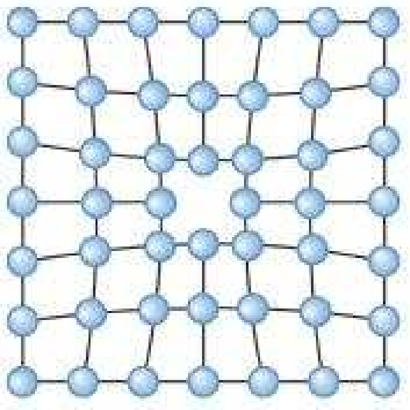
Defeitos



Explicar equilíbrio de vacâncias. Mostrar exemplo do Cu (Q_v=20 kcal/mol).

$$n_v = N \exp\left(\frac{-Q_v}{RT}\right)$$

Figure 4.1 Point defects: (a) vacancy.
All of these defects disrupt the perfect arrangement of the surrounding atoms.

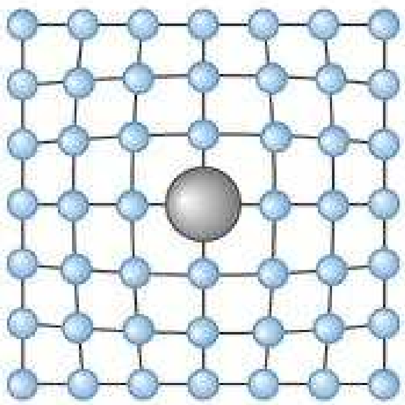


Figure 4.1 Point defects: (d) large substitutional atom. All of these defects disrupt the perfect arrangement of the surrounding atoms.

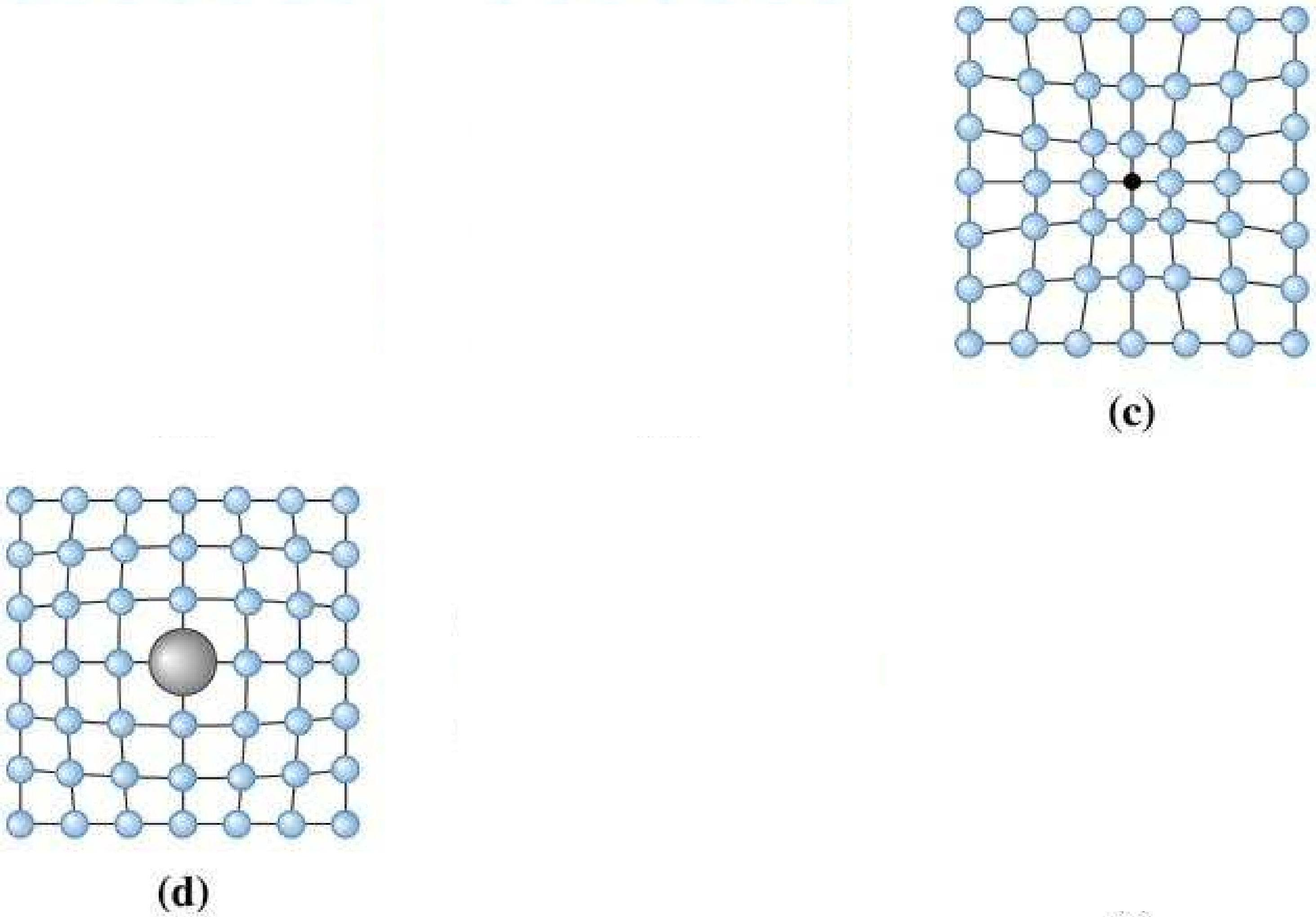


Figure 4.1 Point defects: (c) small substitutional atom, (d) large substitutional atom.
All of these defects disrupt the perfect arrangement of the surrounding atoms.

