ME211: Engineering Materials

Course Objective...

Introduce fundamental concepts in Materials Science

You will learn about:

- material structure
- how structure dictates properties
- how processing can change structure

This course will help you to:

- use materials properly
- realize new design opportunities with materials

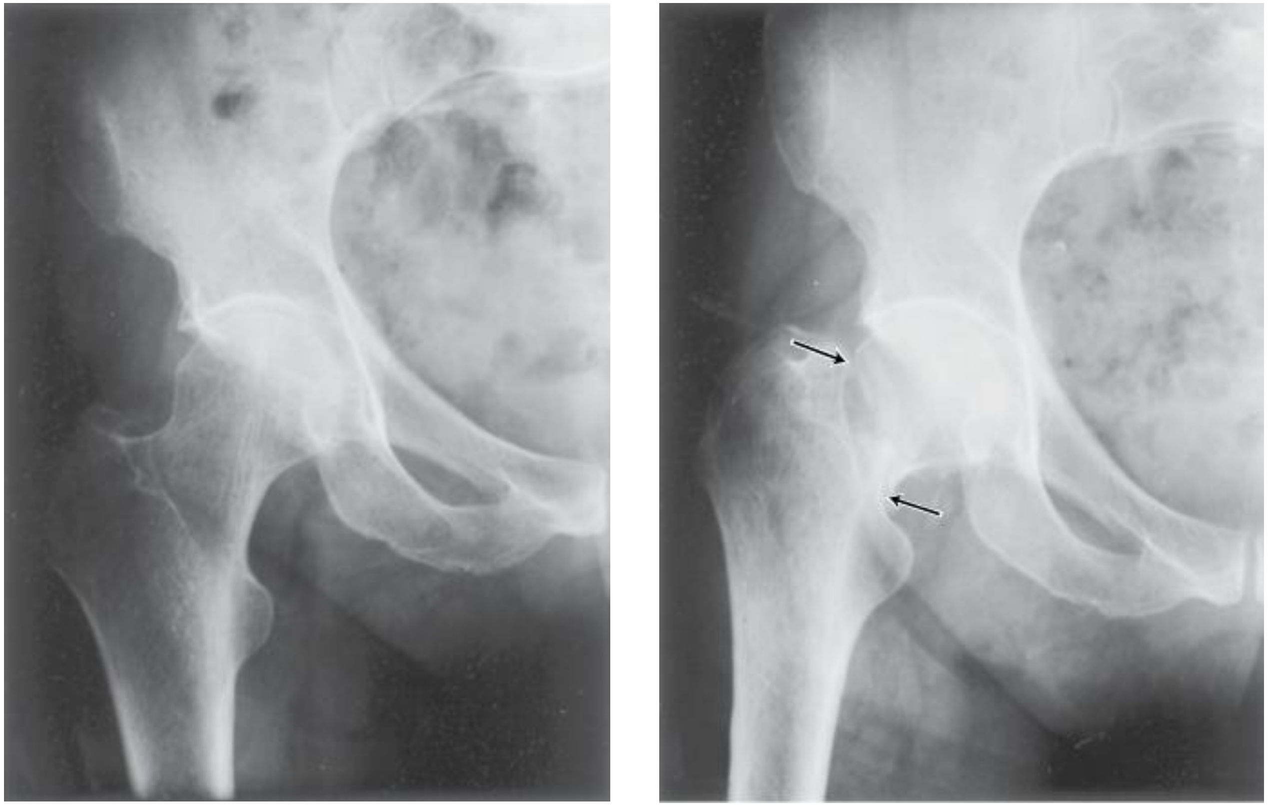
Chapter 1 - Introduction

- What is materials science?
- Why should we know about it?

- Materials drive our society
  - Stone Age
  - Bronze Age
  - Iron Age
  - Now?
    - Silicon Age?
    - Polymer Age?

