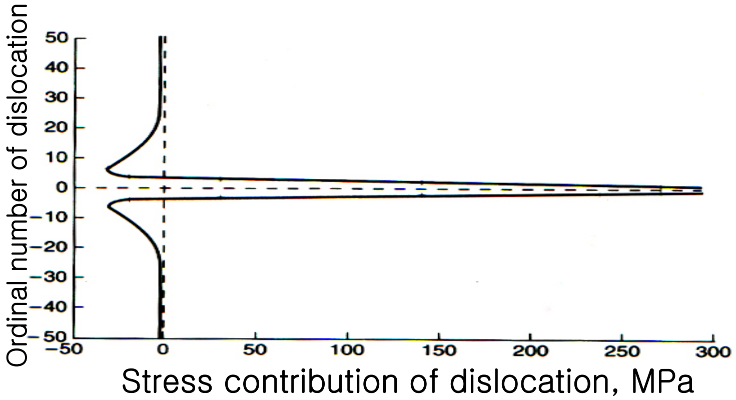


Fig. 6.11 The magnitude of the shear-stress contribution, at point X on the slip plane, of a dislocation in the tilt boundary as a function of its location in the boundary.

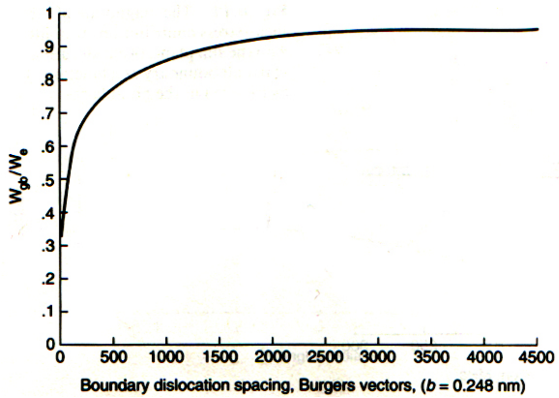


Fig. 6.12 The variation of W_{gb}/W_e with the spacing between the dislocations in a tilt boundary.

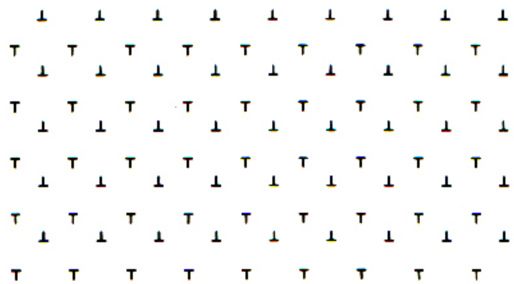


Fig. 6.13 The LEDS known as the Taylor lattice.

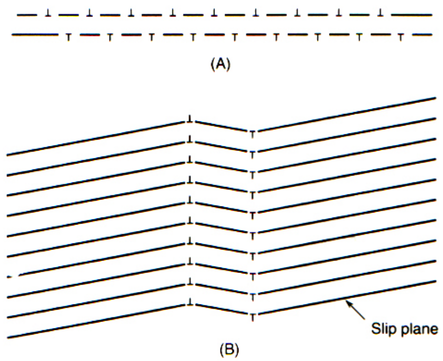
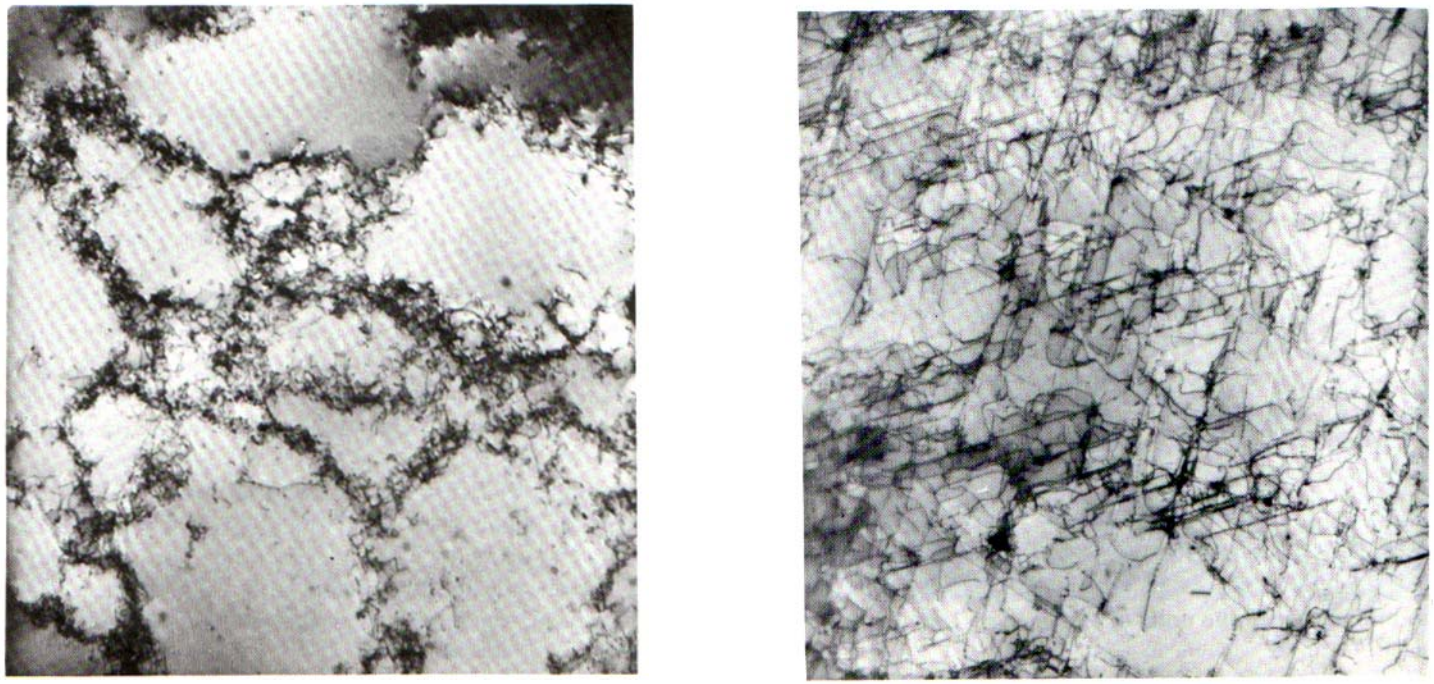


