CHAPTER 1 INTRODUCTION

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What is Material ?

- Basic substance that have mass and occupy space
- It can be natural or human made
- There are now about 300,000 different known materials

What is Materials Science?

- Materials science involve investigating the relationships that exist between the structure and properties of materials

What is Materials Engineering?

- Materials engineering involve, *on the basis of these structure property correlation*, design/engineer the structure of a material to produce a predetermined set of properties

Who is Materials Scientist?

- To develop/synthesize new materials

Who is Materials Engineer?

- To create new product/systems using existing materials
- To develop new techniques for processing materials

STRUCTURE, PROCESSING, & PROPERTIES

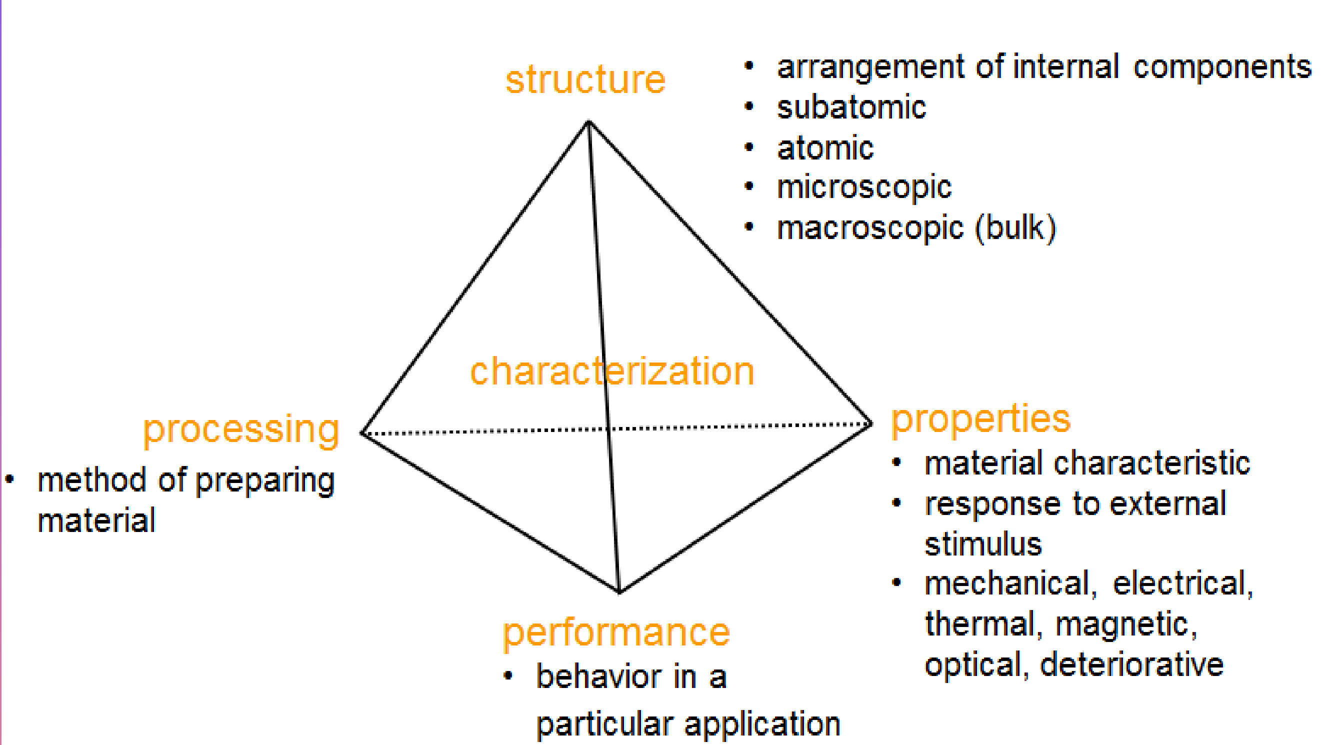
Four components that involve in the design, production and utilization of materials?

