HACETTEPE UNIVERSITY

KMU 396
Introduction to Materials Science and Technology I

Hacettepe University
Department of Chemical Engineering
Spring Semester

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KMU396 Staff: Instructor

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Educational Background

Post Doctoral Studies in Biomedical Engineering (2007-2011)
Specializing in Nonequilibrium Solidification during Biopreservation of cells
Harvard Medical School and Massachusetts General Hospital
Boston, MA, USA

Ph.D. in Mechanical Engineering (2006)
Specializing in Mathematical Modeling in Materials Science and Engineering
Northeastern University, Boston, MA, USA
Advisor: Dr. Teiichi Ando

M.S. in Chemical Engineering (2000)
Specializing in Heat and Mass Transfer and Energy Optimization
Middle East Technical University, Ankara, Turkey
Advisor: Dr. Güniz Gürüz

B.S. in Chemical Engineering (1997)
Middle East Technical University, Ankara, Turkey

Lycee Diploma, Mathematics Section (1992)
American Collegiate Institute, İzmir, Turkey

Course Objectives

- Introduce fundamental concepts in Materials Science and Engineering
- You will learn about:
  - Material structure
  - How structure determines properties
  - How processing can change structure
- This course will help you to:
  - Use/select materials properly
  - Realize new design opportunities with materials

Lectures

Time: 10.00 AM-12.20 PM
(with one break or two short breaks)

- Location: D1
- Activities:
  - Present new material
  - Announce reading and homework
  - Take quizzes and midterms

Make-ups given only for emergencies
Discuss potential conflicts *beforehand*

Recitation at the end of each class

- Purpose:
  - Discuss homework, quizzes, exams
  - Hand back graded quizzes, exams
  - Discuss concepts from lecture

Recitation minutes will be at the end of each class as necessary

No Labs?

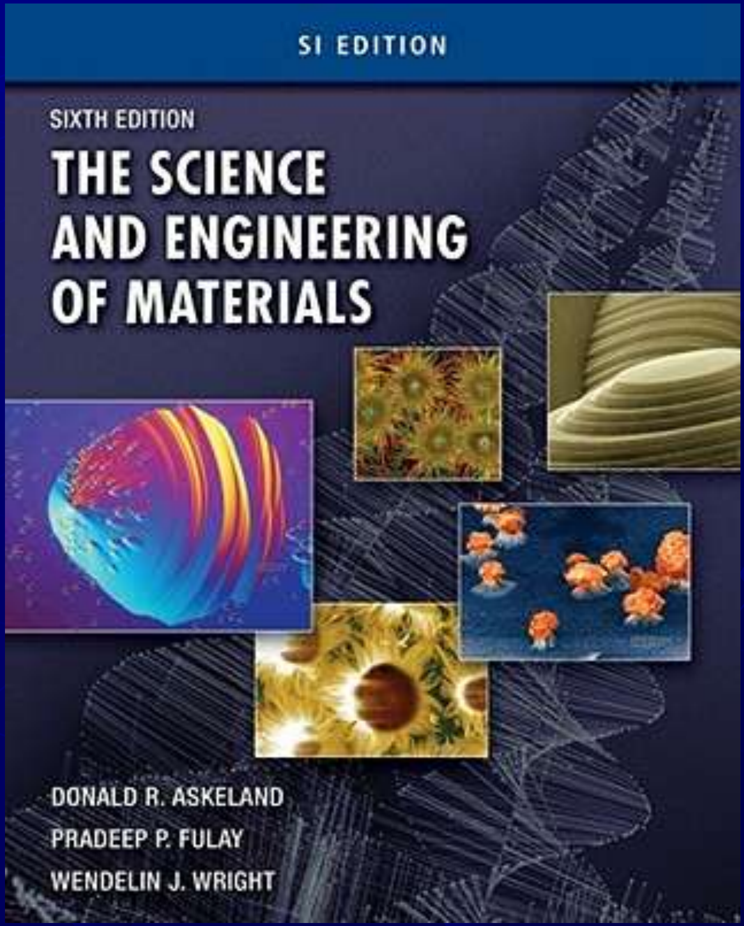
- No lab/application section with this class

However

- There might be visits to certain labs in our/various departments
- Purpose: To learn more about materials by relating lecture material with observations. To learn to properly formulate and write engineering reports and proposals.

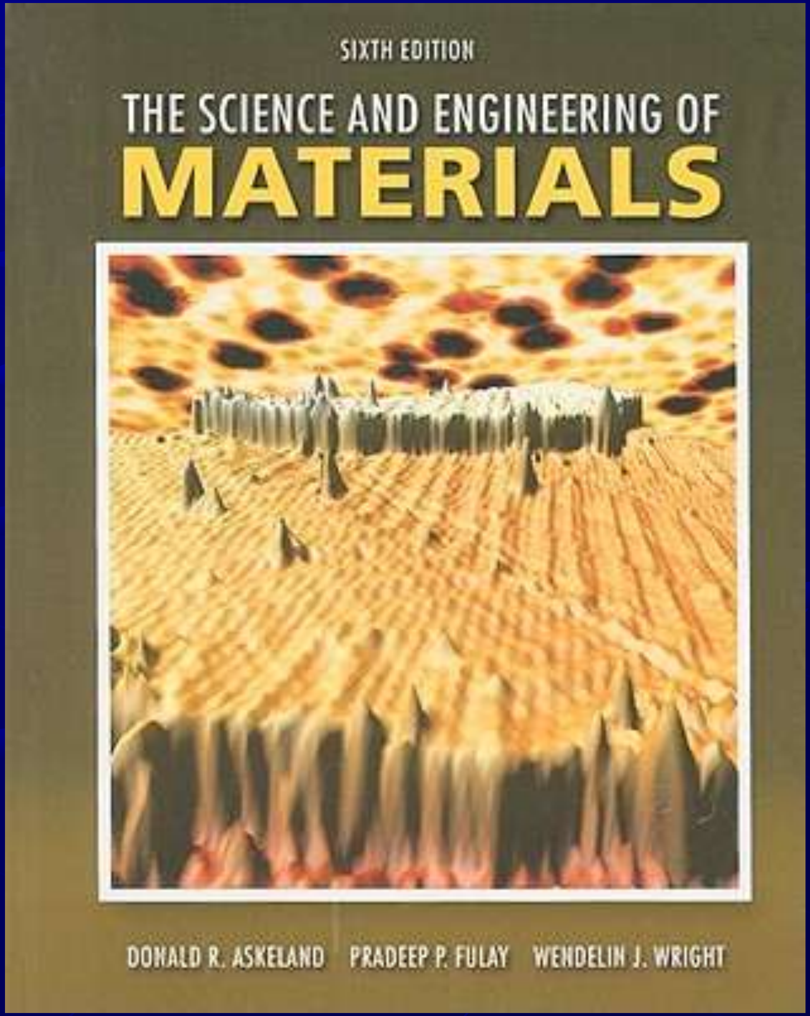
Course Materials

- Donald R. Askeland, Pradeep P. Fulay,
- Wendelin J. Wright
  The Science & Engineering of Materials
  SI Edition ©2011



