

Introduction to Materials Science & Engineering

LECTURER : F.JAVANROODI

Course Objective...

Introduce fundamental concepts in MSE

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**

COURSE MATERIAL

Required text:

- ***Materials Science and Engineering: An Introduction***
W.D. Callister, Jr., 6th edition, John Wiley and Sons, Inc. (2003). Both book and accompanying CD-ROM are needed.

Optional Material:

- ***Engineering Materials 1, An Introduction to Their Properties & Applications***, Ashby, M.F. & Jones, D.R.H. 2nd edition, Butterworth-Heinemann, Woburn, UK, 1996
- ***Van Vlack, L. H., Elements of Materials Science and Engineering***, 7th edition, Addison-Wesley Longman, Reading, MA, 1996.

READING SCHEDULE

Week	Topic	Chapter
1	General Intro; Atomic Bonding	1,2
2	Crystalline Structure; Imperfections	3*,4
3	Diffusion; Mechanical Properties	5,6*
4	Strengthening Mechanisms; Failure	7*,8*
5	Phase Diagrams	9*
6	Kinetics & Phase Transformations	10*
	Processing & Applications of Metals	11
7	Struc., Prop., Proc., Applic. of Ceramics	12,13*
8	Struc., Prop. of Polymers; Composites	15,16
9	Corrosion; Elec. & Thermal Prop.	17*,18*,19*
10	Magnetic & Optical Prop.	20,21
	Econ. & Envir. Issues; Materials Selection	22*

Lectures: will highlight important portions of each chapter.

CHAPTER 1: MATERIALS SCIENCE & ENGINEERING

Materials are...

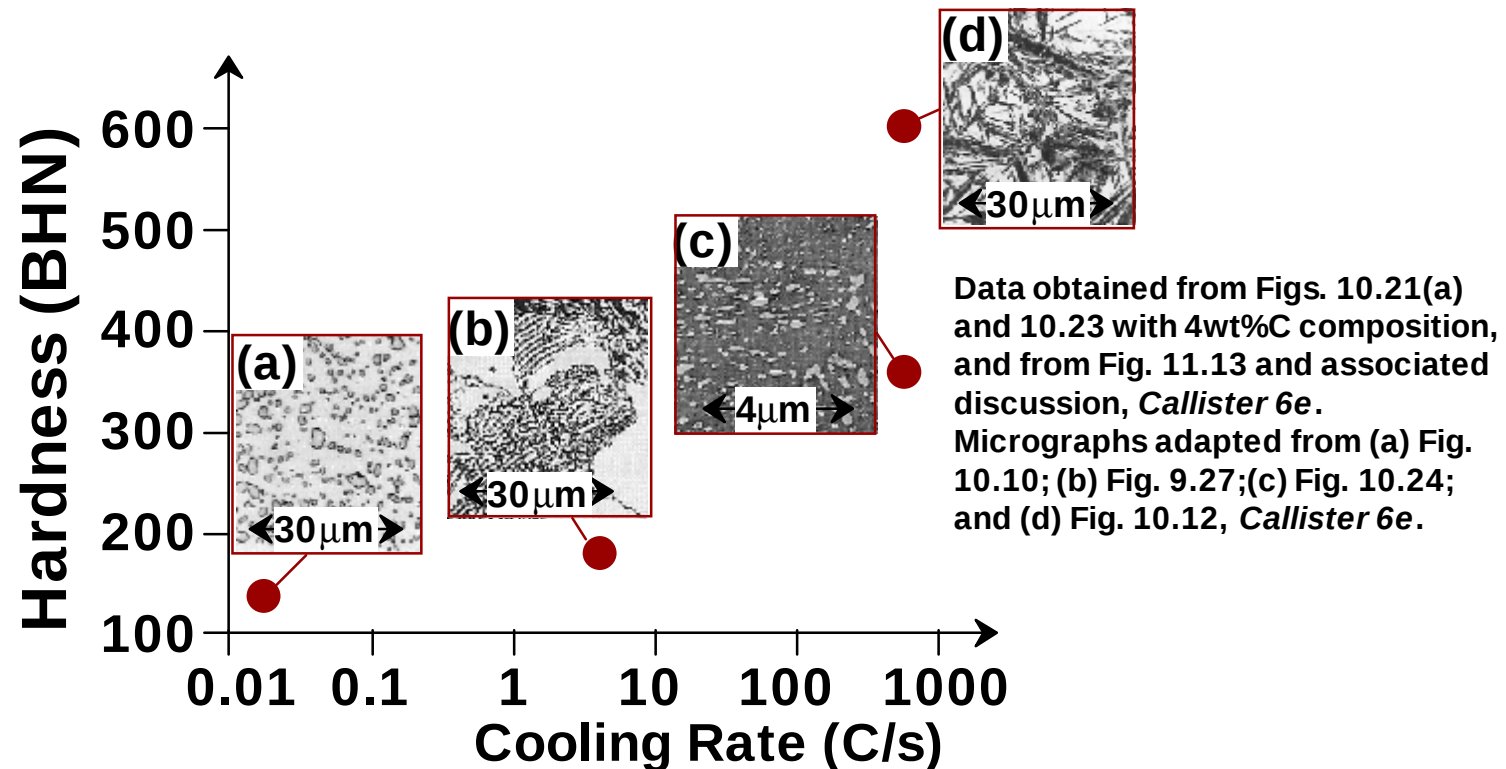
engineered structures...not blackboxes!