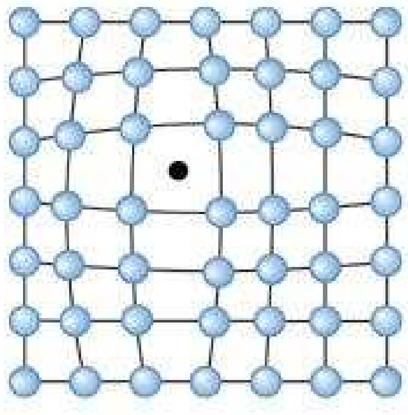
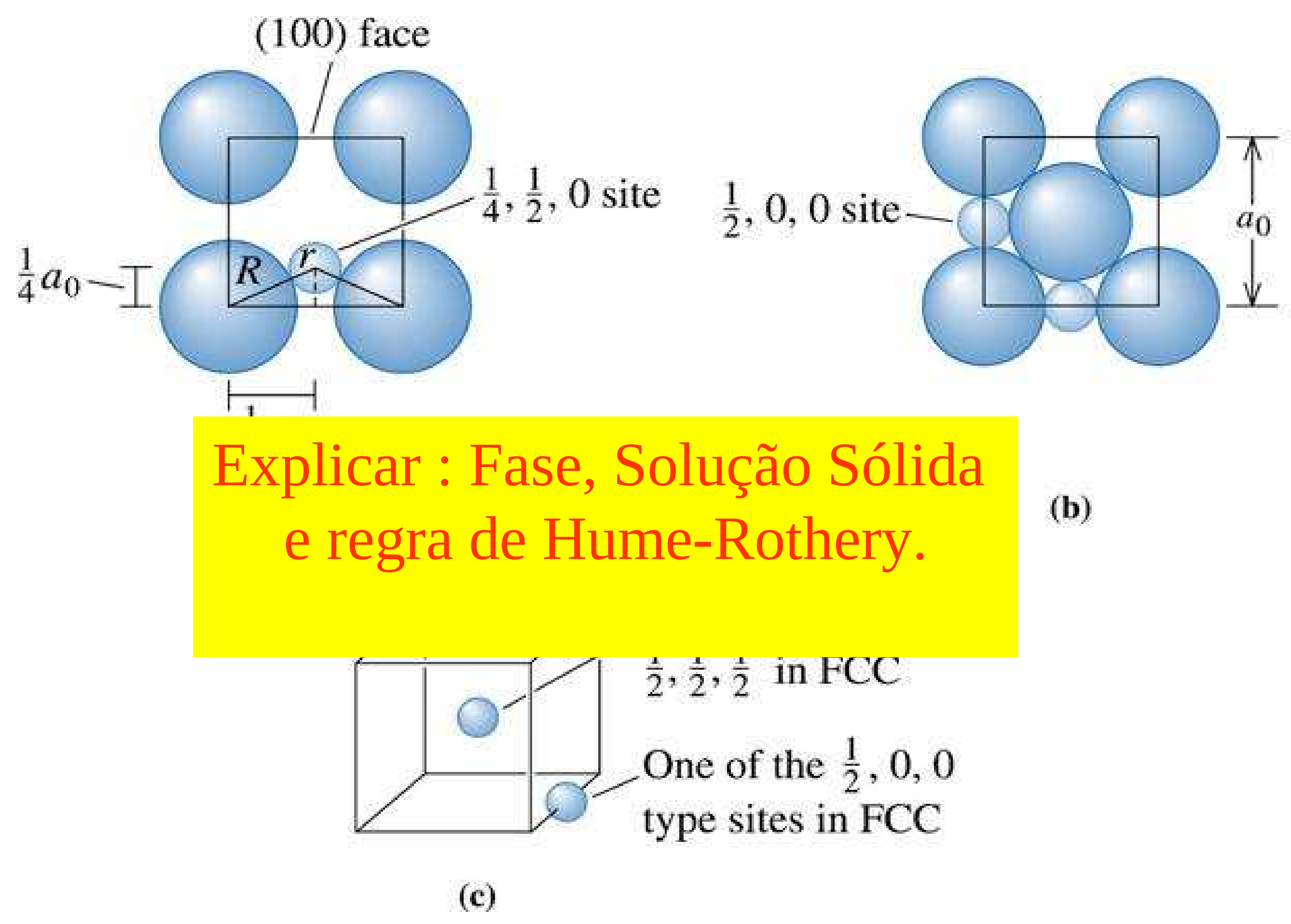


Figure 4.1 Point defects: (b) interstitial atom.
All of these defects disrupt the perfect arrangement of the surrounding atoms.



Explicar : Fase, Solução Sólida e regra de Hume-Rothery.

Figure 4.2 (a) The location of the ¼, ½, 0 interstitial site in BCC metals, showing the arrangement of the normal atoms and the interstitial atom (b) ½, 0, 0 site in FCC metals, (for Example 4.3). (c) Edge centers and cube centers are some of the interstitial sites in the FCC structure (Example 4.3).

Discordância em cunha

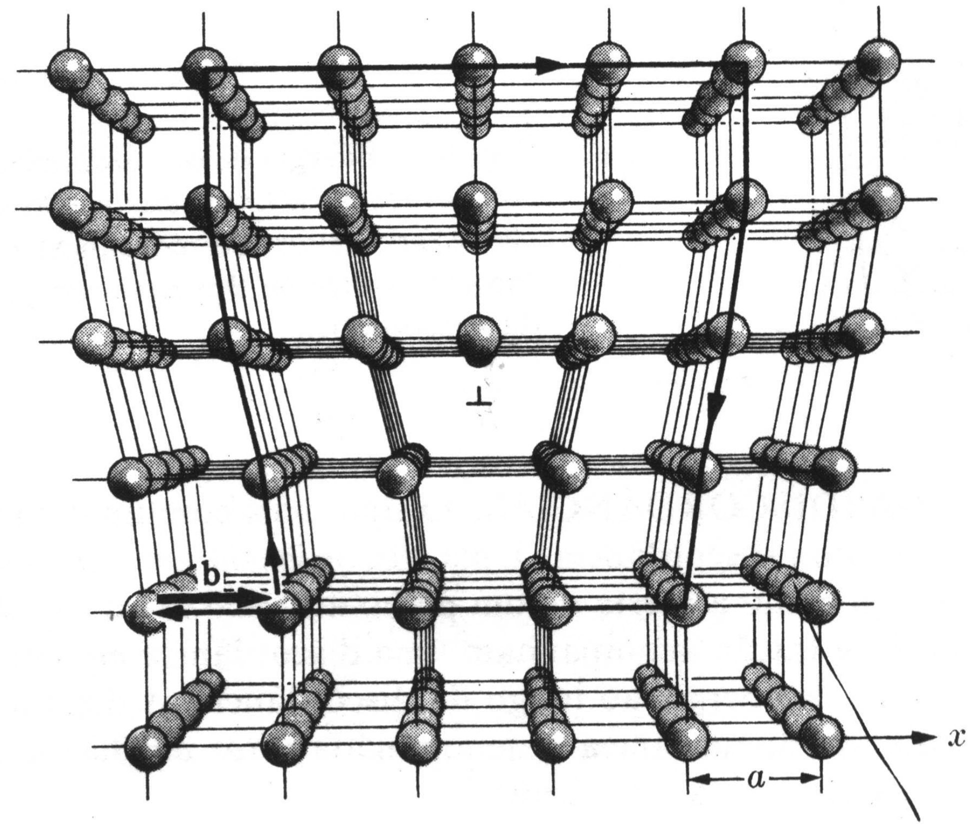


Fig. 4-10. Discordância em cunha. Um defeito de linha ocorre na aresta de um plano atômico extra. (*Guy, A. G., Elements of Physical Metallurgy*, Reading, Mass.: Addison Wesley, 1959, pág. 110).

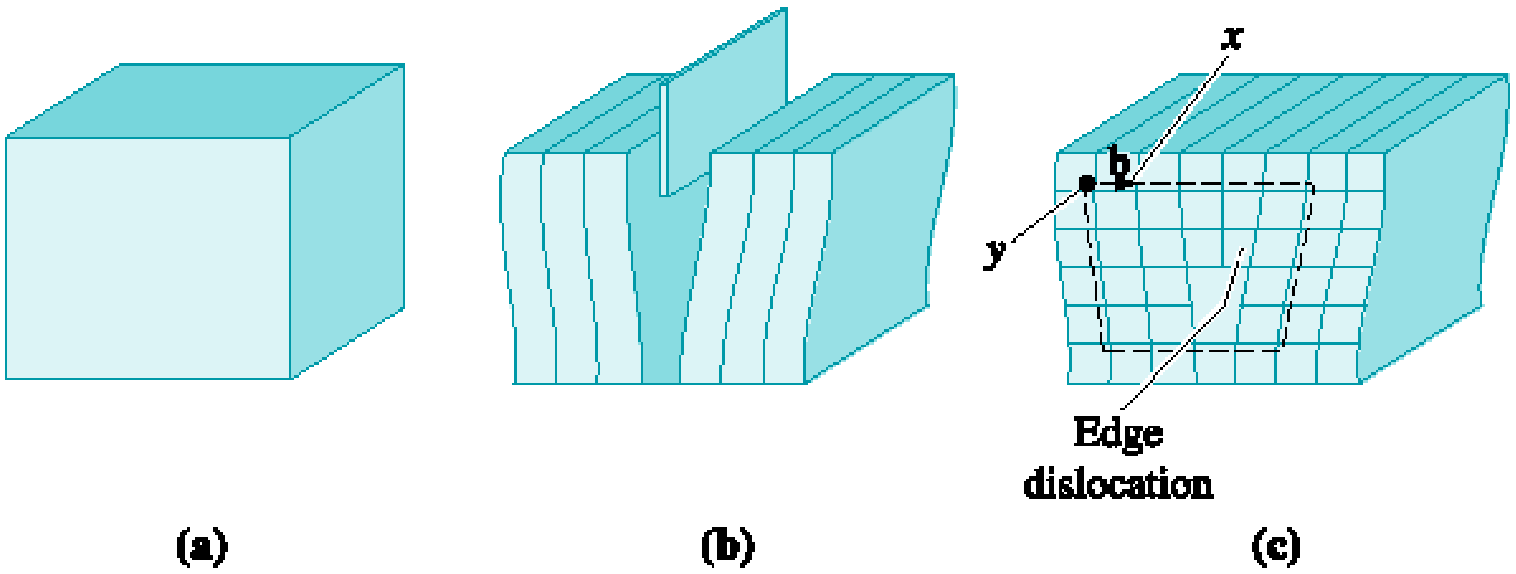


Figure 4.5 The perfect crystal in (a) is cut and an extra plane of atoms is inserted (b). The bottom edge of the extra plane is an edge dislocation (c). A Burgers vector b is required to close a loop of equal atom spacings around the edge dislocation. (*Adapted from J.D. Verhoeven*, Fundamentals of Physical Metallurgy, *Wiley, 1975*.)

