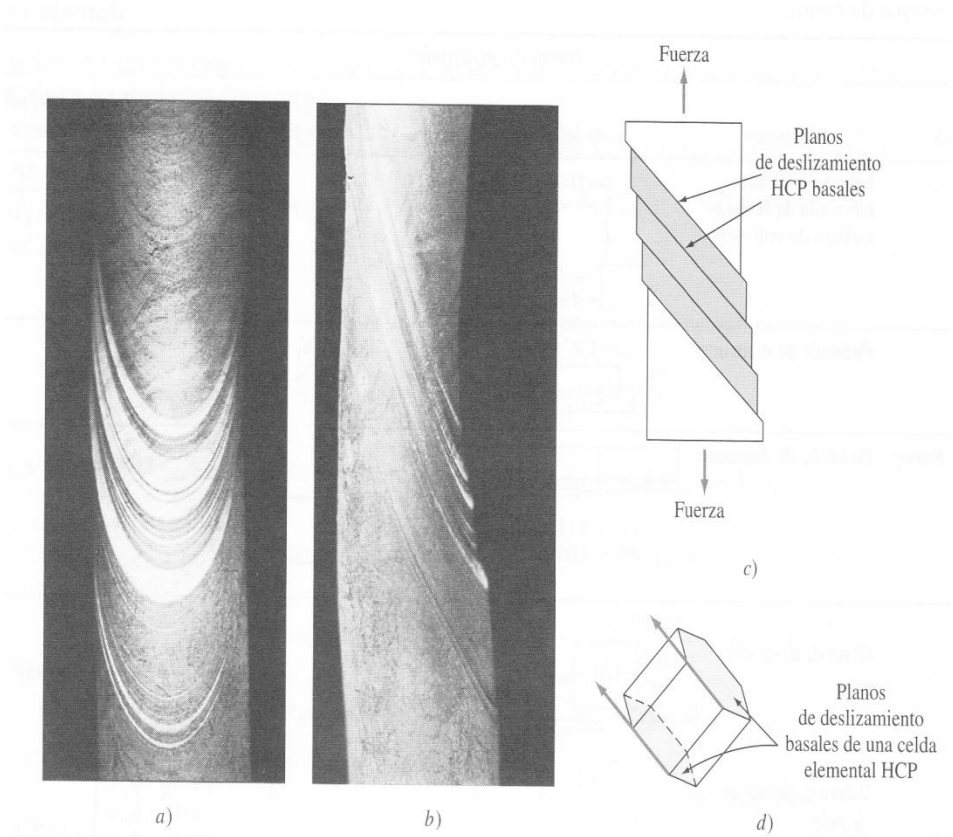
Dislocaciones: Campos de esfuerzo, energía y dislocaciones parciales

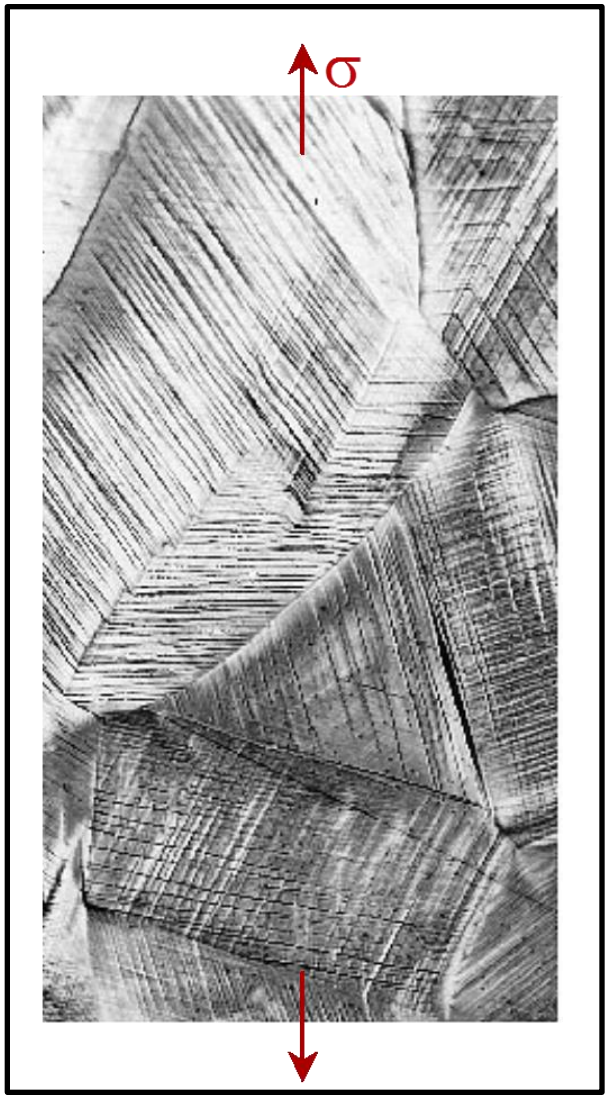
El mecanismo más importante de Deformación plástica en metales



-Tracción.

