LECTURE SUMMARY

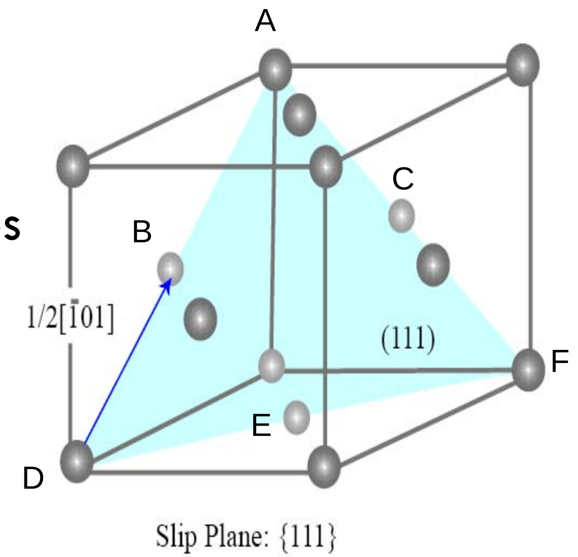
September 30th 2009

Key Lecture Topics

- **Crystal Structures in Relation to Slip Systems**
- **Resolved Shear Stress**
- **Using a Stereographic Projection to Determine the Active Slip System**

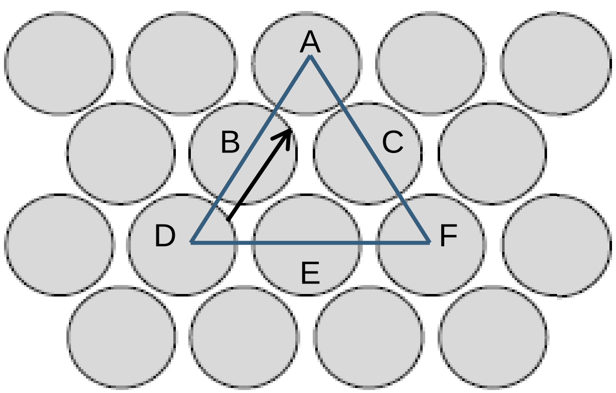
Slip Planes and Slip Directions

- *Slip Planes*
  - Highest Planar Density
    - Corresponds to most widely spaced planes
- *Slip Directions*
  - Highest Linear Density
- *Slip System*
  - Slip Plane + Slip Direction



Figures by MIT OpenCourseWare.

The FCC unit cell has a slip system consisting of the {111} plane and the <110> directions.



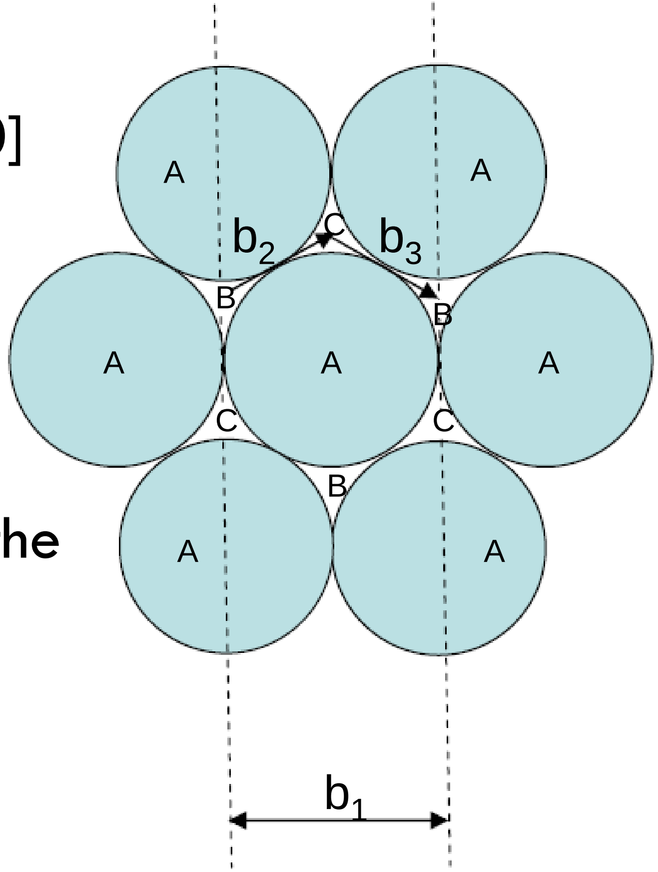
Face Centered Cubic Slip Systems

FCC (eg. Cu, Ag, Au, Al, and Ni)

Slip Planes {111} **Slip Directions** [110]

- The shortest lattice vectors are ½[110] and [001]
- According to Frank's rule, the energy of a dislocation is proportional to the square of the burgers vector, b^2
- Compare energy
  - ½[110] dislocations have energy $2a^2/4$
  - [001] dislocations have energy a^2
  - → Slip Direction is [110]

Figure by MIT OpenCourseWare.