Discordância em hélice

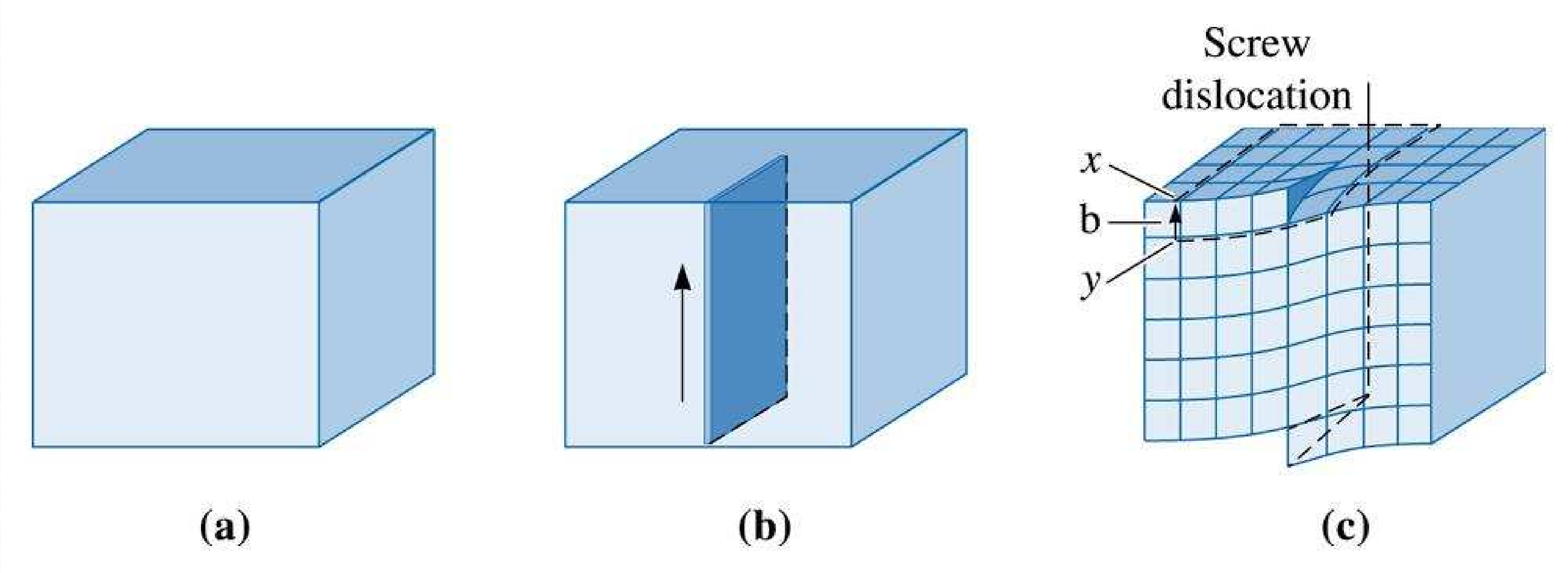


Figure 4.4 the perfect crystal (a) is cut and sheared one atom spacing, (b) and (c). The line along which shearing occurs is a screw dislocation. A Burgers vector *b* is required to close a loop of equal atom spacings around the screw dislocation.

Discordância em hélice

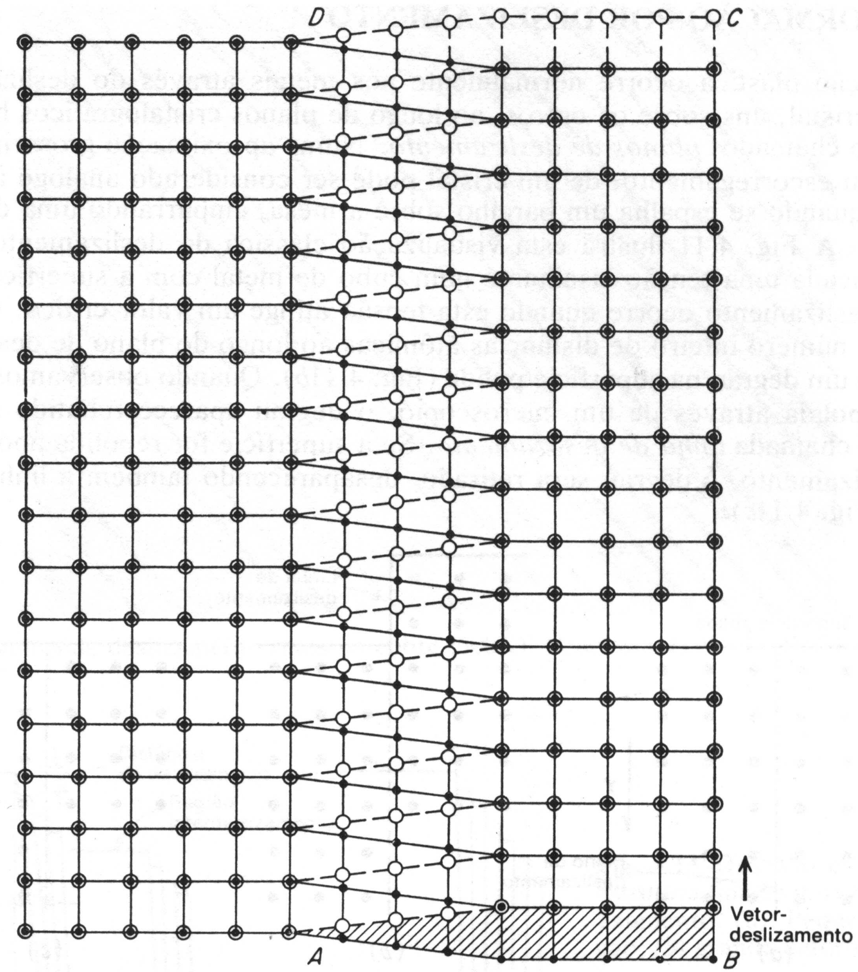
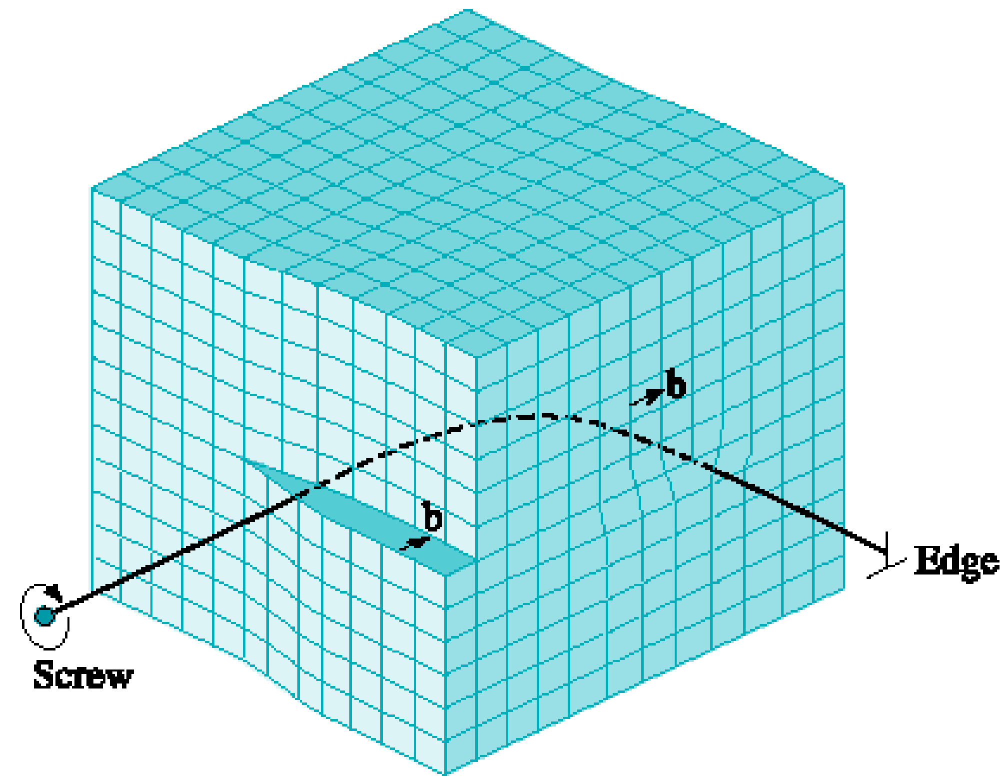