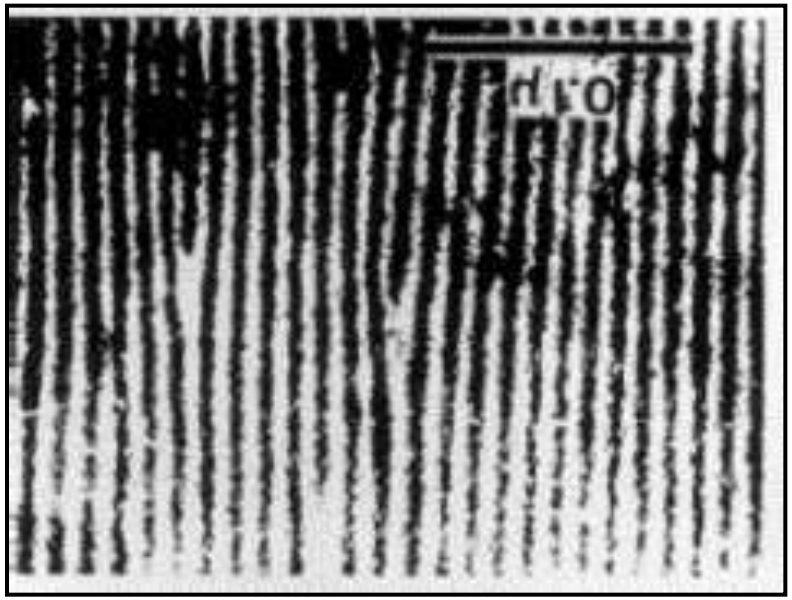
-Deformación plástica (irreversible) de un monocristal de Zinc, apropiadamente orientado.

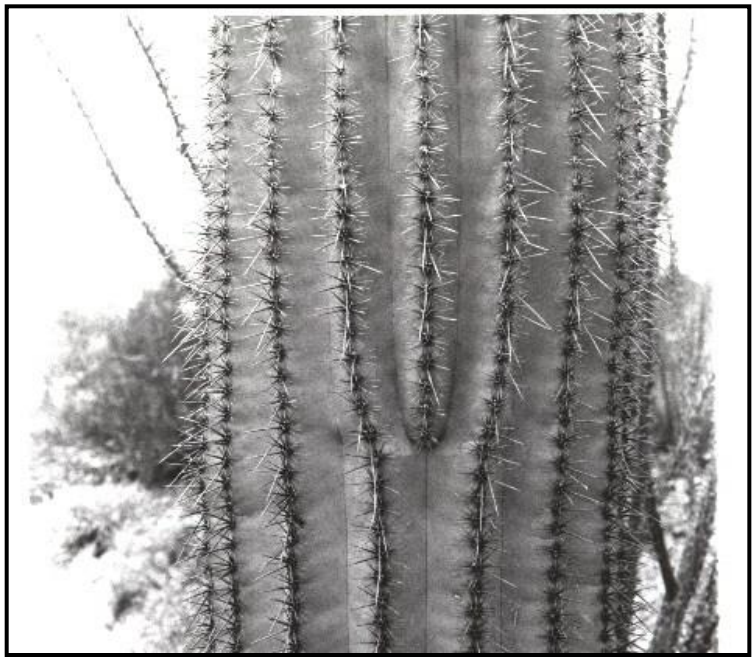
- Bandas de deslizamiento



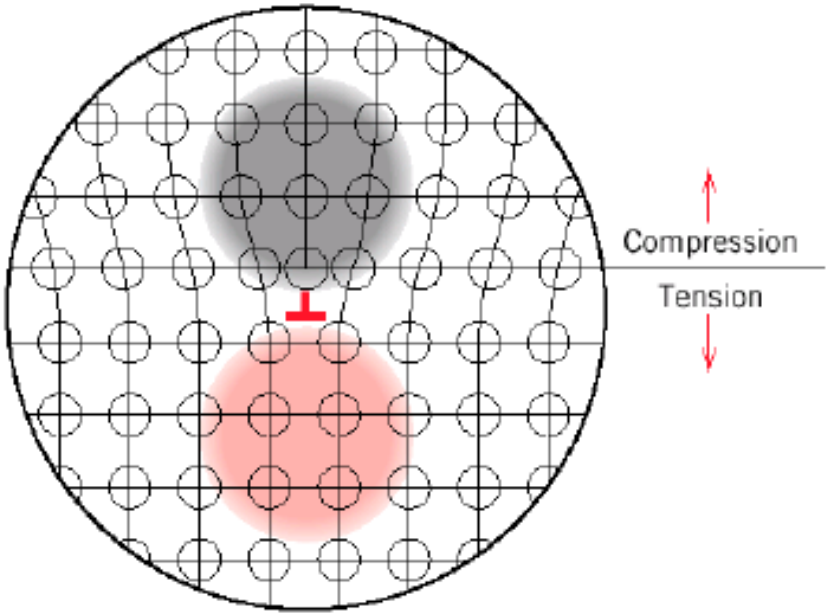
En los cristales, afortunadamente, no todo es perfecto

En los cristales existen defectos , que bajo la acción de fuerzas externas, se mueven...

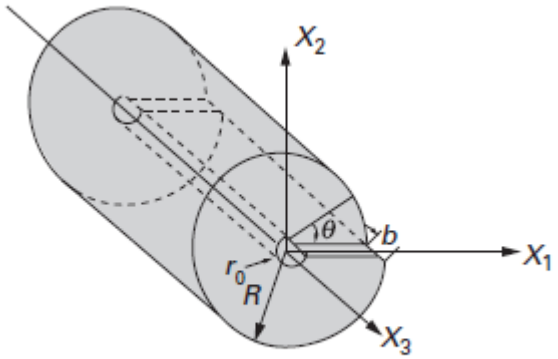




Strain field around dislocations



Campos de esfuerzo alrededor de una dislocación



(a)

Dislocación helicoidal

$$u_1 = 0, \quad u_2 = 0, \quad u_3 \neq 0.$$

$$u_3 = f(\theta) = \frac{b}{2\pi}\theta. \qquad u_3 = \frac{b}{2\pi}\arctan\frac{x_2}{x_1}.$$

