INSULATING MATERIALS

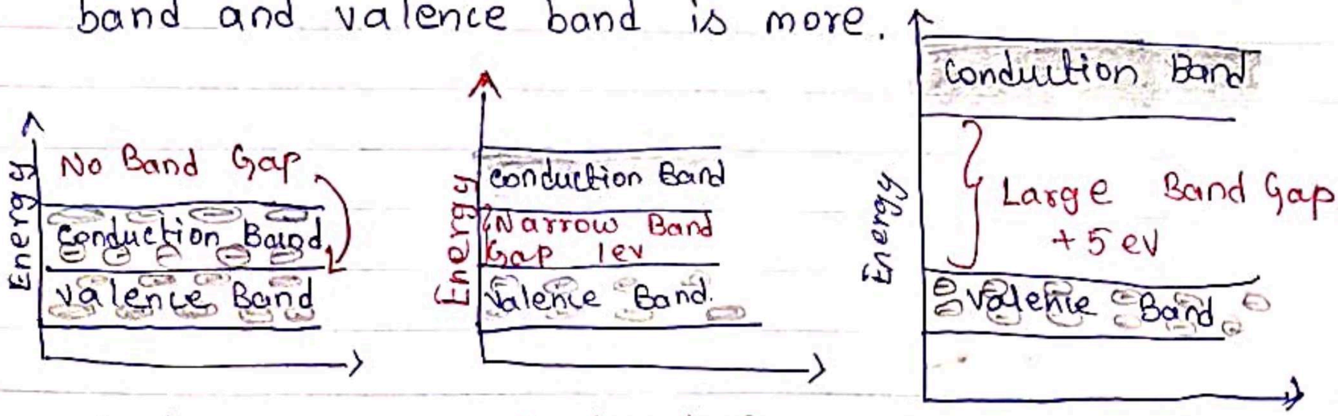
-> Insulators are as important as any other electrical component, the entire reliability of the electrical installation depends on them.

-> Majority of breakdown in field of electrical equipment is due to the failure of insulation.

-> Life of the electrical equipment depends on the type of material used.

-> In a conductor, electric current can flow freely, whereas in an insulator it cannot.

In conductors the outer electrons are not tightly bound and hence free to move whereas in case of insulators, they have valence 8 e's (or) nearer to 8 in an outermost shell and obviously in stable condition and offer very high resistance as there are no free e's and also the band gap between conduction band and valence band is more.



conductors   Semiconductor   Insulator

-> Insulating materials are the materials that heat transmission, electric current (or) noise.
-> All the insulating materials have negative temperature co-efficient of resistance.
[decrease in electrical resistance when the temp is raised.]
-> Insulation resistance measures the total resistance between any two points seperated by electrical insulation.
-> It is measured in Megaohms. (MΩ)

PROPERTIES OF INSULATORS

Properties of the insulating material are required for the proper functioning of the insulating material

-> A good insulator should have high resistance.
-> Should have high dielectric strength.
-> Should posses high mechanical strength
-> It should not absorb Moisture
-> It should not be porous in nature and also free from impurities.
-> It should be stable (i.e) should not be affected by change in temp, weather etc,
-> It must be uniform
-> Solid insulating material should have high melting point.
-> Should be Non-Ignitable
-> Should be resistant to various chemicals.

CLASSIFICATION

Insulating materials are used in various form and applied under many different conditions. classification based on

* Physical State
* Thermal Stability

Physical State

- Solid
  Eg: Mica, Ceramics, Glass, Rubber, Silk, Wood, Fibrous, Epoxy resins, Asbestos
- Liquid Insulating Materials
  Eg: Varnish, Transformer oil, Silicone oils, cable oil, Synthetic Liquids.
- Gaseous state
  Eg: Air, Sulphur, Hexafluoride, SF_6 gas, Nitrogen, Freon, Halogens, Hydrogen.

THERMAL STABILITY:

Electrical components is divided into different classes according to their maximum operating temperature In order to ensure long term functionality in operation, these limit values must not be exceeded.

-> This different classes are defined by IEC [International Electrochemical commission] and IS: 271 [Indian Standards].

