UNIT-V

NEW MATERIALS 9

Ceramics – types and applications – composites: classification, role of matrix and reinforcement, processing of fiber reinforced plastics – metallic glasses: types, glass forming ability of alloys, melt spinning process, applications - shape memory alloys: phases, shape memory effect, pseudoelastic effect, NiTi alloy, applications – nanomaterials: preparation (bottom up and top down approaches), properties and applications – carbon nanotubes: types.

Introduction

- Mechanical engineers search for high temp material so that gas turbines, jet engines etc. can operate more efficiently and wear resistance materials to manufacture bearing materials.
- Electrical engineers search for materials by which electrical devices or machines can be operated at a faster rate with minimum power losses
- Aerospace & automobile engineers search for materials having high strength-to weight ratio.
- Electronic engineers search for material that are useful in the fabrication & miniaturization of electronic devices
- Chemical engineers search for highly corrosion-resistant materials

In this chapter let us discuss new engineering materials such as ceramics, composites, metallic glasses, shape memory alloys, Nano-phase materials and carbon Nano tubes.

Ceramics

Introduction

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

Definition

- Ceramic materials are inorganic, non-metallic materials. Most ceramics are compounds between metallic and non-metallic elements for which the interatomic bonds are either totally ionic or predominantly ionic but having some covalent character.

Properties of ceramics:

- Ceramics are non-metallic and inorganic solids that are processed at high temperature.
- They are hard, wear resistant and brittle with low toughness and ductility.
- They are good electrical and thermal insulators due to the absence of conducting electrons.
- They have relatively high melting temperature and good chemical stability.
- They possess a very low thermal conductivity since they do not have enough free electrons.
- Oxidation resistant.

Classification of ceramics

Natural ceramics (Traditional ceramics)

- They are made from three basic components: clay, silica and feldspar. Structural clay products such as building brick, sewer pipe, drain pipe, roof and floor title etc., are made of natural clay, which contain all three basic components.

- ❖ Example: Glasses, tiles, bricks and porcelain.
- ❖ Silica is used as refractory component in traditional ceramics. This is also called as flint or quartz having a high melting temperature.

Manufactured ceramics (Engineering ceramics)

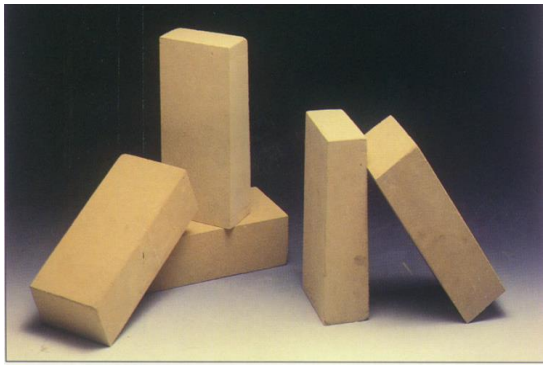
- ➢ Manufactured ceramics like SiC, $Al_2 O_3$, Silicon Nitride (Si_3N_4), Magnesia (Magnesium oxide, MgO) and many varieties of oxides, carbides, nitrides, borides and more complex ceramics.
- ➢ The manufactured ceramics are usually called as "High-tech ceramics" or "fine ceramics".

Functional classification

- ➢ Abrasives: Ex-Alumina, Carborundum
- ➢ Pure oxide ceramics: Ex-MgO, $Al_2 O_3$, SiO_2
- ➢ Fired clay products: Ex-Bricks, Tiles, Porcelain
- ➢ Inorganic glasses: Ex-Window glass, lead glass
- ➢ Cementing materials: Ex-Portland cement, lime
- ➢ Rocks: Ex-Granites, Sandstones
- ➢ Minerals: Ex-Quartz, calcite
- ➢ Refractories: Ex-Silica bricks, Magnesite

Structural classification

- Crystalline ceramics: Single phase like MgO , Multiphase like $Al_2 O_3$,
- Non-Crystalline ceramics: Inorganic glasses like window glass
- Glass –bonded ceramics: Fired clay products
- Cement-Crystalline and non-crystalline phases

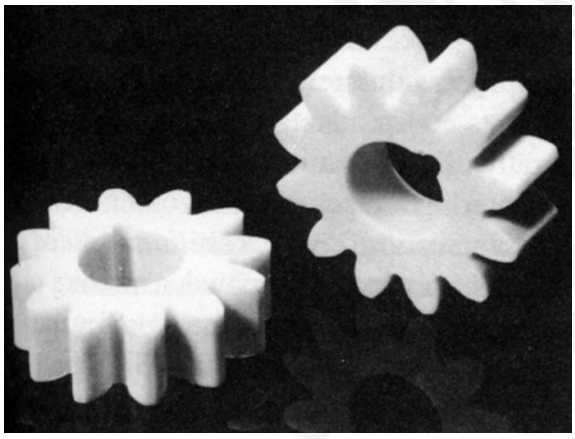


Refractory brick

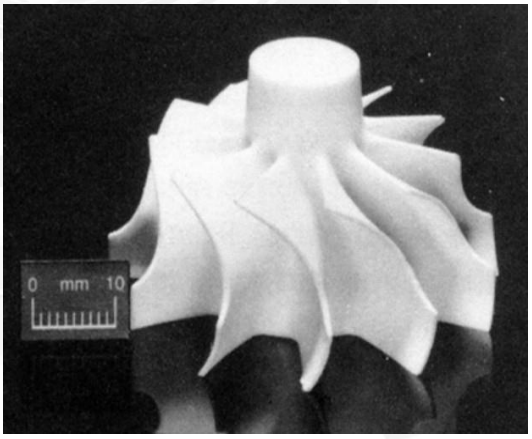
Ceramic brake disc

Automotive SiC components

Glass containers



Gear (Alumina)



Rotor (Alumina)

Figure 5.1 Examples of Ceramics

Ceramic processing

Processing of ceramics generally takes place in 4 steps:

- ❖ Powder processing (raw materials)

- ❖ Forming (desired shape)
- ❖ sintering (firing)
- ❖ Finishing-include densification, sizing, heat treatment, painting, and electroplating.