Fig. 6.14 (A) A dipolar mat that can form as a result of the interaction between dislocations of opposite sign moving on a pair of adjacent and parallel slip planes. (B) When a kink band form in a crystal, a dipolar array of edge dislocations of a different type is created.

Dynamic recovery



(A) (B)

Fig. 6.16 Alloying normally reduces the stacking-fault energy of a metal. This can have a pronounced effect on the dislocation structure, as can be seen in these two electron micrographs. (A) pure nickel strained 3.1 percent at 293K. Magnification: 25,000X.(B) Nickel- 5.5wt. Percent aluminum alloy strained 2.7 percent at 293K. Magnification : 37,500X. (Photographs courtesy of J. O. Stiegler, Oak Ridge National Laboratories, Oak Ridge, Tenn.)

Surface tension of the grain boundary

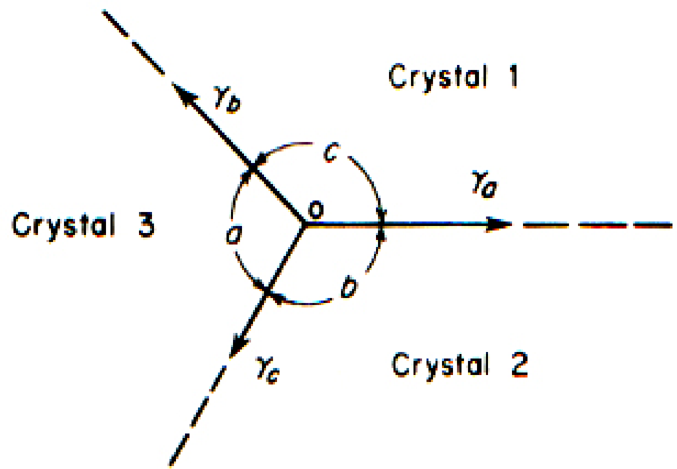
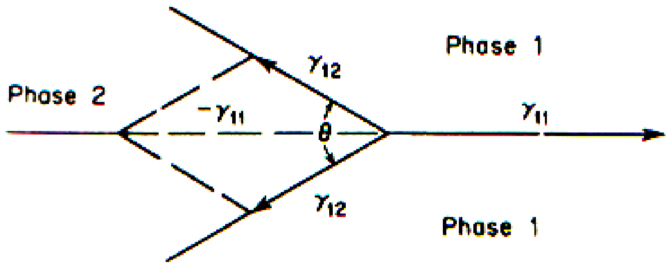


Fig. 6.17 The grain-boundary surface tensions at a junction of three crstals

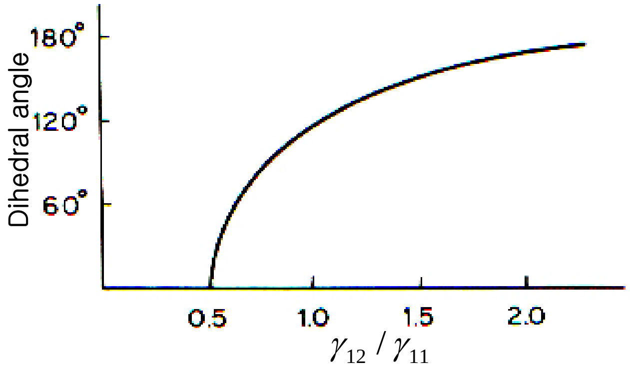
$$\frac{\gamma_a}{\sin a} = \frac{\gamma_b}{\sin b} = \frac{\gamma_c}{\sin c}$$

Elements of Grain Boundaries

Boundary between crystal of different phases

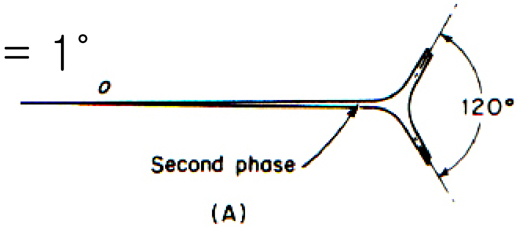


$$\gamma_{11} = 2\gamma_{12}\cos\frac{\theta}{2}$$

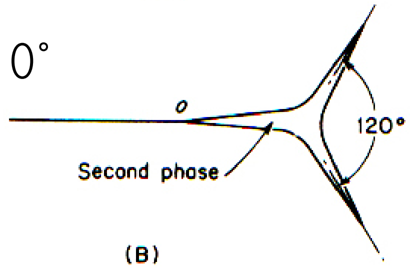


Dihedral angle (θ)

(θ)= 1°



(θ)= 10°



(θ)= 60°