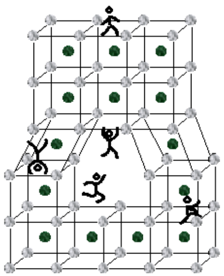
Defects in One Dimension (1D)



MATS275: INTRODUCTION TO MATERIALS SCIENCE

- Review of Chapter 4 (0D Defects)
- (1D Defects) Dislocations and Slip
  - Edge, Screw, and Mixed
  - Burgers Vectors
  - Slip Systems
- (2D Defects)
  - Grains
  - Surfaces
- Slip
- Resolving Stresses
- Slip in Non-metals

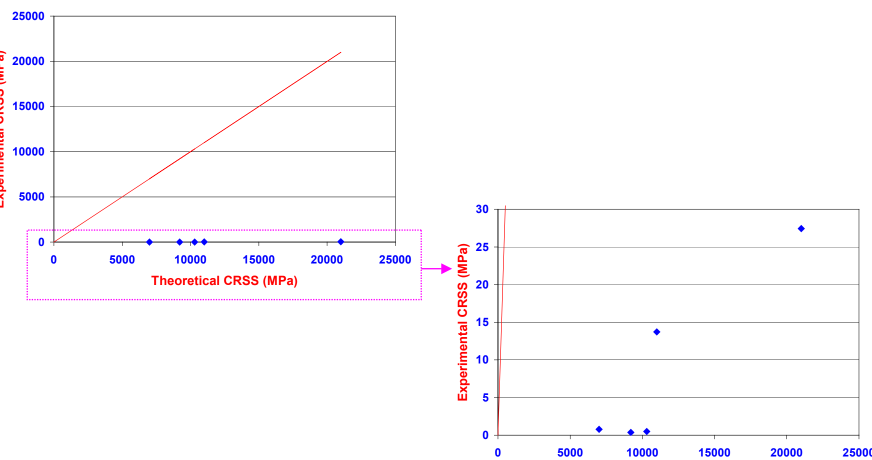
Theory and Experiment Mismatch

"Such a crystal, if perfect has a very high strength. Theoretically, it should be able to withstand a stress of 500,000 psi without permanently deforming. Moderately pure copper, however, has a yield stress far below it's theoretical strength, and can withstand only 1000 to 10,000 psi before it permanently changes shape (**plastically deforms**). If copper is purer, for example 99.999% pure, this makes the situation even worse. The yield stress can fall as low as a few hundred psi, a far cry from the theoretical value. This enormous discrepancy between the theoretical and the experimental strengths of copper was disconcerting to scientists until the 1930s, when they speculated that crystals were not perfect, but full of defects called **dislocations**."

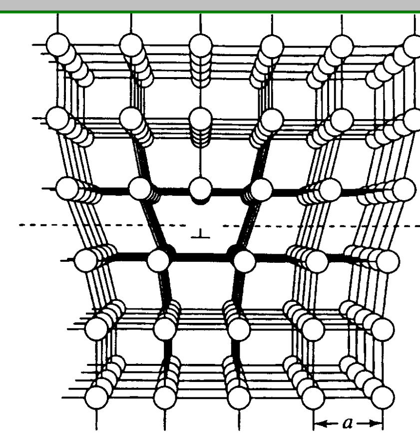
Stephen Sass, "*The Substance of Civilizations*", Arcade Press, p.44