Structure...has many dimensions...

Structural feature	Dimension (m)
atomic bonding	$< 10^{-10}$
missing/extra atoms	10^{-10}
crystals (ordered atoms)	$10^{-8} - 10^{-1}$
second phase particles	$10^{-8} - 10^{-4}$
crystal texturing	$> 10^{-6}$

Structure, Processing, & Properties

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



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

The Materials Selection Process

1. Pick **Application** → Determine required **Properties**

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

2. **Properties** → Identify candidate **Material(s)**

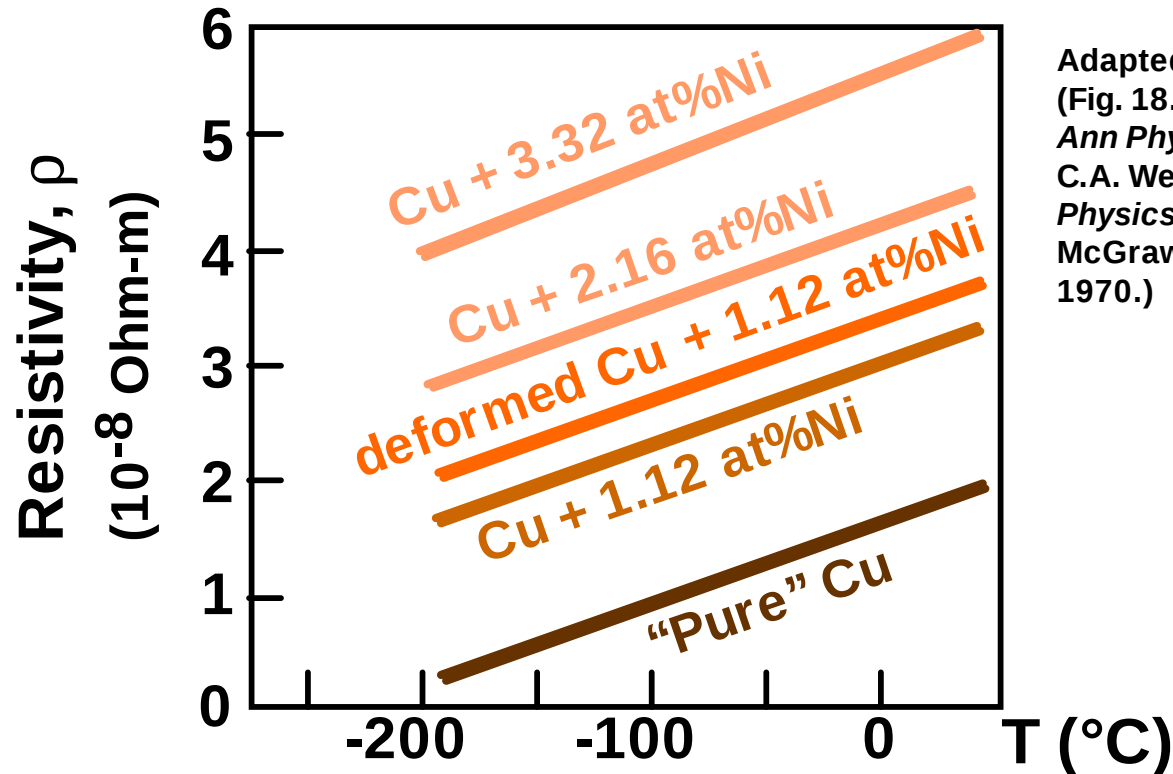
Material: structure, composition.