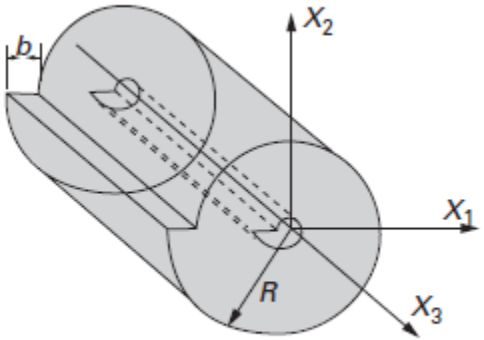
$$\varepsilon_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$$

$$\varepsilon_{11} = 0, \varepsilon_{22} = 0,$$
$$\varepsilon_{12} = 0, \varepsilon_{23} = \frac{1}{2}\frac{\partial u_3}{\partial x_2},$$
$$\varepsilon_{13} = \frac{1}{2}\frac{\partial u_3}{\partial x_1}, \varepsilon_{33} = \frac{\partial u_3}{\partial x_3} = 0.$$

$$\varepsilon_{13} = \frac{-bx_2}{4\pi(x_1^2 + x_2^2)},$$
$$\varepsilon_{23} = \frac{bx_1}{4\pi(x_1^2 + x_2^2)},$$
$$\sigma_{33} = 0.$$

$$\sigma_{13} = \sigma_{31} = -\frac{Gbx_2}{2\pi(x_1^2 + x_2^2)},$$
$$\sigma_{23} = \sigma_{32} = \frac{Gbx_1}{2\pi(x_1^2 + x_2^2)}.$$

Campos de esfuerzo alrededor de una dislocación



(b)

Dislocación de Borde

$$\sigma_{11} = -\frac{G\,b x_2(3x_1^2 + x_2^2)}{2\pi(1-\nu)(x_1^2 + x_2^2)^2},$$

$$\sigma_{12} = \frac{G\,b x_1(x_1^2 - x_2^2)}{2\pi(1-\nu)(x_1^2 + x_2^2)^2},$$

$$\sigma_{22} = \frac{G\,b x_2(x_1^2 - x_2^2)}{2\pi(1-\nu)(x_1^2 + x_2^2)^2}.$$

$$\sigma_{33} = \nu(\sigma_{11} + \sigma_{22}) = -\frac{G\,b\nu x_2}{\pi(1-\nu)(x_1^2 + x_2^2)}.$$

Energía de una dislocación

$$U = \frac{1}{2}\sigma_{ij}\varepsilon_{ij}. \qquad U = \frac{1}{2G}\left[\frac{1}{2(1+\nu)}(\sigma_{11}^2+\sigma_{22}^2+\sigma_{33}^2)+(\sigma_{12}^2+\sigma_{13}^2+\sigma_{23}^2)-\frac{\nu}{(1+\nu)}(\sigma_{11}\sigma_{33}+\sigma_{11}\sigma_{22}+\sigma_{22}\sigma_{33})\right].$$

Para una dislocacion helicoidal

$$U_s = \frac{G\,b^2}{8\pi^2(x_1^2+x_2^2)}. = \frac{G\,b^2}{8\pi^2 r^2}.$$

$$U_s = \int_{r_0}^{R} \frac{G\,b^2}{8\pi^2 r^2} 2\pi r\,dr = \frac{G\,b^2}{4\pi}\ln\frac{R}{r_0}.$$

Para una dislocación de borde

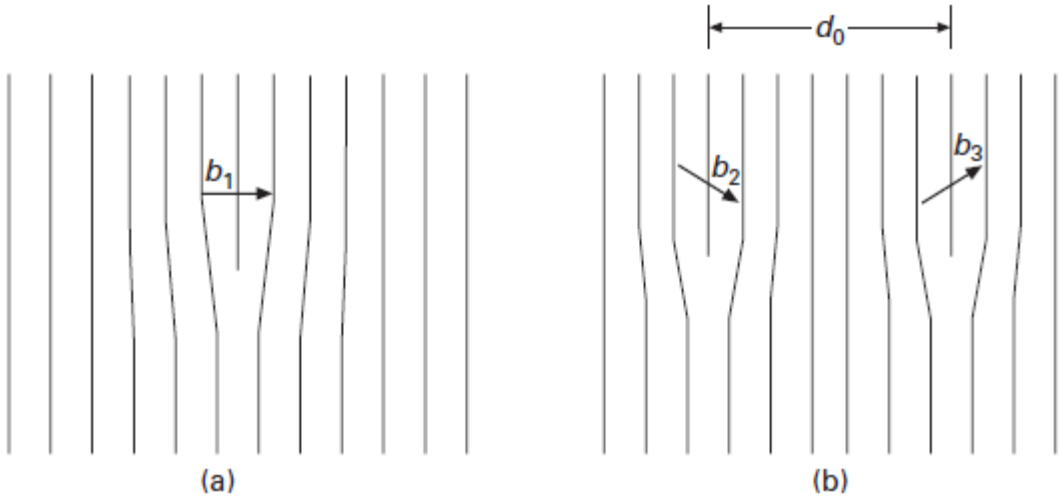
$$U_\perp = \frac{G\,b^2}{4\pi(1-\nu)}\ln\frac{R}{r_0}.$$

$$U_{borde} > U_{helic}$$

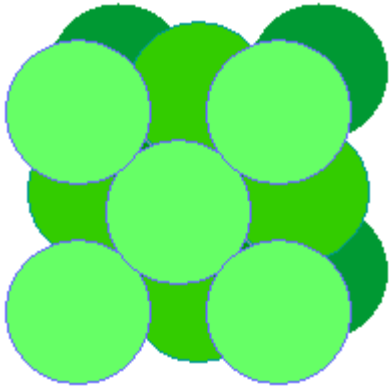
Dislocaciones parciales

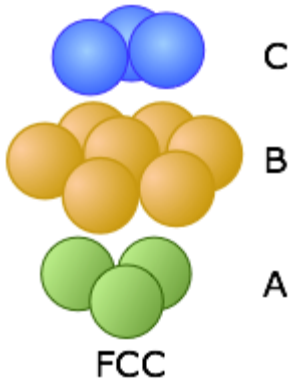
Una dislocación extendida b1 se puede descomponer en 2 parciales b2 y b3 si la energía de la b1 es mayor que la del sistema b2 y b3. Ademas, b1 debe ser igual a la suma vectorial de b2+b3

