Lecture 1 Ceramics: I

The word ceramic is derived from the greek term *keramos*, which means "potter's clay" and *keramikos* means "clay products". Till 1950s, the most important types of ceramics were the traditional clays, made into pottery, bricks, tiles etc. Ceramic artefacts play an important role in historical understanding of the technology and culture of the people who lived many years ago.

A ceramic material is an inorganic, non-metallic material and is often crystalline. Traditional ceramics are basically clays. The earliest application was in pottery. Most recently, different types of ceramics used are alumina, silicon carbide etc. Latest advancements are in the bio-ceramics with examples being dental implants and synthetic bones.

A comparative analysis of ceramics with other engineering materials is shown in table 1. The purpose of presenting this comparative analysis is to show importance of ceramics among different engineering metals and polymers. This comparison would enable to justify application areas of ceramics.

Table 1 Comparison of ceramics with metals and polymers

Property	**Ceramic**	**Metal**	**Polymer**
Density	Low	High	Lowest
Hardness	Highest	Low	Lowest
Ductility	Low	High	High
Wear resistance	High	Low	Low
Corrosion resistance	High	Low	Low
Thermal conductivity	Mostly low	High	Low
Electrical conductivity	Mostly low	High	Low

Applications

- Pottery products, sanitary ware, floor and roof tiles
- Crucibles, kiln linings, other refractories
- High end applications such as in ceramic matrix composites, tiles in space shuttle, bullet proof jackets, disk brakes, ball bearing applications, bio-ceramics

Classification of ceramics materials

Ceramics can be classified in diverse ways i.e. there are number of ways to classify the ceramic materials. Most commonly, the ceramics can be classified on the following basis:

- Classification based on composition
- Classification based on applications

The detailed classification is shown in figure 1.

