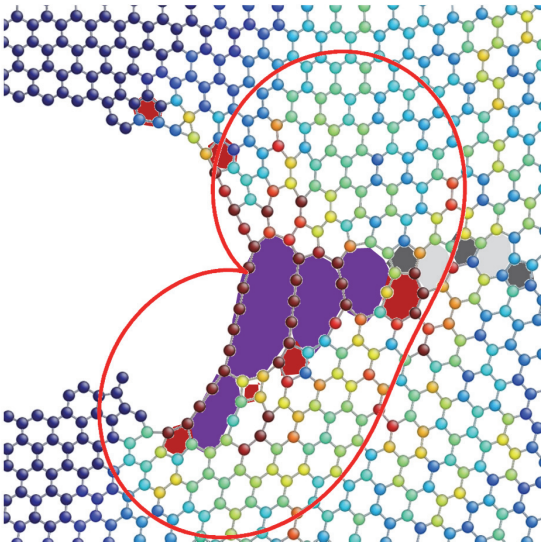
Spring, 2017

Materials Science and Engineering



March 02, 2017

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Materials Science and Engineering

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  - Office Hour: Tuesday 16:00~18:00

- **Textbook:**
  - W. D. Callister, Jr. & D. G. Rethwisch, Materials Science and Engineering, 9th Ed., SI Version, Wiley, 2015.

- **Evaluation** (Relative Evaluation; A이상(50%미만), B이상(90%미만))
  1. Attendance: 5 %
  2. Homework (Quiz): 15 %
  3. Mid-Term Exam: 40 %
  4. Final Exam: 40 %

Chapter 1. Introduction

- **What is materials science?**
  - *Materials science* investigates the relationships between the structures and properties of materials.
  - *Materials engineering* involves, on the basis of these structure-property correlations, designing or engineering the structure of a material to produce a predetermined set of properties.

- **Why should we know about it?**

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

Example: Titanic on April 15, 1912

Processing, Structure, Properties, & Performance

- **Four Components for Design, Production, and Utilization of Materials**

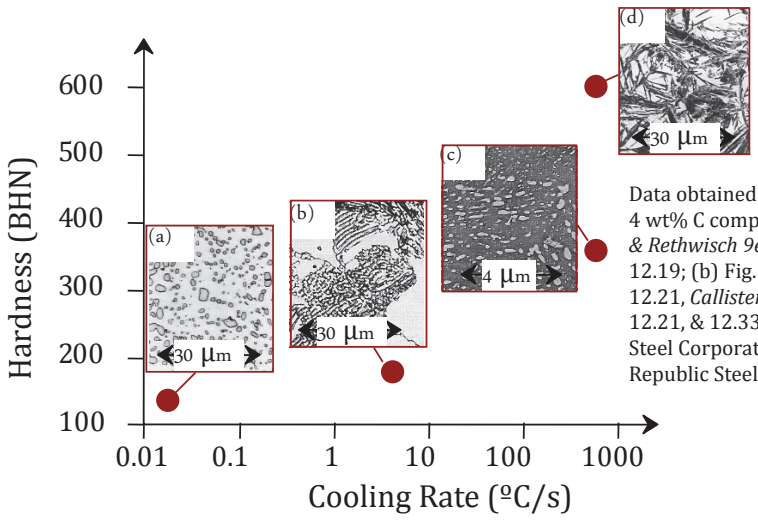
Fig. 1.1 The four components of the discipline of materials science and engineering, and their interrelationship.

- **Structure**
  - The structure of a material usually relates to the arrangement of its internal components.
  - Multiscale structures: subatomic structure (electrons), organization of atoms or molecules (crystal structures), microscopic structure (grains), macroscopic structure.
- **Property**
  - A material trait in terms of the kind and magnitude of response to a specific imposed stimulus.
  - Generally, definitions of properties are made independent of material shape and size.
  - Six different categories of material properties: mechanical, electrical, thermal, magnetic, optical, and deteriorative.