Example – Hip Implant

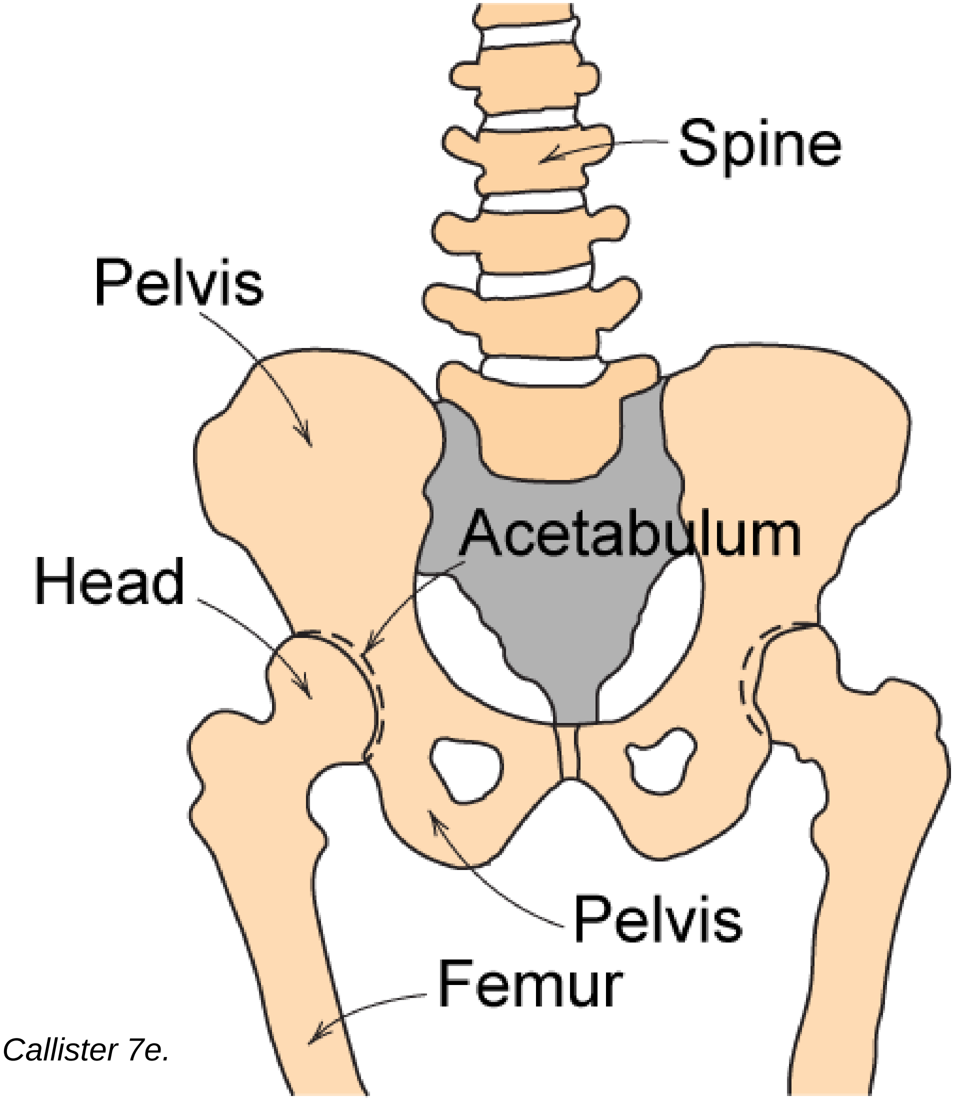
- With age or certain illnesses joints deteriorate. Particularly those with large loads (such as hip).



