Chemical Engineering 378

Science of Materials Engineering
Dr. Matthew J Memmott

Introduction

Hard Work + The Spirit

Face the future with optimism. I believe we are standing on the threshold of a new era of growth, prosperity, and abundance. Barring a calamity or unexpected international crisis, I think the next few years will bring a resurgence in the economy as new discoveries are made in communication, ***medicine***, ***energy***, ***transportation***, physics, ***computer technology***, and ***other fields*** of endeavor.

Many of these discoveries, as in the past, will be ***the result of the Spirit whispering insights into and enlightening the minds of truth-seeking individuals***. Many of these discoveries will be made for the purpose of helping to bring to pass the purposes and work of God and the quickening of the building of His kingdom on earth today. With these discoveries and advances will come new employment opportunities and prosperity *for those who work hard and especially to those who strive to keep the commandments of God*. This has been the case in other significant periods of national and international economic growth.

-Elder M. Russell Ballard

BYU Idaho Commencement Remarks

April 6, 2012

YOUR Destiny

"I am both hopeful and expectant that from this university there will rise brilliant stars in drama, literature, music, art, science, and all the scholarly graces. This university can be the refining host for many such individuals who in the future, long after they have left this campus, can lift and inspire others around the globe." –Spencer W. Kimball

"As I reread 'Education for Eternity' and the now-familiar charge to become a "refining host' for 'brilliant stars,' it struck me that President Kimball was thinking primarily about the accomplishments of BYU students, not faculty. After all, it is our students whose achievements will bless the world "long after they have left this campus." Likewise, it is our students who make up BYU's orchestras, orchestras that President Kimball predicts will one day rival in quality the Philadelphia Orchestra and the New York Philharmonic. This does not mean that President Kimball lacks high expectations for faculty scholarship and creative work... It does mean that he anticipated that BYU's greatest contributions will come through its students." -John Tanner

Family







I am Ironman!

Better Learning

"Make it Stick, The science of successful learning"

- Based on hundreds of rigorous studies
  - Re-reading/highlighting is least effective!
  - Most effective learning methods include:
    - Grouping knowledge into "concepts or principles"
    - Delayed Recall (i.e. quizzes/self quizzes)
    - Solving unfamiliar problems
    - Struggling through HARD problems
  - It's easy to ask for help first… DON'T!!!!

Course Guidance

- TAs: Andrew Thomsen, Isaac Garlick
- Reading Quizzes (5%)
- Homework (25%)
- Open Ended Problems (OEPs) 10%
- Exams (30%)
- Final Exam (30%)
  - Wednesday, December 20th, 2023, 11:00 AM to 2:00 PM
- Plagiarism/Ethics

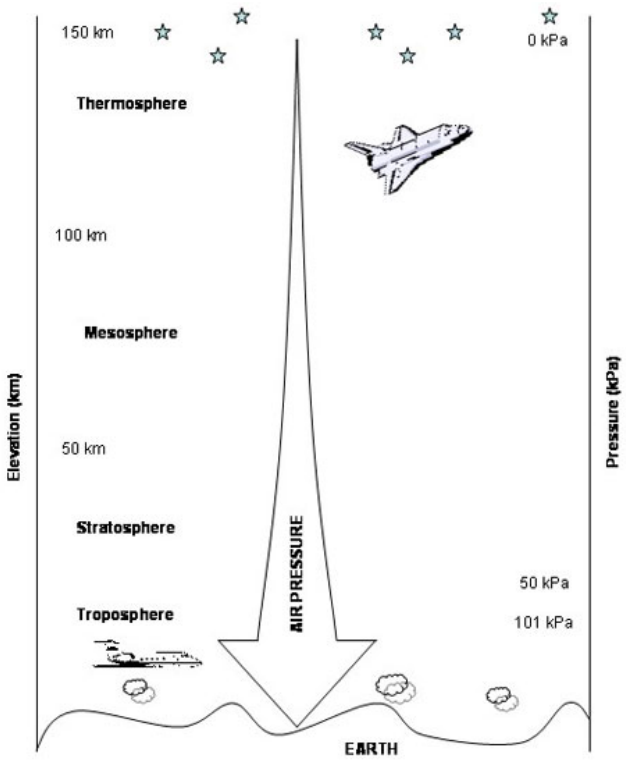
Open-Ended Problems (OEP)

- The world is made up of open-ended problems:
  - Who should I marry?
  - What is the average flight velocity of a coconut-laden swallow?
  - What is the best catalyst for a TCC?
  - How far could Aragorn safely toss a dwarf?
  - What do I need to power a geothermal microwave emitter?
  - What is the best investment strategy?
  - How can I optimize my errands and child transportation?
  - Should we resurrect the dinosaurs?
  - What is the best thermodynamic system for a nuclear power plant?
  - Seriously… why didn't Thor go for the head??