Fig. 4.10 Arranjo atômico em volta da discordância espiral mostrada na Fig. 4.9. O plano da figura é paralelo ao plano de deslizamento. A área deslizada é *ABCD*, e *AD* é a discordância-espiral. Os círculos abertos representam os átomos imediatamente acima do plano de deslizamento; os círculos fechados são os átomos no plano imediatamente abaixo do plano de deslizamento. (De W. T. Read, Jr., *Dislocations in Crystals*, p. 17, McGraw-Hill Book Company, New York, 1953.)

Mista



McGraw-Hill, 1953.)

Discordâncias

Figure 4.6 A transmission electron micrograph of a titanium alloy in which the dark lines are dislocations. 51,450×. (Courtesy of M. R. Plichta, Michigan Technological University.)

Vetor de Burgers

A sketch of a dislocation in magnesium oxide (MgO), which has the sodium chloride crystal structure and a lattice parameter of 0.396 nm, is shown in Figure 4.9. Determine the length of the Burgers vector.

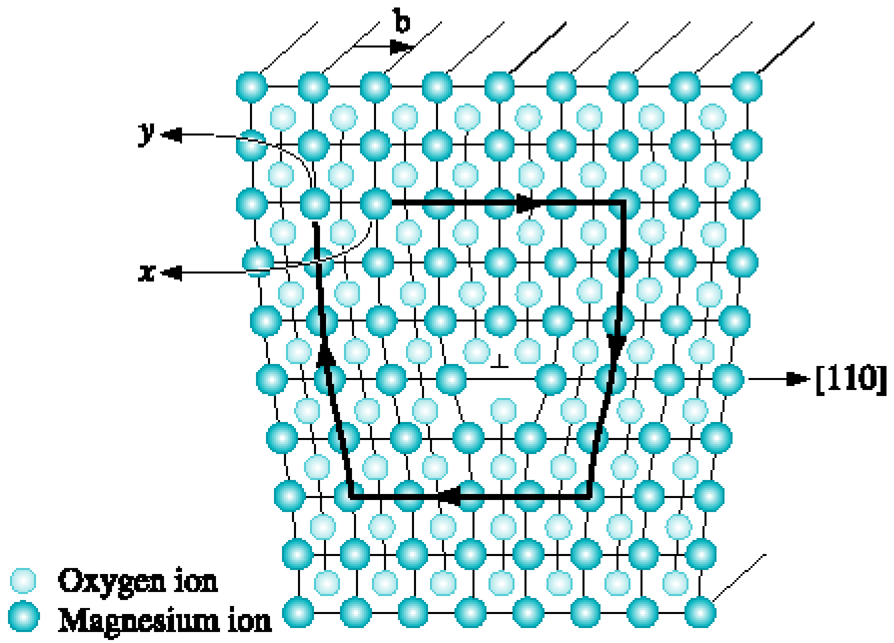


Figure 4.9 An edge dislocation in MgO showing the slip direction and Burgers vector (for Example 4.7). (*Adapted from W.D. Kingery, H.K. Bowen, and D.R. Uhlmann,* Introduction to Ceramics*, John Wiley, 1976*.) for Example 4.7)

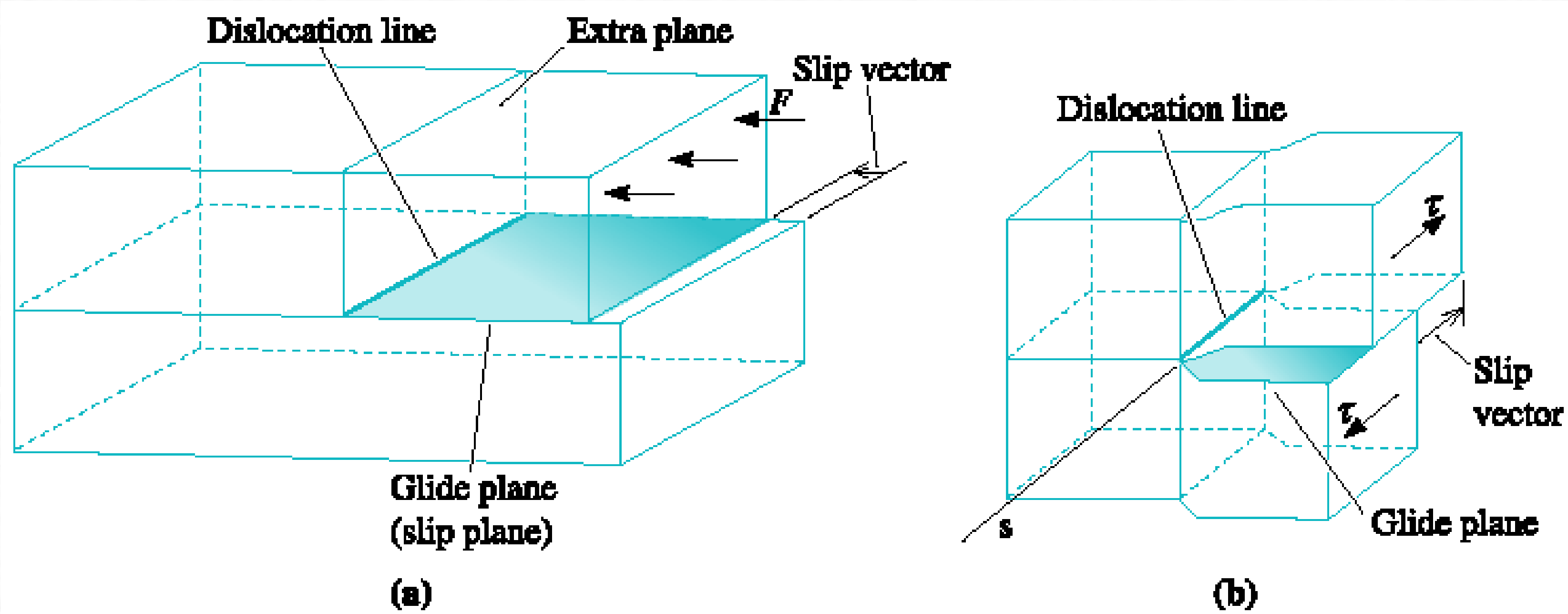


Figure 4.7 Schematic of slip line, slip plane, and slip (Burgers) vector for (a) an edge dislocation and (b) for a screw dislocation. (*Adapted from J.D. Verhoeven,* Fundamentals of Physical Metallurgy*, Wiley, 1975*.)