Adapted from Fig. 22.25, *Callister 7e.*

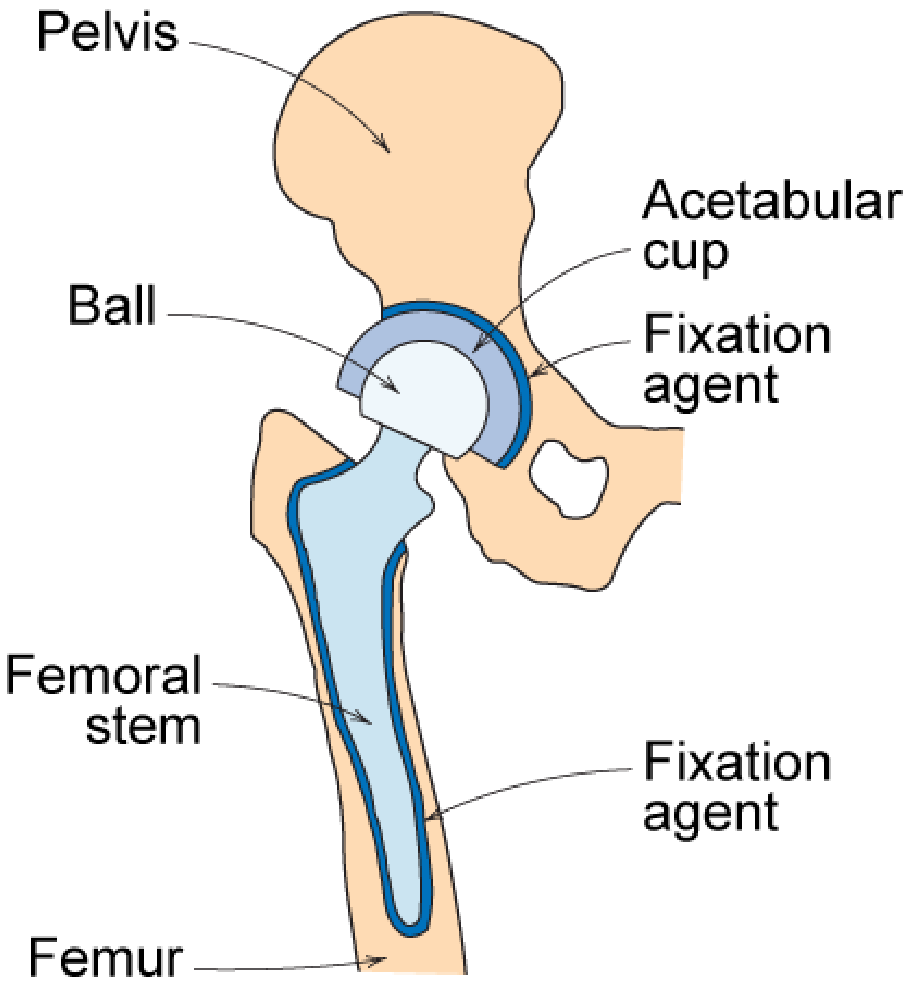
Example – Hip Implant

- Requirements
  - mechanical strength (many cycles)
  - good lubricity
  - biocompatibility



Adapted from Fig. 22.24, *Callister 7e.*

Example – Hip Implant



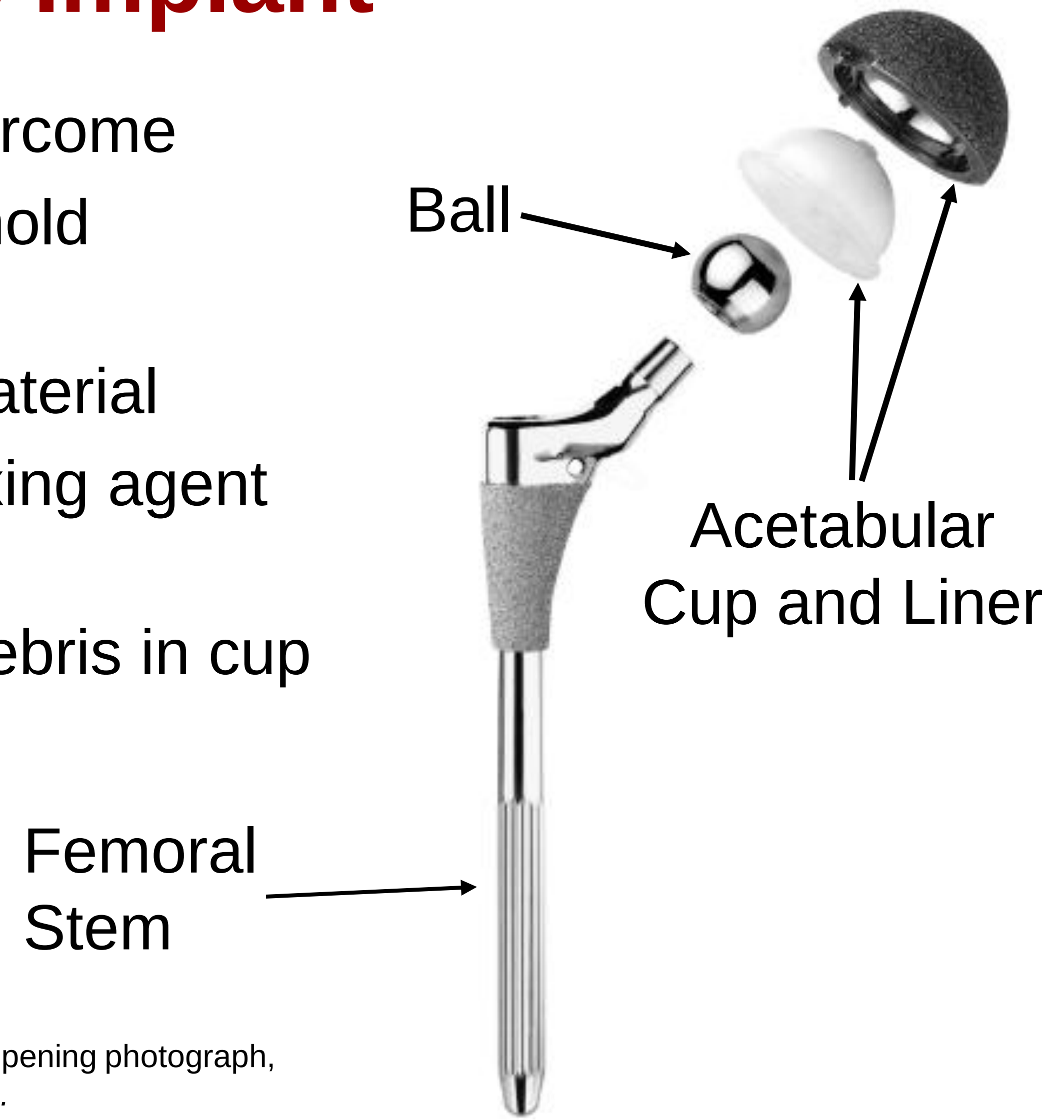
(a)