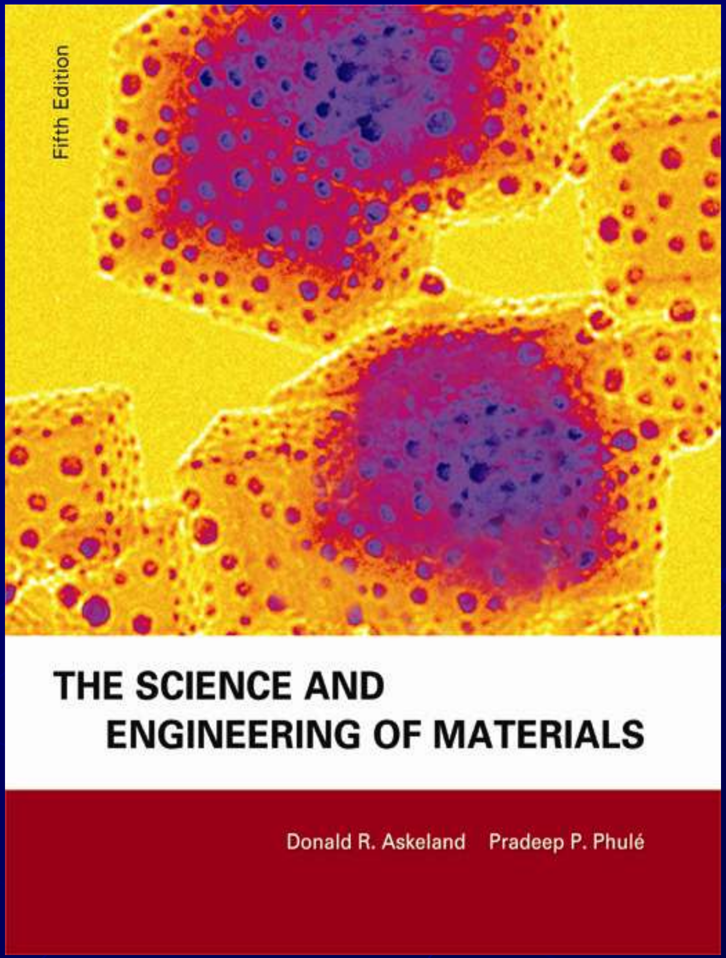
Course Materials

- Donald R. Askeland, Pradeep P. Fulay,
- Wendelin J. Wright
  The Science & Engineering of Materials
  6th Edition © 2010
  ISBN: 0534553966
  ISBN13: 9780534553968



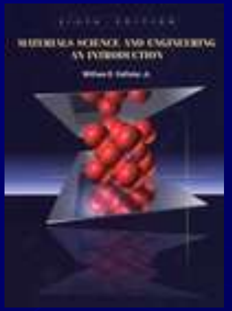
Course Materials

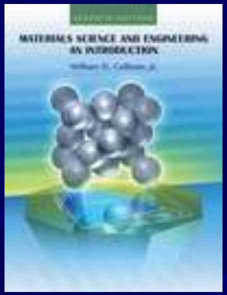
- Donald R. Askeland, Pradeep P. Fulay
  The Science & Engineering of Materials
  5th Edition ©2006
  ISBN: 0534553966
  ISBN13: 9780534553968

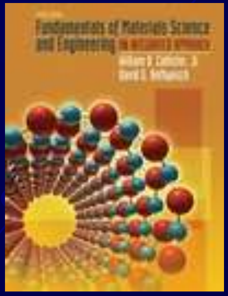


Optional Course Materials

- William D. Callister, Jr. Materials Science and Engineering: An Introduction, 6th Edition, Wiley
- William D. Callister, Jr. Materials Science and Engineering: An Introduction, 7th Edition, Wiley
- W. Callister, D. Rethwisch, Fundamentals of Materials Science and Engineering: An Integrated Approach, 3rd Edition , Wiley, 2008
  ISBN 978-0-470-12537-3







Course Website

- http://yunus.hacettepe.edu.tr/~selis/teaching.html
  - Syllabus
  - Lecture notes (some of them)
  - Homework questions
  - Answer keys
  - Grades
  - Announcements

Grading

My goal is that you to learn the material and make a high grade in the course!

- Homeworks 10%
- Midterm I 30%
- Weekly in-lecture quizzes 20%
  - Based on class content or core homework problems
- Project/Class presentation 10%
- Written final exam 30%

Grading

- Under certain conditions, the grade for the midterm test may be raised by reworking the test out of class and turning it in within one week after the exam
- Final test grade will then be 65% in-class and 35% at-home. Bonus points may be added to the at-home grade for creativity in presentation

Request for Fix-it

- Any thoughtful suggestions and requests are welcome
- Do not suffer in silence and wait to go home or the weekend to learn the stuff: if something you thought you understood becomes unclear, or after half an hour of lecturing the instructor is still making no sense whatsoever, raise your hand and ask a question. You can always come to my office to ask questions or share your opinions

Grading

Late Submission of Work

- Problem sets are due exactly one week after the date they are posted on the course web site
- Extensions cost 10% of your grade for each 24 hour beyond the deadline, up to a maximum of 30%
- Medical and beyond-your-control problems will be dealt with individually
- Plant trips and other scheduled activities are not beyond your control--allocate your time to accomplish all your obligations

