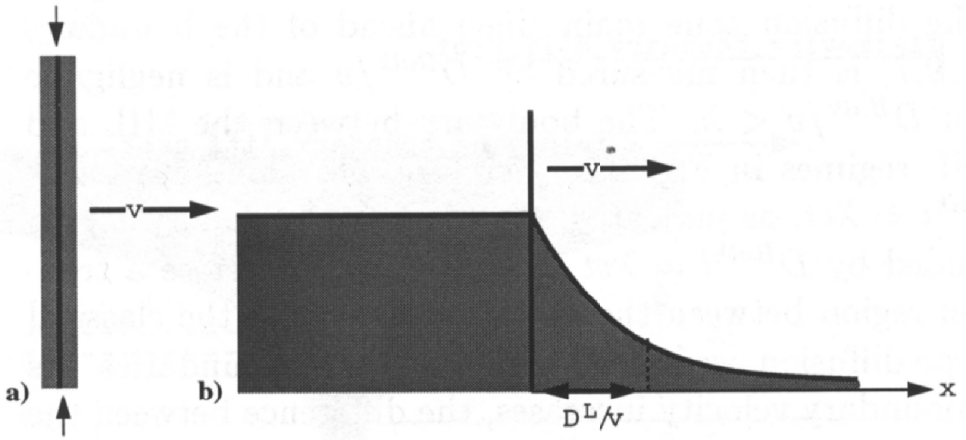
Previous lecture

- Review of grain boundary structure
- Diffusion paths in polycrystals
- Regimes of grain boundary diffusion for stationary boundaries

Today

- Migration of a moving grain boundary diffusion source
- Regimes of grain boundary "short-circuit" diffusion for stationary and moving boundaries
- Some grain boundary diffusion mechanisms
- Dislocation core structure and dislocation "short circuits"
- Some phenomena where short-circuits are important

• Steady-state migration of a moving boundary diffusion source



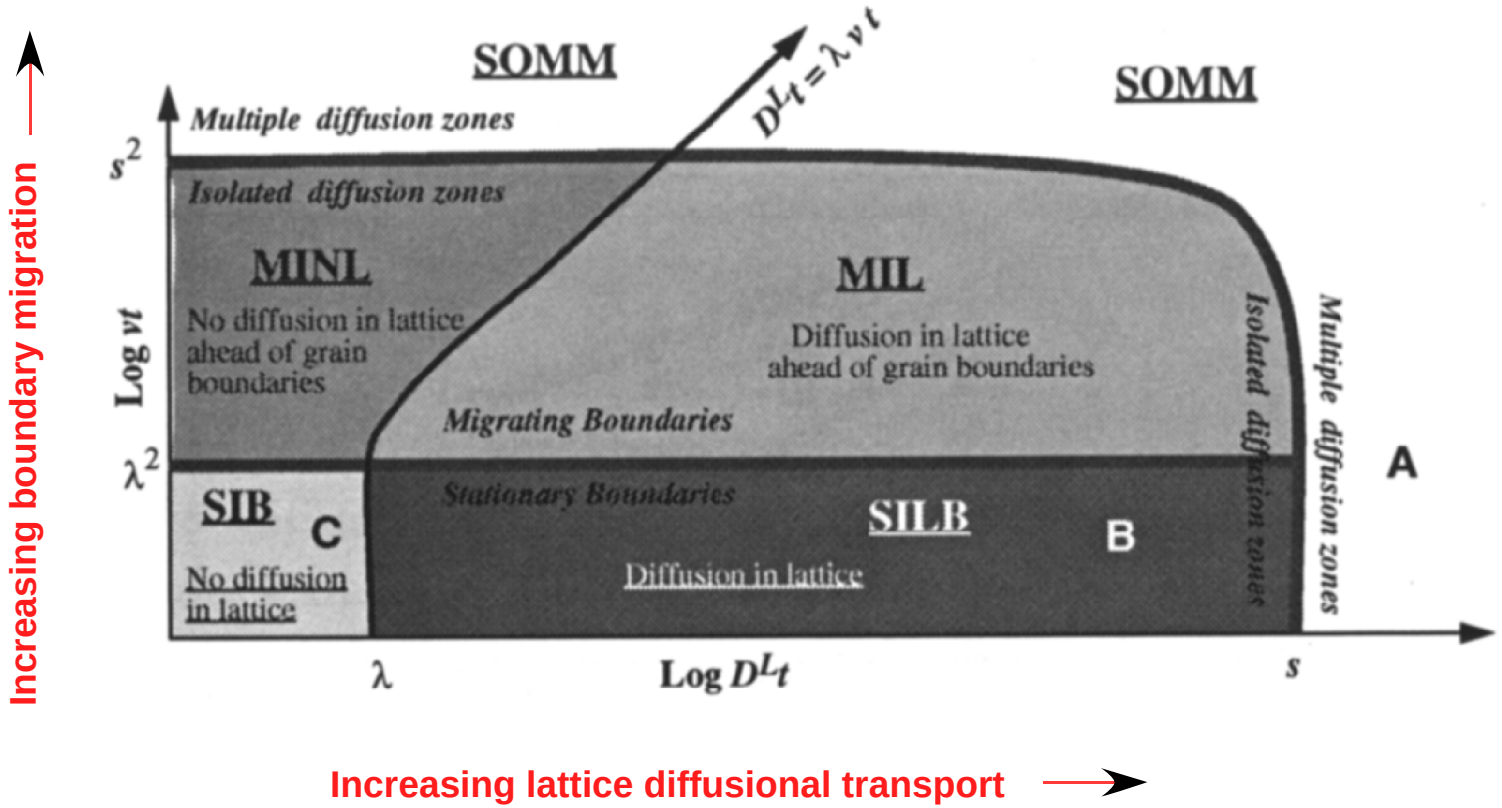
Diffusion with respect to a frame at the interface migrating at velocity *v* :