CLASS	Temp	Examples
CLASS Y	90°C	Eg: Cotton, Paper, Silk, PVC, etc
CLASS A	105°C	Eg: Cotton, Paper, Silk etc [impregnated with varnish or insulating oi
CLASS E	120°C	Eg: Enameled wire insulating on base of Polyurethane, epoxy resins, Powder plastic
CLASS B	130°C	Eg: Inorganic materials such as mica, Fiber glass, Asbestos impregnated with varnish.
CLASS F	155°C	Eg: Class B materials in that are upgrade with adhesives, silicone, alkyl resin varnish of. higher thermal endurances.
CLASS H	180°C	Eg: Inorganic material glued with Silicone resin (or) adhesive of equivalent performance.
CLASS C	>180°C	Eg: Glass, Mica, Quartz, Ceramics, teflo etc

Average insulation life of the insulating material gets halved (Reduced => பாதியாக) for every 10°c rise of temp from its maximum permissible temperature.

APPLICATION OF INSULATING MATERIALS

-> Circuits, electrical boards, electronic systems
-> Power system
-> Domestic portable appliances
-> Electrical cable insulating tape
-> Cable & transmission lines
-> Electrical rubber mats.

SOLID INORGANIC INSULATORS

GLASS INSULATORS:

Glass insulators started and being used in the 18^{th} century for telegraph and telephone lines, which were then replaced by ceramic and porcelain types in 19^{th} century.

→ To overcome this, toughened glass types were introduced which become popular due to their life span.

PREPARATION:

- The raw materials [Silica, Quartz, Soda ash, Limestone and cullet (broken pieces of glass) are weighed accurately and grinded separately.

The glass batch (raw material) is heated in a furnace until the evolution of CO_2, O_2, SO_2 and other gases stops (i.e) glass melt free from glass bubbles.

The cullet melts first and helps in fusion of rest of the materials. A high temp of 1500 - 1800 °C is maintained to reduce the viscosity of glass melt and to obtain homogeneous liquid.

$$CaCO_3 + SiO_2 \longrightarrow CaSiO_3 + CO_2$$

$$Na_2CO_3 + SiO_2 \longrightarrow Na_2SiO_3 + CO_2$$

$$K_2CO_3 + SiO_2 \longrightarrow K_2SiO_3 + CO_2$$

Undecomposed raw materials and impurities form a scum called glass gall which is skimmed off (removed). The clear liquid is allowed to cool after adding necessary decolouriser or colouring agents.

It is cooled to 700 - 1200°c, so that it will have the proper viscosity for shaping.

- → The molten glass is run into moulds and cooled gradually and slowly. Rapid cooling causes fracture.
- → The process of slow and homogeneous cooling of glass article is called annealing of glass.
- → After annealing the glass articles are subjected to finishing such as cleaning, Polishing, Cutting etc.

Collection of raw materials [Silica, Quartz, Soda ash, Lime stone, Cullet]

↓

Preparation of Batch

↓

Heating in furnace (1500-1800°c)

↓ & Cooled to 700 - 1200°c to have proper viscosity

Shaping

↓

Annealing

↓

Finishing ⟨Includes cleaning, polishing, cutting etc.,⟩

PROPERTIES :

-> Possess Good Mechanical Strength
-> Posses high dielectric strength 140 kv /cm.
-> Possess compressive strength of about 1000 kg /cm^2
-> Possess high tensile strength of about 35,000 kg /cm^2
-> Possess Low co-efficient of thermal expansion.
-> High cracking resistance and electrical resistance
-> Corrosion resistance.

ADVANTAGES :

-> As glass insulators are transparent in nature, it is not heated up in sunlight.
-> Because of its transparency, the air bubble and other impurities can be easily detected.
-> Mechanical and electrical properties remain same over a long time service.
-> They are light in weight
-> Glass is cheaper than porcelain
-> Due to high dielectric strength they are easy to design
-> Thermal expansion co-efficient of glass insulator is low and hence its relative deformation is very low due to temperature variation

DISADVANTAGES :

-> Moisture and rain drops condense on the glass insulator and hence the deposition of dust which leads to the leakage of current.
-> Complex transportation with extra care,
-> They can't be designed in asymmetrical and irregular shapes,
-> By a strong impact all insulator will break.

APPLICATIONS :

-> Used in transmission towers, Distribution poles and telephone poles.
-> Used as Dielectric in capacitors
-> Used in electric bushings, fuse bodies etc
-> Glass fibres are used for overhead insulation in electric lines.

POLYMER AS INSULATING MATERIAL

Majority of Polymers are insulators (i.e) it prevents the flow of electric current such insulator is also called dielectric material.

-> These polymers are commonly used in electrical application as insulator due to their exceptional electrical, Mechanical chemical and thermal properties.