Partial dislocations along {111} planes in FCC metals.

More Slip Systems

Metals	*Slip Plane*	*Slip Direction*	*Number of Slip Systems*
Cu, Al, Ni, Ag, Au	**FCC** $\{111\}$	$\langle 1\bar{1}0 \rangle$	12
α-Fe, W, Mo	**BCC** $\{110\}$	$\langle \bar{1}11 \rangle$	12
α-Fe, W	$\{211\}$	$\langle \bar{1}11 \rangle$	12
α-Fe, K	$\{321\}$	$\langle \bar{1}11 \rangle$	24
Cd, Zn, Mg, Ti, Be	**HCP** $\{0001\}$	$\langle 11\bar{2}0 \rangle$	3
Ti, Mg, Zr	$\{10\bar{1}0\}$	$\langle 11\bar{2}0 \rangle$	3
Ti, Mg	$\{10\bar{1}1\}$	$\langle 11\bar{2}0 \rangle$	6

Resolved Shear Stress

- What do we need to move dislocations?
  - **A Shear Stress!**

$$\sigma = F / A$$

$F \cos\lambda$ *Component of force in the slip direction*

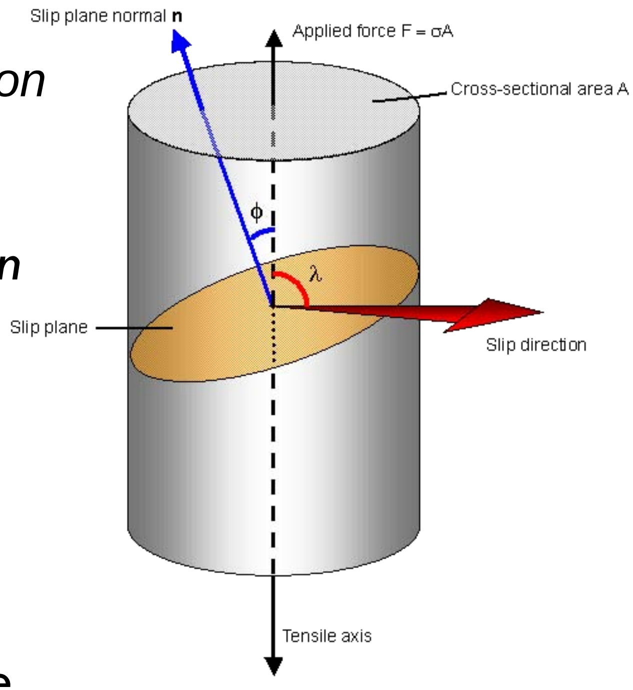
$A / \cos\phi$ *Area of slip surface*

  - *Thus the shear stress τ, resolved on the slip plane in the slip direction*

$$\tau = F / A \cos\phi \cos\lambda = \sigma \boxed{\cos\phi \cos\lambda}$$

Schmid Factor

  - *Note that $\Phi + \lambda \neq 90$ degrees because the tensile axis, slip plane normal, and slip direction do not always lie in the same plane*



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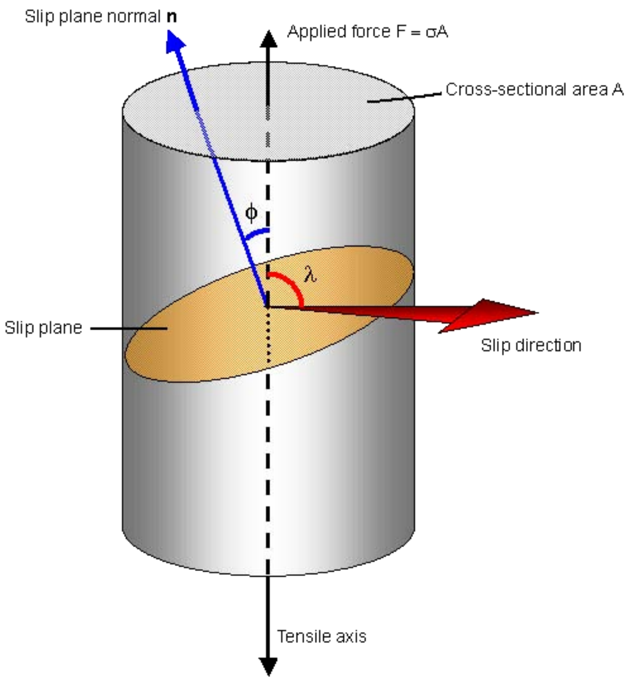
Critical Resolved Shear Stress

- *Critical Resolved Shear Stress,* τ_{CRSS} - the minimum shear stress required to begin plastic deformation or slip.
  - Temperature, strain rate, and material dependent
  - The system on which slip occurs has the largest Schmid factor

$$\tau = F / A \cos\phi \cos\lambda = \sigma \cos\phi \cos\lambda$$

- The minimum stress to begin yielding occurs when $\lambda = \Phi = 45^\circ$
  - $\sigma = 2\tau_{CRSS}$