Processing, Structure, Properties, & Performance

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

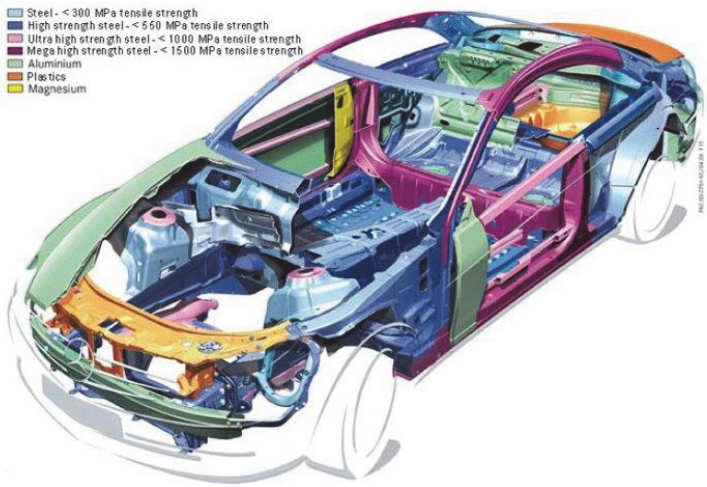
- **Properties depend on structure**
  - Ex: hardness vs. structure of steel



Data obtained from Figs. 12.31(a) and 12.32 with 4 wt% C composition, and from Fig. 17.8, *Callister & Rethwisch 9e.* Micrographs adapted from (a) Fig. 12.19; (b) Fig. 11.29; (c) Fig. 12.33; and (d) Fig. 12.21, *Callister & Rethwisch 9e.* (Figures 12.19, 12.21, & 12.33 copyright 1971 by United States Steel Corporation. Figure 9.30 courtesy of Republic Steel Corporation.)

Example: Ultra High Strength Steel

- Ultra High Strength Steel (UHSS) hot stamping technology is a special process which can enhance the steel tensile strength to 1500MPa. Appling this technology in producing vehicle structure parts can make car lighter and safer.



The skeleton of the Mercedes CL

Source: http://carskeleton.blogspot.kr/2012_06_01_archive.html

Example of hot-stamped parts

- Carrier Understructure
- Mounting plate: Front wall
- Tunnel
- Front bumper
- Rear bumper
- Side member reinforcement
- A-Pillar reinforcement
- Rocker Panel reinforcement
- B-Pillar reinforcement
- Beltline reinforcement
- Roof rail reinforcement
- Door beam

The Materials Selection Process

- **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.)

- **Three criteria important in the materials selection process**
  - In-service conditions: required properties of the material
  - Any deterioration of material properties
  - Cost

Classification of Materials: Metals

- **Based on chemical makeup and atomic structure, solid materials can be grouped into three basic categories: metals, ceramics, and polymers.**

- **Metals:**
  - Metals are composed of one or more metallic elements (e.g., Fe, Al, Cu, Ti, Au, etc.), and often also nonmetallic elements (e.g., C, N, O, etc.) in relatively small amounts.
  - Highly-ordered in atomic scale and relatively dense in comparison to the ceramics and polymers
  - Stiff and strong
  - Ductile: capable of large amounts of deformation without fracture
  - Metallic bonding: metallic materials have large numbers of nonlocalized electrons.
    - High thermal & electrical conductivity
    - Opaque, reflective.

Classification of Materials: Ceramics & Polymers

- **Ceramics**
  - Ceramics are compounds between metallic and nonmetallic elements; they are most frequently oxides (e.g., Al_2O_3, SiO_2), nitrides (e.g., Si_3N_4), and carbides (e.g., SiC).
  - Ionic bonding (refractory)
  - Relatively stiff and strong
  - Brittle, glassy, elastic
  - Non-conducting (insulators)

- **Polymers**
  - Covalent bonding → sharing of electrons
  - Polymers have very large molecular structures, often chainlike in nature, that usually have a backbone of carbon atoms
  - Soft, ductile, low strength, low density
  - Thermal & electrical insulators
  - Optically translucent or transparent.