-> These polymer based electric insulators exhibit high dielectric strength, high resistivity, low dielectric loss and adequate mechanical properties.

POLARIZATION OF POLYMER

-> The majority of Polymers have polarized covalent bonds, that is the electrons are drawn closer to the more electronegative atoms.

-> These dipoles will orient themselves to align up with the electrical field and hence results in stronger dipole polarization and higher dielectric constant.

→ The orientational polarization depends on the temperature and field frequency whereas the electronic ~~polazi-~~ polarization is independent of the frequency and temperature.

→ Both the orientational polazization and electronic polarization depends on the chemical composition of the monomer in the polymer.

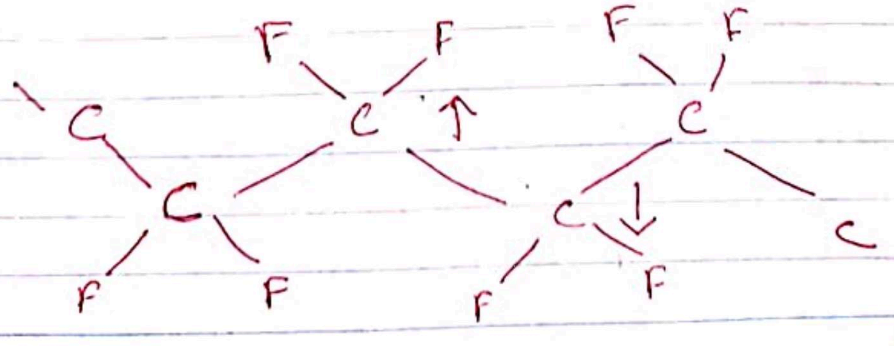
→ For example: Aromatic rings, sulfur, bromine and Phenol increase the relative permittivity because they are highly polarizable.

→ Similarly, the π bonds in the aromatic rings are highly polarizable than σ bonds, and hence increase the relative permittivity.

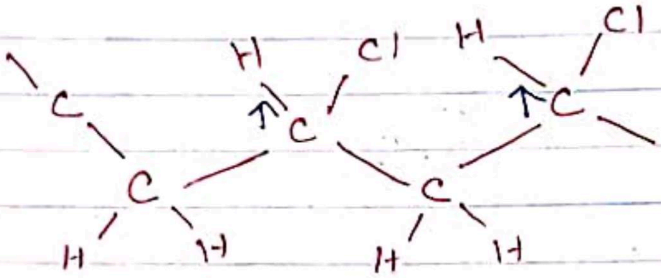
→ Chain geomentry determines whether a polymer is polar (or) non-polar.

→ If the polymer is held in fix confirmation, the resulting dipole will depend whether their dipole moments reinforce or cancel each other.

For example: In non-polar PTFE the high dipole moment of $-CF_2-$ units at each alternating carbon cancelled each other since their vectors are in opposite direction. Therefore the dielectric is low.



→ On the other hand, PVC has its dipole moment directing parallel to each other resulting in reinforcement of dipole. Hence, it has high dielectric constant.



NON - POLAR POLYMERS :-

Non-polar polymers have symmetrical structure and covalent bond there are no dipoles present in this polymer and application of electric field does not try to allign any dipoles.

→ However, when electric field is applied the electron cloud is slightly displaced from nuclei in direction opposite to electric field.

→ This results in separation of +ve & -ve charge and molecule behave as dipole. This polarization is called electronic polarization.

Example for non-polar Polymers

PE - Polyethylene

PP - Polypropylene

PS - Polystyrene

PTFE - Teflon - Poly tetra fluro Ethylene

POLAR POLYMERS:

Polar polymers do not have a fully covalent bond and there is a slight imbalance in the electronic charge of the molecule and hence there exist a dipole.

- → when electric field is applied externally, the molecules with dipole orient themselves according to the direction of applied field.
- → This orientation of permanent dipole along axis of applied electric field is called orientational polarization.

Example: PMMA, PVC, Nylon etc.

POLAR POLYMER	NON-POLAR POLYMER
→ Have permanent dipole	→ Does not have permanent Dipole.
→ Passess high dielectric constant	→ Posses low dielectric constant
→ On applying electric field Both electronic & Orientational polarization occurs.	→ On applying electric field electronic polarization occurs.
Eg: PMMA, PVC, Nylon	→ Examples: PE, PP, PS PTFE