(b)

Adapted from Fig. 22.26, *Callister 7e.*

Hip Implant

- Key problems to overcome
  - fixation agent to hold acetabular cup
  - cup lubrication material
  - femoral stem – fixing agent (“glue”)
  - must avoid any debris in cup



Adapted from chapter-opening photograph, Chapter 22, *Callister 7e.*

Example – Develop New Types of Polymers

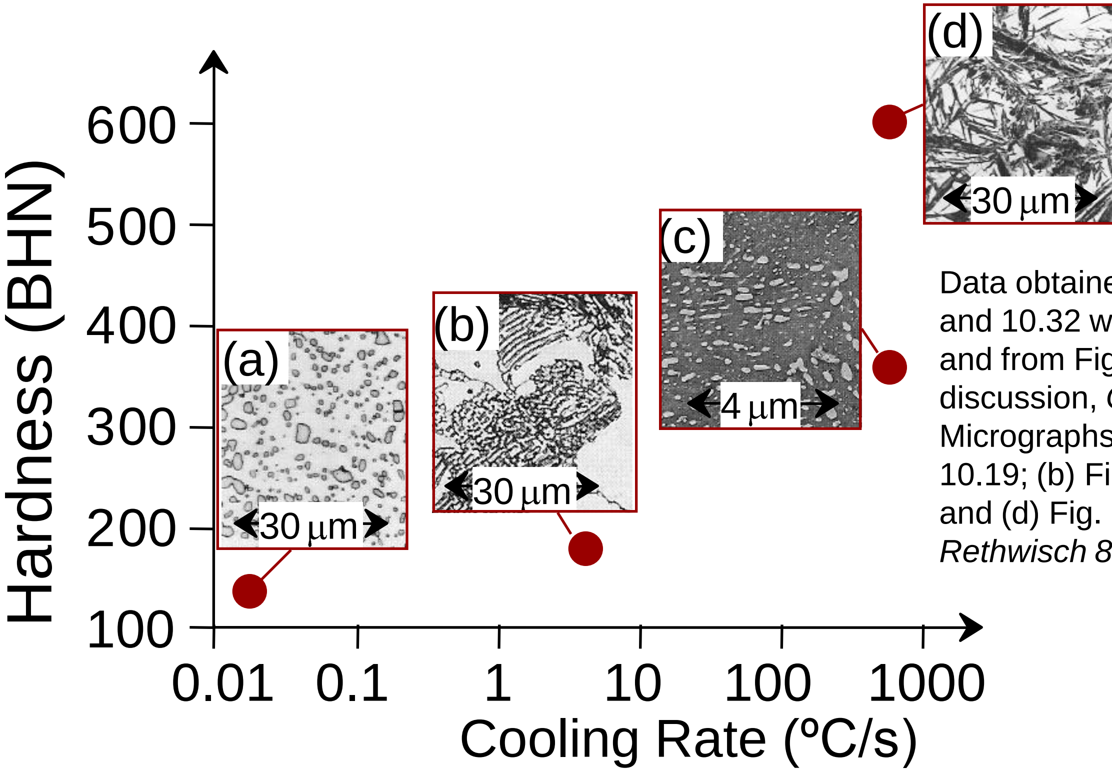
- Commodity plastics – large volume ca. $0.50 / lb
  Ex. Polyethylene
  Polypropylene
  Polystyrene
  etc.