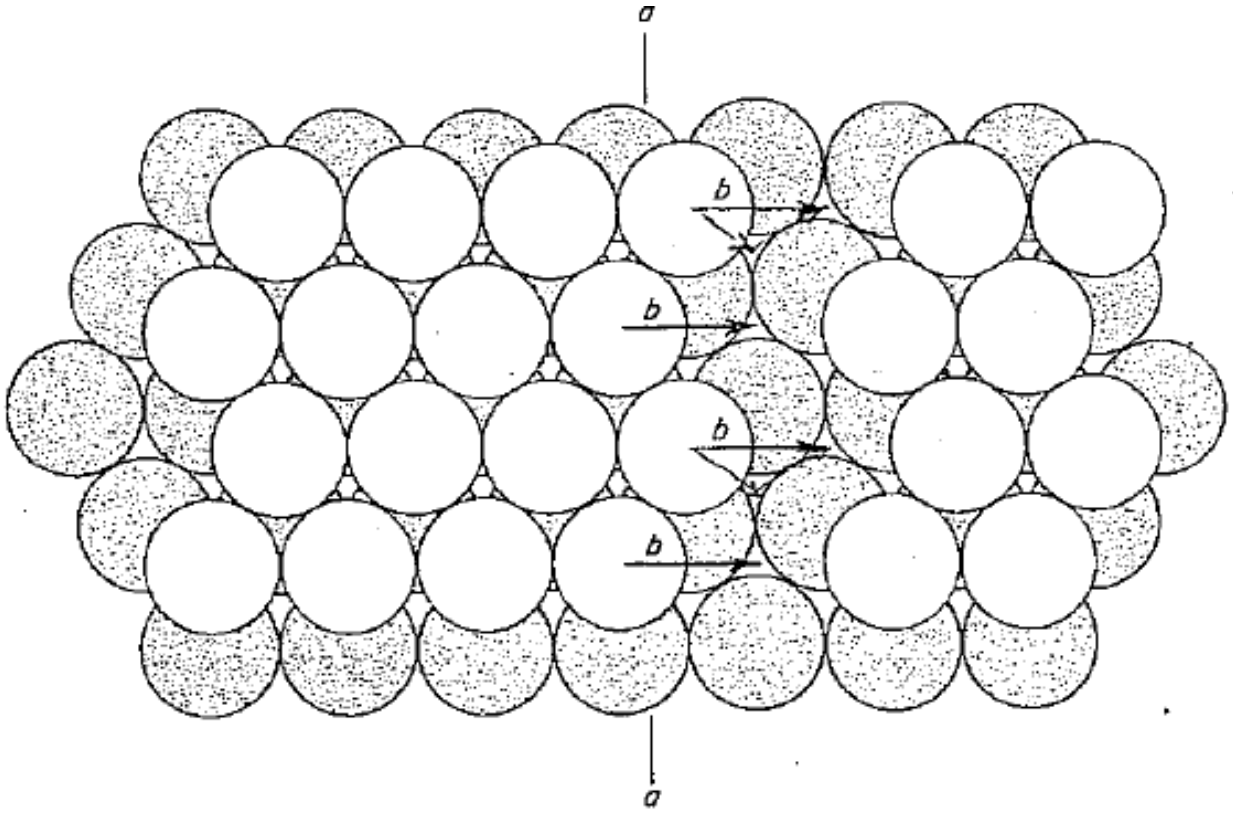
$$Gb_1^2 > Gb_2^2 + Gb_3^2$$



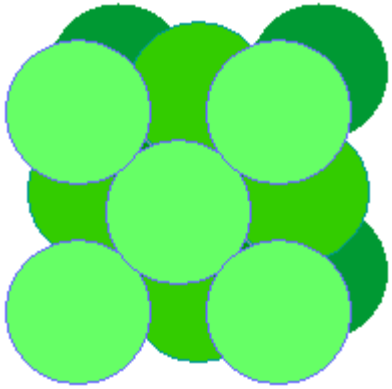
FCC

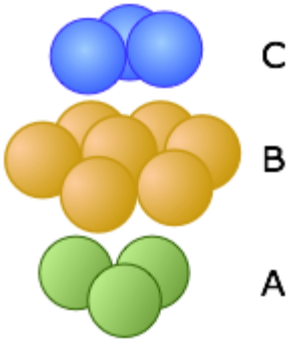


