Last Time

- Some phenomena where short-circuits are important

Diffusion in noncrystalline materials

- Gasses and liquids
- Self-diffusion in metallic glasses
- Interstitials in metallic glasses
- Conformation of long-chain polymers

3.21 Spring 2001: Lecture 21

Diffusion in polymer melts
Motion of Dislocations (KPIM Chapter 11)

- Forces on dislocations
- Dislocation glide and climb

Dislocation motion

- Glide motion
  - plastic deformation of crystals at low temperature
  - movement of glissile interfaces at low temperature

- Climb motion
  - contributes to high temperature deformation
  - results from operation of sources and sinks of vacancies

Forces on Dislocations

- external stresses
- osmotic force $\vec{F} = \vec{F}_\sigma + \vec{F}_\mu + \vec{F}_\kappa$
- curvature force
- external stresses:
  - are given by the *Peach-Koehler equation* $\vec{F}_\sigma = (\vec{b} \cdot \sigma) \times \vec{\xi}$
- osmotic force:
  - arises if nonequilibrium concentrations of point defects are present: $\vec{F}_\mu = (\vec{\xi} \times \vec{b}) \frac{kT}{\Omega} \ln \frac{N_\nu}{N^{eq}}$
- curvature force:
  - line length can change if a curved dislocation moves $\vec{F}_\kappa \approx \frac{\mu b^2}{R} \hat{n} = \mu b^2 \frac{d\vec{\xi}}{ds}$
- Total force: $\vec{F} = \vec{F}_\sigma + \vec{F}_\mu + \vec{F}_\kappa$

Screw dislocation glide

- Dislocation velocity v is limited by the sound velocity c in the material—essentially a relativistic effect
- Drag forces arise from
  - Sound emission

- Elastic dissipation
- Phonon and electron scattering
- Solute atom interactions

