IME 301 - ENGINEERING MATERIALS **OCTOBER 13, 2016**

DISLOCATIONS AND INTERFACES

Class Preparation and Reading Review

Key Concepts to Be Discussed in Class:

Interfaces and Dislocations are not Thermodynamically Stable - Why and so What?

What a dislocation is and the effect on plastic deformation.

What an interface is and the effect on plastic deformation.

Questions About Subject Matter for Class Session:

Interfaces and Dislocations are not Thermodynamically Stable - Why and so What?

What a dislocation is and the effect on plastic deformation.

What an interface is and the effect on plastic deformation.

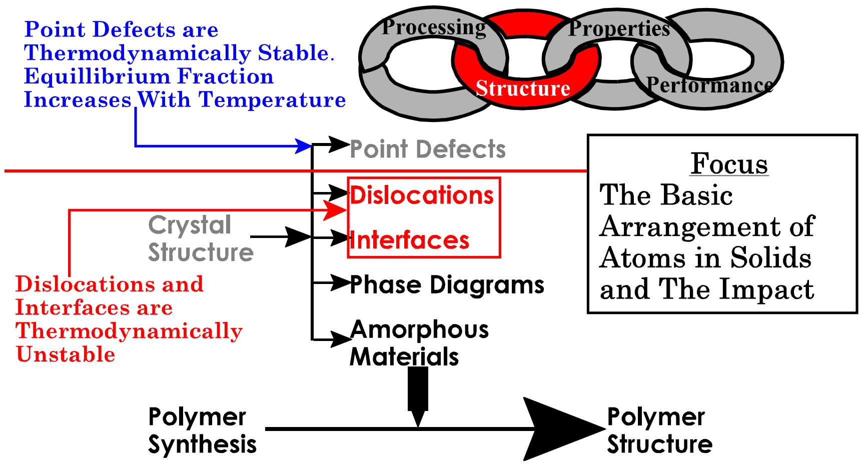
DISLOCATIONS AND INTERFACES

Why?

- Lines of Atoms Move Through A Crystal Causing Permanent Deformation
  - Cause of Ductility
  - Key to Strengthening Ductile Metals
- Internal Boundaries Inhibit Strengthen Materials by Inhibiting such Motion
- When Subjected to Elevated Temperature Exposure
  - These Lines Disappear
  - Particles / Grains Grow and Become Spherical
  - Materials, Especially Metals, Become Weaker Based on Yield Strength

DISLOCATIONS AND INTERFACES

Where We Are

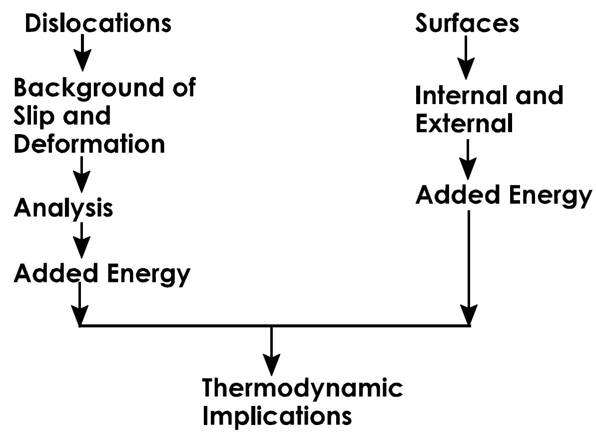


DISLOCATIONS AND INTERFACES

Outline

- Review of Point Defects
  - Thermodynamically Stable
- Dislocations
  - Plastic Deformation
  - Atomic Mechanism
- Surfaces
  - Energy
  - Role in Solids

Focus
- Not Pt. Defects
- Not Stable
- Implications



End of On-Line Intro

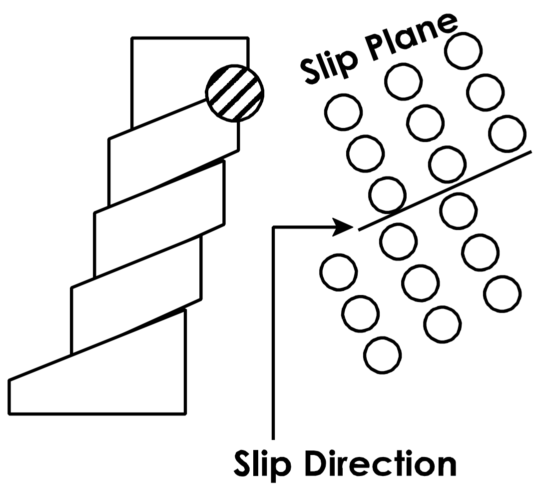
Concept Question[1]

- Compare Dislocations and Interfaces
  - Similarities
  - Differences
- Compare these to Point Defects
  - Similarities
  - Differences

[1]Description or Definition is a Necessary but not Sufficient for a Good Comparisons. All Comparisons include discussion of similarities and differences.