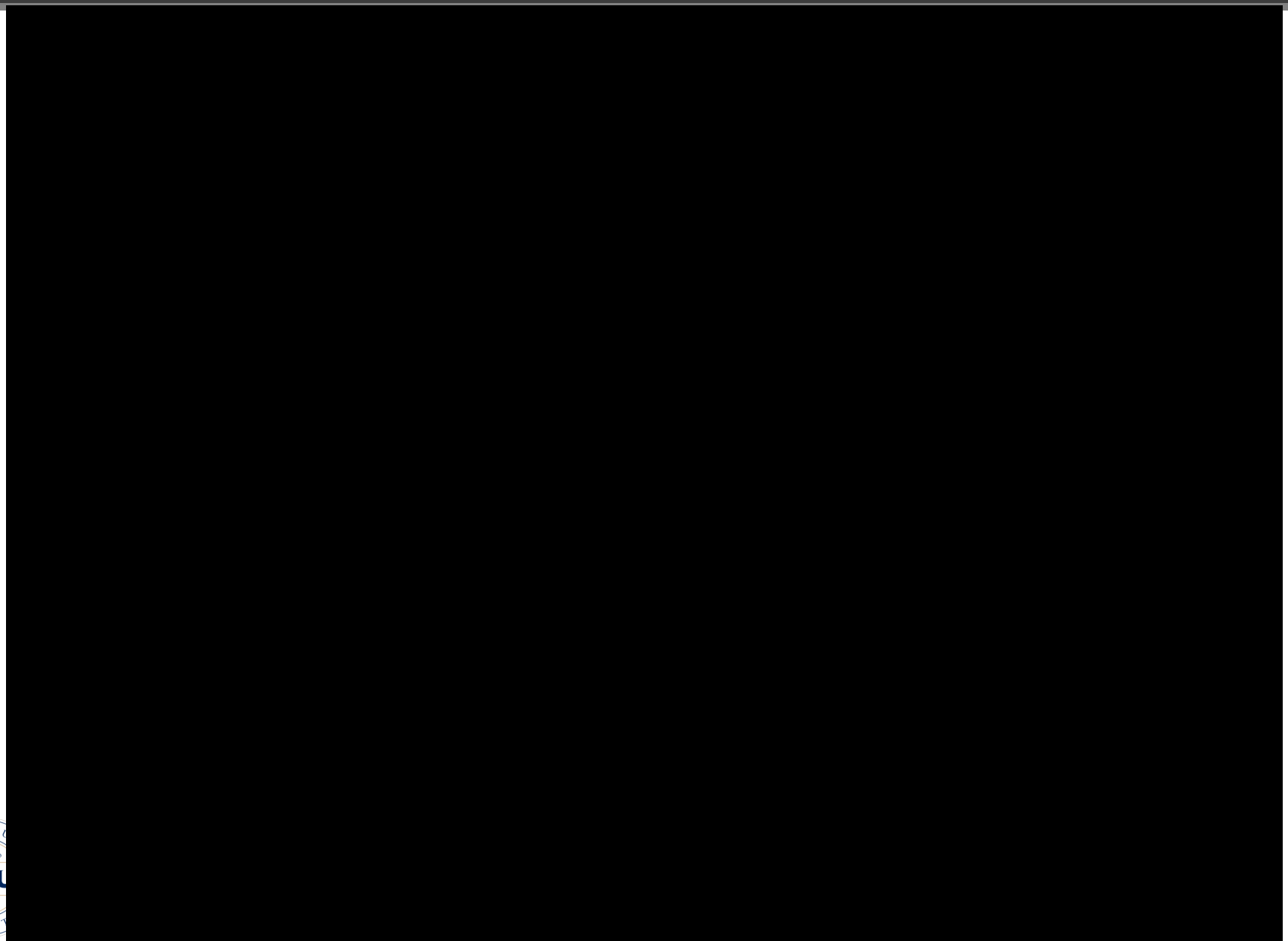
- No "exact, right" answer, though you can provide a reasonably close solution, and develop understanding.
- Key is to know HOW to solve, then check results
- School vs. the world (OEPs) – like swinging a baseball bat

Methodology

1. Find what the problem actually asking for
2. Draw a sketch of the problem region of interest
3. What physical laws/phenomena apply to the problem?
4. What equations can be used to represent the problem?
5. What variables/values do we know? What do we ***need*** to know?