$$J = -\frac{d}{dx}\left(D^L \frac{dc}{dx} - vc\right) = 0$$

which has the solution

$$c = c_0 \exp\left[\left(-v/D^L\right)x\right]$$

- **Regimes of grain boundary "short-circuit" diffusion for stationary and moving boundaries**



- **Mechanism of grain boundary diffusion (continued)**

Dislocation short-circuit diffusion (continued)

Ring mechanism:

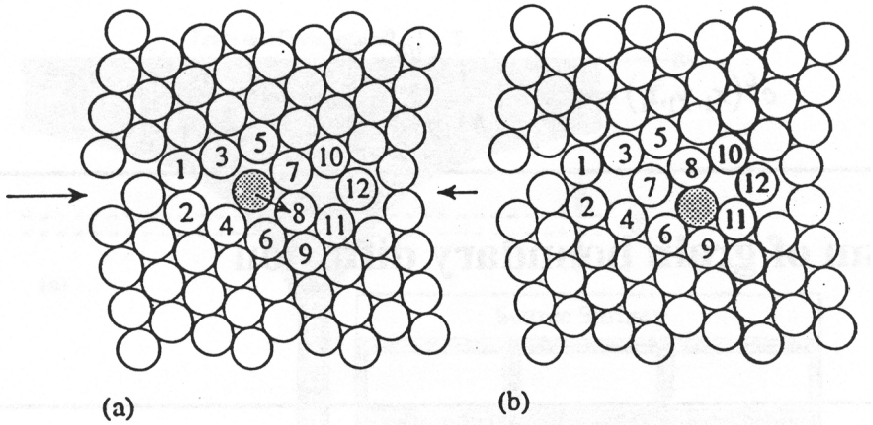


Figure 8.18 Schematic representation of rotational 'ring' mechanism for grain boundary diffusion. In the sequence (a) → (b), the marked (shaded) atom replaces atom 8, 8 replaces 7, and 7 replaces the marked atom (Sutton and Balluffi 1995, p. 492).