Experiment and Theory

A Bad Match



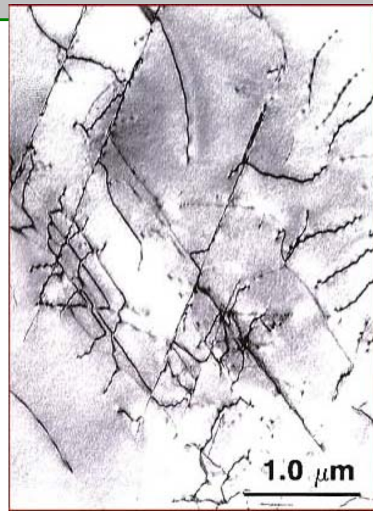
Line Defects—Edge Dislocation



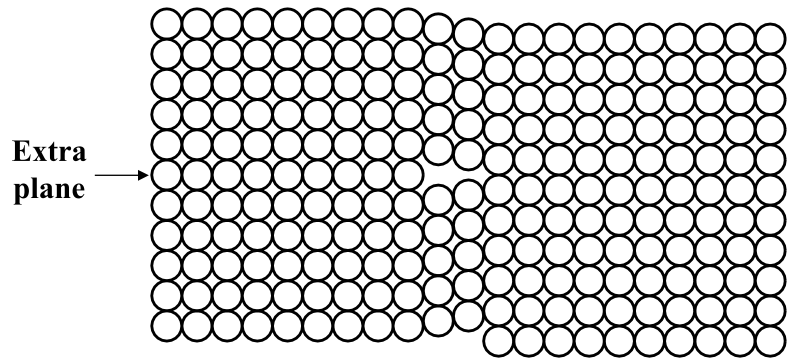
A line defect represented by the edge of an extra half-plane of atoms

Microscopy of Dislocations

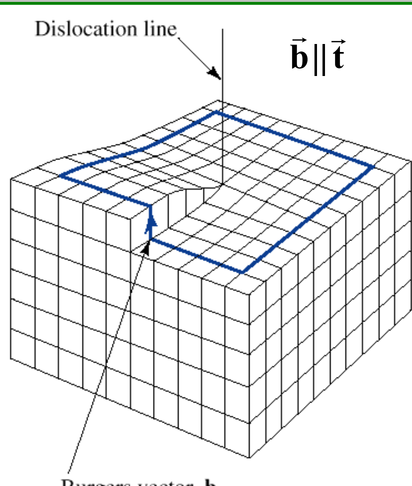
Dislocations in Al demonstrated in Transmission Electron Microscopy (TEM)



Quantifying Dislocations



Screw Dislocation

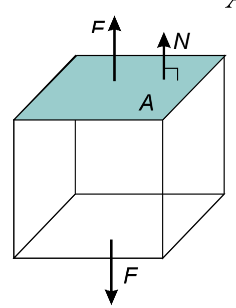


$$\vec{\mathbf{b}} \,||\, \vec{\mathbf{t}}$$

Stresses

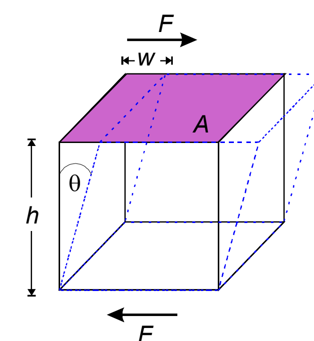
Normal Stress, σ

$$\sigma = \frac{F}{A}$$

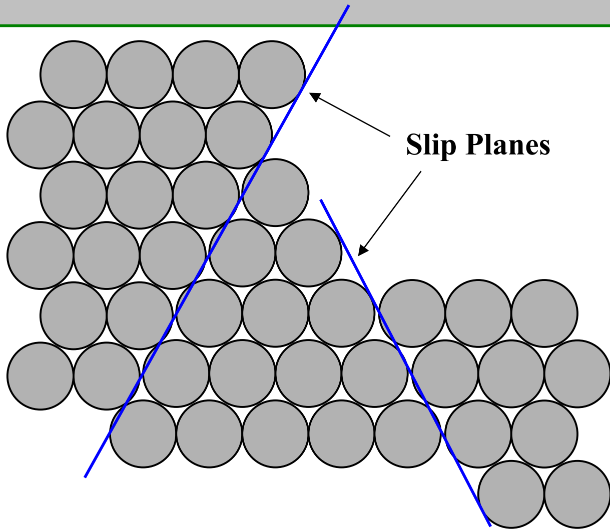


Shear Stress, τ

$$\tau = \frac{F}{A}$$



Slip Planes



Why Along the Close Packed Directions?