OEP 1 (clip)



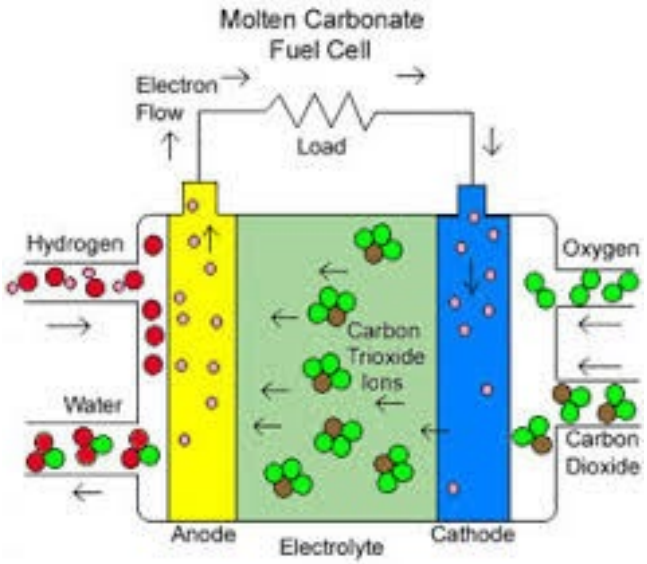
OEP 1

Open Ended Problem #1
Iron Man 2
Individual work only, Due 9/13/23 at beginning of class
(Don't be afraid to "Google" for reasonable assumptions; just provide references!)

Tony had developed the miniature ARC Reactor in his chest but was daunted the Pd poisoning that was occurring on a regular basis as a result. Thankfully, he realized that his dad discovered a new element, (only creatable by using a particle accelerator) that behaved just like Pd, save for the fact that it was too large to enter his blood and poison him. Considering that this new element was yet undiscovered, what is the electron structure for this new element?

Why Materials?

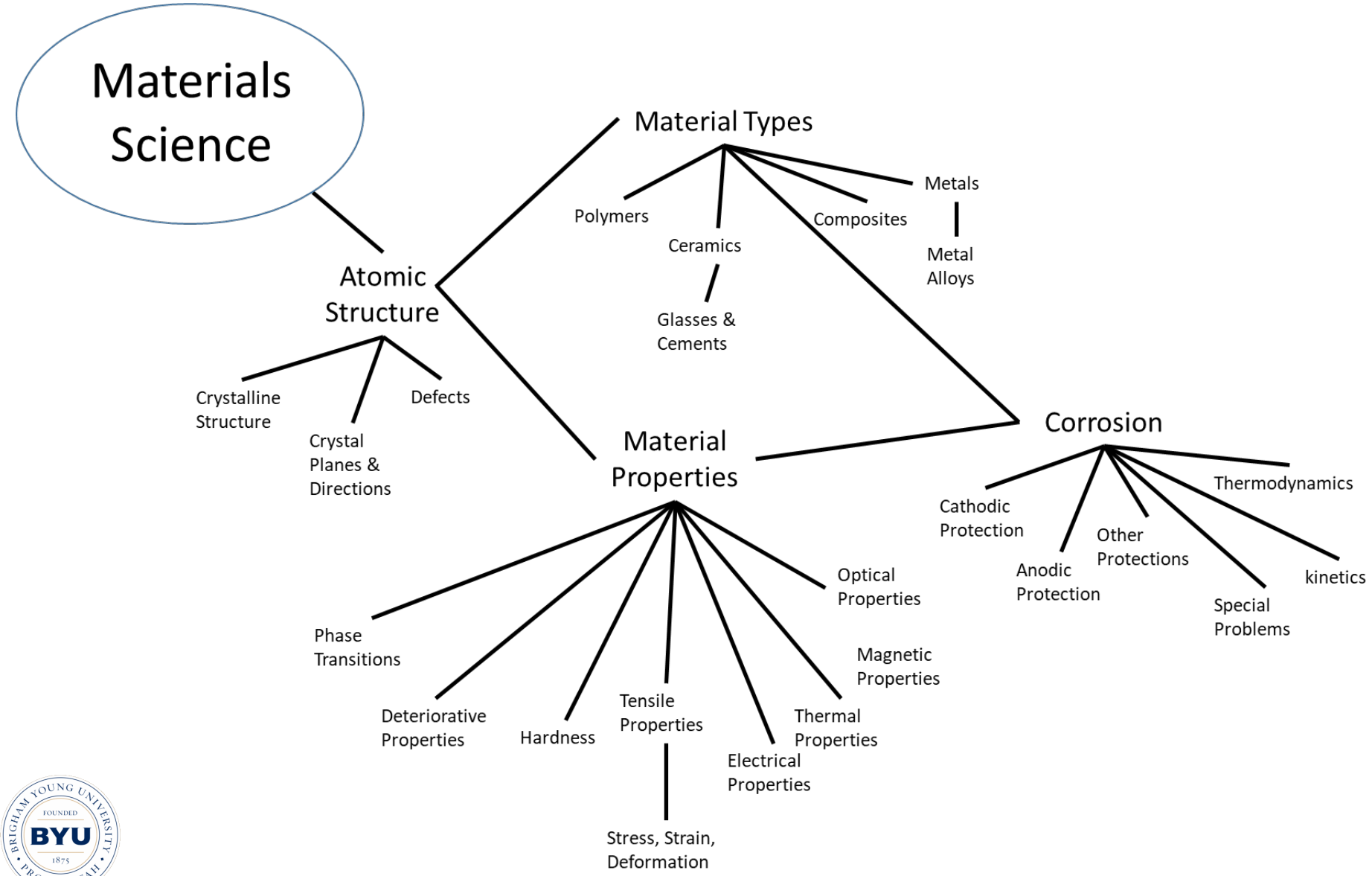
- Space Elevator



- Fuel Cells

- Nuclear Reactors

Course Roadmap



Materials Selection

Engineers often solve materials selection problems.