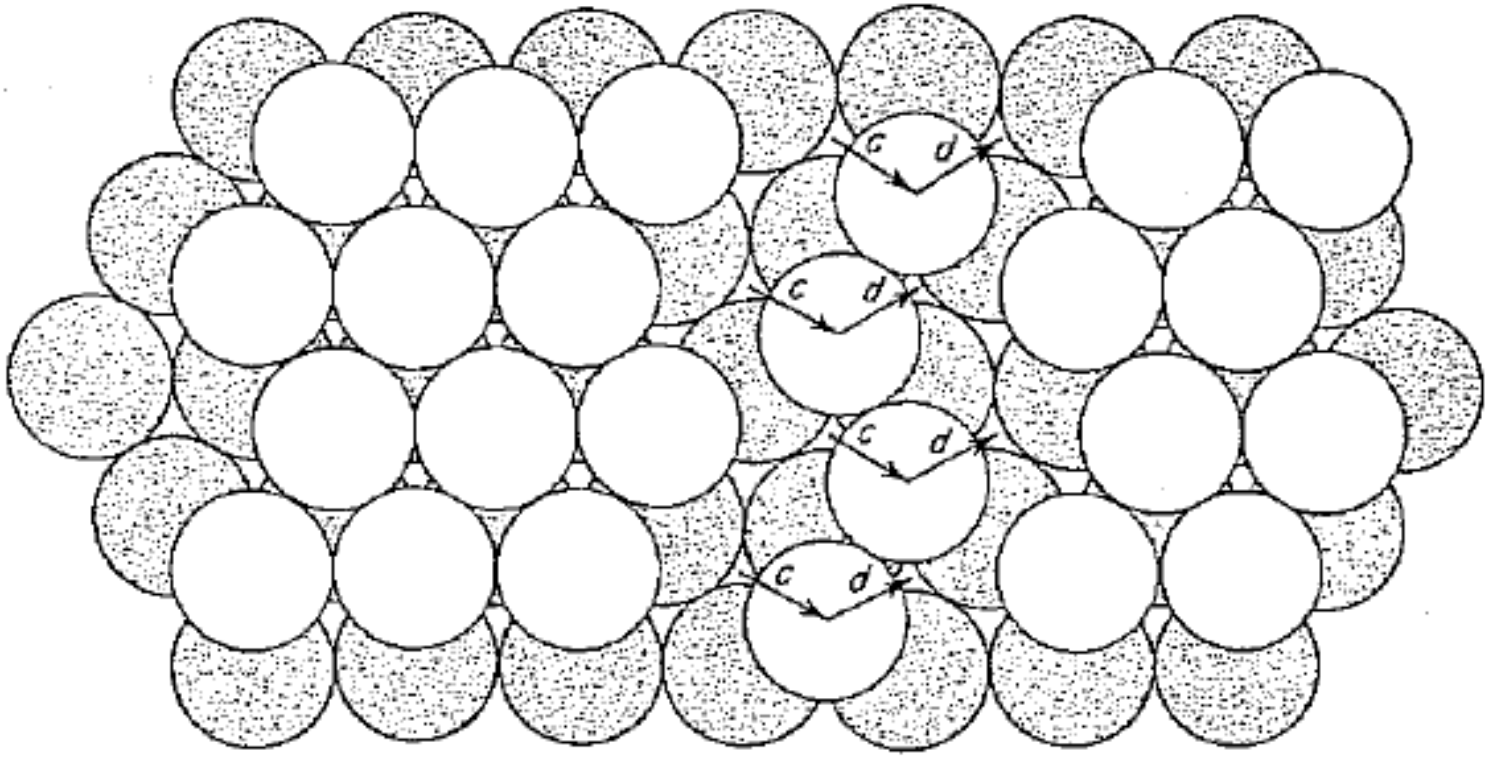


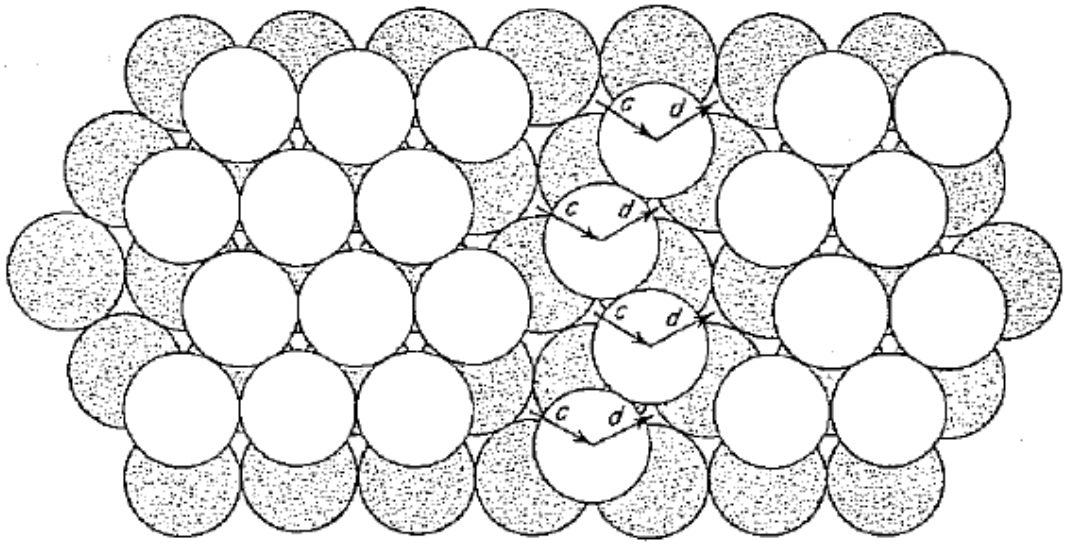


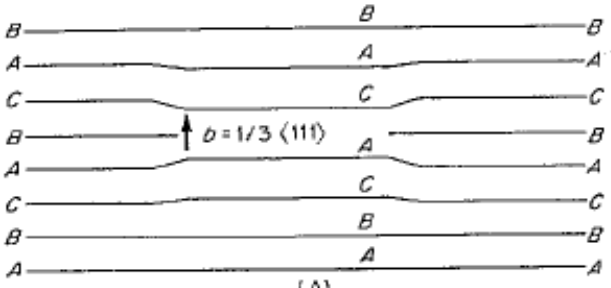
FCC



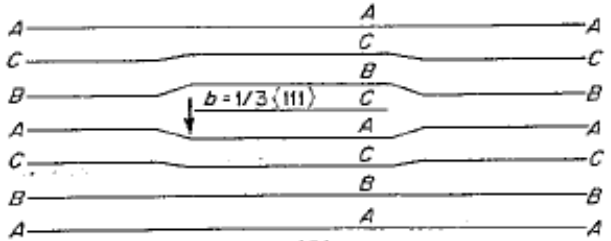