Vacancy mechanism:

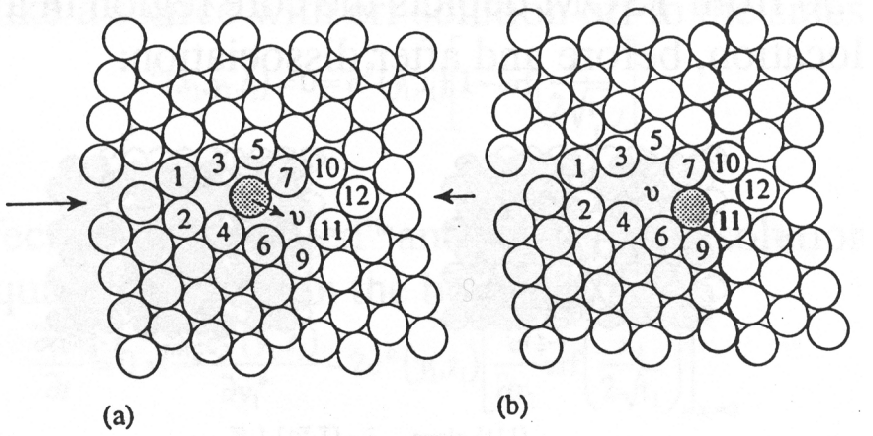


Figure 8.19 Schematic representation of vacancy exchange mechanism for grain boundary diffusion. In the sequence (a) → (b), the marked (shaded) atom exchanges places with a neighboring vacancy (Sutton and Balluffi 1995, p. 493).

• Mechanism of grain boundary diffusion (continued)

