Chapter 1

Introduction to materials science and engineering

Have you ever wondered?

What are materials?

What do materials scientists and engineers study?

Outline of Chapter 1

1-1 ***Historical perspective of materials***

1-2 ***What is materials science and engineering?***

1-3 ***Classification of Materials?***

1-4 ***Why study MSE?***

Historical Perspective

Materials are probably more deep-seated in our culture than most of us realize.

Materials: **substances of which something is composed or made.**

Every segment of our everyday lives is influenced to one degree or another by materials.

Transportation

Building

Clothing

Communication

Recreation

Historical Perspective

Historical

The development and advancement of societies have been intimately tied to the members’ ability to produce and manipulate materials to fill their needs.

Early civilizations have been designated by the level of their materials development.

Materials form the milestones and physical basis of human civilization.

What is MSE?

- ***Materials science:*** **a scientific discipline which is primarily concerned with the research for basic knowledge about materials.**

  Strcuture, Properties, Processing

- ***Materials engineering:*** **an engineering discipline which is primarily concerned with using applied knowledge about materials.**

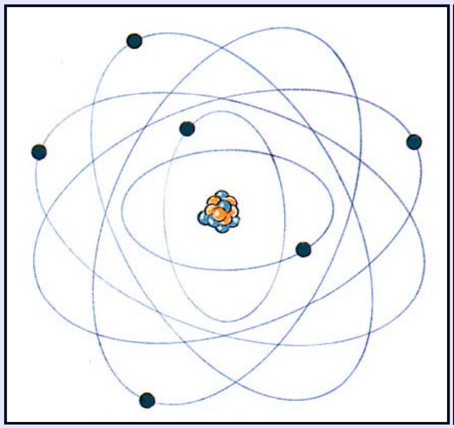
  How to convert materials into products

- **Four basic elements**

  Structure, Property, Processing, Performance

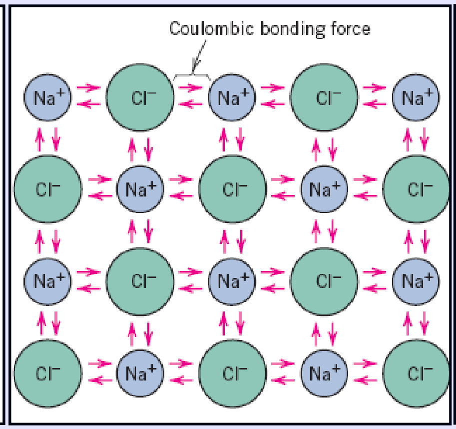
Structure

The ***structure*** of a material usually relates to the arrangement of its internal components.



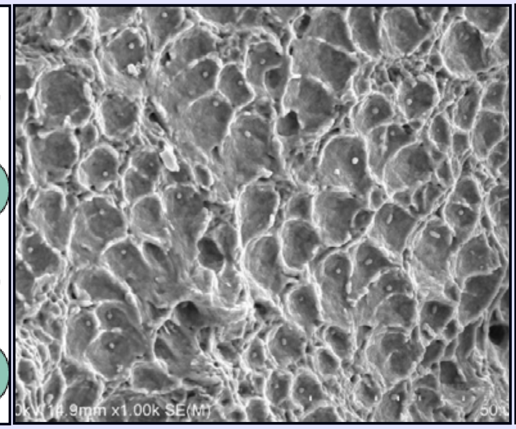
subatomic

Electrons within individual atom and interaction with nuclei



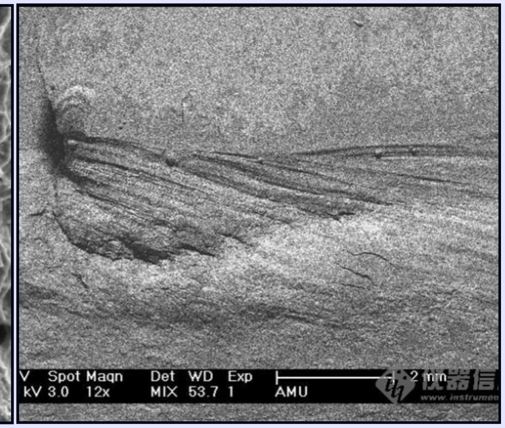
atomic

Organization of atoms or molecules related to one another



microscopic

Large groups of atoms, direct observation by microscope



macroscopic

Structural elements may be viewed with naked eye

Property

Property is a material trait in terms of the kind and magnitude of response to a specific imposed stimulus.