TABLE 4-1 ■ ***Slip planes and directions in metallic structures***

Crystal Structure	Slip Plane	Slip Direction
BCC metals	{110}	⟨111⟩
	{112}	
	{123}	
FCC metals	{111}	⟨110⟩
HCP metals	{0001}	⟨100⟩
	$\{11\bar{2}0\}$ See Note	⟨110⟩
	$\{10\bar{1}0\}$ See Note	or $\langle 11\bar{2}0\rangle$
	$\{10\bar{1}1\}$ See Note	
MgO, NaCl (ionic)	{110}	⟨110⟩
Silicon (covalent)	{111}	⟨110⟩

Note: These planes are active in some metals and alloys or at elevated temperatures.

TABLE 4-2 ■ ***Summary of factors affecting slip in metallic structures***

Factor	FCC	BCC	HCP $\left(\frac{c}{a} > 1.633\right)$
Critical resolved shear stress (psi)	50–100	5,000–10,000	50–100[a]
Number of slip systems	12	48	3[b]
Cross-slip	Can occur	Can occur	Cannot occur[b]
Summary of properties	Ductile	Strong	Relatively brittle

[a] *For slip on basal planes.*

[b] *By alloying or heating to elevated temperatures, additional slip systems are active in HCP metals, permitting cross-slip to occur and thereby improving ductility.*

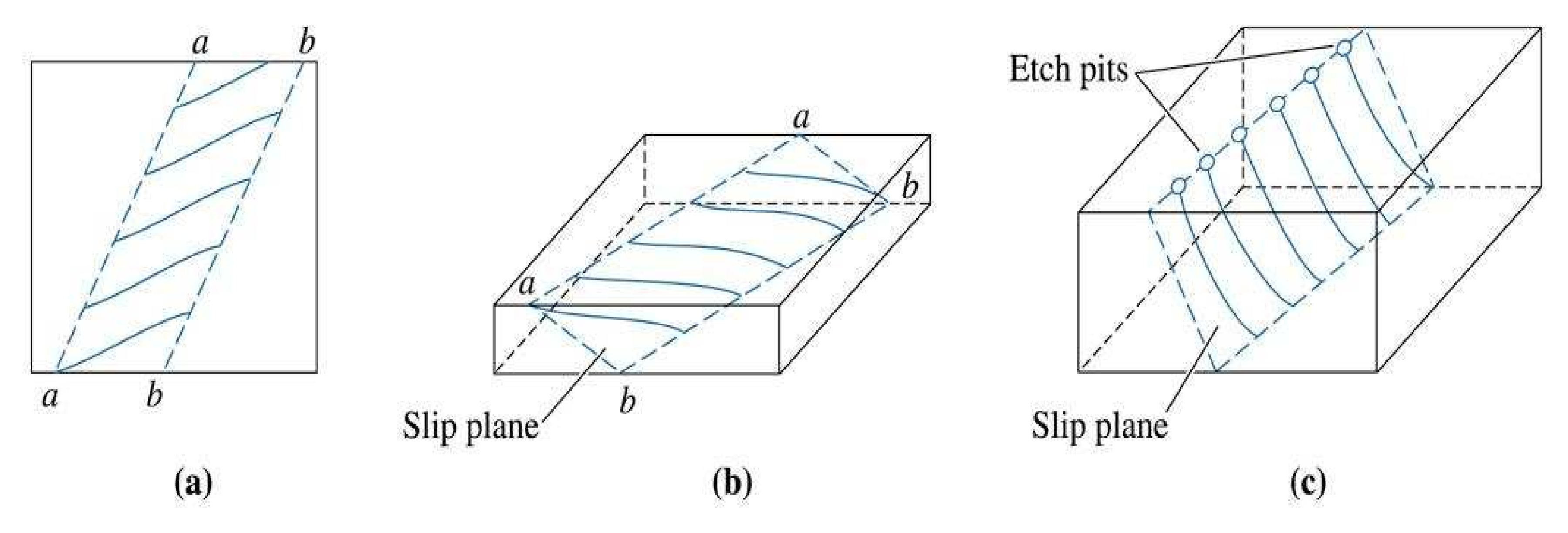


Figure 4.11 A sketch illustrating dislocations, slip planes, and etch pit locations. (*Source: Adapted from* Physical Metallurgy Principles*, Third Edition, by R.E. Reed-Hill and R. Abbaschian, p. 92, Figs. 4-7 and 4-8. Copyright (c) 1992 Brooks/Cole Thomson Learning. Adapted by permission.)*

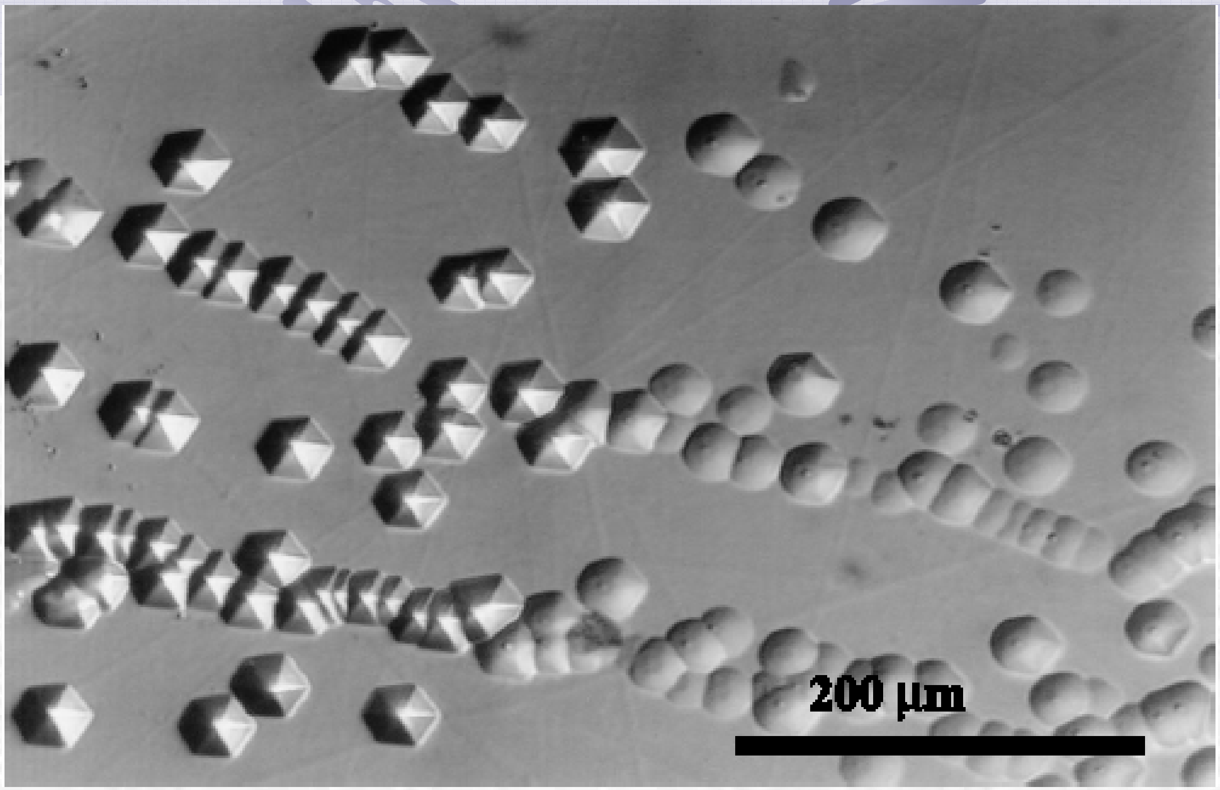


Figure 4.12 Optical image of etch pits in silicon carbide (SiC). The etch pits correspond to intersection points of pure edge dislocations with Burgers vector a/3 $\langle 1\bar{1}20 \rangle$ and the dislocation line direction along [0001] (perpendicular to the etched surface). Lines of etch pits represent low angle grain boundaries (*Courtesy of Dr. Marek Skowronski, Carnegie Mellon University*.)