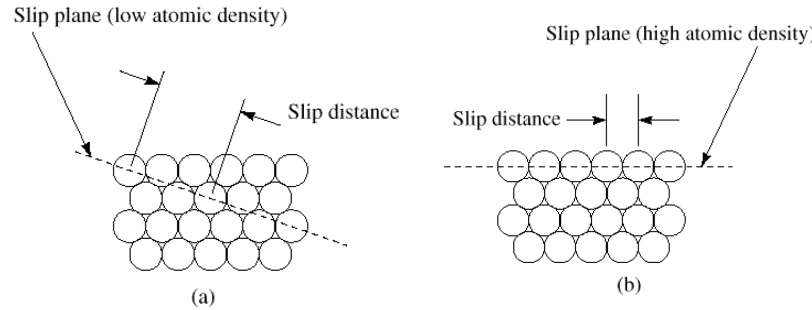
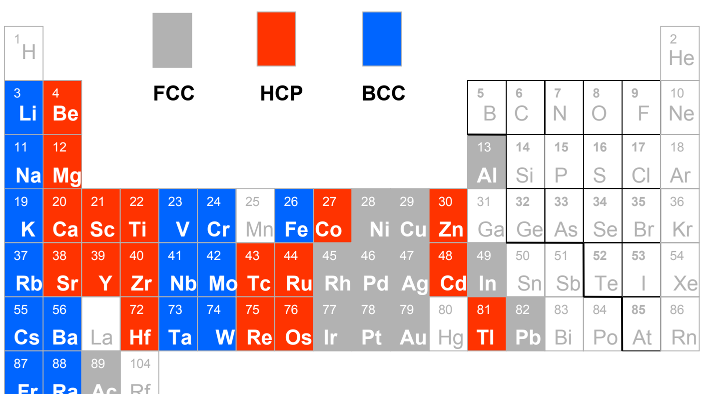
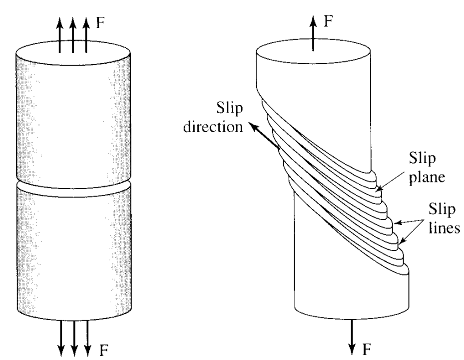


FIGURE 4-33

Metal Crystal Structures



Dislocations + Stress + Slip = Plastic Deformation



Single crystal of zinc (hcp) stressed at 300°C

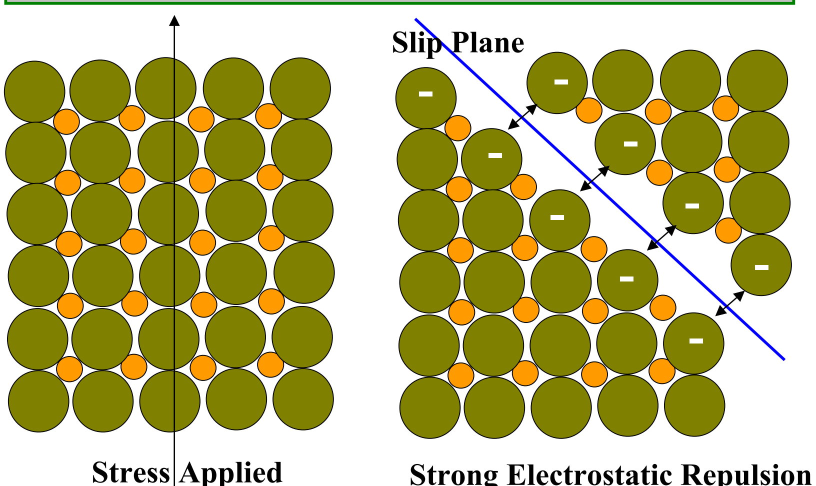
Summary of Slip in Metal Crystals

	HCP	FCC	BCC
Close Packed?	Yes	Yes	No
Packing Efficiency	74%	74%	68%
Stacking Sequence of Close Packed Planes	ABABAB	ABCABC	n/a
# of unique, non-parallel slip planes	1	4	6
# slip directions in each plane	3	3	2
# of total slip systems	3	12	12
Ductile or Brittle?	Brittle	Ductile	Ductile
Atoms per cube	N/a, not a cube	4	2
Examples:	Mg, Zn	Al, Fe (austentite), Au, Ag, Cu	Fe (ferrite), W, Nb

Summarizing Slip Systems

	Plane	Direction	Number
• FCC	$\{111\}$	$\langle 1\bar{1}0\rangle$	12
• BCC	$\{110\}$	$\langle \bar{1}11\rangle$	12
	$\{211\}$	$\langle \bar{1}11\rangle$	12
	$\{321\}$	$\langle \bar{1}11\rangle$	24
• HCP	$\{0001\}$	$\langle 11\bar{2}0\rangle$	3
	$\{10\bar{1}0\}$	$\langle 11\bar{2}0\rangle$	3
	$\{10\bar{1}1\}$	$\langle 11\bar{2}0\rangle$	6

Why are Ceramics Brittle?