Slip or Permanent Deformation

- One Part of Crystal Slides over Another Part
  - Shear Process

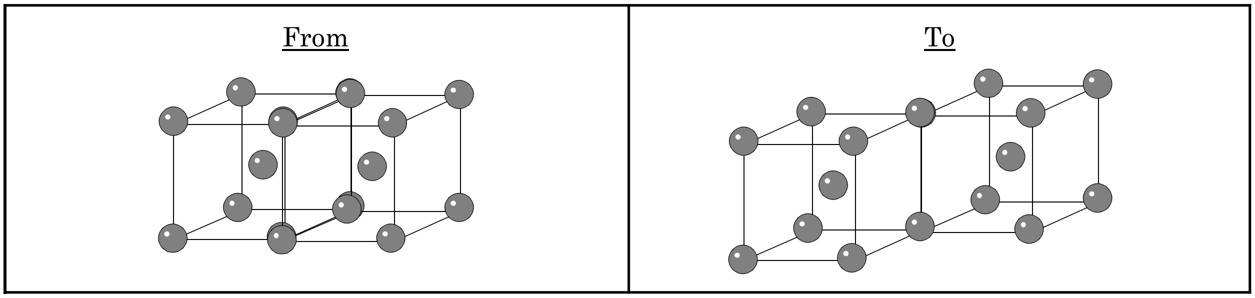


- Specific Slip System
  - Plane

  - Direction

<u>Stress Required for Slip</u>

- Slide One Plane Over Another
- Frenkel
  - Break All Bonds and Reform all But One