Interfaces

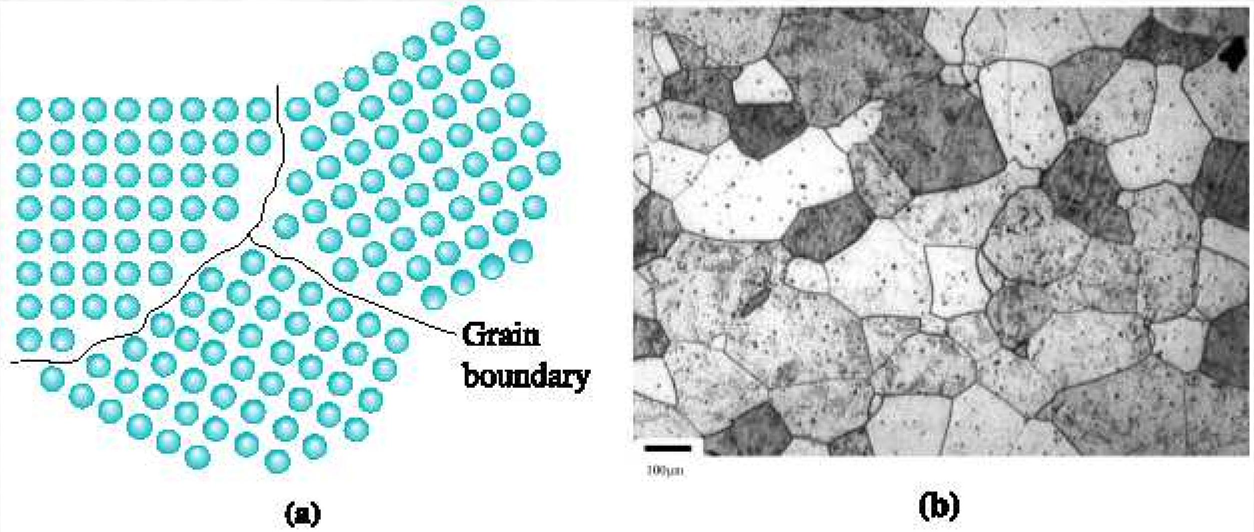


Figure 4.16 (a) The atoms near the boundaries of the three grains do not have an equilibrium spacing or arrangement. (b) Grains and grain boundaries in a stainless steel sample. (*Courtesy Dr. A. Deardo*.)

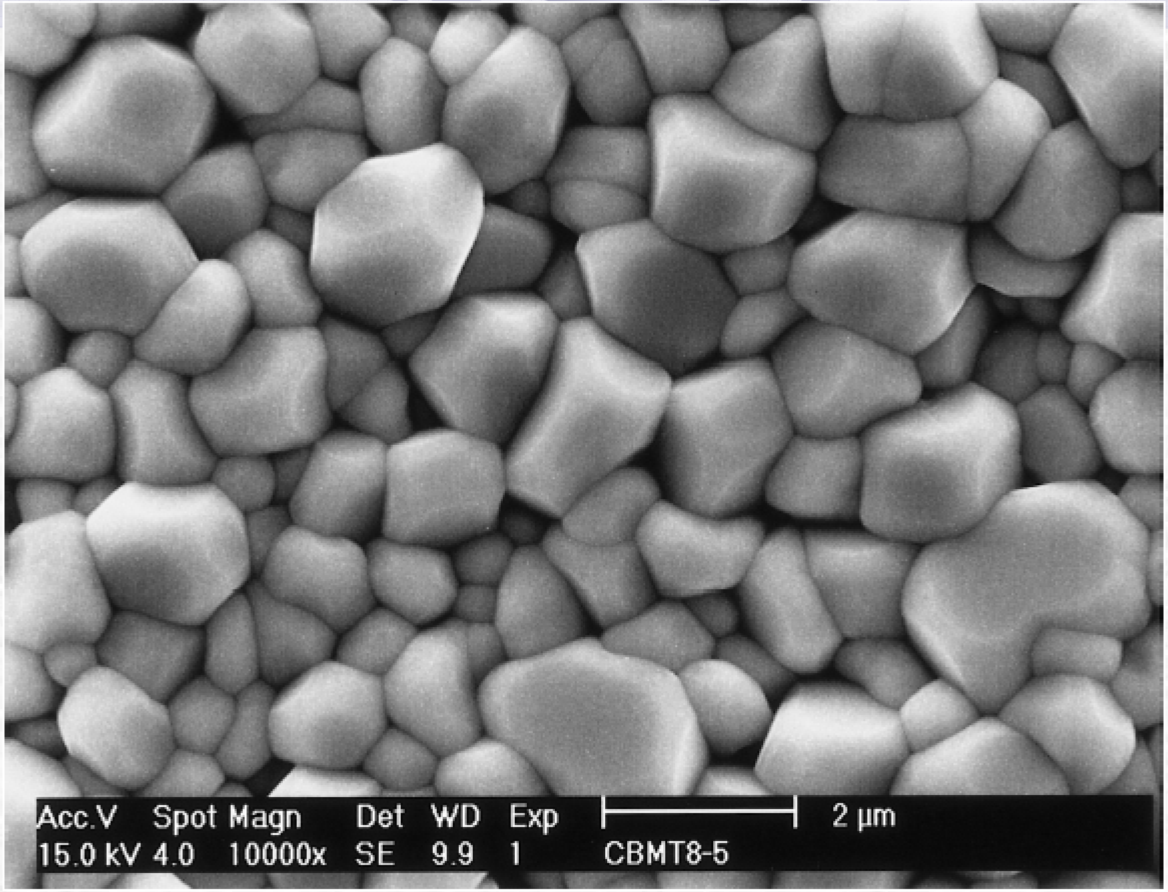


Figure 4.24 The microstructure of BMT ceramics obtained by compaction and sintering of BMT powders. (*Courtesy of H. Shirey*.)

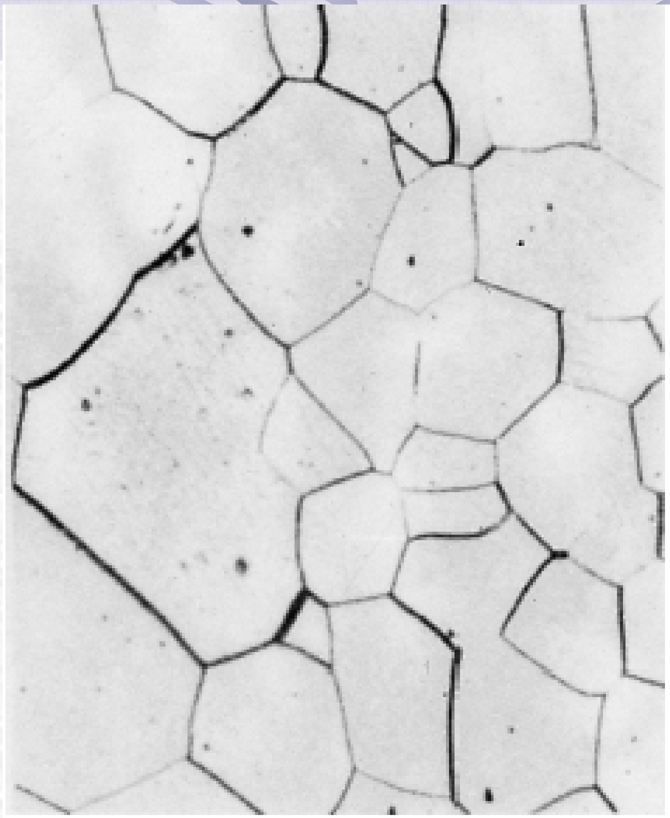


Figure 4.18 Microstructure of palladium (x 100). (*From* ASM Handbook, *Vol. 9, Metallography and Microstructure (1985), ASM International, Materials Park, OH 44073*.)