1. Structure
   → **?**
2. Property
   → **?**
   Classification: mechanical, electrical, thermal, magnetic, optical and deteriorative/chemical.
3. Processing
   → **?**
4. Performance
   → **?**

The relationship between the four components:

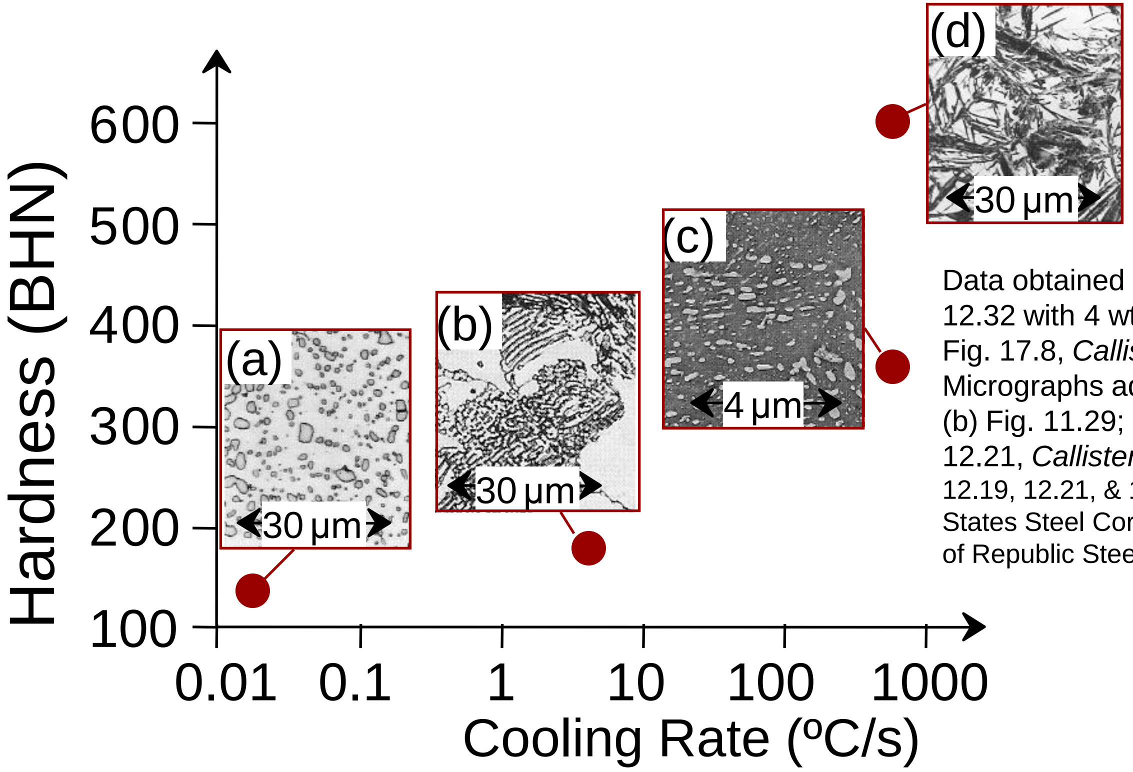
Processing → Structure → Properties → Performance

STRUCTURE, PROCESSING, & PROPERTIES



Structure, Processing, & Properties

- 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.)

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

CLASSIFICATION OF MATERIALS

1. Metals

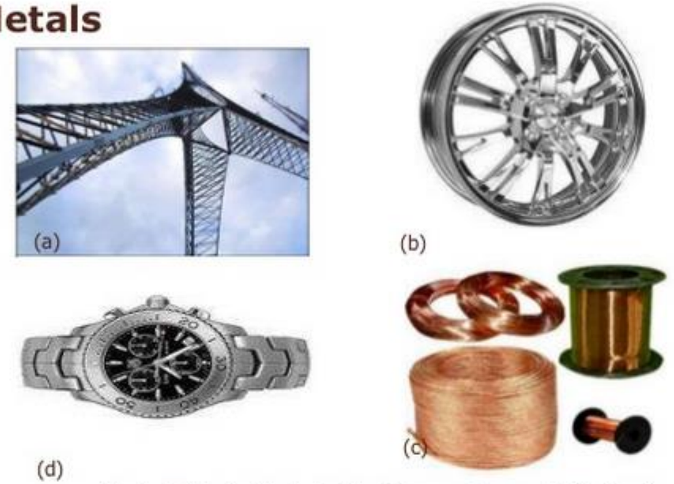


Fig.2. Metals (a. Steel; b. Aluminium; c. Copper; d. Titanium)