Resolving The Stress

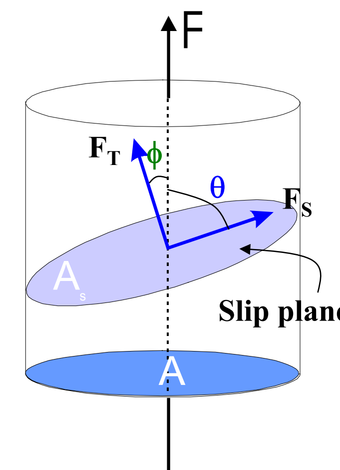
A_s = resolved area

θ = angle to slip direction

ϕ = angle to slip plane normal

$$F_s = F\cos\theta \qquad A_s = \frac{A}{\cos\phi}$$

$$\frac{F_s}{A_s} = \frac{F}{A}\cos\theta\cos\phi$$



Resolved Stresses

- Slip occurs only on certain planes
- Resolved <u>Shear</u> Stress

$$\tau_R = \sigma \cos\phi \cos\theta$$

Applied stress

Between slip direction and applied force

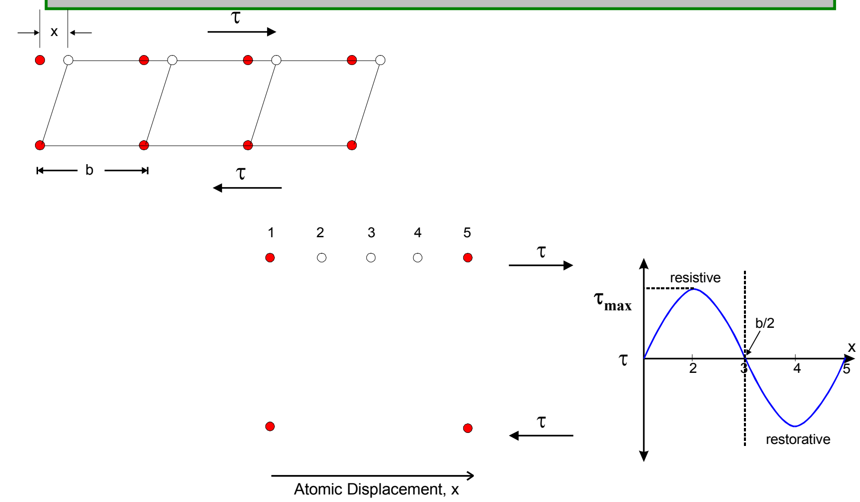
Between normal to slip plane and applied force

- Critical Resolved Shear Stress

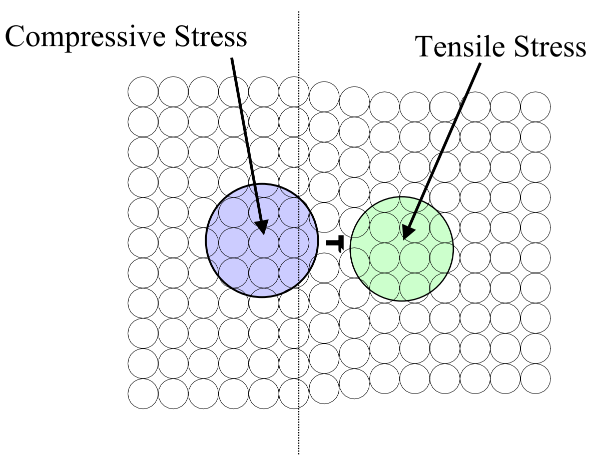
$$\sigma_C = \frac{\tau_{CR}}{\cos\phi \cos\theta}$$

Property of the material

Wave Motion Through a Crystal



Lattice Energy



Multiplication of Dislocations

Frank-Read Sources

Dislocation densities are in per cm^2.