Lembrar de Hall-Petch

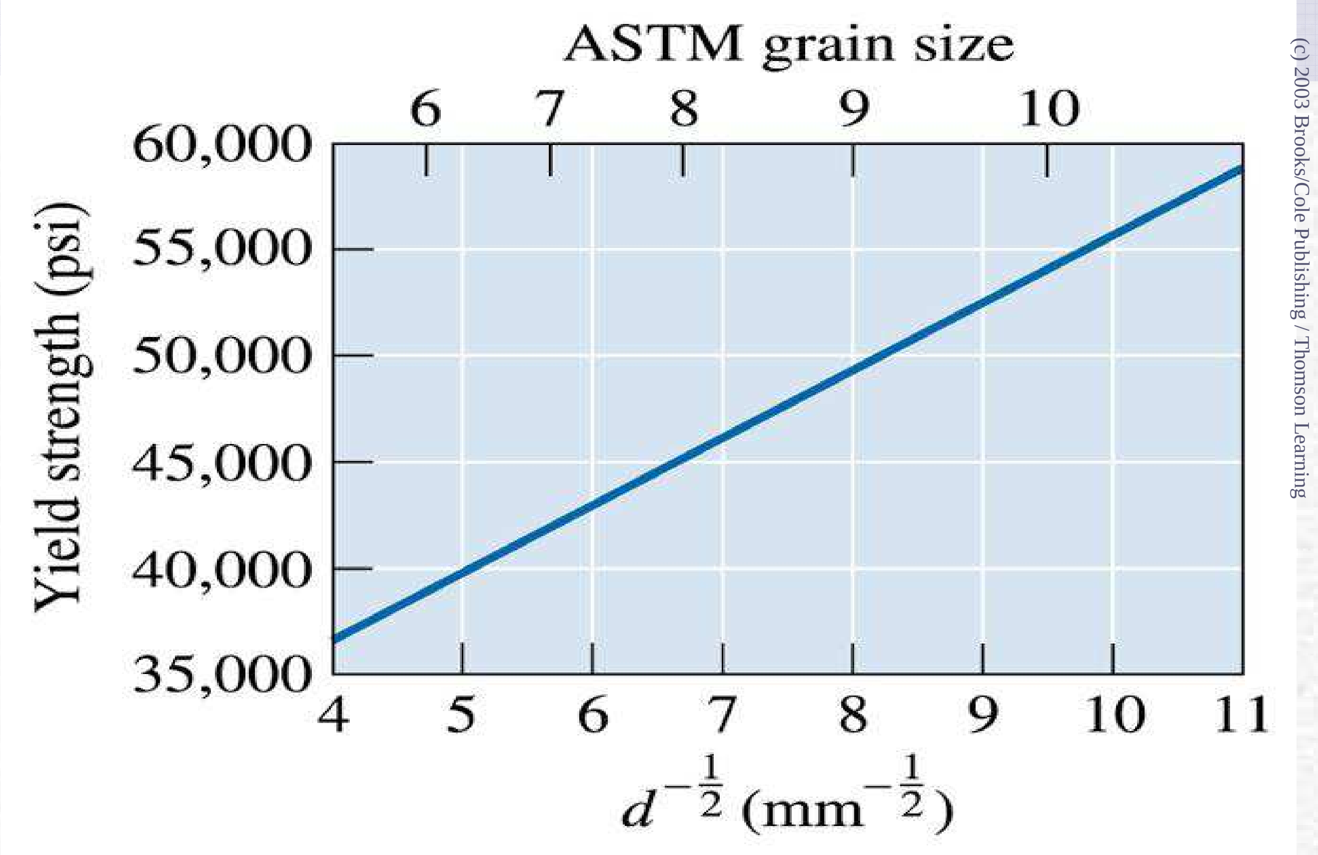


Figure 4.17 The effect of grain size on the yield strength of steel at room temperature.

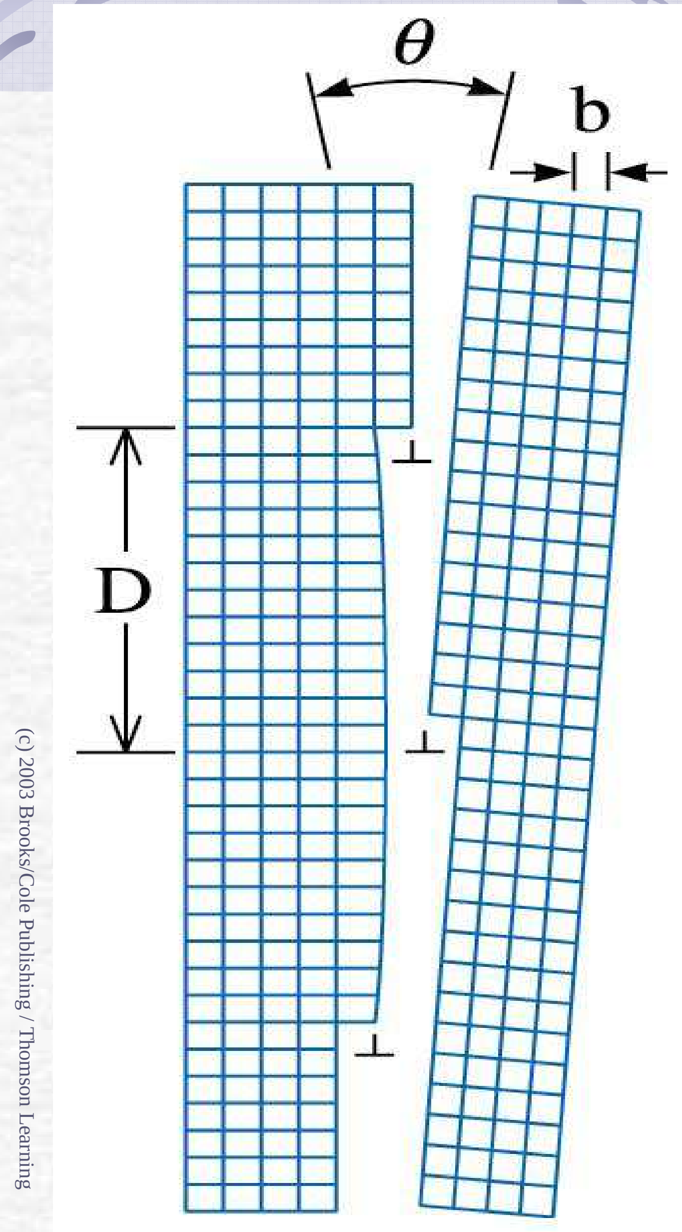


Figure 4.19 The small angle grain boundary is produced by an array of dislocations, causing an angular mismatch *θ* between lattices on either side of the boundary.