- Engineering Resins – small volume > $1.00 / lb
  Ex. Polycarbonate
  Nylon
  Polysulfone
  etc.

Can polypropylene be “upgraded” to properties (and price) near those of engineering resins?

Structure, Processing, & Properties

- Properties depend on structure
  ex: hardness vs structure of steel



Data obtained from Figs. 10.30(a) and 10.32 with 4 wt% C composition, and from Fig. 11.14 and associated discussion, *Callister & Rethwisch 8e*. Micrographs adapted from (a) Fig. 10.19; (b) Fig. 9.30;(c) Fig. 10.33; and (d) Fig. 10.21, *Callister & Rethwisch 8e*.

- Processing can change structure
  ex: structure vs cooling rate of steel

Types of Materials

- Metals:
  - Strong, ductile
  - High thermal & electrical conductivity
  - Opaque, reflective.

- Polymers/plastics: Covalent bonding → sharing of e's
  - Soft, ductile, low strength, low density
  - Thermal & electrical insulators
  - Optically translucent or transparent.

- Ceramics: ionic bonding (refractory) – compounds of metallic & non-metallic elements (oxides, carbides, nitrides, sulfides)
  - Brittle, glassy, elastic
  - Non-conducting (insulators)

The Materials Selection Process

1. Pick Application → Determine required Properties

   Properties: mechanical, electrical, thermal, magnetic, optical, deteriorative.

2. Properties → Identify candidate Material(s)

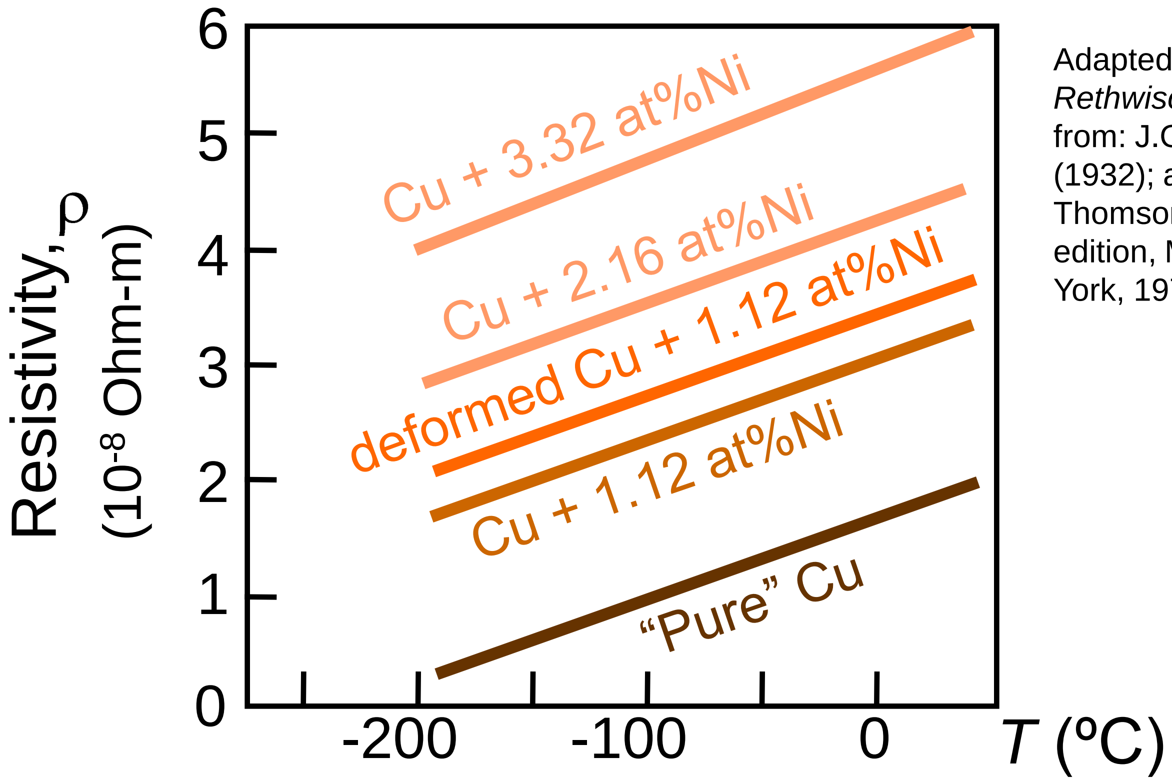
   Material: structure, composition.