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 6e*.
(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.)

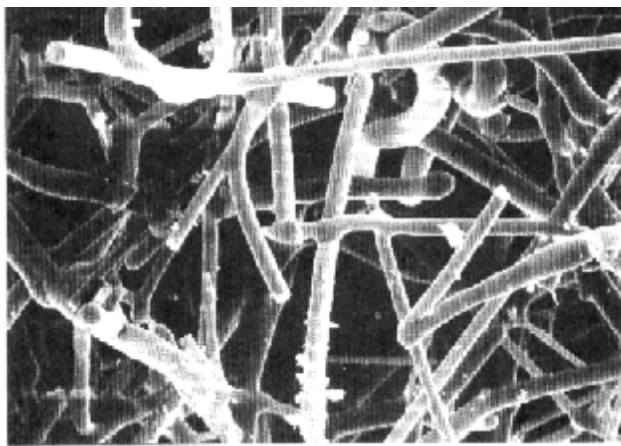
- Adding “**impurity**” atoms to Cu increases **resistivity**.
- Deforming** Cu increases **resistivity**.

THERMAL

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



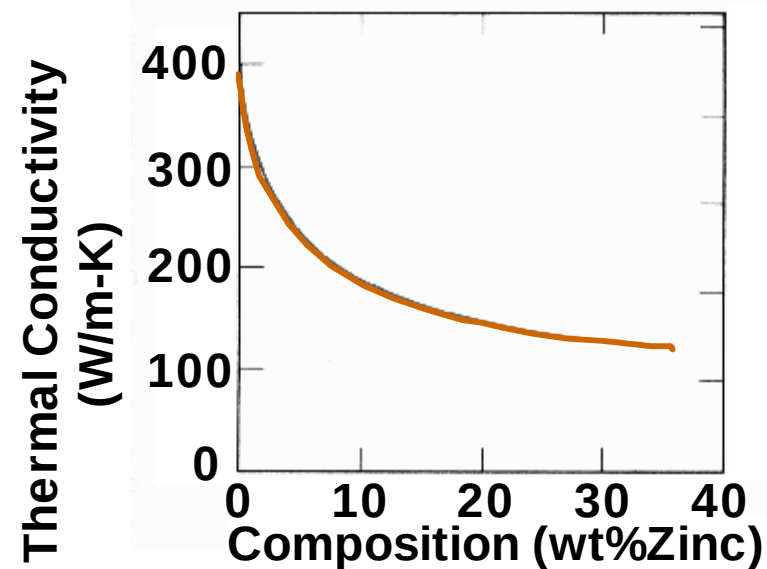
Fig. 19.0, *Callister 6e*.
(Courtesy of Lockheed Missiles and Space Company, Inc.)



← 100 μm →

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 6e*.
(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.