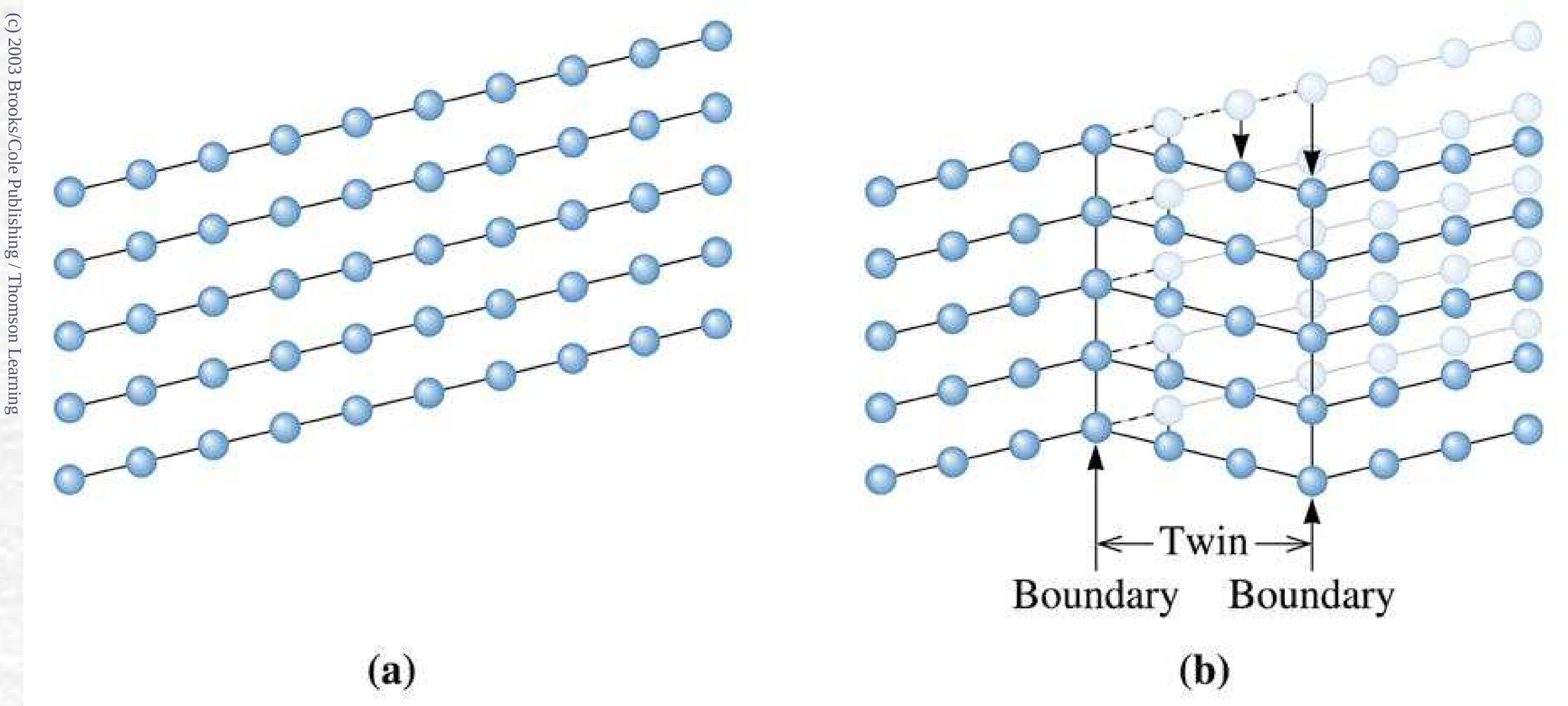
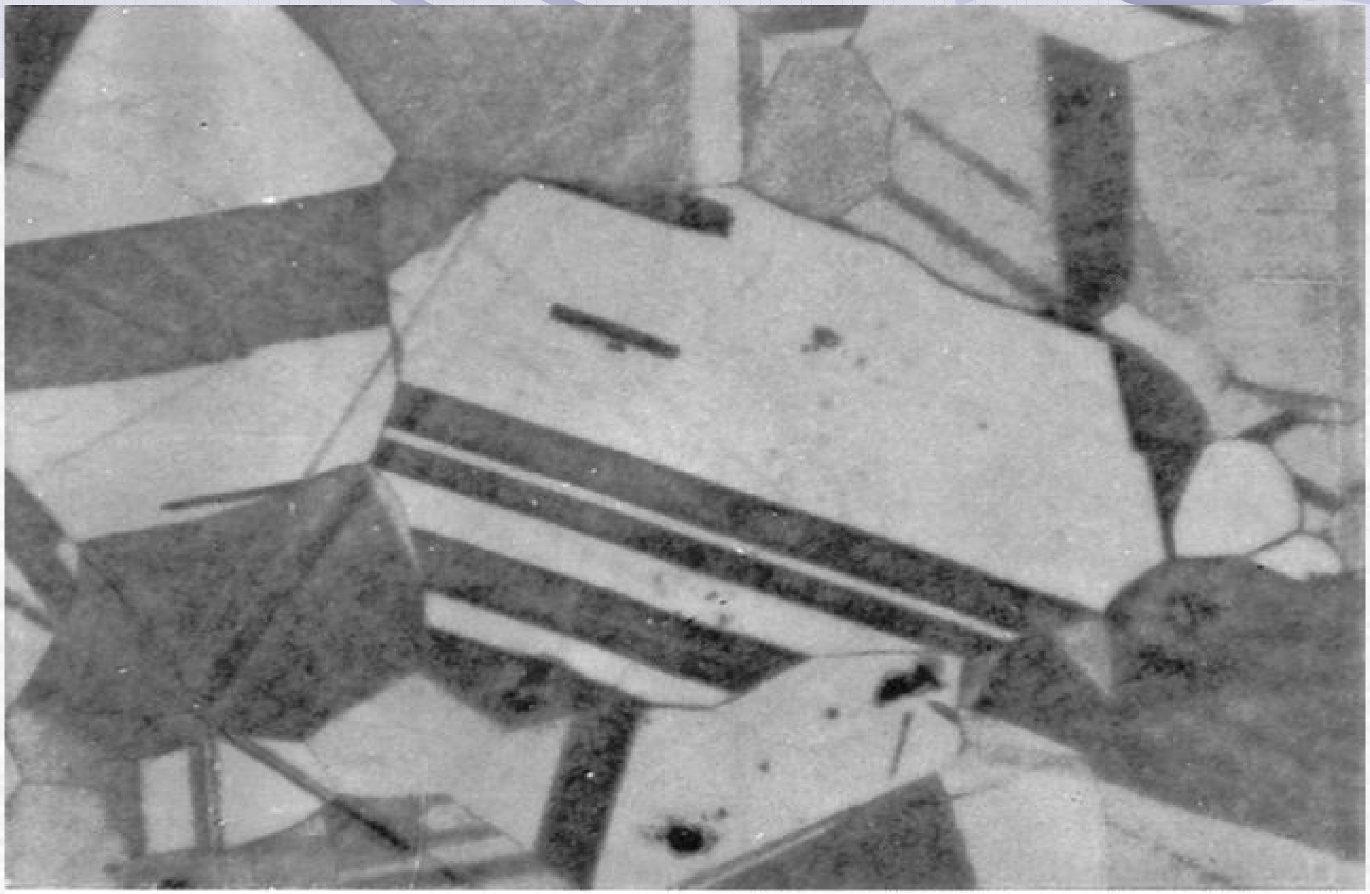


Figure 4.20 Application of a stress to the perfect crystal (a) may cause a displacement of the atoms, (b) causing the formation of a twin. Note that the crystal has deformed as a result of twinning.



(c)

Figure 4.20 (c) A micrograph of twins within a grain of brass (x250).

TABLE 4-3 ■ ***Energies of surface imperfections in selected metals***

Surface Imperfection (energy/cm^2)	Al	Cu	Pt	Fe
Stacking fault	200	75	95	—
Twin boundary	120	45	195	190
Grain boundary	625	645	1000	780

Explicar falha de empilhamento

Defeitos de volume

- microestruturais
  - poros
  - trincas
  - inclusões