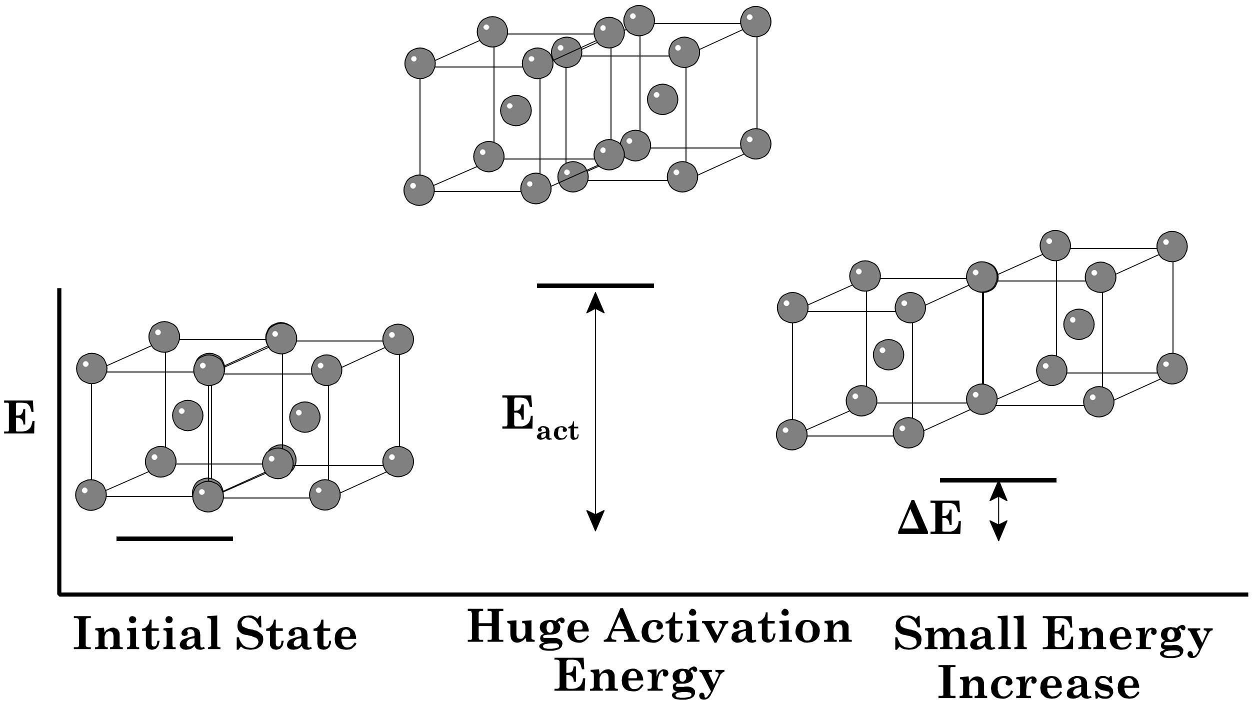
- Experimental Results

Material	Pred (MPa)	Meas (MPa)
Steel	6000	600
Cast Iron	5500	580
Al	2300	320
Monel	6000	280

Do you Think the Model is Valid based on the Data?

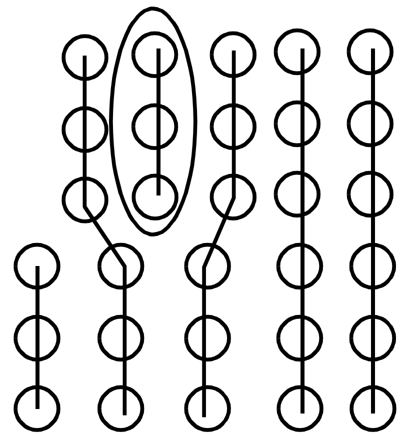
What does this mean?

Reason for Discrepancy



Dislocations

- Explain Discrepancy



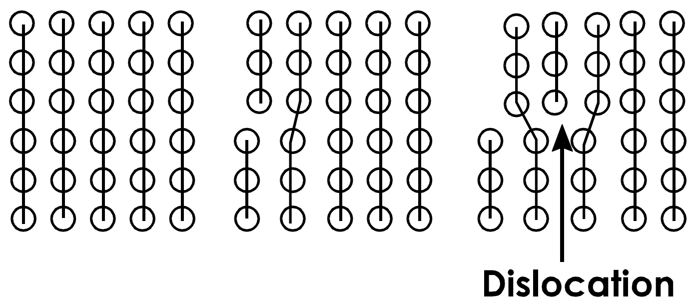
- A dislocation is a linear defect
  - a line (1-D) of atoms wedged into the crystal.

- Not Stable

- Not a Combination of Interstitials

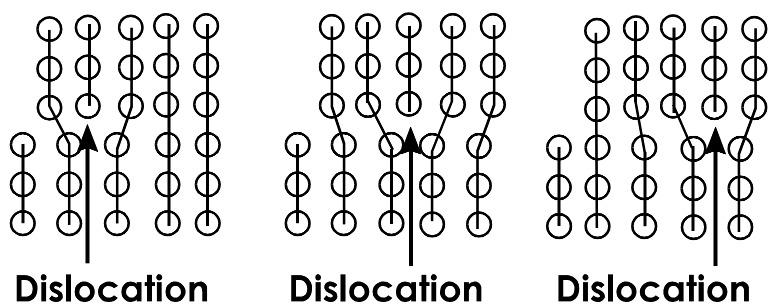
<u>Dislocation Formation</u>

- Explains Why Plastic Deformation Requires Less Strength
  - Than Predicted by Frenkel
  - Break A Single Bond At A Time



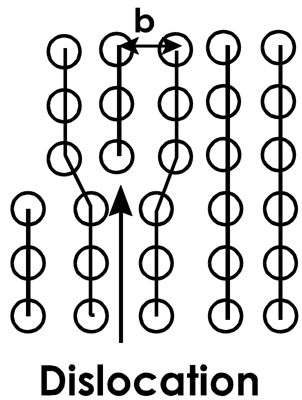
<u>Dislocation Motion</u>

- Break One Bond at a Time
- Requires Regular Structure



Energy of Dislocation

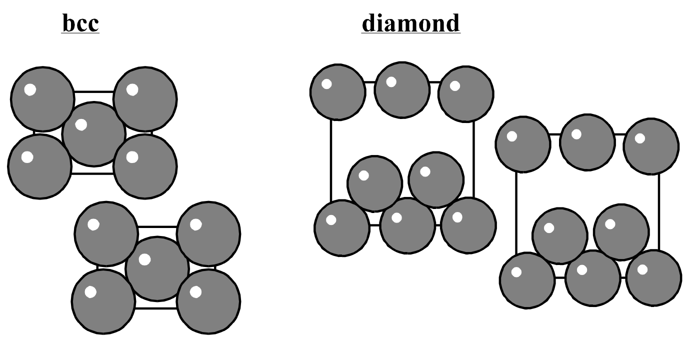
- Adds Energy to Crystal
- $E \alpha G|b|^2$
  - b - Interatomc Distance in the Slip Direction
  - $b = 2r_a$



