Class: `1st Stage
Subject: Engineering Materials
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Materials Science and Engineering

Materials Science and Engineering (MSE) is an interdisciplinary field concerned with inventing new materials and improving previously known materials by developing a deeper understanding of the (microstructure-composition-synthesis-processing) relationships. The term **composition** means the chemical make-up of a material. The term **structure** means a description of the arrangement of atoms, as seen at different levels of detail. The term ''**synthesis**'' refers to how materials are made from naturally occurring or man-made chemicals. The term ''**processing**'' means how materials are shaped into useful components.

Classification of Materials

There are different ways of classifying materials. One way is to describe four groups (Table.1):

1. Metals and alloys.
2. Ceramics (glasses, and glass-ceramics).
3. Polymers.
4. Composite materials.

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. They are particularly useful for structural or loadbearing applications. Although pure metals are occasionally used, combinations of metals called **alloys** provide improvement in a particular desirable property or permit better combinations of properties. Atoms in metals and their alloys are arranged in a very

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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.

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. Therefore, we normally prepare fine powders of ceramics and convert these into different shapes. 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.

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.

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Composite Materials: The main idea in developing composites is to blend the properties of different materials. The composites are formed from two or more materials, producing properties not found in any single material. **Concrete**, **plywood**, and **fiberglass** are examples of composite materials. **Fiberglass** is made by dispersing glass fibers in a polymer matrix. The glass fibers make the polymer matrix stiffer, without significantly increasing its density. With composites we can produce lightweight, strong, ductile, high temperature-resistant materials or we can produce hard, yet shock-resistant, cutting tools that would otherwise shatter. Advanced aircraft and aerospace vehicles rely heavily on composites such as carbonfiber-reinforced polymers. Sports equipment such as bicycles, golf clubs, tennis rackets, and the like also make use of different kinds of composite materials that are light and stiff.