Procedure:

1. For a Specific Application → Determine Required Properties
   - Properties: mechanical, electrical, thermal, magnetic, optical, deteriorative.

2. From List of Properties → Identify Candidate Material(s)

3. Best Candidate Material → Specify Processing technique(s)
   - To provide required set of properties
   - To produce component having desired shape and size
   - Example techniques: casting, mechanical forming, welding, heat treating

Material Types

Four primary types of materials:

- Metals
- Polymers
- Ceramics
- Composites

Material Property Types

Properties of materials fall into six categories as follows:

- Mechanical
- Electrical
- Thermal
- Magnetic
- Optical
- Deteriorative

Mechanical Properties

Affect of carbon content on the hardness of a common steel:

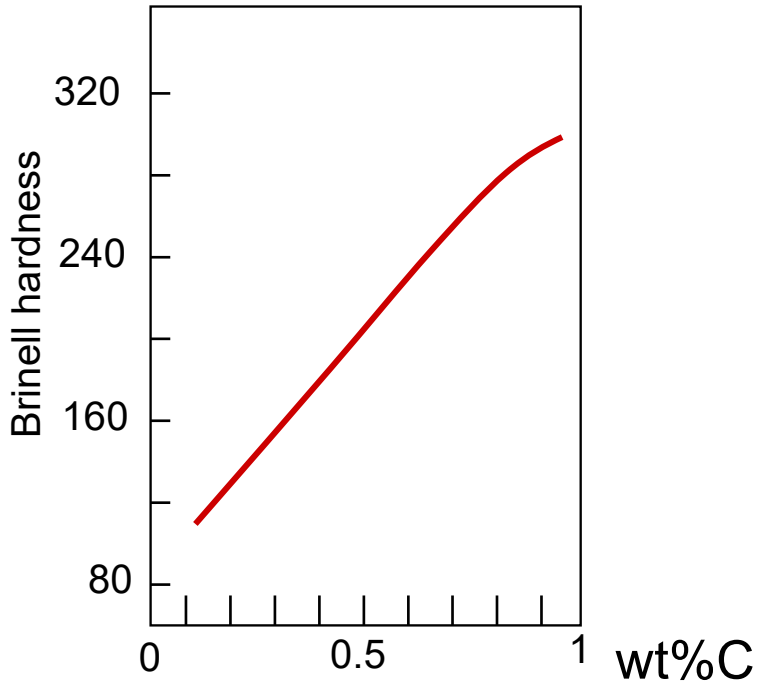


Fig. 10.31, *Callister & Rethwisch 10e.* [Data taken from *Metals Handbook: Heat Treating*, Vol. 4, 9th edition, V. Masseria (Managing Editor), 1981. Reproduced by permission of ASM International, Materials Park, OH.]

- Increasing carbon content increases hardness of steel.

Electrical Properties

Factors that affect electrical resistivity – for copper:

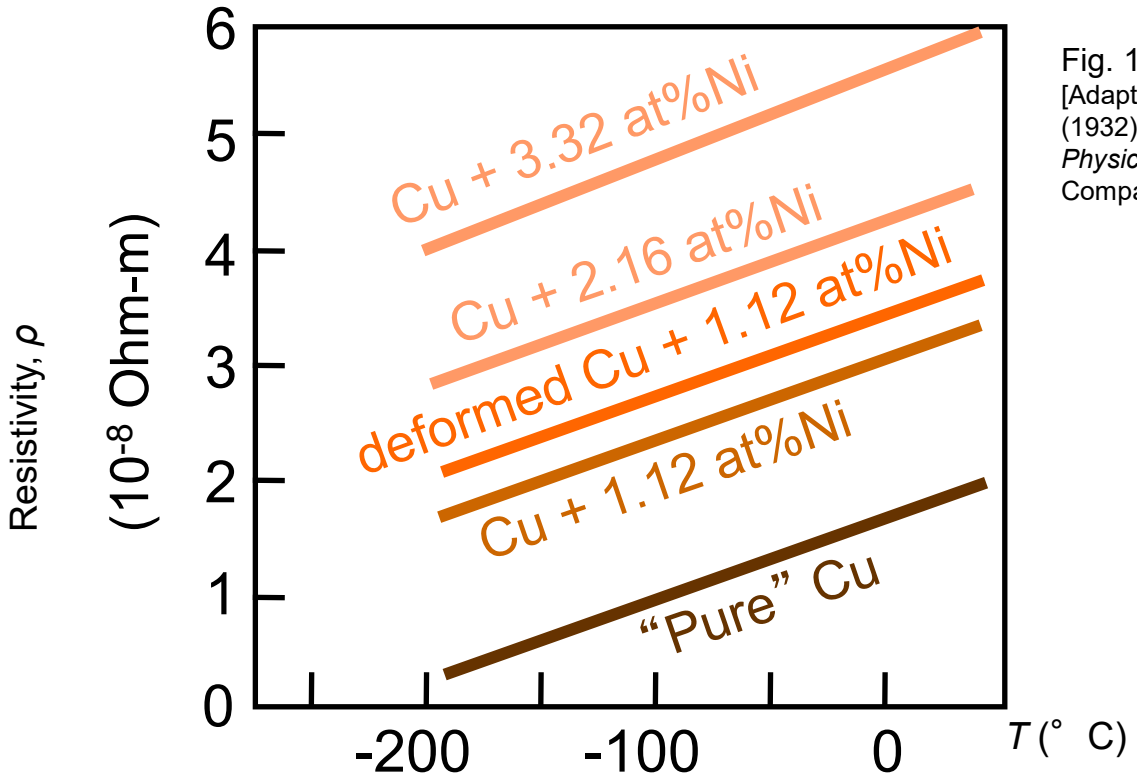


Fig. 18.8, *Callister & Rethwisch 9e.* [Adapted from: J.O. Linde, *Ann Physik* **5**, 219 (1932); and C.A. Wert and R.M. Thomson, *Physics of Solids*, 2nd edition, McGraw-Hill Company, New York, 1970.]

- Increasing temperature increases resistivity.
- Increasing impurity content (e.g., Ni) increases resistivity.
- Deformation increases resistivity.

Thermal Properties

Thermal Conductivity – measure of a material's ability to conduct heat

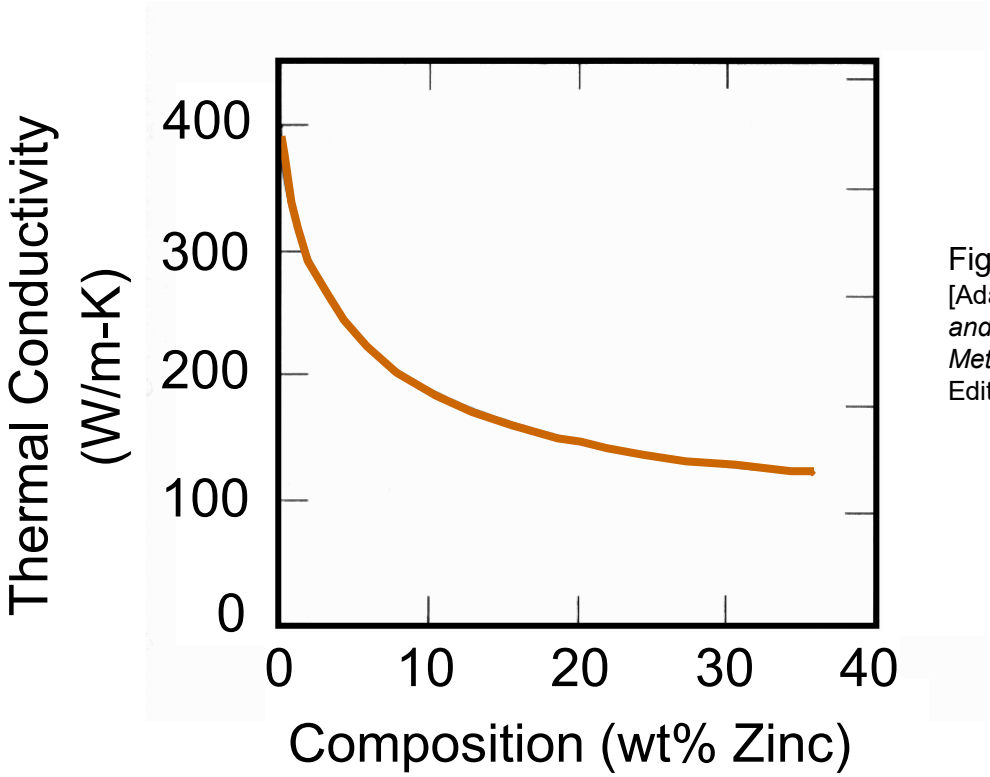
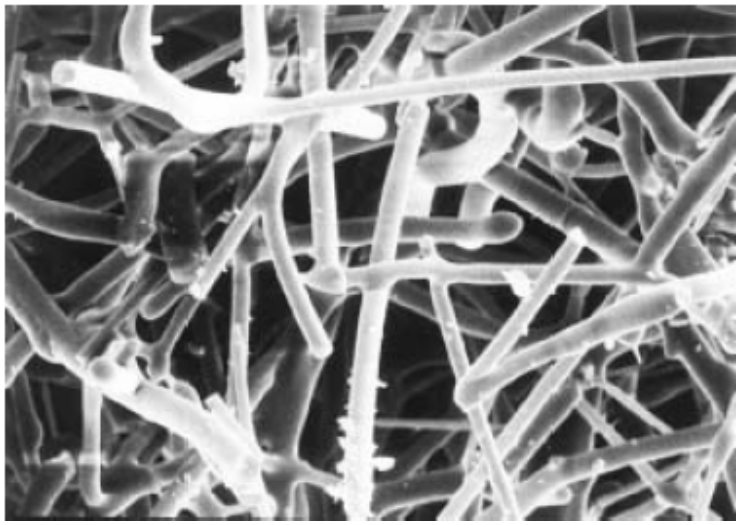