3. Material → Identify required Processing

   Processing: changes *structure* and overall *shape*
   ex: casting, sintering, vapor deposition, doping
   forming, joining, annealing.

ELECTRICAL

- Electrical Resistivity of Copper:



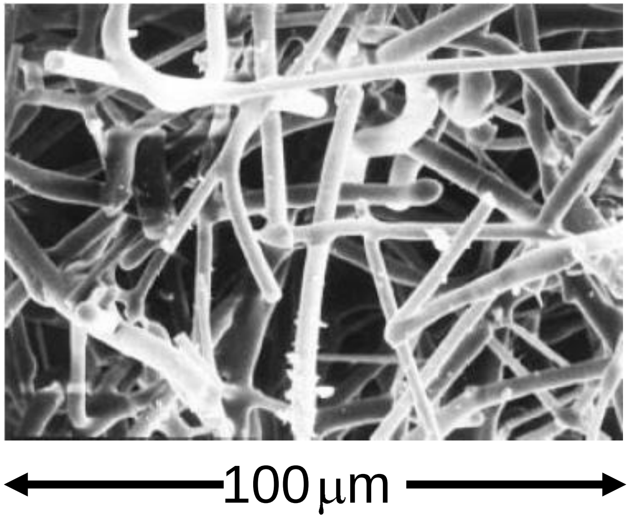
Adapted from Fig. 18.8, *Callister & Rethwisch 8e.* (Fig. 18.8 adapted from: J.O. Linde, *Ann Physik* **5**, 219 (1932); and C.A. Wert and R.M. Thomson, *Physics of Solids*, 2nd edition, McGraw-Hill Company, New York, 1970.)

- Adding "impurity" atoms to Cu increases resistivity.
- Deforming Cu increases resistivity.

THERMAL

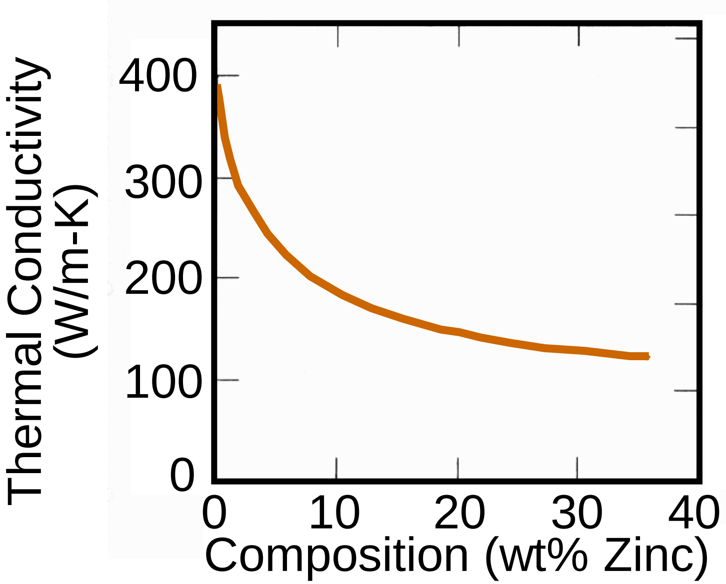
- Space Shuttle Tiles:
  -- Silica fiber insulation offers low heat conduction.

Adapted from chapter-opening photograph, Chapter 17, *Callister & Rethwisch 3e.* (Courtesy of Lockheed Missiles and Space Company, Inc.)



Adapted from Fig. 19.4W, *Callister 6e.* (Courtesy of Lockheed Aerospace Ceramics Systems, Sunnyvale, CA) (Note: "W" denotes fig. is on CD-ROM.)

- Thermal Conductivity of Copper:
  -- It decreases when you add zinc!



Adapted from Fig. 19.4, *Callister & Rethwisch 8e.* (Fig. 19.4 is adapted from *Metals Handbook: Properties and Selection: Nonferrous alloys and Pure Metals*, Vol. 2, 9th ed., H. Baker, (Managing Editor), American Society for Metals, 1979, p. 315.)

MAGNETIC

- Magnetic Storage:
  -- Recording medium is magnetized by recording head.