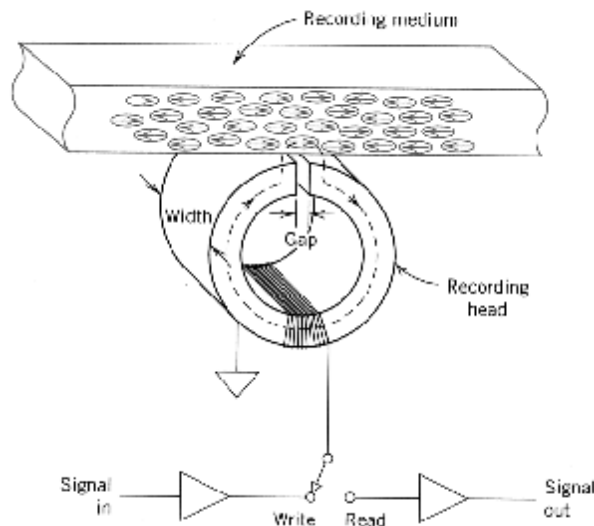
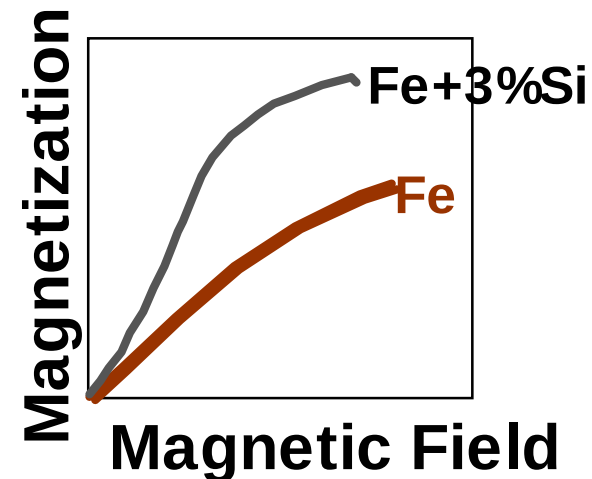


Fig. 20.18, *Callister 6e*.
(Fig. 20.18 is from J.U. Lemke, *MRS Bulletin*, Vol. XV, No. 3, p. 31, 1990.)

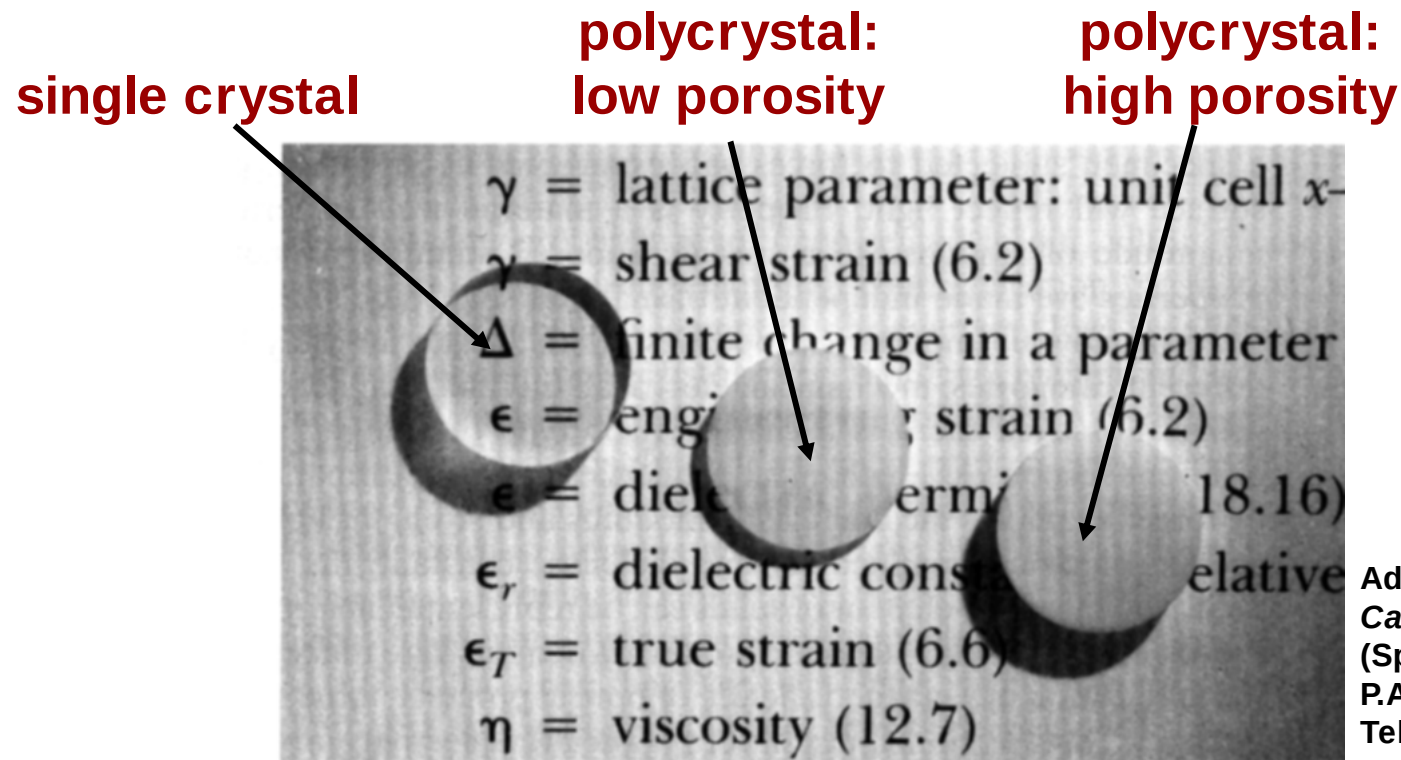
- **Magnetic Permeability vs. Composition:**
 - Adding 3 atomic % Si makes Fe a better recording medium!