Fig. 19.4, *Callister & Rethwisch 10e.* [Adapted from *Metals Handbook: Properties and Selection: Nonferrous alloys and Pure Metals*, Vol. 2, 9th ed., H. Baker, (Managing Editor), ASM International, 1979, p. 315.]

- Increasing impurity content (e.g., Zn in Cu) decreases thermal conductivity.

Thermal Properties (continued)

Highly porous materials are poor conductors of heat



Courtesy of Lockheed Aerospace Ceramics Systems, Sunnyvale, CA

- Ceramic Fibers:
  - significant void space
  - low thermal conductivity

Material used for space shuttle

Courtesy of Lockheed Missiles and Space Company, Inc.

- Demonstration:
  - low thermal conductivity of this material

Magnetic Properties

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

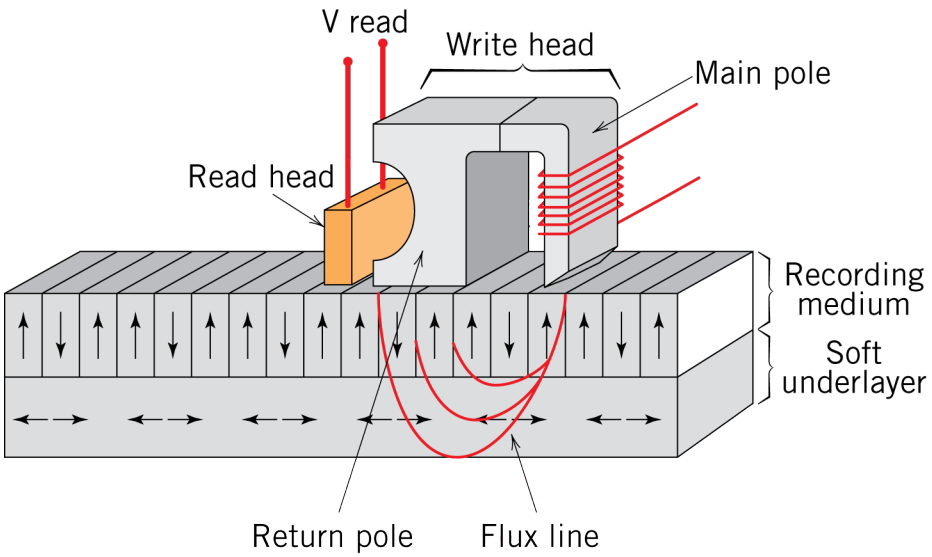
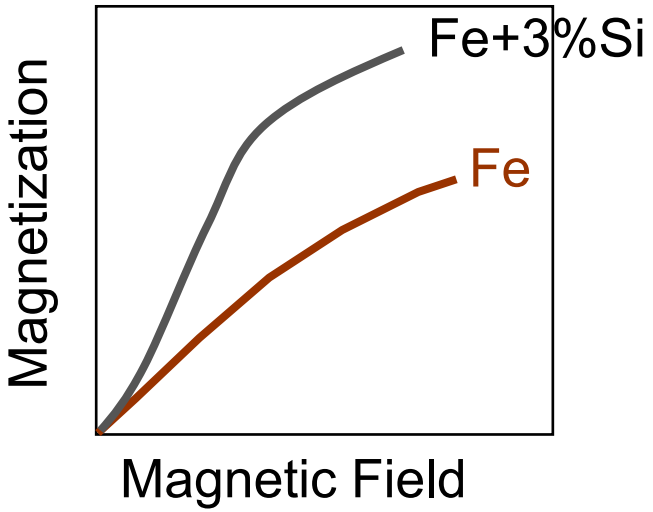


Fig. 20.23, *Callister & Rethwisch 10e.*
(Courtesy of HGST, a Western Digital Company.)

- 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.)

