Lec1: Introduction to material science and engineering, classification of materials.

Materials Science and Engineering:

Materials Science and Engineering (MSE) is involves investigating the relationships that exist between the structures and properties of materials.

In contrast, materials engineering is on the basis of these structure–property correlations, designing or engineering the structure of a material to produce a predetermined set of properties.

- **Four Key Elements of MSE:**

1. **Structure:** arrangement of atoms, microstructure, crystal structure.
2. **Properties:** mechanical, electrical, thermal, magnetic, optical, etc.
3. **Processing:** techniques to shape and treat materials (casting, forging, heat treatment, additive manufacturing).
4. **Performance:** how a material behaves in service (strength, durability, corrosion resistance).

- **Importance:**
  - Enables technological advancement (from semiconductors to aerospace).
  - Provides solutions to global challenges (energy, sustainability, healthcare).

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Classification of Materials:

There are different ways of classifying materials. One way is to describe four groups:

1. Metals and alloys.

2. Ceramics (glasses, and glass-ceramics).

3. Polymers.

4. Composite materials.

1. Metals and alloys:

These include steels, aluminum, magnesium, zinc, cast iron, titanium, copper, and nickel. In general, metals have **good electrical and thermal conductivity.** **Metals and alloys have relatively high strength, high stiffness, ductility or formability (i.e., capable of large amounts of deformation without fracture), and shock resistance.** Atoms in metals and their alloys are arranged in a very orderly way, and in comparison to the ceramics and polymers, are relatively dense. Some of the metals (viz., Fe, Co, and Ni) have desirable magnetic properties.

2. Ceramics (glasses, and glass-ceramics):

Ceramics can be defined as inorganic materials, **compounds between metallic and nonmetallic elements**; they are most commonly **oxides, nitrides, and carbides.** For example, some of the common ceramic materials include aluminum oxide (or alumina,Al_2O_3), silicon dioxide (or silica, SiO_2), silicon carbide (SiC), silicon nitride (Si_3N_4), and, in addition, what some refer to as the traditional ceramics those composed of clay minerals (i.e., porcelain), as well as cement, and glass. With respect to mechanical behavior, ceramic materials are relatively **stiff and strong**

stiffness and strengths are comparable to those of the metals. In addition, ceramics are typically very hard. On the other hand, they are extremely **brittle (lack ductility) due to the presence of porosity (small holes), and are highly susceptible to fracture.** These materials are typically insulates to the passage of heat and electricity (i.e., have low electrical conductivities, and are more resistant to high temperatures and harsh environments than metals and polymers.

3. Polymers:

Polymers are typically organic materials produced using a process known as polymerization. Polymeric materials include rubber (elastomers), polyethylene (PE), nylon, poly(vinyl chloride) (PVC), polycarbonate (PC), polystyrene (PS), and silicone rubber. Many polymers have very good electrical resistivity. They can also provide good thermal insulation. Although they have lower strength, polymers have a very good strength-to-weight ratio. They are typically not suitable for use at high temperatures. Many polymers have very good resistance to corrosive chemicals. Polymers have thousands of applications ranging from bulletproof vests, compact disks (CDs), ropes, and coffee cups.

4. Composite materials:

A composite is composed of two (or more) individual materials that come from the categories previously discussed metals, ceramics, and polymers. The design goal of a composite is to achieve a combination of properties that is not displayed by any single material and also to incorporate the best characteristics of each of the component materials.

A large number of composite types are represented by different combinations of metals, ceramics, and polymers. Furthermore, some naturally occurring materials are composites for example, wood and bone. However, most of those we consider in our discussions are synthetic or human-made composites.

One of the most common and familiar composites is fiberglass in which small glass fibers are embedded within a polymeric material (normally an epoxy or polyester).The glass fibers are relatively strong and stiff (but also brittle whereas the polymer is more flexible.

Advanced Materials:

Materials utilized in high-technology (or high-tech) applications are sometimes termed advanced materials. Such, Semiconductors, Biomaterials, Smart materials.

- **Properties of Some Types of Materials:**

1. Metals and Alloys:

- They usually have a crystalline structure and are good thermal and electric conductors.
- Many metals have high strength and high elastic module.
- They also have sufficient ductility, which is important for many engineering applications.
- They are least resistance to corrosion.

2. Ceramics and glasses:

- They are good electrical and thermal insulators.
- They have high hardness, high moduli, and high temperature strength.
- They are resistant to high temperature and corrosive environments.
- They are very brittle.

3. Polymers:

- They are generally have low density and are not stable at high temperatures.
- They generally have a good strength to weight ratio.
- Most of them are corrosion resistant, but cannot be used at high Temperatures.
- They provide a good electrical and thermal insulation.

❖ Classification of materials Based on Structure:

- ➢ Crystalline materials.
- ➢ Single Crystals.
- ➢ Polycrystalline.
- ➢ Amorphous materials.

❖ Classification of materials Based on Function:

- Mechanical material
- Electronic material
- Magnetic material
- Optical material
- Medical material

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