Vacancies and self-interstitials in grain boundary diffusion

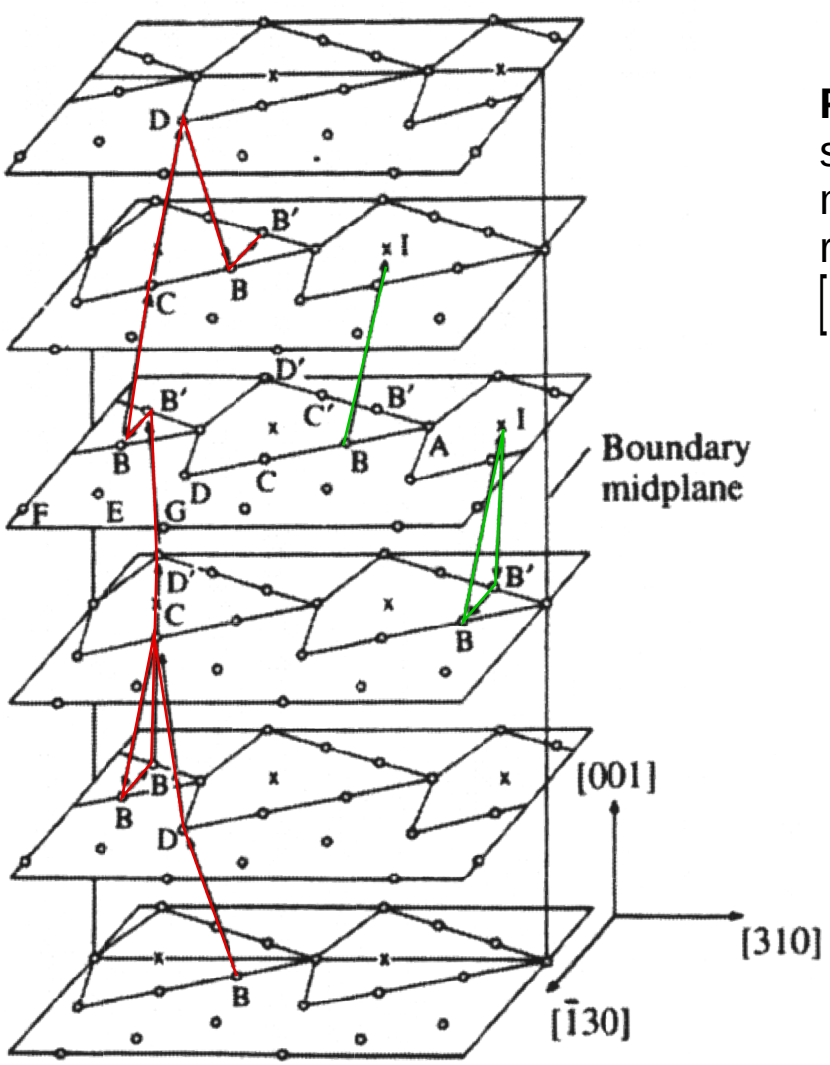


Figure 9.9 Atom jumping events in $\sum 5\langle 001\rangle(310)$ symmetric tilt boundary in BCC-Fe calculated by molecular dynamics using pair potential model. The ratios of the scales used in the drawing are $[\bar{1}30]:[310]:[001] = 1:1:5$

vacancy trajectory, confined to grain boundary sites

vacancy/interstitial pair creation

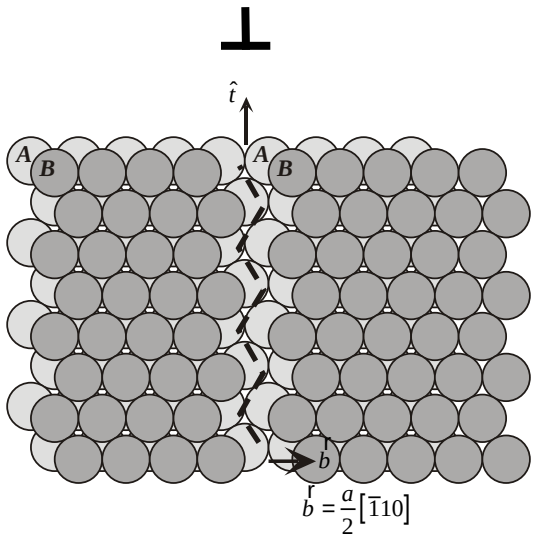
• Dislocation short-circuit diffusion

Dislocations, especially edge dislocations, can act as short-circuit diffusion paths.

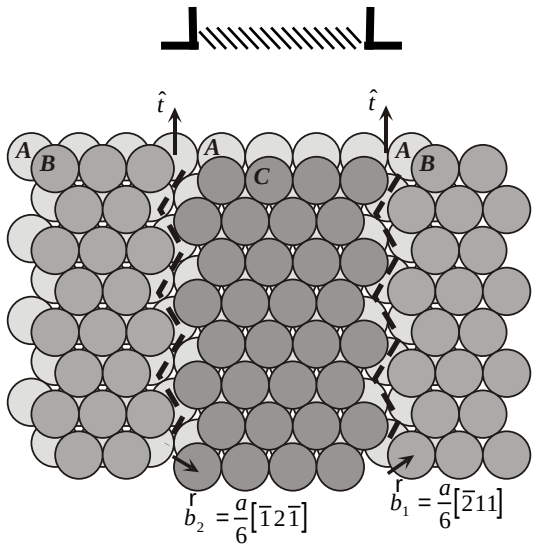
Dissociated dislocations have cores that are more spread out, connected by a ribbon of stacking fault:

(111) plane

$\hat{t} = [\bar{1}\,\bar{1}2]/\sqrt{6}$



(a) Perfect dislocation



(b) Dislocation dissociated into partials

(Allen and Thomas 1999, p. 324)

• Surface short-circuit diffusion

- **Some practical phenomena where these short-circuit diffusion paths are important**

  Sintering

  "Coble" creep

  Superplasticity

References for additional study:

R W Balluffi and A Sutton, *Interfaces in Crystalline Materials*, 1995

p. 762–763 explains theory of Coble creep

Chiang, Birnie, and Kingery *Physical Ceramics,* 1997

Section 5.3 on "Single-Phase Sintering"

Nieh, Wadsworth, and Sherby, *Superplasticity in metals and ceramics*, Cambridge University Press, 1997

Chapter 3 provides an overview of mechanisms of superplasticity