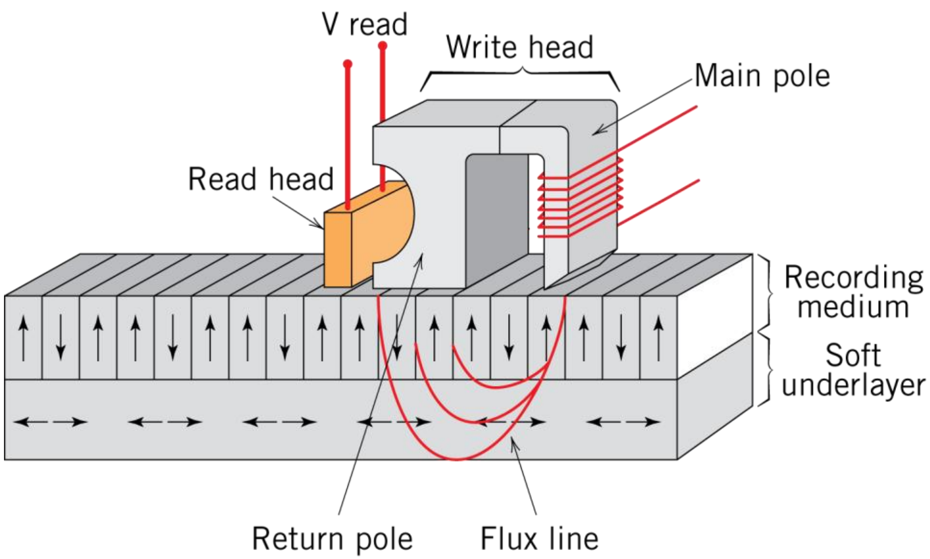
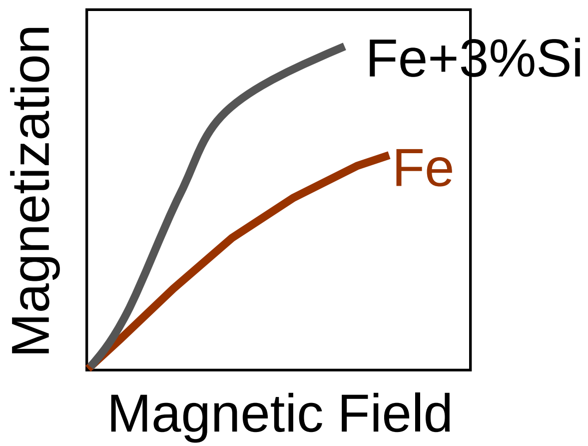


Fig. 20.23, *Callister & Rethwisch 8e.*

- Magnetic Permeability vs. Composition:
  -- Adding 3 atomic % Si makes Fe a better recording medium!



Adapted from C.R. Barrett, W.D. Nix, and A.S. Tetelman, *The Principles of Engineering Materials*, Fig. 1-7(a), p. 9, 1973. Electronically reproduced by permission of Pearson Education, Inc., Upper Saddle River, New Jersey.