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

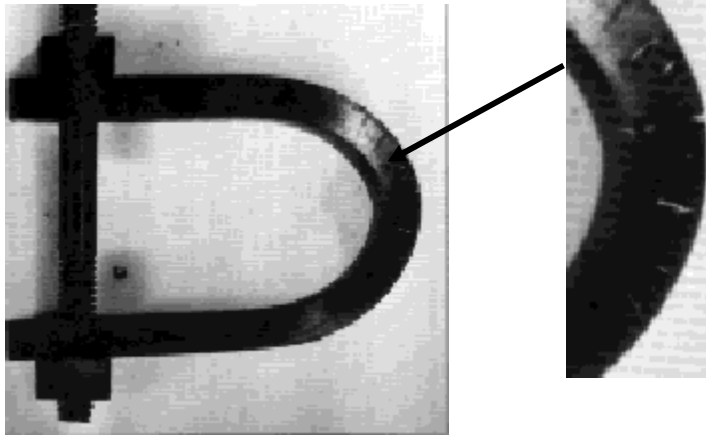
- **Transmittance:**
 - Aluminum oxide may be transparent, translucent, or opaque depending on the material structure.



Adapted from Fig. 1.2,
Callister 6e.
(Specimen preparation,
P.A. Lessing; photo by J.
Telford.)

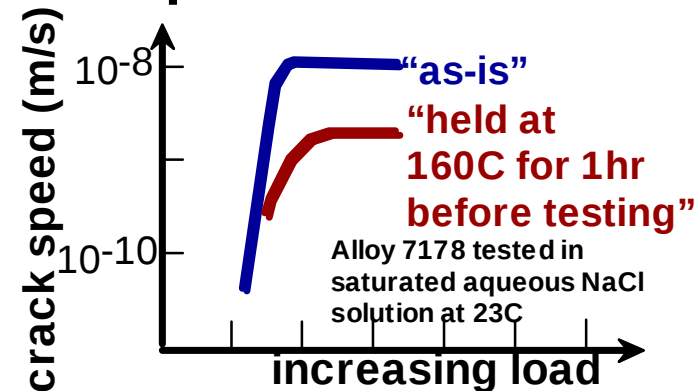
DETERIORATIVE

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



Adapted from Fig. 17.0, *Callister 6e*.
(Fig. 17.0 is from *Marine Corrosion, Causes, and Prevention*, John Wiley and Sons, Inc., 1975.)

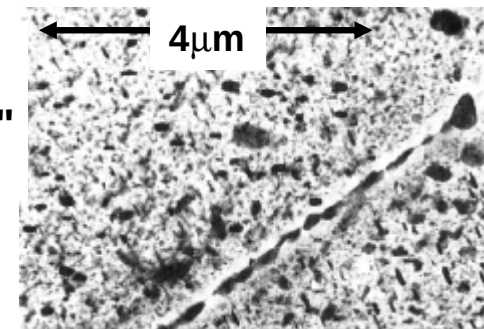
- Heat treatment: slows crack speed in salt water!



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. 11.24, *Callister 6e*. (Fig. 11.24 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.