Typical Material Properties

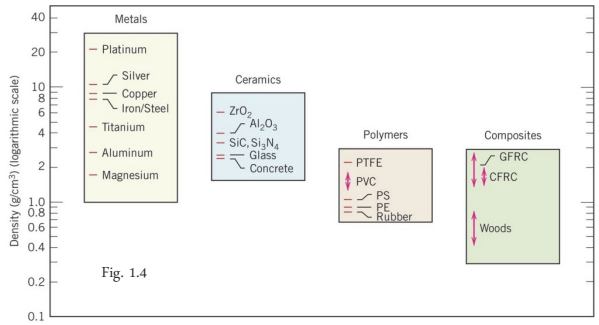


Fig. 1.4

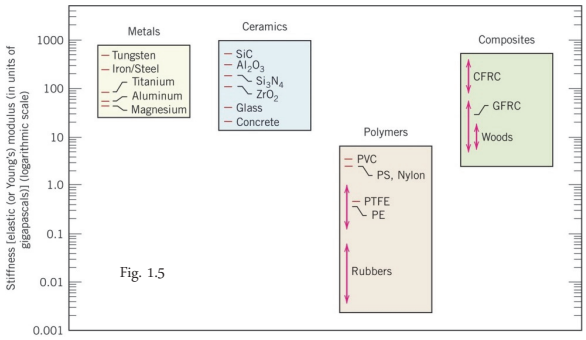


Fig. 1.5

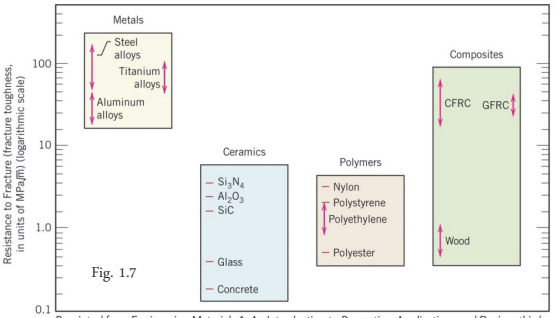


Fig. 1.7

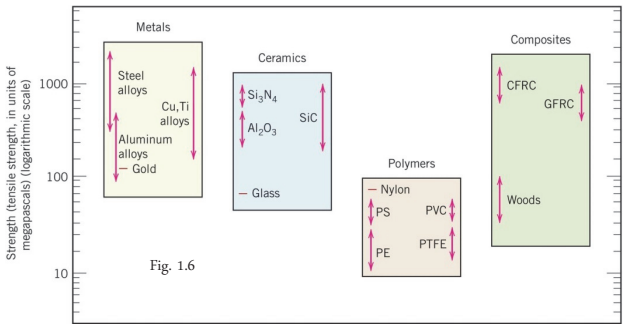


Fig. 1.6

Advanced Materials & Modern Materials' Needs

- **Advanced Materials**
  - ***Semiconductors*** have made possible the advent of integrated circuitry that has totally revolutionized the electronics and computer industries (not to mention our lives) over the past three decades.
  - ***Biomaterials*** are employed in components implanted into the human body to replace diseased or damaged body parts.
  - ***Smart (or intelligent) materials*** are able to sense changes in their environment and then respond to these changes in predetermined manners-traits that are also found in living organisms.
  - ***Nanomaterials*** may be any one of the four basic types-metals, ceramics, polymers, or composites. However, unlike these other materials, some of the physical and chemical characteristics of nanomaterials may experience dramatic changes as particle size approaches atomic dimensions.

- **Modern Materials' Needs**
  - Green technology (environmental issues)
  - Renewable energy