- Slip System
  - Close Packed Directions
  - Close Packed Planes

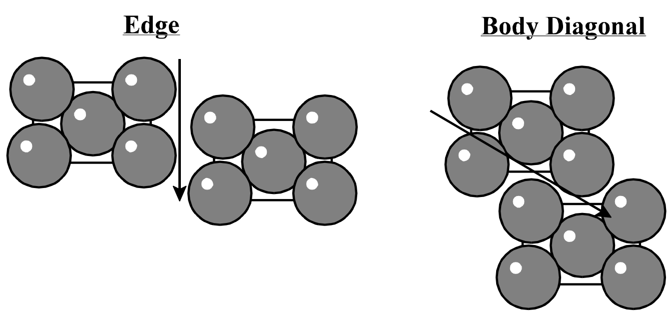
Slip Planes

- One Plane Must Slide Over Another



Slip Directions

- Easiest Direction to Slide



Slip Systems

- Plane of Atoms
  - Planes Slide Over Each Other
  - Highest Packing Factor
- Direction of Slip
  - Close Packed
- Ductile Materials Have Multiple (>5) Independent Slip Systems
  - hcp and bct are brittle

DISLOCATIONS AND INTERFACES

<u>Discussion Question</u>

- What is Permanent Deformation? How does it Occur in Ductile Metals?
- Include a description of macroscopic,

Think of This as a HW/Test Question

- Jot Down Ideas
- Organize Them
- Explanation Required

- microscopic and

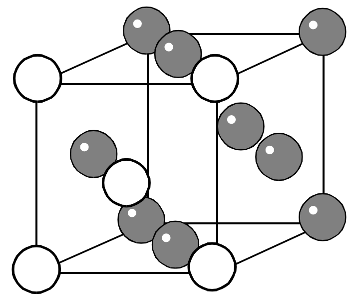
- atomic level phenomena in your answer.

3) Compare dislocations and interfaces. Make sure this comparison includes their respective role in plastic deformation of metals, the effect of long-time high-temperature exposure, how they are affected by crystal structure, and how they appear in optical micrographs.

TSR Exercize

- Review the Last 11 Slides and Last 9 Pages of the Notes
  - What information is key for the HW and Studying for the Tests?
  - What is Supporting Information

DISLOCATIONS AND INTERFACES



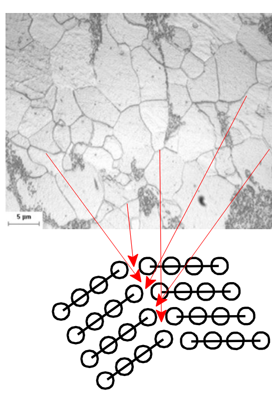
External Surfaces

- Where the crystal meets the rest of the world
  - Missing Bonds at the surface.
  - Surface atoms in higher energy state relative to bulk.
- Minimize surface area
- React with other chemicals

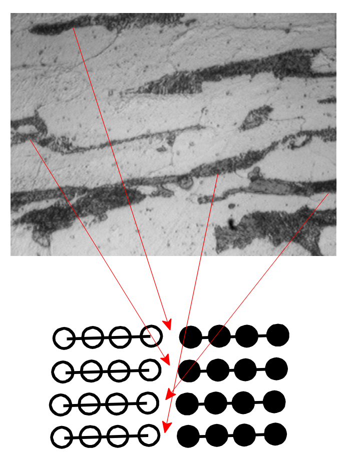
Interfaces (**Inter**nal Sur**faces**)

- Energetically Similar to External Surfaces
- Grain boundaries
  - Most crystalline materials are polycrystalline
  - Crystals in a polycrystalline material are called grains.
  - Where grains make contact with other grains are called *grain boundaries*
- Alloys and Second Phases
  - Where second phase crystals make contact with the continuous phase are called *phase boundaries*