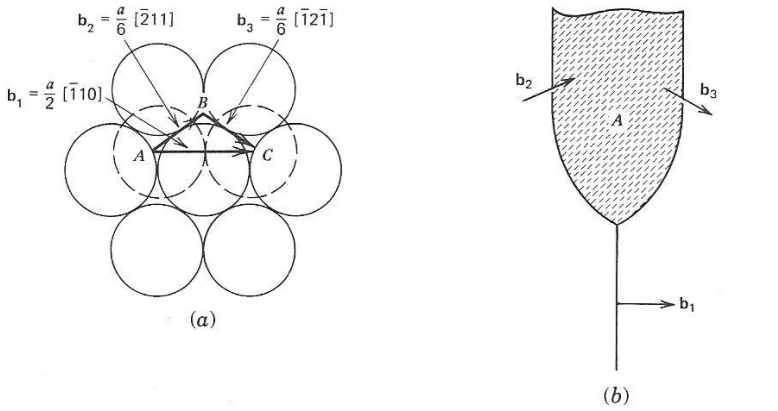


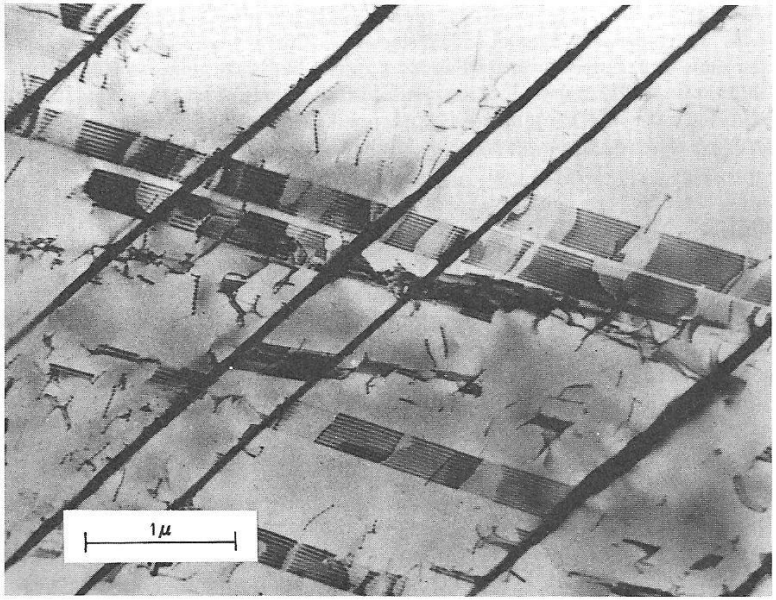


(A)



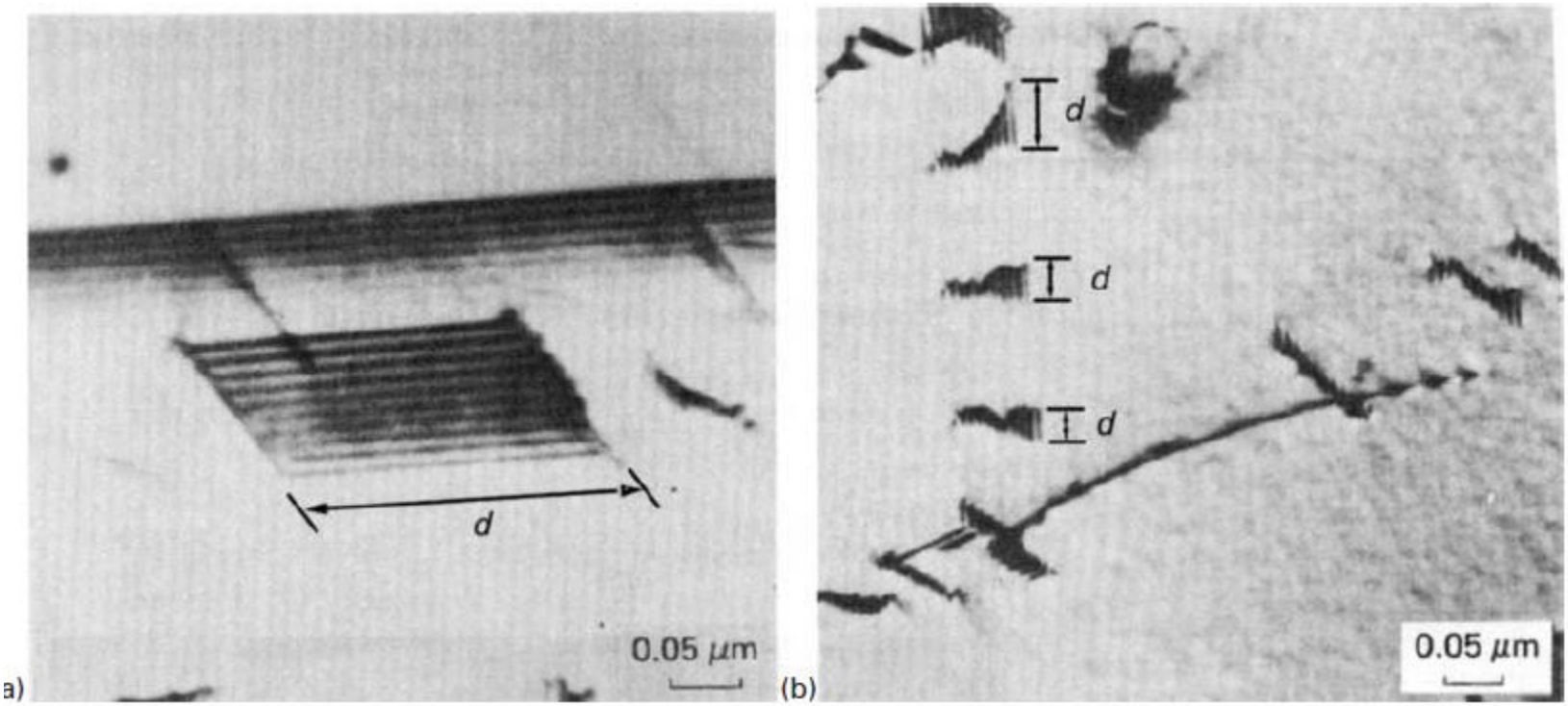
(B)