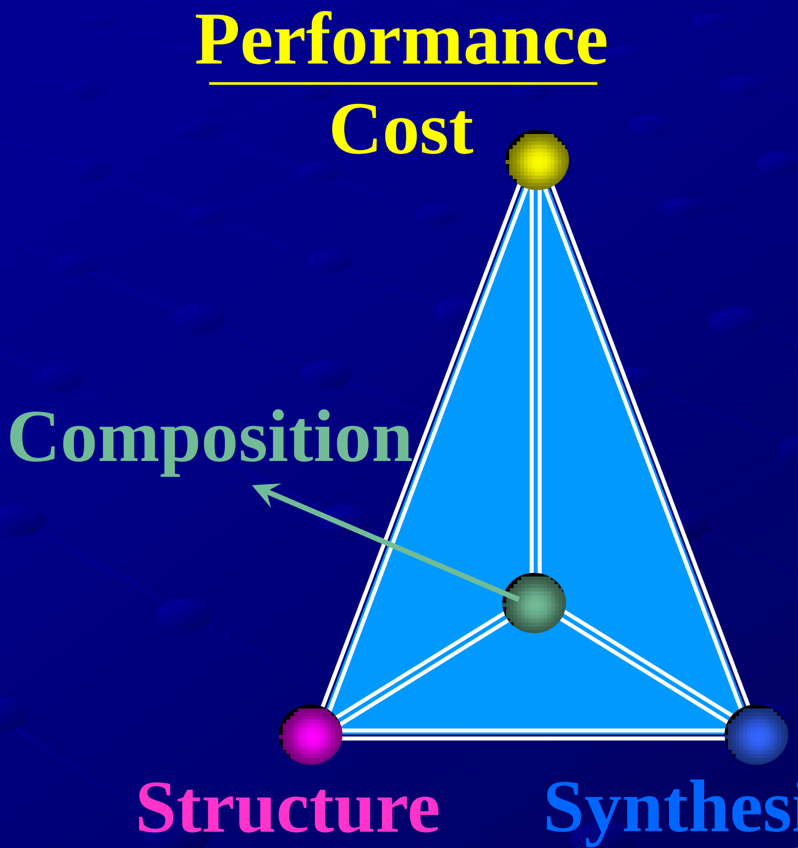
Chapter 1 - Introduction

- What is materials science and engineering
- Why should we know about it

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

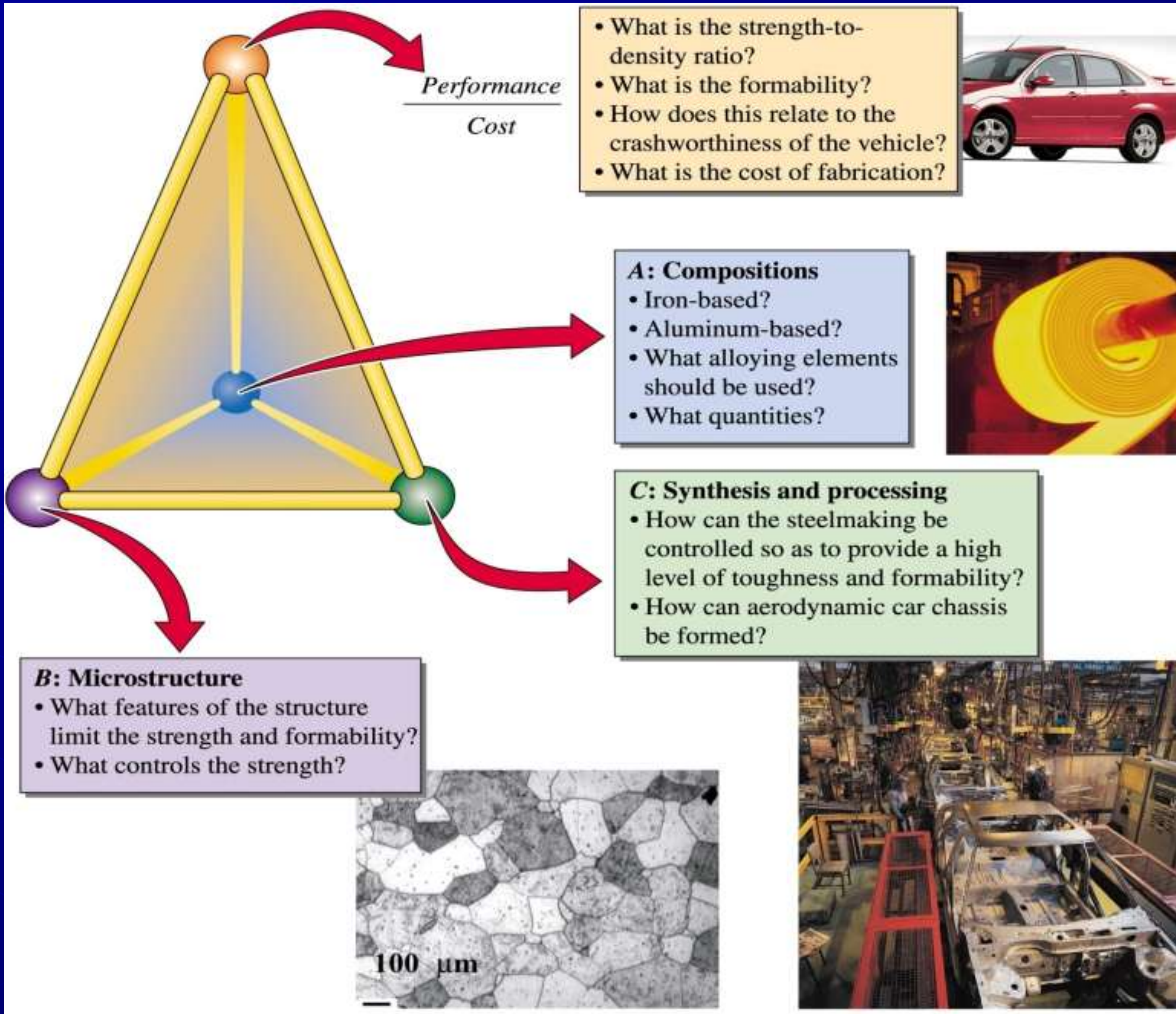
Tetrahedron of Materials Science and Engineering

Properties ←Microstructure ←Processing



- *Material properties depend on the material micro/nano structure, which in turn, results from its composition and processing*

Sheet steels for automotive chassis



D. Askeland and P. Phule, The Science and Engineering of Materials, 5th Ed., Thomson Learning, London, 2006, pg.5

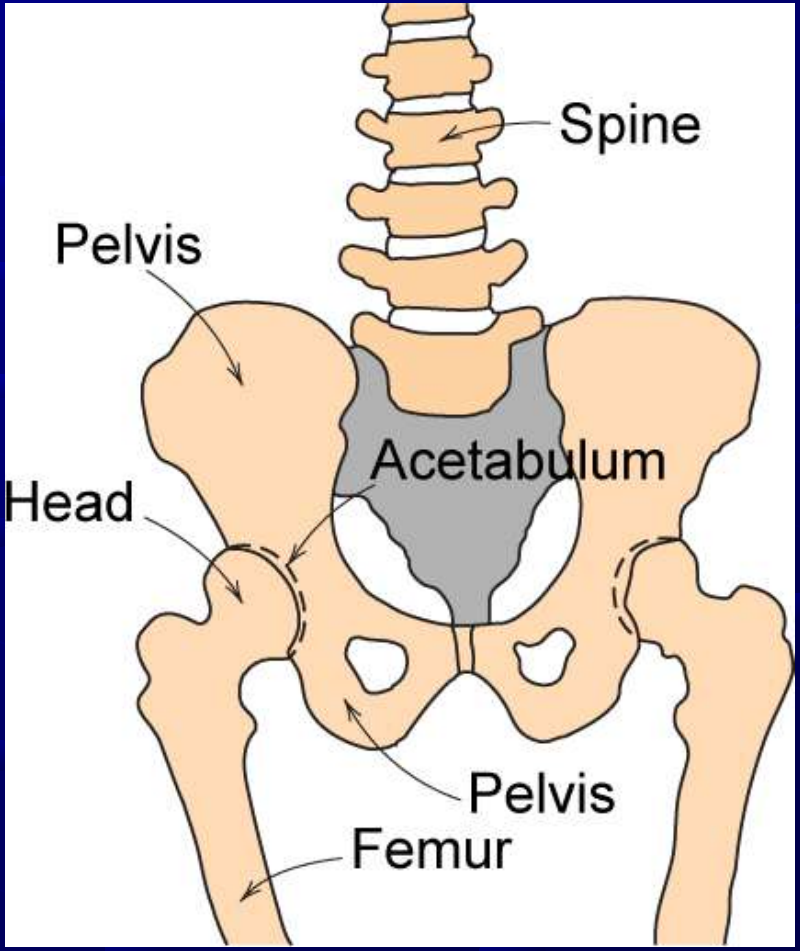
Example – Hip Implant

- **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

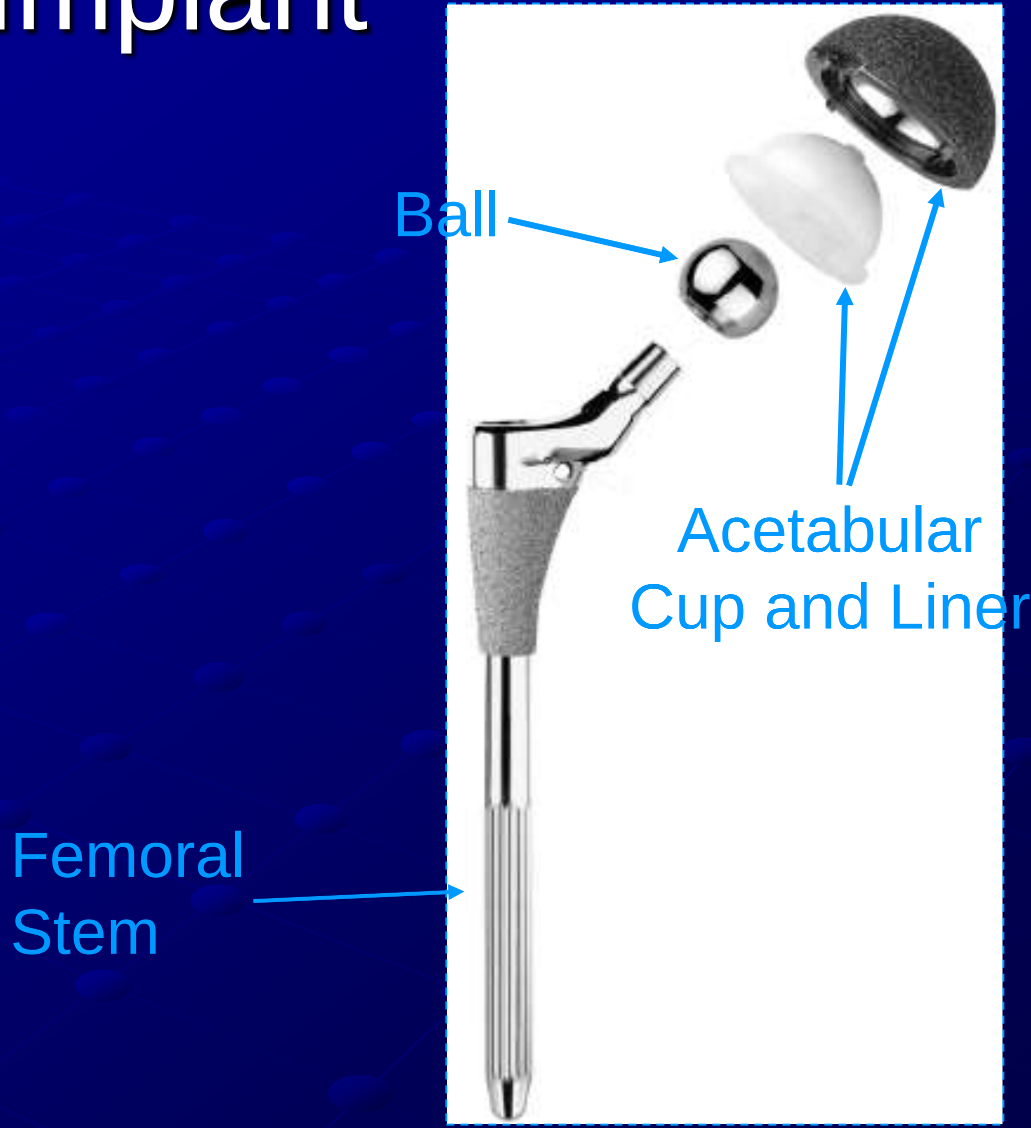
- **Requirements**
  - **mechanical strength (many cycles)**
  - **good lubricity**
  - **biocompatibility**