Grain Boundaries

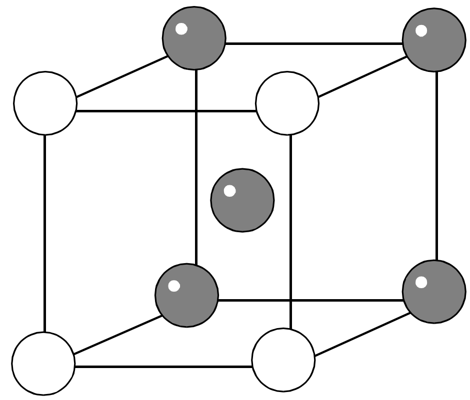


Phase Boundaries



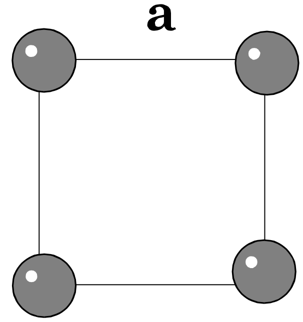
Light Phase α-Fe (bcc)
Dark Phase Fe_3C (bct)

<u>Interfaces (Surface Model)</u>



- Grain Boundaries, Phase Boundaries, Exposed Surfaces
  - Bonded to Fewer Atoms
  - Higher Energy
- Face Plane of bcc
  - Bonded to 4 atoms
  - Should be 8 atoms

<u>Energy</u>



- Surface Energy is
  - Energy Per Area
  - *Not the Energy of the Surface*
- Terms
  - Atoms Per Plane
  - Bonds Broken / Atom
  - Area of Plane

$$\Delta G = \gamma A$$

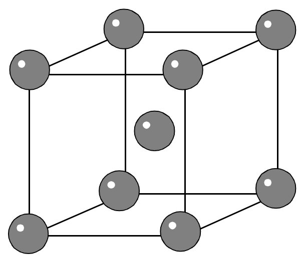
$$\gamma = \frac{dG}{dA} = \frac{N_{atoms} N_{bonds} E_{bond}}{A_{plane}}$$

<u>Example - Surface Energy of face plane in α (bcc)-Fe</u>

- Base Equation

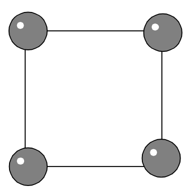
$$\gamma = \frac{dG}{dA} = \frac{N_{atoms} N_{bonds} E_{bond}}{A_{plane}}$$

- Number Bonds Broken Per Atom



$$\mathbf{N_{bonds} = 4}$$

- Other Information Regarding Face Plane in bcc



N_{atoms} = 1
A_{plane}= 0.082 x $10^{-18}$$m^2$
E_{bond}= 415 kJ/mole

$$a = \frac{4r}{\sqrt{3}}$$

$$A = a^2 = \left(\frac{4r}{\sqrt{3}}\right)^2 = \frac{16}{3} r^2$$

- Final Calculation

$$\gamma = \frac{dG}{dA} = \frac{N_{atoms} N_{bonds} E_{bond}}{A_{plane}}$$

$$\gamma = \frac{(1\,\text{atom})(4\,\text{bonds})\,415\,{}^{\text{kJ}}\!/_{\text{mole}}}{\left(6.02 \times 10^{23}\,\text{atoms}/_{\text{mole}}\right)\left(0.082 \times 10^{-18}\,\text{m}^2\right)}$$

$$\gamma = 33.6\,\frac{\text{mJ}}{\text{m}^2}$$

Team Problem 2

- When Ductile Metals are Held at an Elevated Temperature and then cooled to room temperature (at any speed) will they likely become stronger or weaker?
  - Consider Expected Changes in Structure[2]
  - Consider Impact of these Changes on Properties[3]

> Think of This as a HW/Test Question
> - Jot Down Ideas
> - Organize Them
> - Explanation Required

[2]Will the Number of Interfaces Decrease or Increase? Why?

[3]Will this Make Dislocation Motion More or Less Difficult? Why?

3) Compare dislocations and interfaces. Make sure this comparison includes their respective role in plastic deformation of metals, the effect of long-time high-temperature exposure, how they are affected by crystal structure, and how they appear in optical micrographs.

TSR Exercize

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Summary

- Defects in Solids
  - "Non-Ideality" of Real Structures
  - Not Bad
- Point Defects
  - Thermodynamically Stable
  - General Equation
- Line and Surface Defects
  - Line - Not Array of Point Defects
  - Surface - Not Array of Line Defects
  - Not Stable

Final Notes
This should be filled out after class

Key Concepts	HW Connection	Questions Remaining