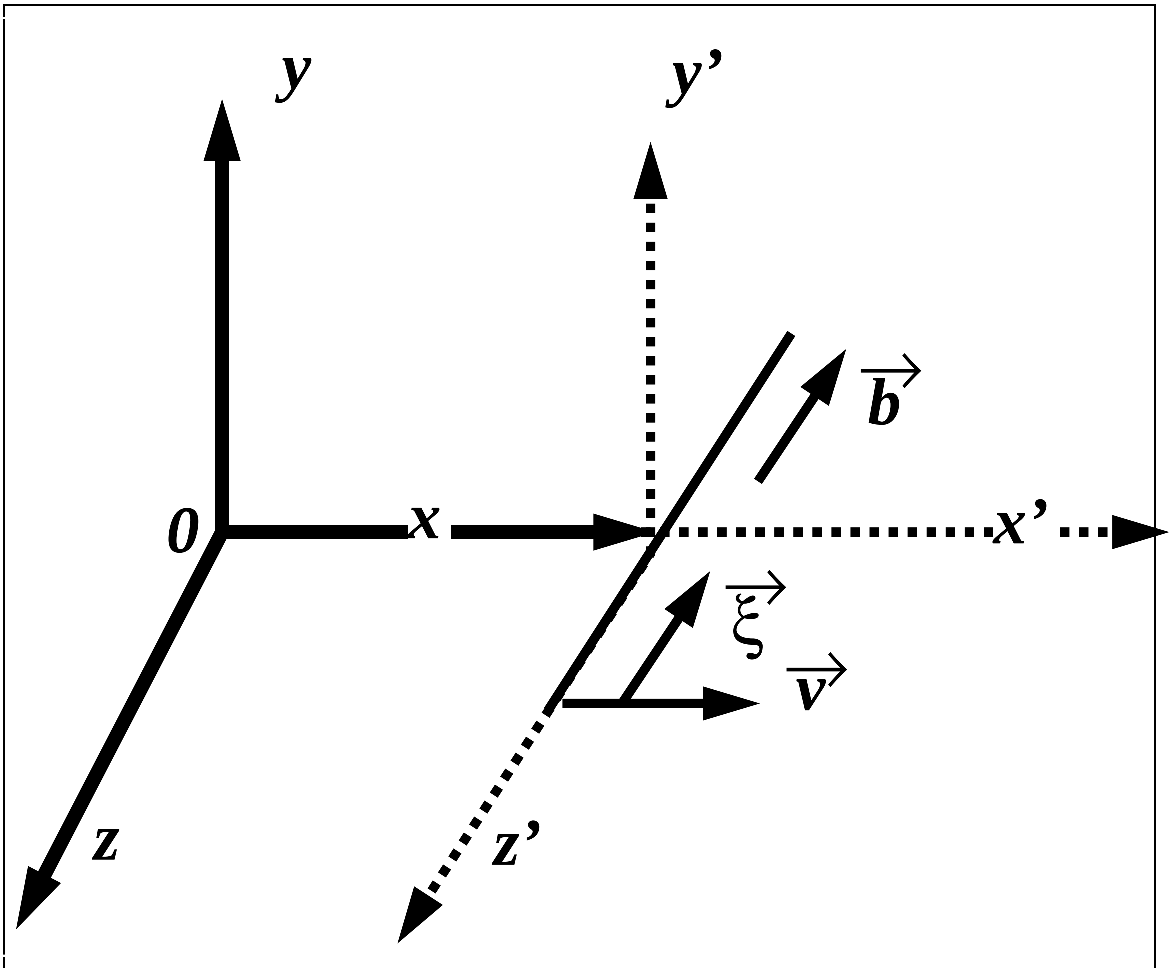

Figure 21-1:

Experimental studies of dislocation motion

- Extensive studies of LiF in 1960's by Gilman and Johnson
- Velocities increase rapidly with increasing stress and appear to level off as they approach sound velocity

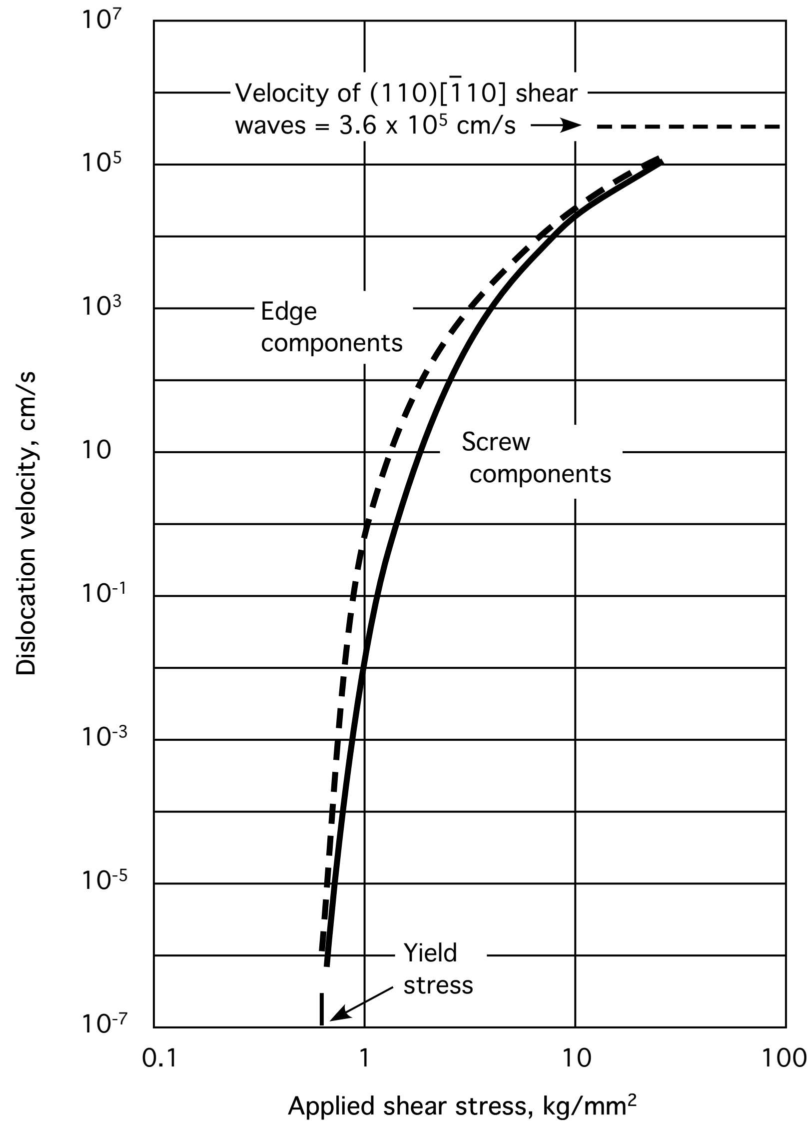

Figure 21-2:

Dislocation climb

- Edge dislocations can absorb or emit vacancies by climbing
- *Jogs* are especially favorable sites for vacancy creation and destruction

  A vacancy diffuses from within bulk and annihilates at a jog

  B vacancy diffuses to dislocation core and attaches

  C vacancy diffuses along core

  D vacancy diffuses along core to jog and annihilates

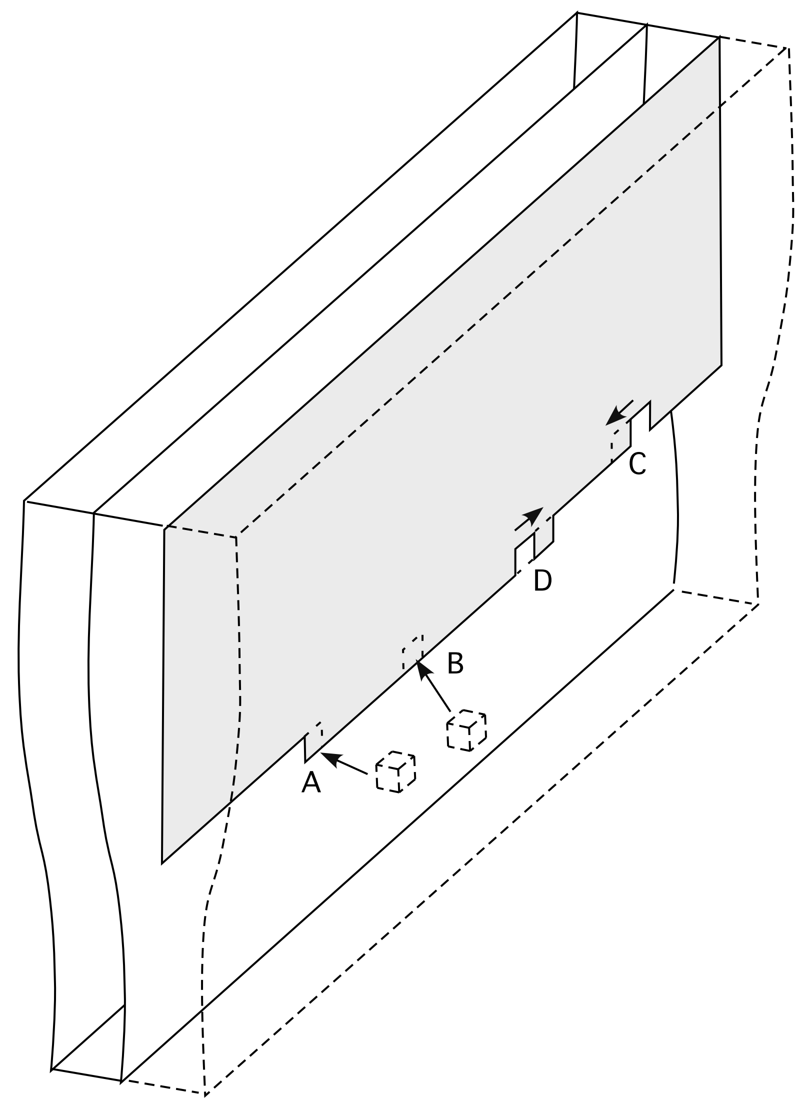

Figure 21-3:

Vacancy condensation on screw dislocations

- Formation of helical edge segments

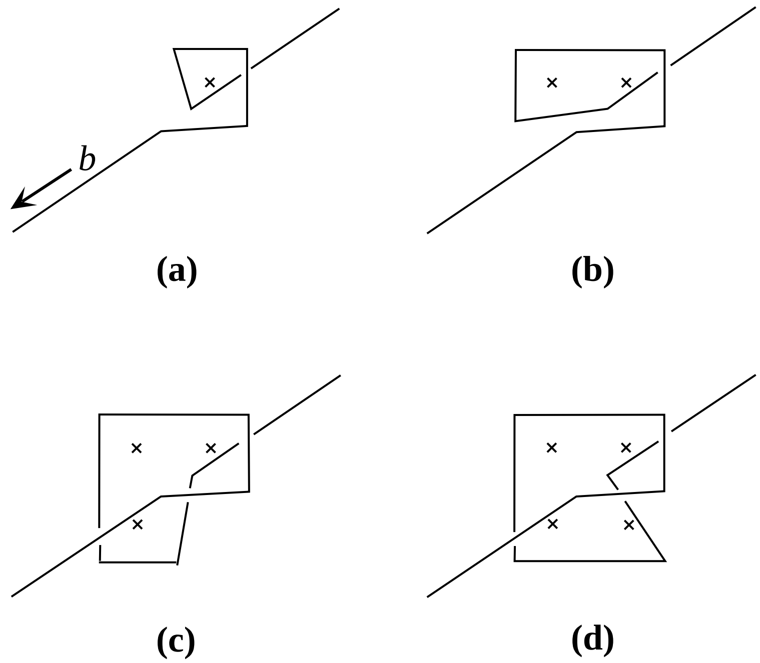

Figure 21-4: Left-hand screw dislocation in a primitive cubic crystal collects 1, 2, 3, and 4 vacancies.

Vacancy condensation kinetics on edge dislocations

- Supersaturations can be relieved by diffusion of vacancies to dislocation cores

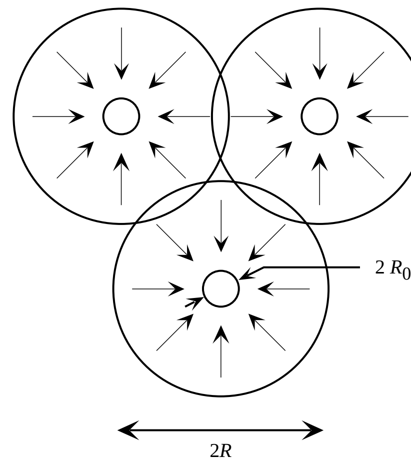

Figure 21-5:

- Model as diffusion within finite cylinder of radius R where

$$\begin{array}{lll} & R = \sqrt{\pi\rho} & \\ c_\nu = c_\nu^{eq} & R = r_0 & t \geq 0 \\ c_\nu = c_\nu^0 & R_0 < r \leq R & t = 0 \\ \frac{\partial c}{\partial r} = 0 & r = R & t \geq 0 \end{array} \tag{21-1}$$

- Approximate solution for fraction of excess vacancies remaining

$$f(t) = \exp(-\alpha_1 D_\nu t) \tag{21-2}$$

Shrinkage of prismatic dislocation loops by vacancy condensation

- Driving force for loop shrinkage is $\Delta\mu$ between dislocation loop and free surface

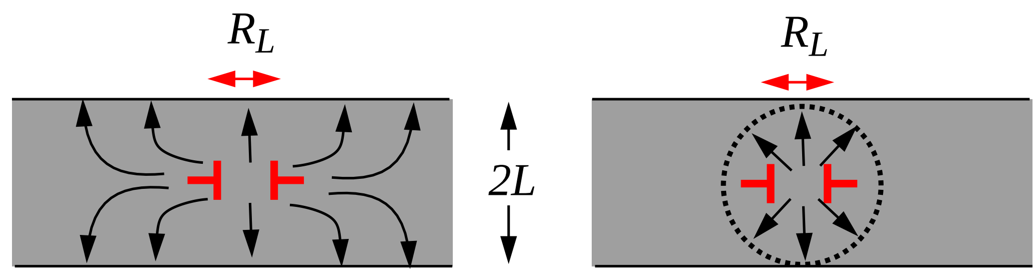

Figure 21-6:

- KPIM has a solution for the rate of decrease of loop radius adapted from electrostatics (Eq. 11.33)