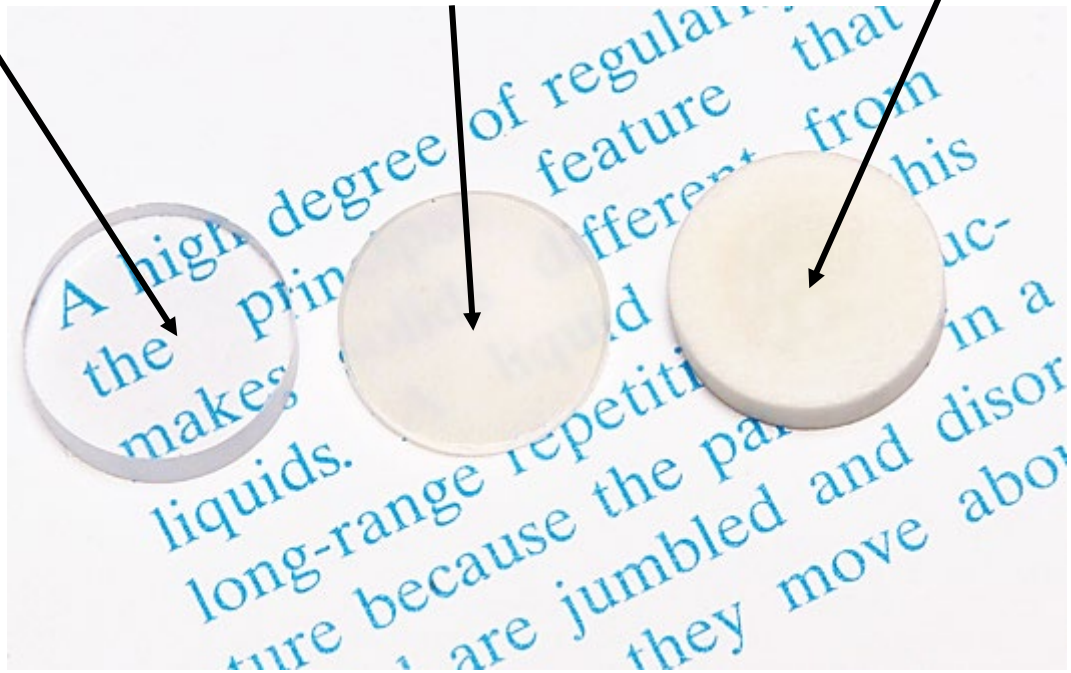
Optical Properties

- The light transmittance of some materials depend on their structural characteristics:

Aluminum oxide single crystal (high degree of perfection)—is optically transparent

Aluminum oxide polycrystalline material (having many small grains)—is optically translucent

Aluminum oxide polycrystalline material having some porosity—is optically opaque



(Specimen preparation, P.A. Lessing)

Deteriorative Properties

- Small cracks formed in steel bar that was simultaneously stressed and immersed in sea water
  - Form of stress-corrosion cracking