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

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**

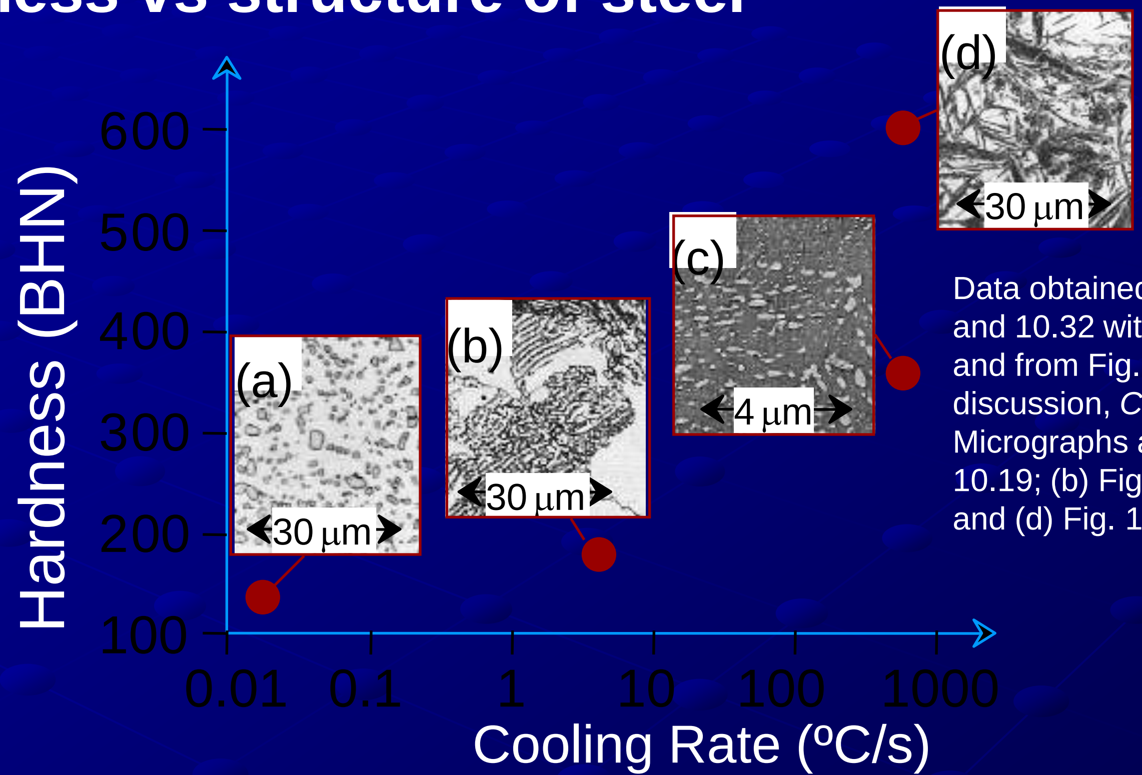


Adapted from chapter-opening photograph, Chapter 22, *Callister 7e.*

Structure, Processing, Properties

- **Properties depend on structure**

ex: hardness vs structure of steel

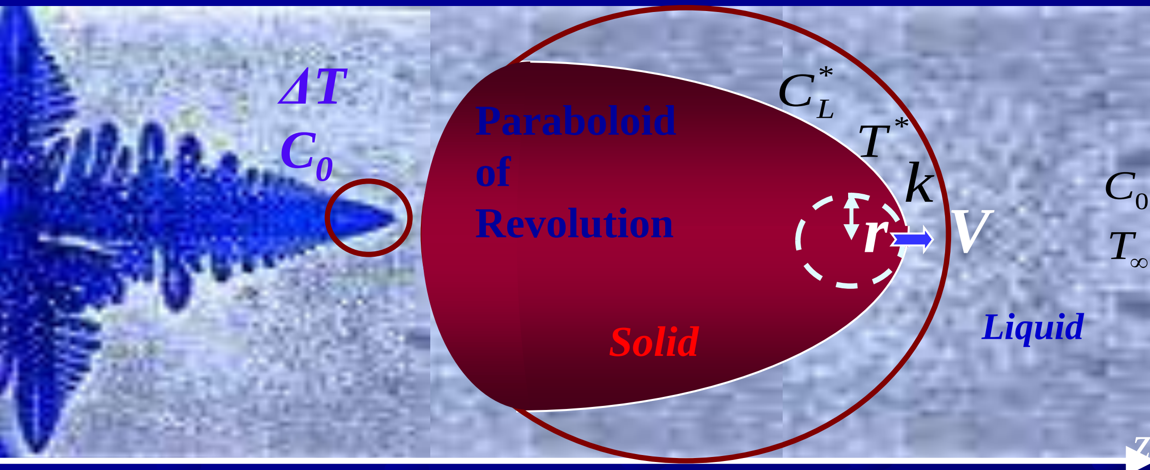


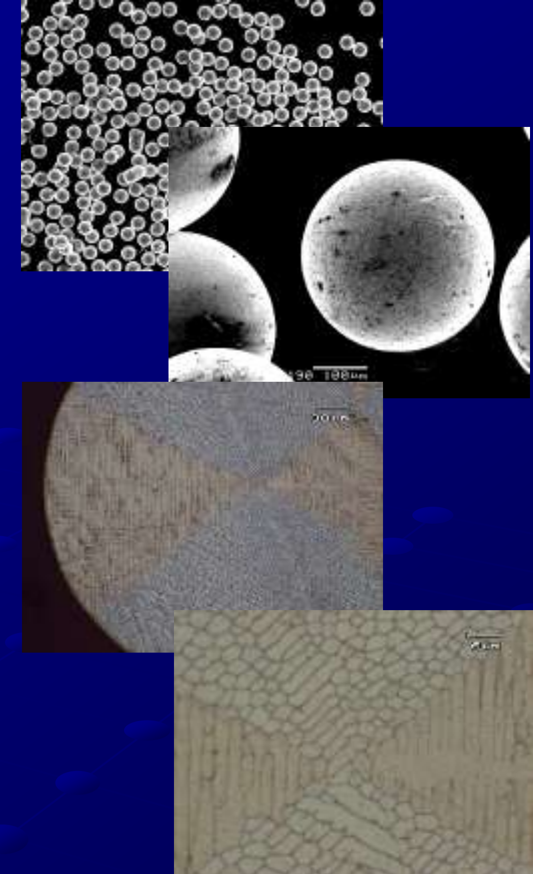
Data obtained from Figs. 10.30(a) and 10.32 with 4 wt% C composition, and from Fig. 11.14 and associated discussion, *Callister 7e*. Micrographs adapted from (a) Fig. 10.19; (b) Fig. 9.30;(c) Fig. 10.33; and (d) Fig. 10.21, *Callister 7e*.

