① Ceramic :

Ceramic Materials : (Keramikos, Greek word for clay Product)
فخاريات

Compounds of Metallic and nonmetallic elements.

Such as:

- Simple binary compounds : MgO, LiF → which is have equal no.s of positive and negative ions.
- Complex Materials : clay

The metallic elements → Lose their valance electrons and become positive ions.
(Lower half and/or on the left side of the periodic Table).

The non metallic elements → accept (or share) electrons to become negative ions.
(uper-right Section of the periodic table).

Characteristics of Ceramic :

① hard and Brittle.
② good electrical and thermal insulator
③ good resistance to chemical attack and tend to have Low thermal shock resistance.

because of their Low thermal Cond. and Low thermal expansivity.

They Can be grouped as:

ⓐ Natural Ceramic : stone

ⓑ Eng. Ceramic : oxides, nitrides, carbids, silicates.

they are used : as Furnace Components, Combustion tubes, tool tips and grinding tools.

ⓒ Glasses and glass Ceramics : Amorphous states :

Silica molten → cooled more rapidly → solid is a disorderly arrangement which is called a "glass".

glass Ceramic : fine grained polycrystaline materials produced by a controlled crystallisation of glasses.

ⓓ Electronic Mat. : Ferrites, ferroelectrics and S.C.

"properties of Ceramic are determined by it's composition, and it's microstructure produced as a result of it's Fabrication"

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② Ceramic

- methods used to manufacture SiC products:
  - Reaction bonding
  - Sintering
  - Hot pressing
- methods used to manufacture silicon nitride products:
  - Reaction bonding,
  - Hot pressing
  - Sintering

Sialon: Ceramic formed when Silicon, nitride, alumina, silica and alumina nitride are combined.

Sintering: Agglomeration of particles by diffusion through the solid.

P/M: products are made by compacting metal powders into a mold.

metal ductile deformed at points of contact. Compaction is followed by sintering which: ① bind the powder particals together. ② reducing the porosity.

work treatment also.

4.23. GLASS

4.23.1. Introduction

- **Glass** *is any substance or mixture of substances that has solidified from the liquid state without crystallization.* Elements, compounds and mixture of wide varying composition can exist in the glass state, but the term *"glass"* as ordinarily used *refers to material which is made by the fusion of mixture of silica, basic oxides and a few other compounds that react either with silica or with the basic oxides.* No definite chemical compounds can be identified in glass. Many of its properties correspond to those of supercooled liquid whose ingredients cannot be identified because they have not separated from the solution in crystalline form.
- *Glass* may also be defined as a *hard, brittle, transparent or transluscent material chiefly compound of silica, combined with varying proportions of oxides of sodium, potassium, calcium, magnesia, iron and other minerals.*
- Glass is an amorphous substance having a homogeneous texure.

Structure of glass:

The *glass is a random arrangement of molecules, the great majority of which are oxygen ions bonded together with the network forming ions of silicon, boron or phosphorous.* A glass made of silica alone has many desirable characteristics but unfortunately the high temperatures involved make it expensive, and difficult to prepare. In order to reduce the temperature, required network-modifying ions are added. *Sodium, potassium, and calcium* are the most common. The network-modifying ions increase the competition for the oxygen ions, thus loosening the Si-O bonds. Certain other ions may substitute for either the network-forming ions or network-modifying ions; *aluminium, zinc, beryllium, lead and ion* are a few of these intermediate ions.

4.23.2. Constituents of Glass and their Functions

The various *constituents of glass* and their *functions* are described below :

1. Silica :

- It is the principal constituent of glass.
- If silica alone is used in the manufacture of glass, it could be fused only at a very high temperature but it would give a good glass on cooling. However, it is imperative to add some alkaline materials (sodium or potassium carbonate) and lime in suitable proportions to make the molten silica glass sufficiently viscous to make it amply workable and resistant against weathering agencies.

2. Sodium or potassium carbonate :

- It is an alkaline material and forms an essential component of glass.
- It is added in suitable proportion to *reduce the melting point* of silica and to *impart viscosity to the molten glass.*

3. Lime :

- It is added in the form of chalk.
- It imparts durability to the glass.

In place of lime, sometimes, *lead oxide* is also added; it makes the glass *bright and shining.*

4. Manganese dioxide :

- It is added in suitable proportion to *correct the colour of glass due to the presence of iron in raw materials of glass.*
- It is also called 'Glass maker' soap.

5. Cullet

- It is the old broken glass of the same type as that which is intended to be prepared.
- It is added in small quantity to provide body to the glass.