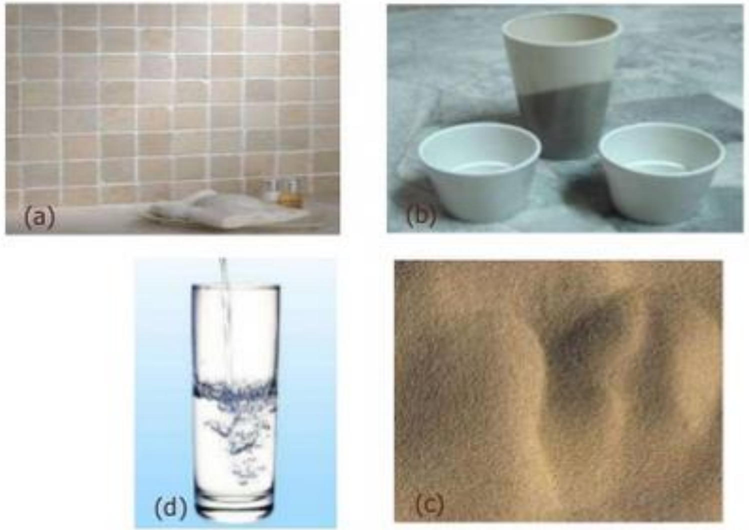


Fig.2. Ceramics (a. tile; b. pottery; c. sand; d. glass)

1. Metals

- Most Utilized Engineering Materials
- Properties that Satisfy a Wide Range of Engineering Design Requirements
- General Properties:
  - Strength & Stiffness ⇧
  - Toughness & Formability ⇧
  - Electrical & Thermal Conductivity ⇧
- Usually used in **Alloys** (mixed of 2 or more metals
- Examples: Steel, Aluminium, magnesium, zinc, cast iron, titanium, copper, nickel, etc.

2. Ceramics

- A Compound containing metallic & non-metallic elements formed by the action of heat
- General Properties:
  - Hard & Brittle
  - Compressive Strength ⇧ tensile strength
  - Resistance to chemical action and weathering
  - Thermal Insulator ⇧ (Thermal Conductivity ⬇)
- Examples: sand, brick, glass, graphite, tile, pottery, etc.

CLASSIFICATION OF MATERIALS

Fig.4. Polymers (a. polyethylene; b. PVC; c. rubber; d. melamine)

4. Composites

Fig.4. Polymers (a. carbon fibres; b. fiberglass; c. wood; d. textile)

3. Polymers

- Organic Compounds, formed by repeating structural unit (Mers), where the atoms share electron to form very large molecules

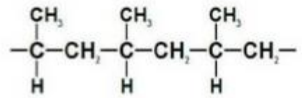


Fig.3. Picture of Polymers Structure (e.g.Polypropylene)

- General Properties:
  - Light Weight
  - Low Thermal & Electrical Conductivity
  - Moderate Resistance on Inorganic Acids, Bases & Salts
- Examples: PVC, polyethylene, polypropylene, rubber, nylon, Teflon,

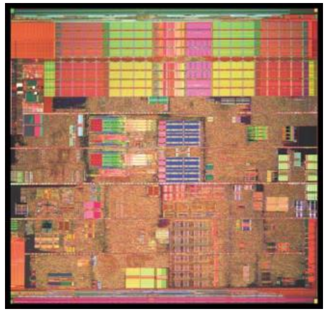
4. Composites

- Combination of Two or More Different Materials
- Combination of the Best Characteristics of Each Components Materials
- Better properties than any individuals component
- Examples: fiberglass, textiles, vehicle tires, wood papers, etc