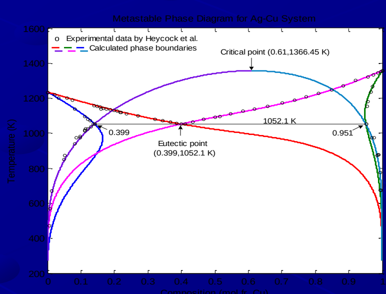
- **Processing can change structure**

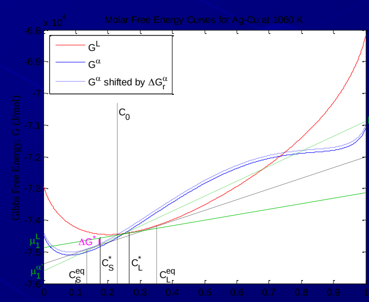
ex: structure vs cooling rate of steel

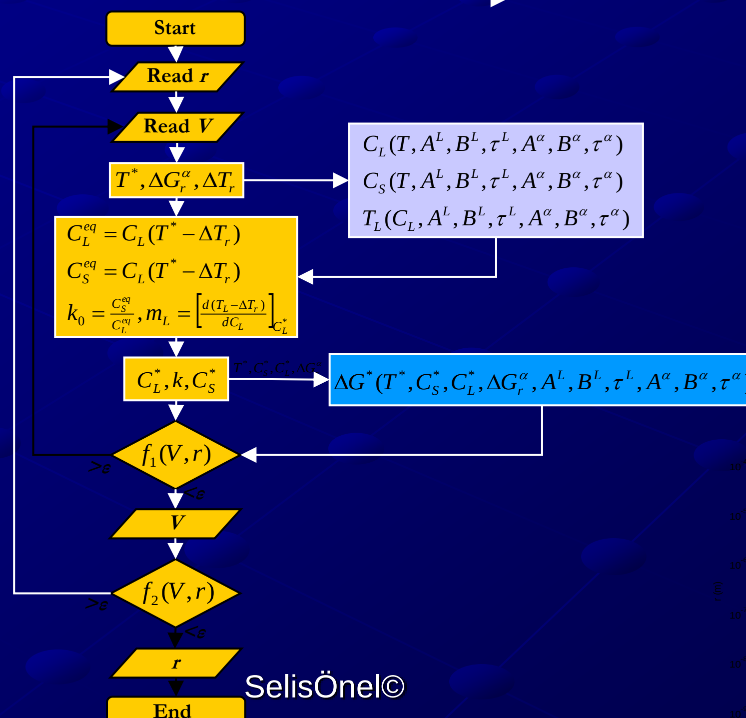
Mathematical Modeling of Crystal Growth

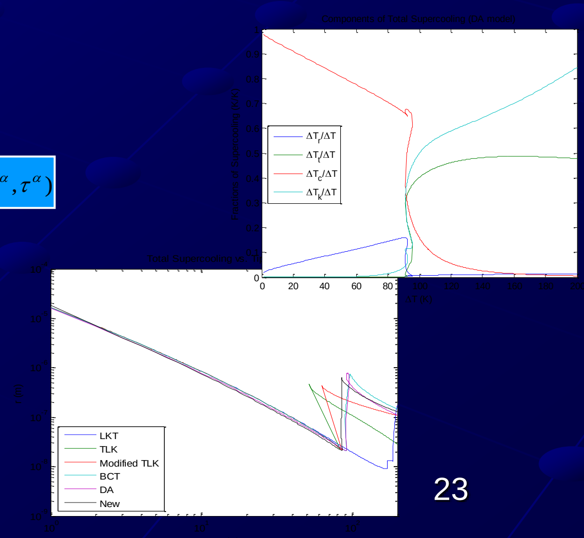








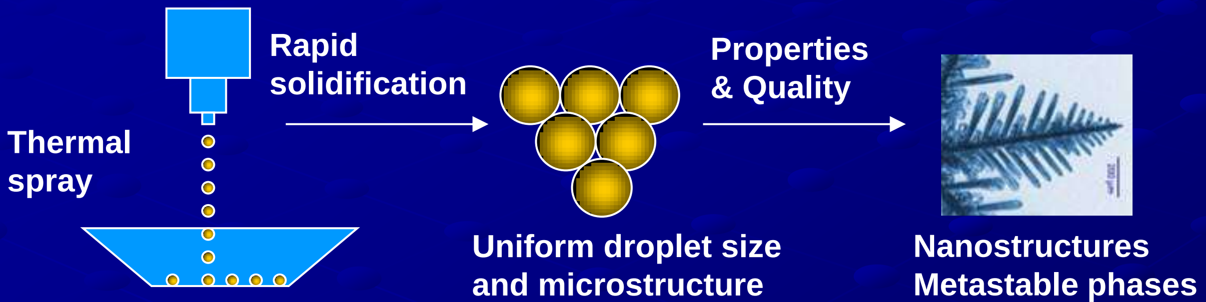




Rapid Solidification Problems

Advanced materials: a**utomotive, aerospace, semiconductor, electronic** industries

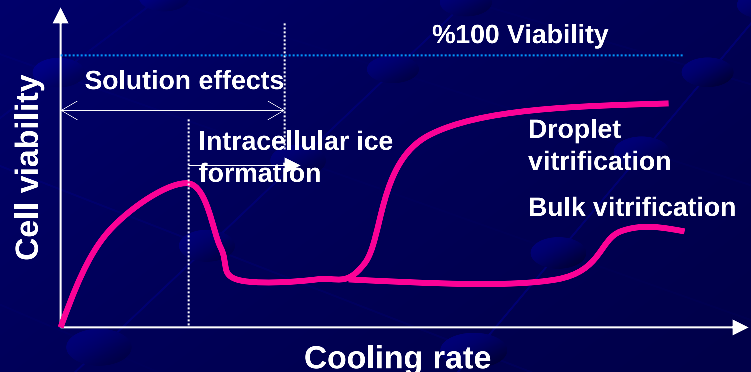
Purpose → Controlling the nano-structures of advanced materials that form during rapid solidification



Improves mechanical, chemical, thermal, electrical, magnetic, optical properties

Biomedicine: **"Cryobiology"!**

Purpose → Reducing the amount of poisonous cryoprotectants and formation of ice crystals detrimental to cells during the freezing/vitrification of cells for cryopreservation



Categories of Materials

Metals & Alloys

Ceramics & Glasses

Polymers

Semiconductors

Composites

Categories of Materials

	Category	Applications	Properties
Metals & Alloys	Alloy steels	Automobile chassis	Strengthened by heat treatment
Ceramics & Glasses	Silica	Optical fibers for transfer of information	Refractive index, low optical losses
Polymers	Epoxy	Encapsulation of integrated circuits	Electrically insulating and moisture resistant
Semiconductors	Silicon	Transistors and integrated circuits	Unique electrical behavior
Composites	Titanium-clad steel	Reactor vessels	Corrosion resistant (due to titanium) low cost and high strength (due to steel)