mechanical	**electrical**	**thermal**
magnetic	**optical**	**deteriorative**

Property

Mechanical **property reflects the relationship between a material's response or deformation to an applied force or load.**

Strength, hardness, ductility, stiffness

Electrical **property refers to the responses of a material to an applied electric field.**

Electrical conductivity, dielectric constant

Thermal **property means the response of a material to the application of heat.**

Heat capacity, thermal conductivity

Property

Magnetic **property demonstrates the response of a material to the application of a magnetic field.**

Magnetic moment, magnetic permeability

Optical **property means a material's response to exposure to electromagnetic radiation and, in particular, to visible light.**

Refraction index, reflectivity

Deteriorative **property relate to the chemical reactivity of materials.**

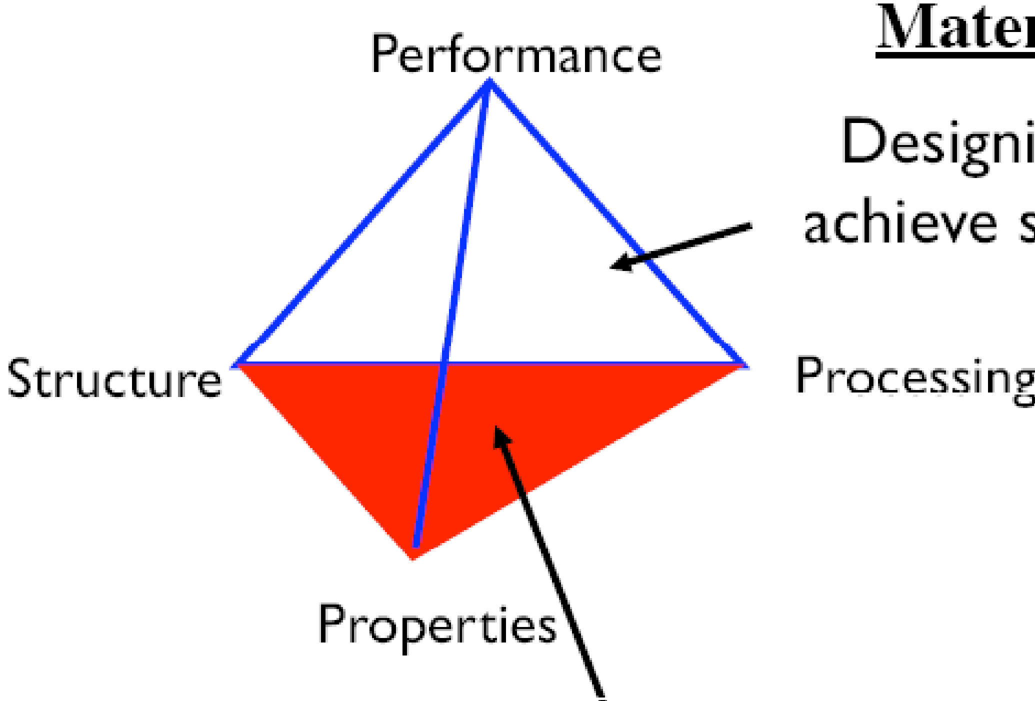
Four basic elements

Structure, Property, Processing, Performance

Processing: **different ways for shaping materials into useful components or changing their properties.**

Performance: **a function of a material's properties.**

Materials Science and Engineering in Tetrahedron



Materials Engineering

Designing the structure to achieve specific properties of materials.

Materials Science

Investigating the relationship between structure and properties of materials.