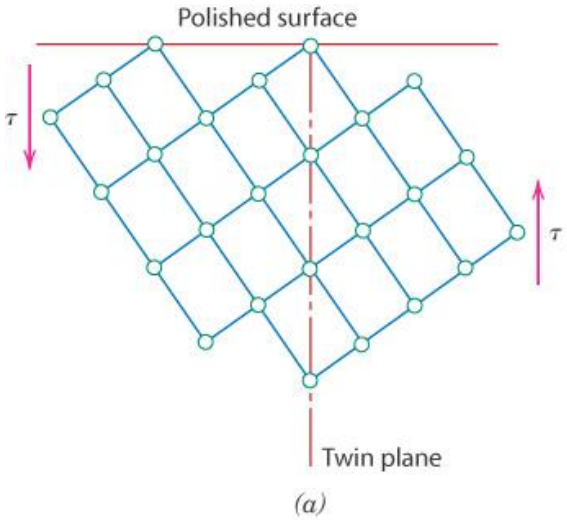


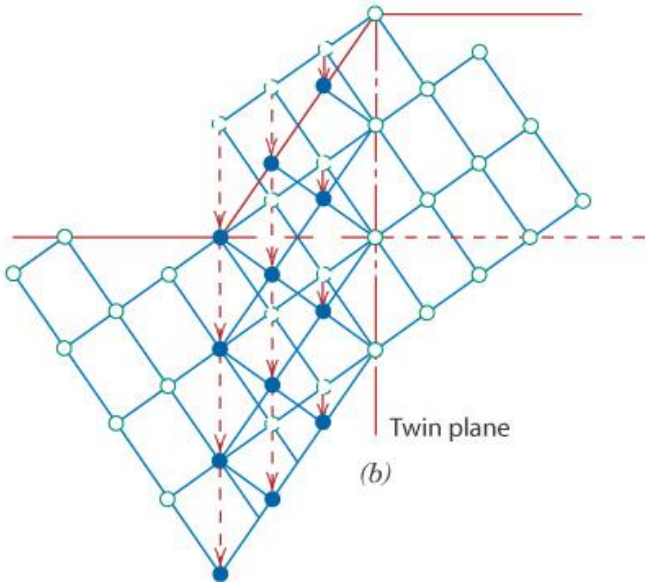
(c)

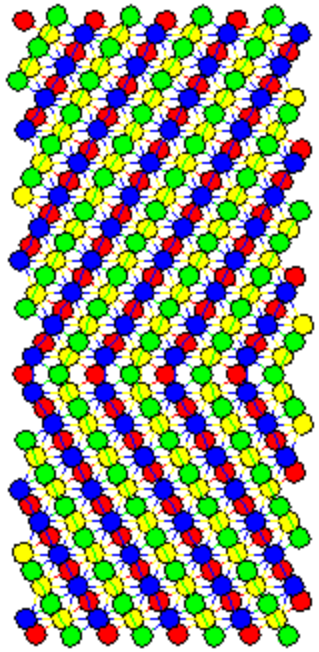
FIGURE 2.17 **(*a*) Path of whole and partial (Shockley) partials; (*b*) Shockley partials b_2 and b_3 surrounding stacking fault region *A*; (*c*) Long stacking fault ribbons (bands of closely spaced lines) in low SFE 18Cr–8Ni stainless steel. Faults are bounded at ends by partial dislocations. Thin black bands are mechanical twins. (After Michalak[18]; reprinted with permission from *Metals Handbook,* Vol. 8, American Society for Metals, Metals Park, OH, © 1973.)**


a)
d
0.05 μm
(b)
d
d
d
0.05 μm

Deformación por Maclado (Twinning)







- Un esfuerzo de corte puede producir desplazamientos atómicos tal que a un lado del plano (límite de macla), los átomos tienen posiciones que corresponde a la imagen especular de las posiciones del otro lado de la macla
- La creación de maclas puede re-orientar favorablemente planos de deslizamiento de dislocaciones, tal que antes de ello el esfuerzo aplicado no alcanzaba el crítico para moverlas.