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Determining Active Slip System

- There are two methods to determine which slip system is active
  - *Brute Force Method*- Calculate angles for each slip system for a given load and determine the maximum Schmid Factor
  - *Elegant Method*- Use stereographic projection to determine the active slip system graphically

Stereographic Projection Method

1. **Identify the triangle** containing the tensile axis
2. **Determine the slip plane** by taking the pole of the triangle that is in the family of the slip planes (i.e. for FCC this would be {111}) and reflecting it off the opposite side of the specified triangle
3. **Determine the slip direction** by taking the pole of the triangle that is in the family of directions (i.e. for FCC this would be <1-10>) and reflecting it off the opposite side of the specified triangle

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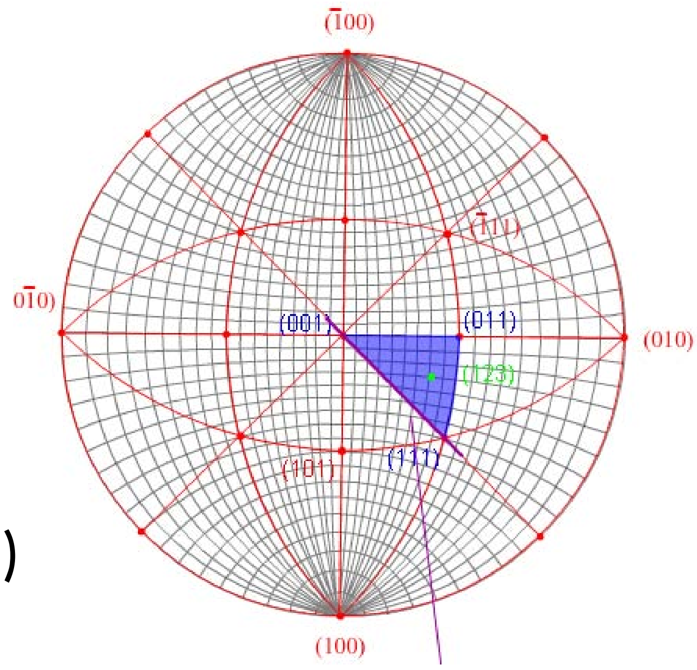
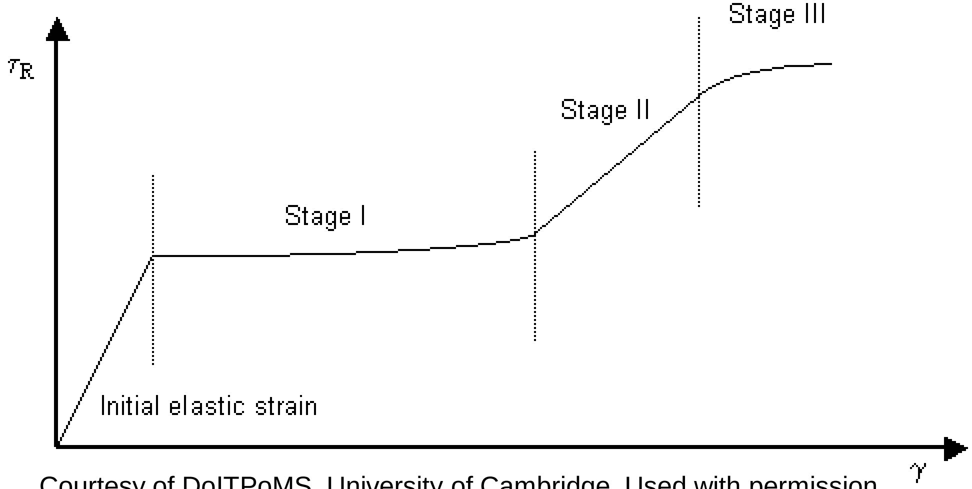


Rotation of Crystal Lattice Under an Applied Load

- With increasing load, the slip plane and slip direction align parallel to the tensile stress axis
- This movement may be traced on the stereographic projection
- The tensile axis rotates toward the slip direction eventually reaching the edge of the triangle
  - Note that during compression the slip direction rotates away from the compressive axis
- At the edge of the triangle a second slip system is activated because it has an equivalent Schmid factor

More Physical Examples



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- *Initial Elastic Strain*- results from bond stretching (obeys Hooke's Law)
- *Stage I (easy glide)*- results from slip on one slip system
- *Stage II*- Multiple slip systems are active. A second slip system becomes active when it's Schmid factor increases to the value of the primary slip system
- In some extreme orientations of HCP crystals, the material fractures rather than deforms plastically

Questions

3.40J / 22.71J / 3.14 Physical Metallurgy
Fall 2009