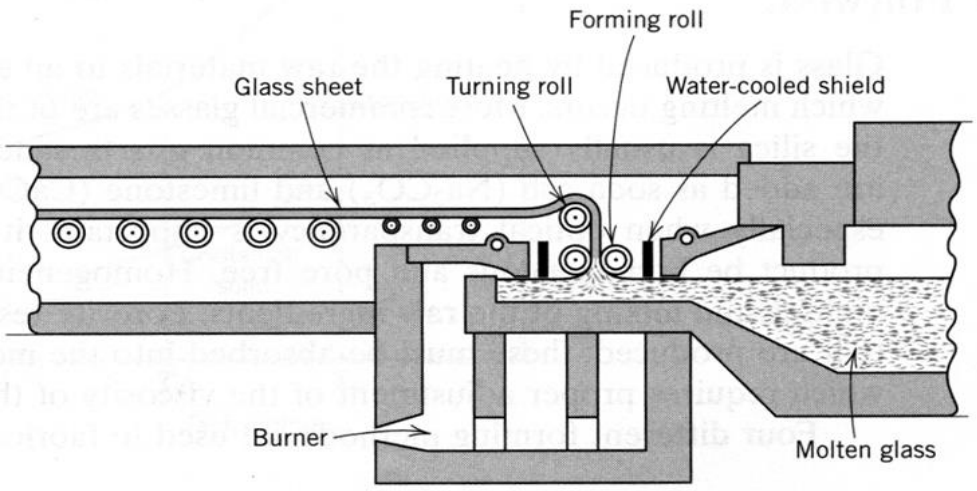


Figure 5.2 Ceramics processing set up

Types of ceramics

Glasses

- ❖ Glasses are amorphous solids. They are non- crystalline silicates containing other oxides like Na_2 O, K_2 O and Al_2 O_3.

Properties

- They are less ductile and more brittle
- They have low thermal conductivity compared to metals
- They are good insulators

Applications

- ❖ They are used for making windows space, furnace windows, vehicle windows
- ❖ They are used in containers and electric bulbs.
- ❖ They are also used in optical systems in spectro photometric devices
- ❖ They are used in sealed beam head lights, ovenware etc.,

Glass ceramics

- ❖ Even though most of the glasses are amorphous, special glasses are made crystalline through a carefully controlled heat treatment. They are called glass ceramics.

Properties

- They are relatively high mechanical strength
- They have low coefficients of thermal expansion
- They have good dielectric properties
- They have good biological compatibility

Applications

- ❖ They are used as ovenware, tableware, oven windows and range tops.
- ❖ They also serve as electrical insulators and as substracts for printed circuit boards.
- ❖ They are used for architectural cladding, heat exchangers and regenerators.

Clay products

- ❖ Ceramics are produced from earth minerals by the action of heat and diffusion techniques are called Clay products.
- ❖ Clay products are classified into two cases (i) structural clay (ii) white ware.

Structural clay

- These products include building bricks, tiles and sewer pipes.

White ware

- It is a class of ceramic products that include porcelain, china, pottery, sanitary ware, vitreous tile, stoneware.

Properties

- Mechanical strength is more when fired at elevated temperature

- Resistance to chemical attack
- They are resistance to wear

Applications

- ❖ They are used for various elements of buildings like walls, wall and floor facing materials, lining materials for chemical industry apparatus, chimney and sewer pipes.
- ❖ Tableware, wall tiles, sanitary ware and roof tiles are used to provide protection and decoration.

Refractories

- ❖ Refractories are ceramics having the capacity to withstand high temperature without melting or decomposing. Refractories are available in the form of bricks, shaped products and coatings. The oxides of Al, Si ad Mg are the most important materials used in the manufacturing of refractories. They are divided into three groups:

(i) Acid refractories

(ii) Basic refractories

(iii)Neutral refractories

Properties

- At high temperatures acid refractories also react with limes and basic oxides.
- They withstand high temperature without melting
- It will provide thermal insulation.

Application

- ❖ They are used for high temperature applications.
- ❖ They are repainted in metal processing applications to provide compatibility with the metal.
- ❖ They are in furnace lining for metal refining

Abrasives

- ❖ They are hard and wear resistant material that is used to wear, grind or cut away other material. To provide toughness, the abrasive particles are bonded by a glass or polymer matrix. Diamond abrasives are typically bonded with a metal matrix.
- ❖ Example: Diamond, silicon carbide, tungsten carbide, aluminium oxide and silica sand.

Cement

- ✓ Ceramic raw materials are joined using a binder that does not require firing or sintering in a process called cementation.
- ✓ Fine alumina powder solutions catalyzed with phosphoric acid produce aluminium phosphate cement at 1650^0 C.

$$Al_2O_3 + 2H_3PO_4 \rightarrow 2AlPO_4 + 3H_2O$$

- ✓ Application: cement is used to bind sand and gravel together to produce concrete.
- ✓ Portland cement is the most important cement.

Advanced ceramics

- ❖ **Advanced ceramics** are prepared from highly refined synthetic raw materials using chemical processing techniques. They are primarily pure compounds oxides, carbides, nitrides and borides. Because of its mechanical strength and its usage in industrial applications, advanced ceramics are termed as fine ceramics or engineering ceramics.