Categories of Materials

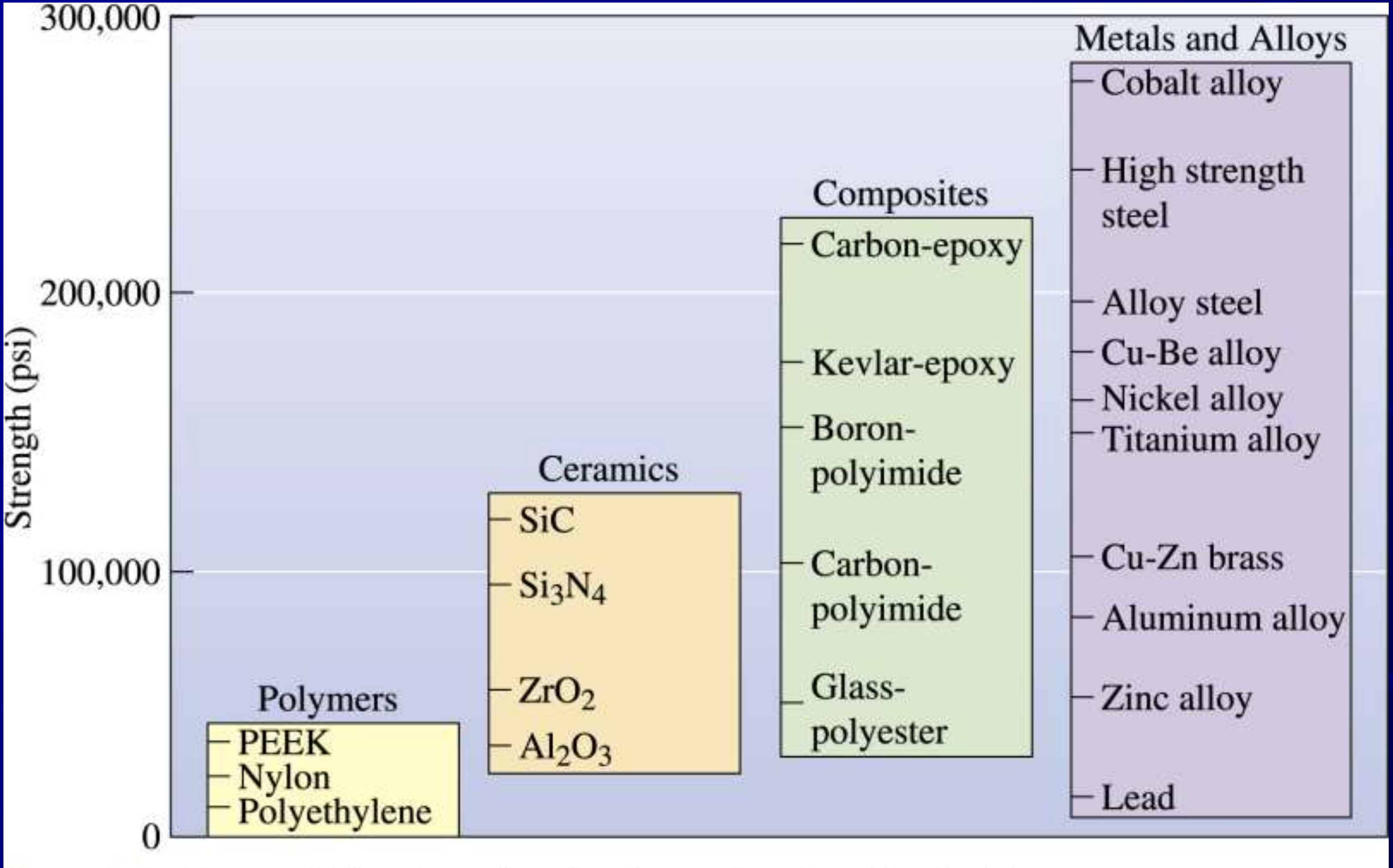


Figure 1-3 Representative strengths of various categories of materials.

D. Askeland and P. Phule, The Science and Engineering of Materials, 5th Ed., Thomson Learning, London, 2006, pg.9

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)

Polymers

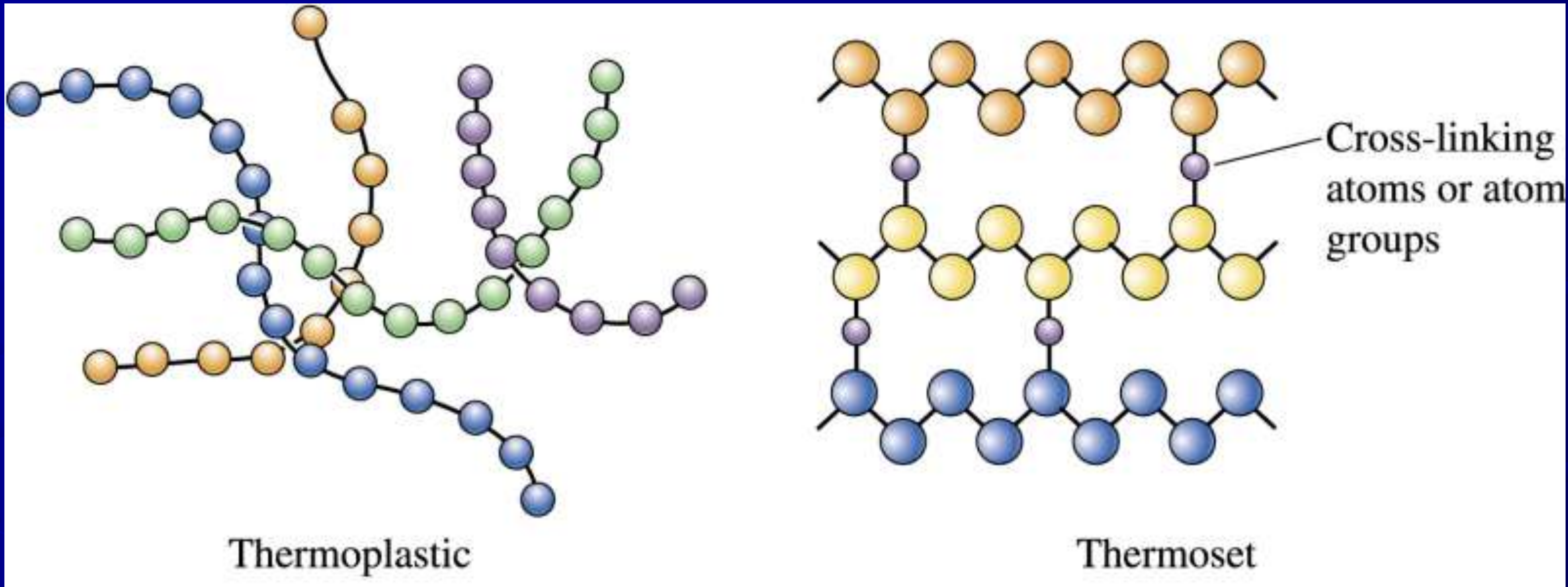


Figure 1-4 Polymerization occurs when small molecules, represented by the circles, combine to produce larger molecules, or polymers. The polymer molecules can have a structure that consists of many chains that are entangled but not connected (thermoplastics) or can form three-dimensional networks in which chains are cross-linked (thermosets).

Molecular chains are not rigidly connected: Good ductility and formability (made by shaping their molten form)

Molecular chains are tightly linked: Stronger but more brittle (made by casting into molds)