- Processing
- Structure
- Properties
- Performance

Classification of Materials

Chemical makeup
&
atomic structure

- *Metals (Ag, Cu, steel...)*
- *Ceramics (glass, SiO_2...)*
- *Polymers (plastics, rubber...)*

Metals

❒ **Composed of one or more metallic elements and nonmetallic elements**

- **Good conductors of electricity and heat**
- **Strong but deformable**

Ferreous alloys

Nonferreous alloys

Ferrous alloys – Fe-base alloys

- Steels – Fe-C alloys, C < 2.06 wt% （钢材）
  ferritic (low carbon – sheet steel)
  austenitic, martensitic
  stainless, magnetic, high-strength
  refractory, cryogenic, tool, etc.

- Cast iron – Fe-C alloys, C > 2.06 wt% （铸铁）
  white (dissolved)
  gray (plates)
  ductile (spheres)
  malleable (popcorn-shaped)
  compacted (rods)

Of all the metallic alloys in use today, ferrous alloys make up the largest proportion both by quantity and commercial value.

Nonferrous alloys

- Al-base alloys
- Cu-base alloys
- Mg-, Ni-, Ti-, Zn-, Pb-, Sn-base alloys

Classification

1. Heavy alloys - $\gamma > 4$ g/cm^3 (Cu, Ni, Zn, St, Pb)
2. Light alloys - $\gamma < 4$ g/cm^3 (Al, Mg)

Ti alloys – medium

$\gamma = 4.5$ g/cm^3

Applications

Aerospace – 80% of an airplan is Al-alloy; standard Boeing 747 ~ 75000kg Al-alloys

Automotive - engine blocks, cylinder heads, heat exchangers, transmission housings, engine parts, wheels

Transportation – rapid trains, boates, ferries

Food industry – Al-foil, cans, cooking

Building construction – windows, doors, frames

Electrical - electric lines, motors, appliances

Ceramics

- **Compounds between metallic & nonmetallic elements**
  - **Oxides, nitrides, and carbides**
  - **Insulative to electricity and heat**
  - **Very hard, but extremely brittle**

The term "ceramic" comes from the Greek word keramikos, which means "burned stuff," indicating that desirable properties of these materials are normally achieved through a high-temperature heat treatment process called firing.

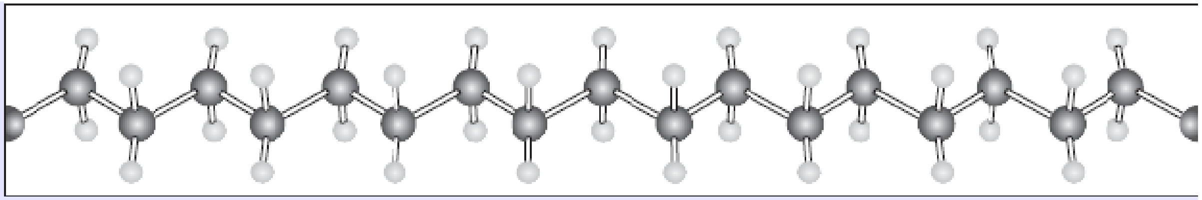
Ceramics

- **Tradtional ceramics**
  - **primary raw material： clay (粘土)**
  - *china(陶器), porcelain(瓷器), bricks(砖), tiles(瓦), glasses，high-temperature ceramics*

- **Advanced ceramics**
  - **oxides (Al_2O_3), nitrides (Si_3N_4), carbides (SiC), and many other materials including the superconductors**
  - **have a rather dramatic effect on our lives**

    electronics, computers, communication, aerospace

Polymers



❒ **Substances having large molecules consisting of repeated structural units**

- **very large molecule structure, chain-like in nature**
- **low density, extremely flexible**
- **plastics, rubber**

Composites

- ❑ **Composed of two or more individual materials (metals, ceramics, polymers)**
- ➢ **designed to display a combination of the best characteristics of each of the component materials**