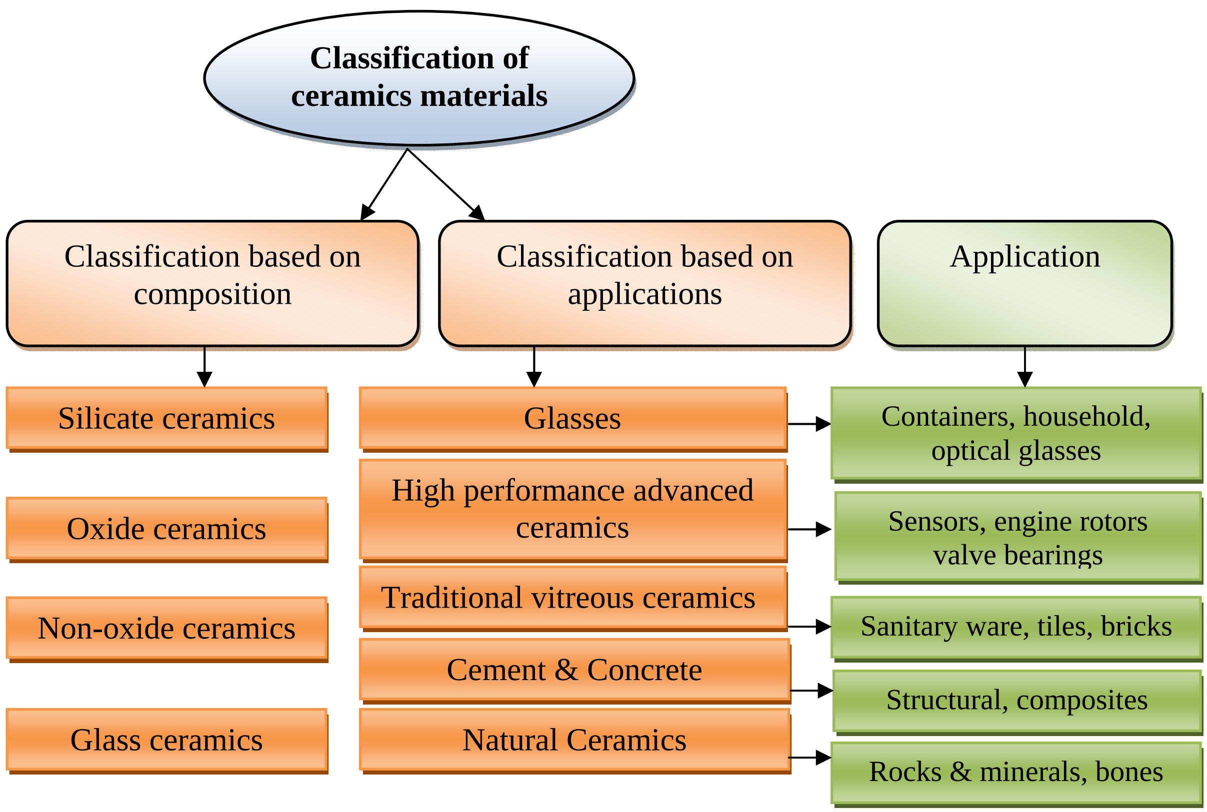

Figure 1 Classification of ceramics materials

Classification based on composition

(i) Silicate ceramics

Silicates are materials generally having composition of silicon and oxygen (figure 2a). Four large oxygen (o) atoms surround each smaller silicon (Si) atom as shown in figure 2b. The main types of silicate ceramics are based either on alumosilicates or on magnesium silicates. Out of these two, the former include clay-based ceramics such as porcelain, earthenware, stoneware, bricks etc. while the latter consists of talc-based technical ceramics such as steatite, cordierite and forsterite ceramics. Silicate ceramics are traditionally categorized into coarse or fine and, according to water absorption, into dense (< 2 % for fine and < 6 % for coarse) or porous ceramics (> 2% and > 6 %, respectively).

Figure 2 (a) Silicate ceramics

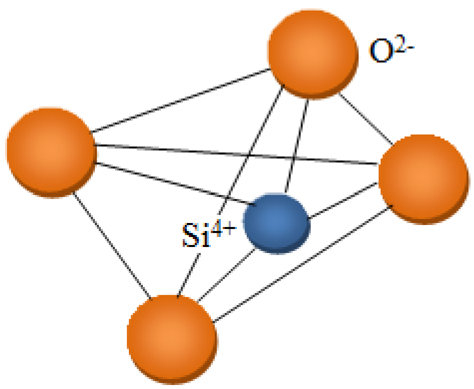

Figure 2 (b) Structure of silicate ceramics

(ii) Oxide ceramics

Oxide ceramics include alumina, zirconia, silica, aluminium silicate, magnesia and other metal oxide based materials. These are non-metallic and inorganic compounds by nature that include oxygen, carbon, or nitrogen. Oxide ceramics possess the following properties:

(a) High melting points

(b) Low wear resistance

(c) An extensive collection of electrical properties

These types of ceramics are available with a variety of special features. For example, glazes and protective coatings seal porosity, improved water or chemical resistance, and enhanced joining to metals or other materials.

Oxide ceramics are used in a wide range of applications, which include materials and chemical processing, radio frequency and microwave applications, electrical and high voltage power applications and foundry and metal processing.

Aluminium oxide (Al_2O_3) is the most important technical oxide ceramic material. This synthetically manufactured material consists of aluminium oxide ranging from 80 % to more than 99 %. (figure 3a and 3b).

Figure 3 (a) Aluminium oxide

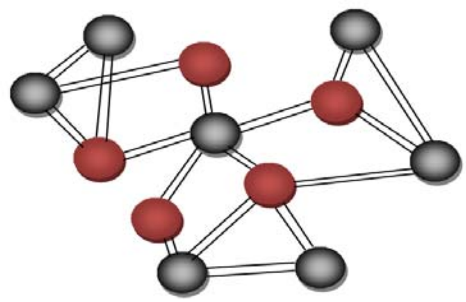

Figure 3 (b) Structure of aluminium oxide

(iii) Non-Oxide ceramics

The use of non-oxide ceramics has enabled extreme wear and corrosion problems to be overcome, even at high temperature and severe thermal shock conditions. These types of ceramics find its application in different spheres such as pharmaceuticals, oil and gas industry, valves, seals, rotating parts, wear plates, location pins for projection welding, cutting tool tips, abrasive powder blast nozzles, metal forming tooling etc.

(iv) Glass ceramics

These are basically polycrystalline material manufactured through the controlled crystallization of base glass. Glass-ceramic materials share many common characteristics with both glasses and ceramics. Glass-ceramics possess an amorphous phase and more than one crystalline phases. These are produced by a controlled crystallization procedure.

Glass-ceramics holds the processing advantage of glass and has special characteristics of ceramics.

Glass-ceramics yield an array of materials with interesting properties like zero porosity, fluorescence, high strength, toughness, low or even negative thermal expansion, opacity, pigmentation, high temperature stability, low dielectric constant, machinability, high chemical durability, biocompatibility, superconductivity, isolation capabilities and high resistivity. These properties can be altered by controlling composition and by controlled heat treatment of the base glass.