D. Askeland and P. Phule, The Science and Engineering of Materials, 5th Ed., Thomson Learning, London, 2006, pg.10

Functional Classification of Materials

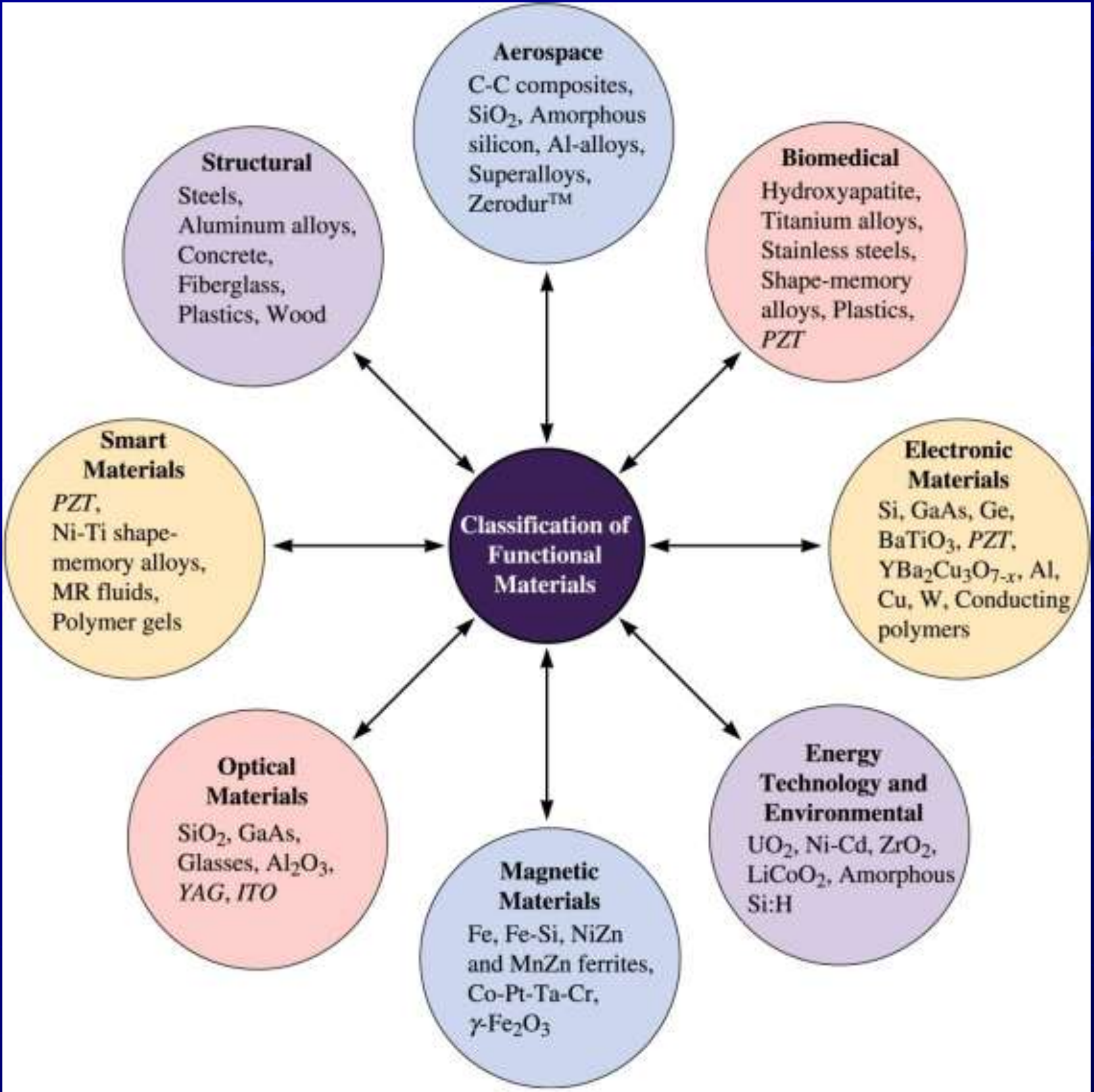


Figure 1-6 Functional classification of materials. Notice that metals, plastics, and ceramics occur in different categories. A limited number of examples in each category are provided.

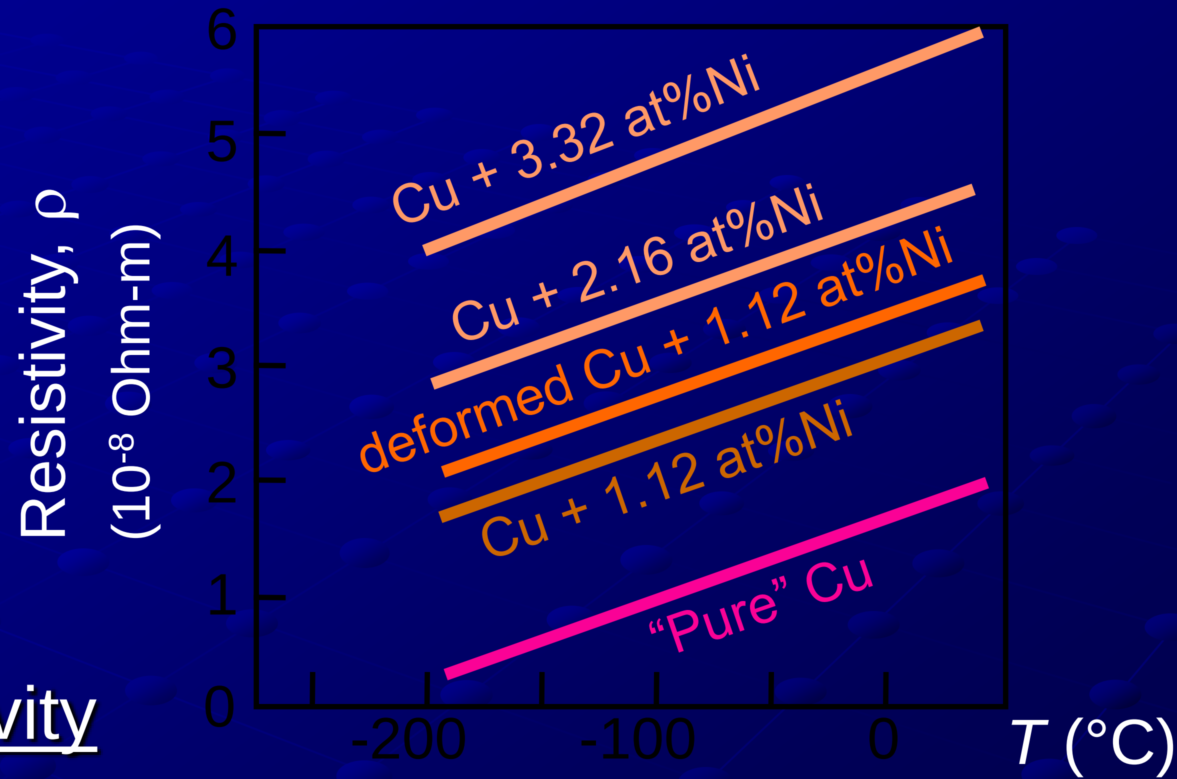
D. Askeland and P. Phule, The Science and Engineering of Materials, 5th Ed., Thomson Learning, London, 2006, pg.12

The Materials Selection Process

1. Pick Application → Determine required properties
   - Properties: Mechanical, electrical, thermal, magnetic, optical, deteriorative
2. Properties → Identify candidate materials
   - Material: Structure, composition
3. Material → Identify required processing
   - Processing: Changes in structure and overall *shape*
   - Ex: Casting, sintering, vapor deposition, doping, forming, joining, annealing

Electrical Poperty

- Electrical Resistivity of Copper
  - Adding impurity atoms to Cu increases <u>resistivity</u>
  - Deforming Cu increases resistivity

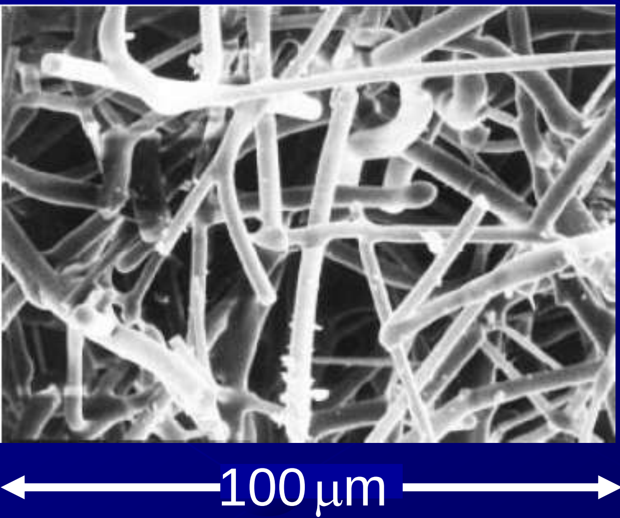


Adapted from Fig. 18.8, *Callister 7e.* (Fig. 18.8 adapted from: J.O. Linde, *Ann Physik* **5**, 219 (1932); and C.A. Wert and R.M. Thomson, *Physics of Solids*, 2nd edition, McGraw-Hill Company, New York, 1970.)

Thermal Properties

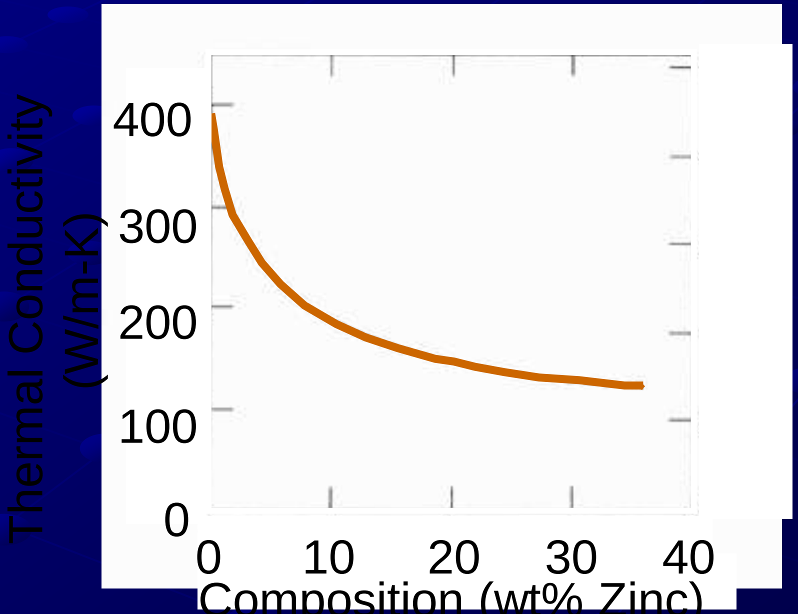
- Space shuttle tiles:
  - Silica fiber insulation offers low heat conduction