Strength

Flexibility

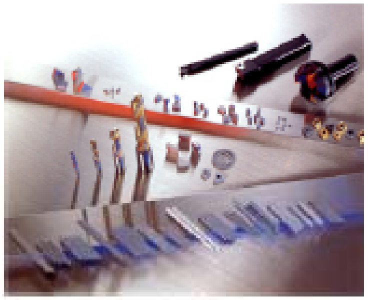
Carbon fiber composites

Carbon fiber(碳纤维)

\+

Epoxy(环氧树脂)

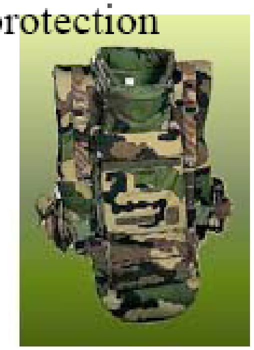
Cemented carbide cutting tools



Composites with lubricating reinforcements (graphite)

Military

Personal protection



Anti-ballistic panels

Sports

High-performance brake disks
strong, light, good heat conductors

Aircraft structure

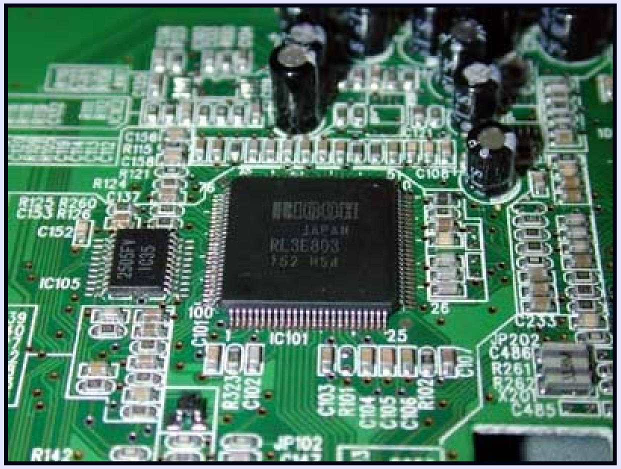
Aircraft cabin parts

Advanced Materials

Materials that are utilized in high-technology applications are sometimes termed *advanced materials.*

Semiconductors

- **Have electrical properties that are intermediate between the electrical conductors and insulators.**
  - ***Electrical characteristics are extremely sensitive to impurity concentration***
  - **Si, Ge, ZnO**



Advanced Materials

Biomaterials

- **Employed in components implanted into the human body for replacement of diseased or damaged body parts.**

- ***not produce toxic substances***
- ***be compatible with body tissues***

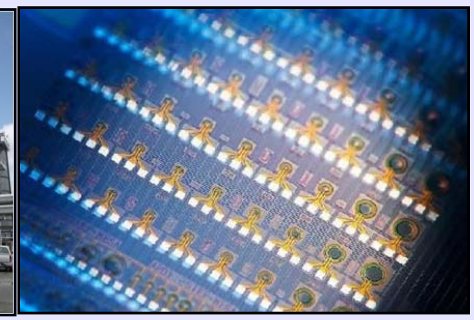
Why study MSE?

Many an applied scientist or engineer, whether mechanical, civil, chemical, or electrical, will at one time or another be exposed to a design problem involving materials.

gear

building

oil refinery



integrated circuits

A materials problem is one of selecting the right material from the many thousands that are available.

Why study MSE?

<u>Criteria for selecting materials</u>

❒ **In-service conditions**

determine the properties required of the material

❒ **Any deterioration of material properties may occur during service operation.**

For example, significant reductions in mechanical strength may result from exposure to elevated temperatures or corrosive environment.

❒ **Economics**

A material may be found that has the ideal set of properties but is prohibitively expensive.

So, a compromise should be made between the cost and properties.

Summary

1. List *six different property classifications* of materials that determine their applicability.

2. Cite the *four components* that are involved in the design, production, and utilization of materials, and briefly describe the *interrelationships* between these components.

3. Cite *three criteria* that are important in the materials selection process.

4. List the three primary *classifications of solid materials*, and then cite the distinctive chemical feature of each.