Comparación movimiento D´s vs Maclado

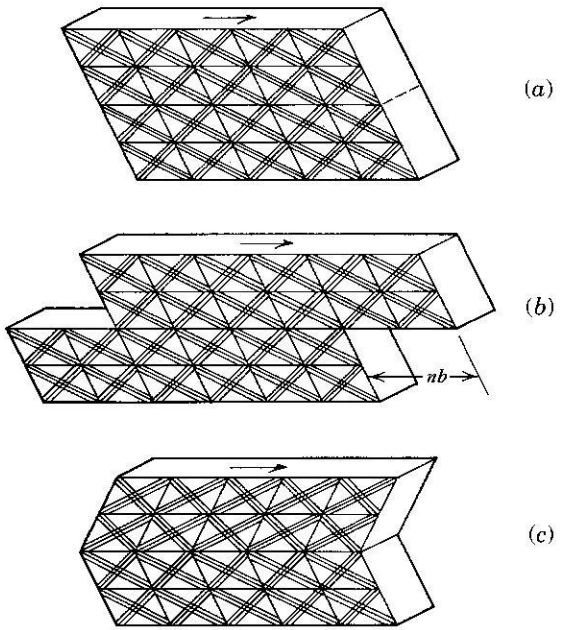
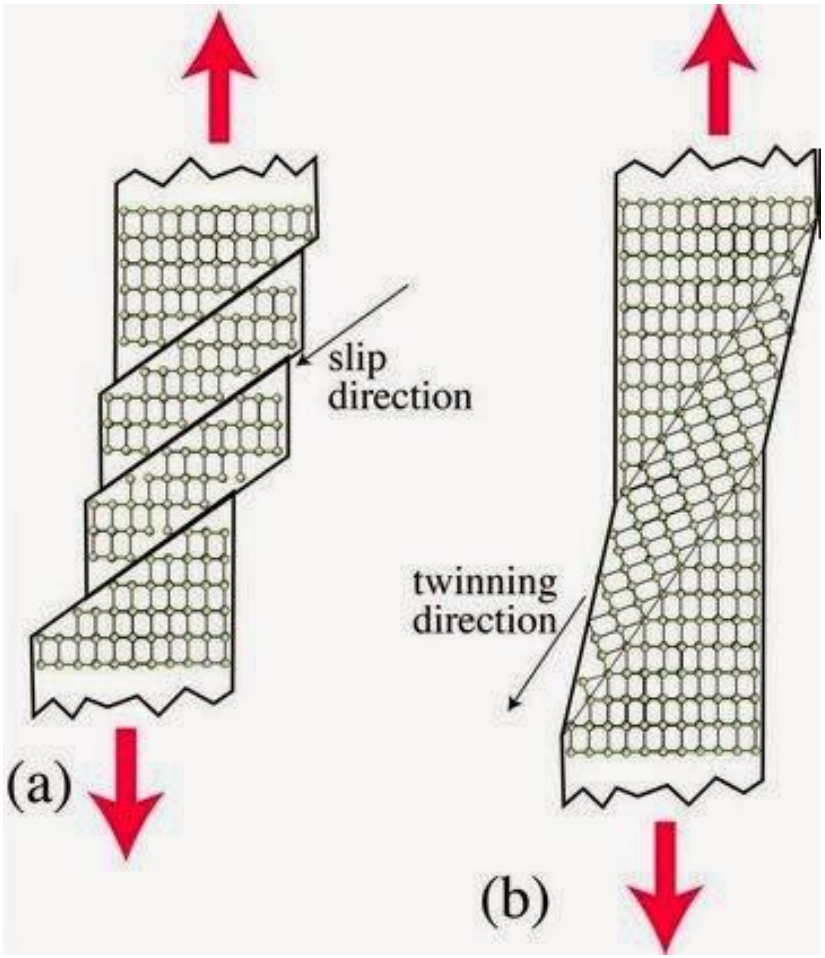
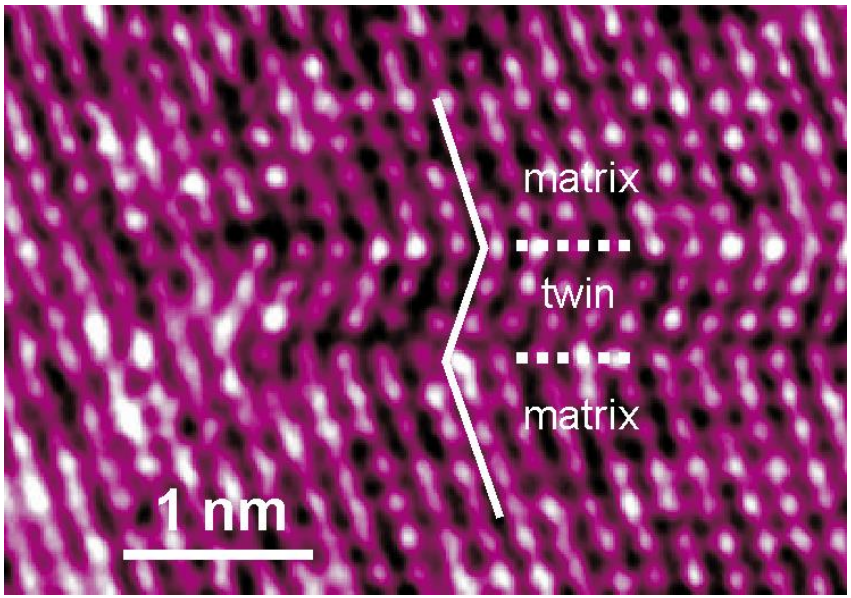


FIGURE 3.12 Shape change in solid cube caused by plastic deformation. (*a*) Undistorted cube; (*b*) slipped cube with offsets *nb*; (*c*) twinned cube revealing reorientation within twin. Displacements are proportional to distance from twin plane.

Maclas


slip
direction
twinning
direction
(a)
(b)


matrix
twin
matrix
1 nm