Adapted from chapter-opening photograph, Chapter 19, *Callister 7e.* (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 Cu decreases when you add Zn



Adapted from Fig. 19.4, *Callister 7e.* (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 Properties

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

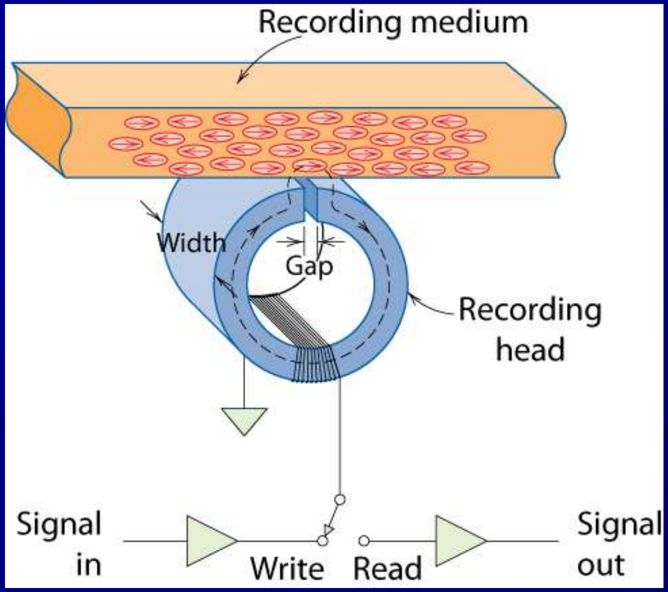
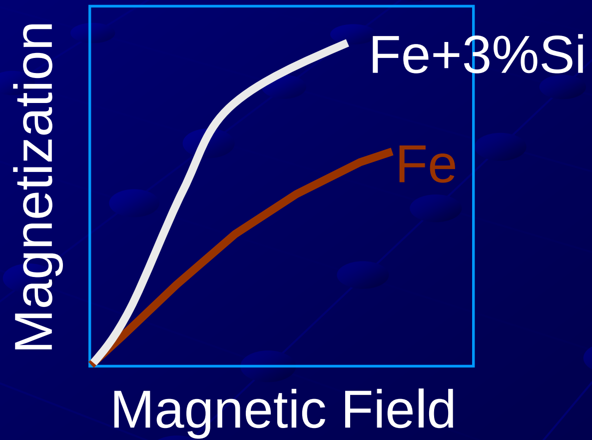


Fig. 20.23, *Callister 7e.*
(Fig. 20.23 is from J.U. Lemke, *MRS Bulletin*, Vol. XV, No. 3, p. 31, 1990.)

- 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.

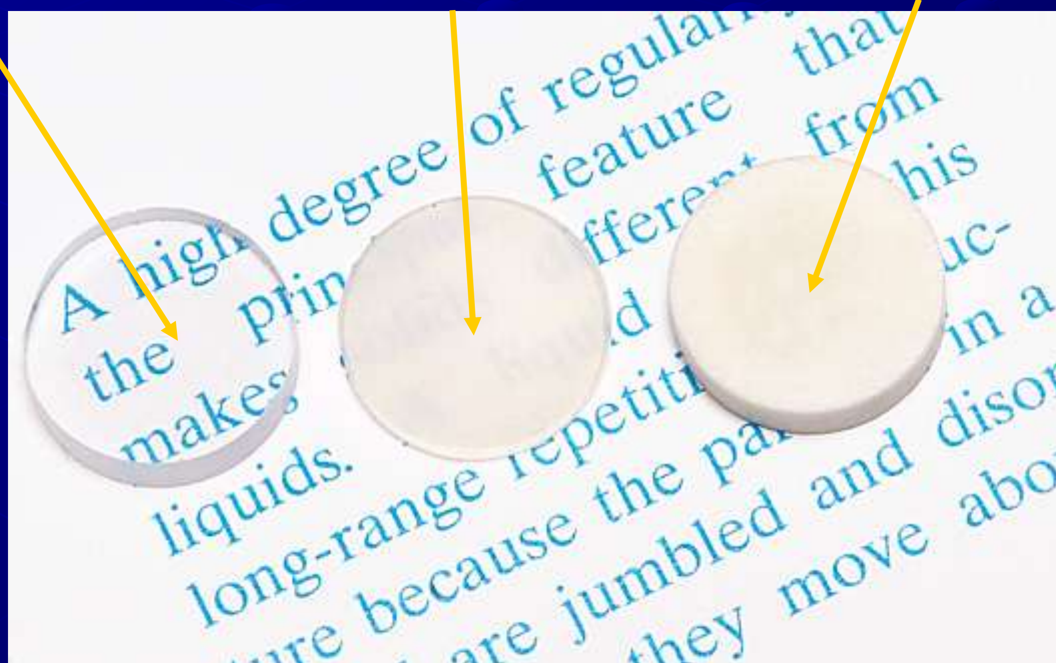
Optical Properties

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

single crystal

polycrystal:
low porosity

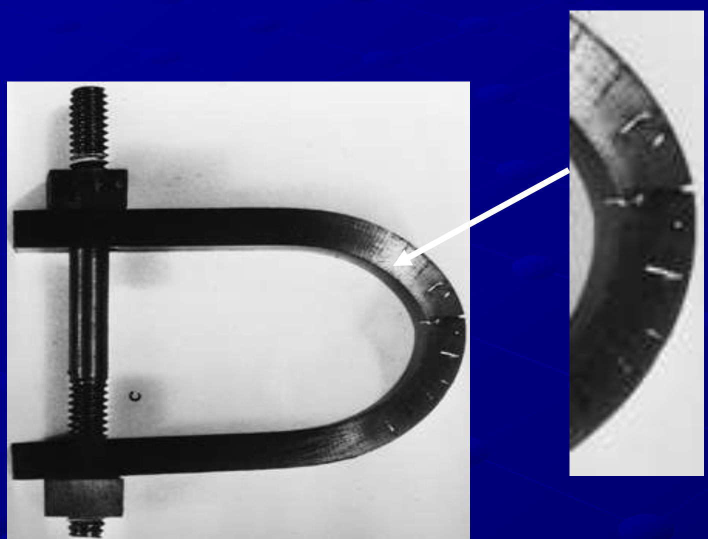
polycrystal:
high porosity



Adapted from Fig. 1.2, *Callister 7e.* (Specimen preparation, P.A. Lessing; photo by S. Tanner.)

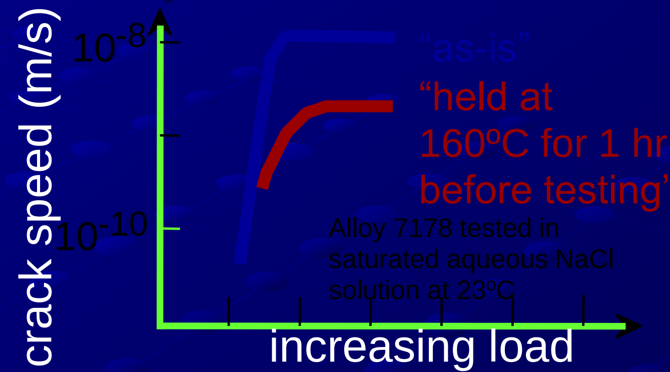
Deteriorative Properties

- Stress and Saltwater
  - Causes cracks



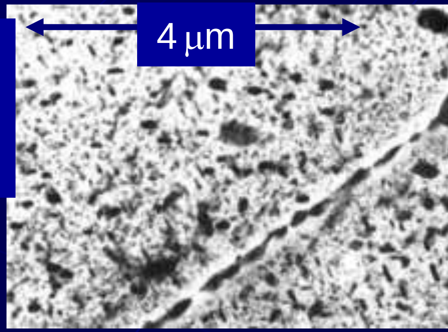
Adapted from chapter-opening photograph, Chapter 17, *Callister 7e.*
(from *Marine Corrosion, Causes, and Prevention*, John Wiley and Sons, Inc., 1975.)

- 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 7e.* (Fig. 11.26 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

Questions

- Why is the structure, compositon, synthesis and processing so important?
- List at least two examples for each of mechanical, electrical, and thermal properties.

HOMEWORK

Problems 1.7,1.12, 1.16, 1.20