Advanced Materials

➔ Materials utilized in high-tech applications

1. Semiconductor
   → ?
   - electrical properties between conductors and insulators
   - electrical properties can be precisely controlled



Intel Pentium 4

2. Biomaterials
   → ?
   - implanted in human body
   - compatible with body tissues

3. Smart Materials
   Components of a smart material/system:
   a. Sensor
   b. Actuators

   Type of materials used for actuators:
   - Shape memory alloys
   - Piezoelectric ceramics
   - Magnetostrictive materials
   - Electrorheological/magnetorheological fluids

4. Nanomaterials
   → ? (*top-down science, bottom-up approach, nanotechnology*)

	Applications	Properties
Metals		
Copper	Electrical conductor wire	High electrical conductivity, good formability
Gray cast iron	Automobile engine blocks	Castable, machinable, vibration-damping
Alloy steels	Wrenches	Significantly strengthened by heat treatment
Ceramics		
SiO_2-Na_2O-CaO	Window glass	Optically useful, thermal insulating
Al_2O_3, MgO, SiO_2	Refractories for containing molten metal	Thermal insulating, melt at high temperature, relatively inert to molten metal
Barium titanate	Transducers for audio equipment	Converts sound to electricity (Piezoelectric behavior)
Polymers		
Polyethylene	Food packaging	Easily formed into thin, flexible, airtight film
Epoxy	Encapsulation of integrated circuits	Electrically insulating and moisture-resistant
Phenolics	Adhesives for joining plies in plywood	Strong, moisture resistant
Semiconductors		
Silicon	Transistors and integrated circuits	Unique electrical behavior
GaAs	Fiber-optic systems	Converts electrical signals to light
Composites		
Graphite-epoxy	Aircraft components	High strength-to-weight ratio
Tungsten carbide-cobalt	Carbide cutting tools for machining	High hardness, yet good shock resistance
Titanium-clad steel	Reactor vessels	Has the low cost and high strength of steel, with the corrosion resistance of titanium

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.

Factors to be considered in selecting a materials for a given application:

- Must have desired physical & mechanical properties
- Can be processed/manufactured into desired shape
- Provide economic solution to design problem (relatively cheap)
- Environmental friendly

Design specification:

- Provides in depth detail information about the requirement for a product
- This including assumptions, constraints, performance, dimensions, weight & reliability

Choosing the right material:

- Relating the design specifications with material properties

Example of relating design specifications with material properties:

Design Specifications	Materials Properties
Must support load without breaking	Strength ↑
Can not be too expensive	Cost per weight (Cost/kg) ↓
Must Conduct Heat	Thermal Conductivity ↑

Case 1: Design/materials selection for a coffee cup

Design specifications for coffee cup:

- Avoid burning the user's hands
- Might be re-used
- Less danger to environment

Materials properties for coffee cup:

- Excellent thermal insulation (thermal conductivity ↓)
- Reusable
- Recyclable

Candidate Materials: **Ceramics & Polymers**

- Both appropriate due to their low thermal conductivity

However:

- Polymers cup (polyethylene) should not be re-used (become poisonous)
- Disposing polymers cause environmental damage → unrecyclable
- Ceramics can be reused and less danger to environment.

Proposed Material: **Ceramics**

Case 2: Design/materials selection for a soda drink container

Design specification for a soda drink container:

- provide a leak free environment for storing liquid
- protect the liquid from health hazards
- withstand internal pressurization and prevent escape of bubbles
- be easy to store and transport
- be cheap to produce for volumes of 10,000+

Materials Properties for a soda drink container:

- Relatively High Strength
- High Corrosion resistance
- Solid & Relatively High Strength
- Light (Low Weight-Density)
- Low Cost per Weight

Candidate Materials: **Light Metals & Polymers**

- Both own all the required materials properties
- Materials must be: Relatively high strength, low weight & high corrosion resistance, low cost in materials & manufacturing

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.