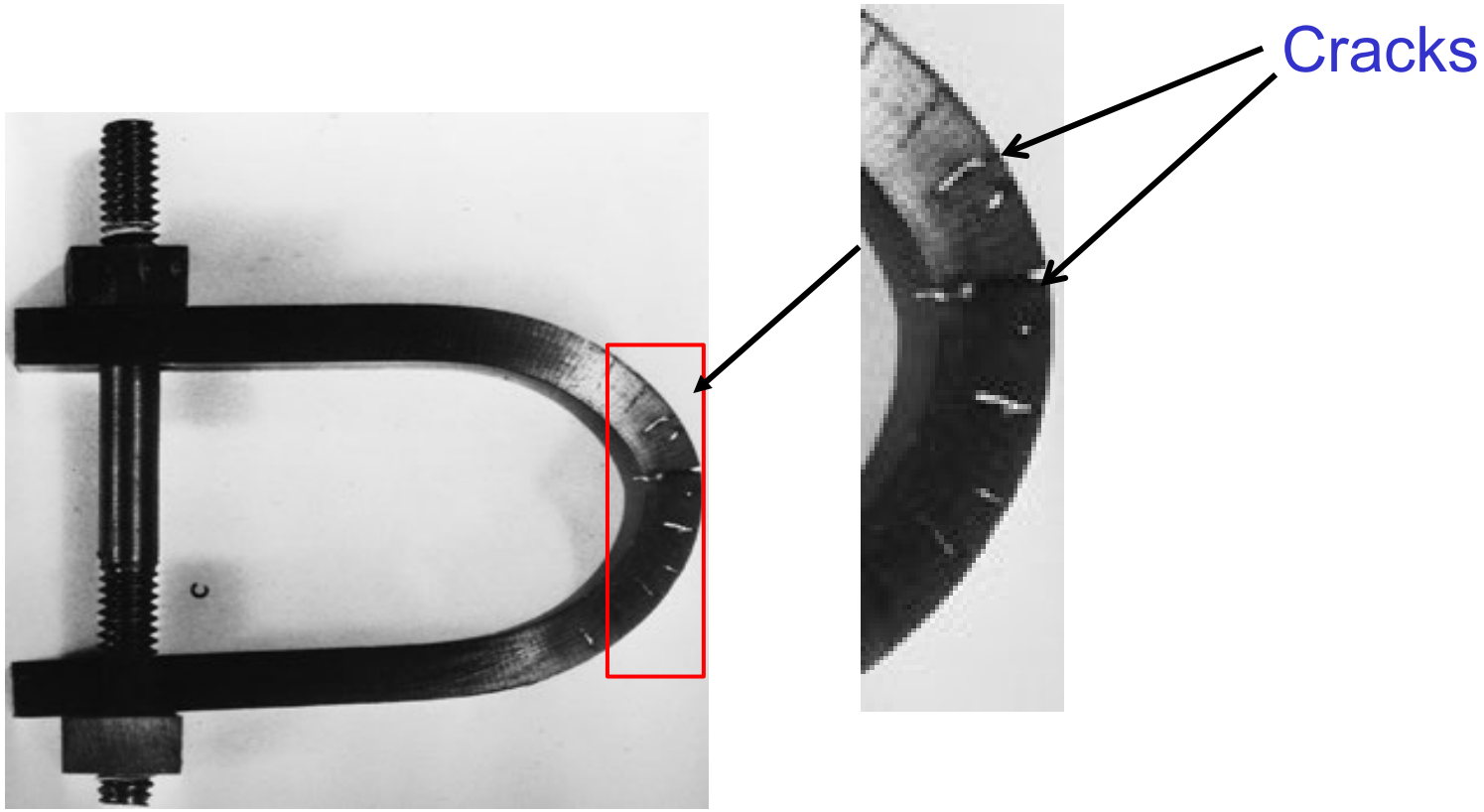
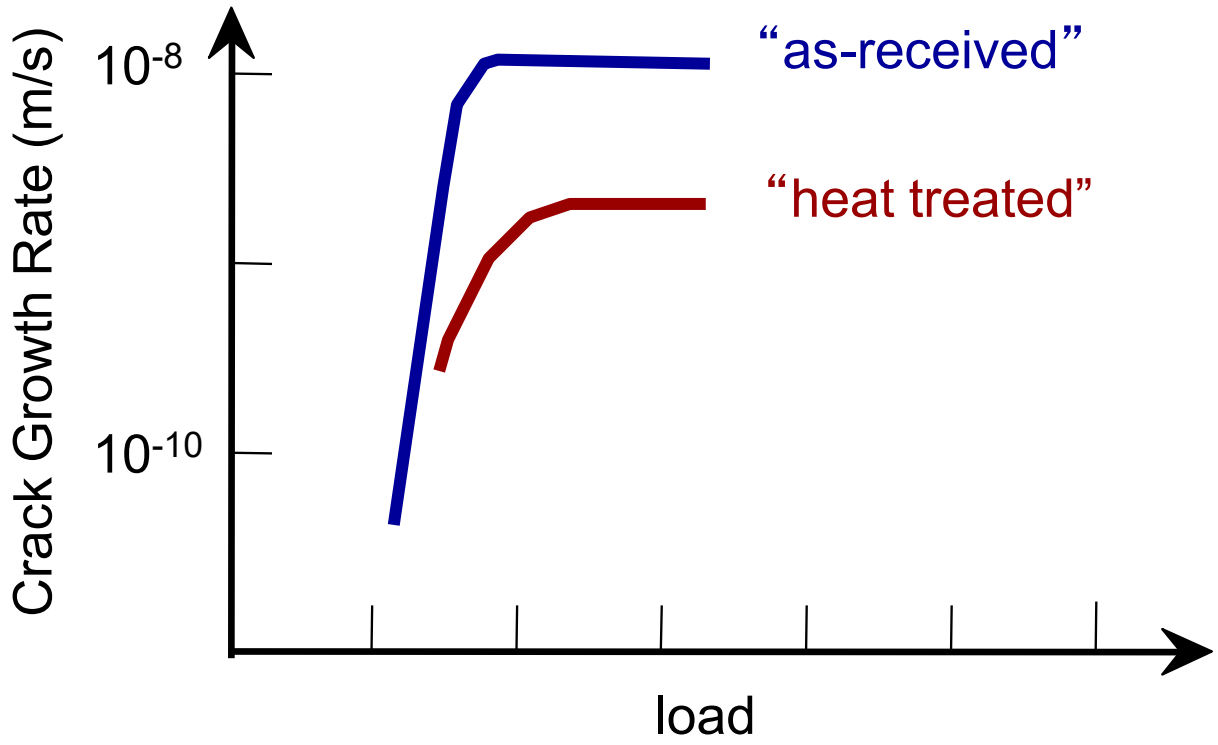


Fig. 17.21, *Callister & Rethwisch 10e.*
(from *Marine Corrosion, Causes, and Prevention*, John Wiley and Sons, Inc., 1975.)

Deteriorative Properties (cont.)

- For stress-corrosion cracking, rate of crack growth is diminished by heat treating



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.)

For Aluminum alloy 7178 that is stressed while immersed in a saturated aqueous NaCl solution, crack growth rate is reduced by heat treating (160°C for 1 h prior to testing).