6. Colouring substance :

While manufacturing a coloured glass, a suitable colouring substance is added at fusion stage to provide the desired colour to the glass.

The various colouring substances for manufacturing glass of different colours are given below:

Colour	*Colouring substance*	*Colour*	*Colouring substance*
1. **Black**	Cobalt, nickel and manganese oxide	4. **Violet**	Manganese dioxide
2. **Green**	Chromic oxide	5. **White**	Cryolite, tin oxide
3. **Red**	Cuprous oxide, selemium	6. **Yellow**	Cadmium sulphate.

4.23.3. Properties of Glass

Following are the *properties* of glass:

1. No definite crystalline structure.
2. No sharp melting point.
3. Absorbs, refracts or transmits light.
4. Affected by alkalies.
5. An excellent electrical insulator at elevated temperatures.
6. Extremely brittle.
7. Available in beautiful colours.
8. Not affected by air or water.
9. Not easily attacked by ordinary chemical reagents.
10. Capable of being worked in several ways.
11. Can take up a high polish (and may be used as substitute for very costly gems).
12. Possible to weld pieces of glass by fusion.
13. As a result of advancement made in the science of glass production, it is possible to make glass lighter than cork or softer than cotton or stronger than steel.
14. Glass can be cleaned easily by any of the following methods:
    (*i*) Applying methylated spirit.
    (*ii*) Rubbing finely powdered chalk.
    (*iii*) Rubbing damp salt for cleaning paint spots.
    (*iv*) Painting the glass panes with lime-wash and leaving it to dry and then washing with clean water.

Commercial glass must meet the following requirements :

1. The material must melt at commercially obtainable temperature. Fused silica cools to a glass that is superior to ordinary glass, but the temperature required to melt it is so high that its production is expensive and its use restricted.

2. The molten mixture must remain in the amorphous or non-crystalline condition after cooling.
3. The fluidity of molten glass must presist to a sufficient extent to permit the formation of *desired shapes while the glass is cooling.*
4. The glass must be reasonably permanent in the use for which it is intended. Glass with a high proportion to sodium oxide is more readily attacked by water and acids than glass that contains less sodium oxide and more lime and magnesia. Glasses low in basic oxides are less readily attacked.

Mechanical Properties :

Ranges of *physical properties* of glasses :

Refractive index	1.46 – 2.179
Specific index	2.215 – 8.120
Compressive strength	600 – 1200 MN/m^2
Tensile strength	27 – 700 MN/m^2
Thermal conductivity	0.0018 – 0.0028 cal/cm °C/sec.
Expansion coefficient	8×10^{-7} – 140×10^{-7} cm/cm/°C
Softening point	500 – 1510°C
Annealing point	350 – 890°C
Volume resistivity	10^8 – 10^{18} ohms/cm^3
Dielectric constant	3.7 – 16.5

Strength. Glass is weak in tension and it always fails in tension no matter how stress is applied. Nevertheless, glass is four to six times as strong in compression as it is in tension and it should, therefore, be used under compressive loads. Strength depends upon the factors such as surface conditions, cross-section and amount of addition etc.

Hardness and brittleness. The hardness of glass cannot be measured by the Brinell or Rockwell machines because the test specimen fails when the surface is ruptured. Yet some glasses will scratch steel. The relative value of hardness can be evaluated by scratch or abrasion test. *For ordinary purpose the hardness of glass is a function of its tensile strength.*

The concept of brittleness has not been clearly defined. When glass is fixed it bends only a little, then shatters. There is no plastic deformation, and the curve of the *stress-strain diagram is straight until the test specimen breaks.*

Thermal endurance. The lower the coefficient of expansion and the thinner the piece the less likely it is to break under thermal shock. Glass does not break from thermal causes but from the tensile stresses set up by the temperature gradient.

Electrical Properties:

Conductivity. Conductivity depends on composition, temperature and surface conditions. Sodium and potassium ions are largely responsible for imparting electrical conduction, but the function of the calcium ions or the mechanism of conduction in an alkali-free glass is not known. Na_2O and K_2O increase the conductivity. Al_2O_3 increases the conductivity slightly; ZnO, PbO, MgO, Fe_2O, BaO, B_2O_2 and CaO decrease the conductivity.

The presence of a film on the surface glass affects the surface resistivity to a marked degree. In high alkali glasses the surface conductivity may exceed the volume conductivity. The presence of CO_2, SO_2 , H_2S, solids and mineral soils also affects the surface conductivity.

In making conductivity tests on glass a precise value is seldom obtained because of the influence of the surrounding medium. Even oil immersion will not give the true value because it