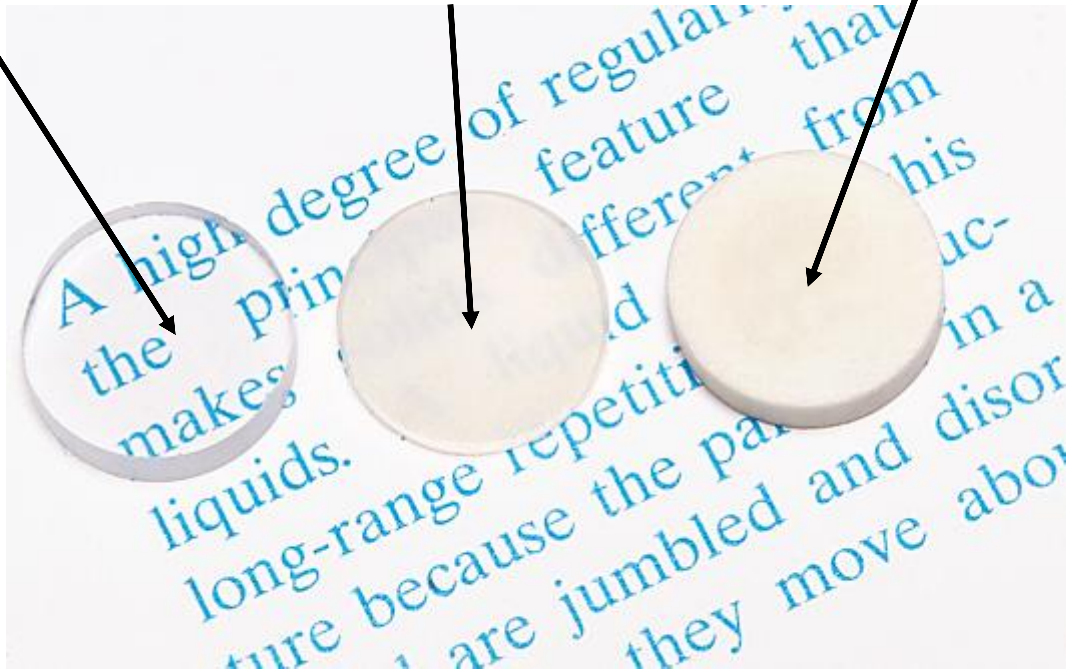
OPTICAL

- Transmittance:
  -- Aluminum oxide may be transparent, translucent, or opaque depending on the material structure.

single crystal

polycrystal:
low porosity

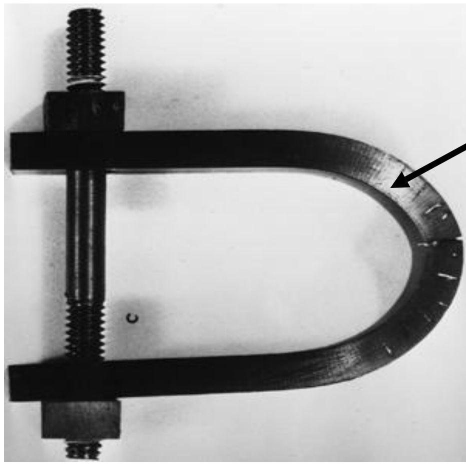
polycrystal:
high porosity



Adapted from Fig. 1.2, *Callister & Rethwisch 8e.* (Specimen preparation, P.A. Lessing; photo by S. Tanner.)

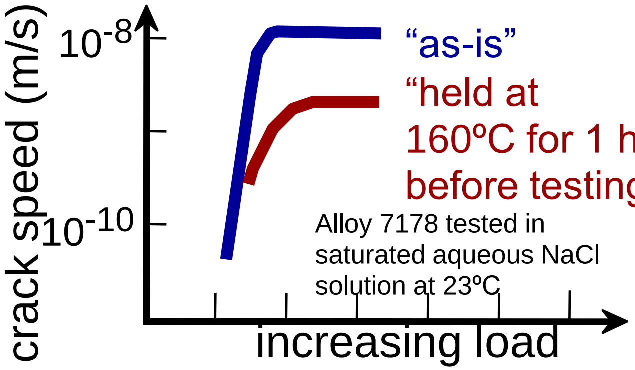
DETERIORATIVE

- Stress & Saltwater...
  -- causes cracks!



Adapted from chapter-opening photograph, Chapter 16, *Callister & Rethwisch 3e.* (from *Marine Corrosion, Causes, and Prevention*, John Wiley and Sons, Inc., 1975.)

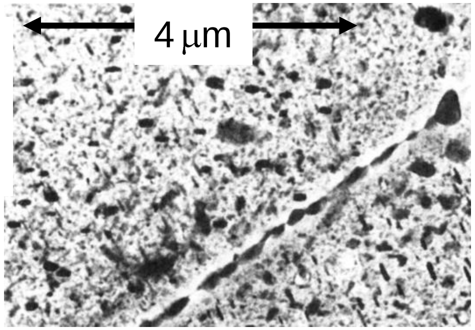
- Heat treatment: slows crack speed in salt water!



Adapted from Fig. 11.20(b), R.W. Hertzberg, "Deformation and Fracture Mechanics of Engineering Materials" (4th ed.), p. 505, John Wiley and Sons, 1996. (Original source: Markus O. Speidel, Brown Boveri Co.)

-- material:

7150-T651 Al "alloy" (Zn,Cu,Mg,Zr)



Adapted from Fig. 11.26, *Callister & Rethwisch 8e.* (Provided courtesy of G.H. Narayanan and A.G. Miller, Boeing Commercial Airplane Company.)

SUMMARY

Course Goals:

- Use the right material for the job.
- Understand the relation between properties, structure, and processing.
- Recognize new design opportunities offered by materials selection.