INSULATING MATERIALS

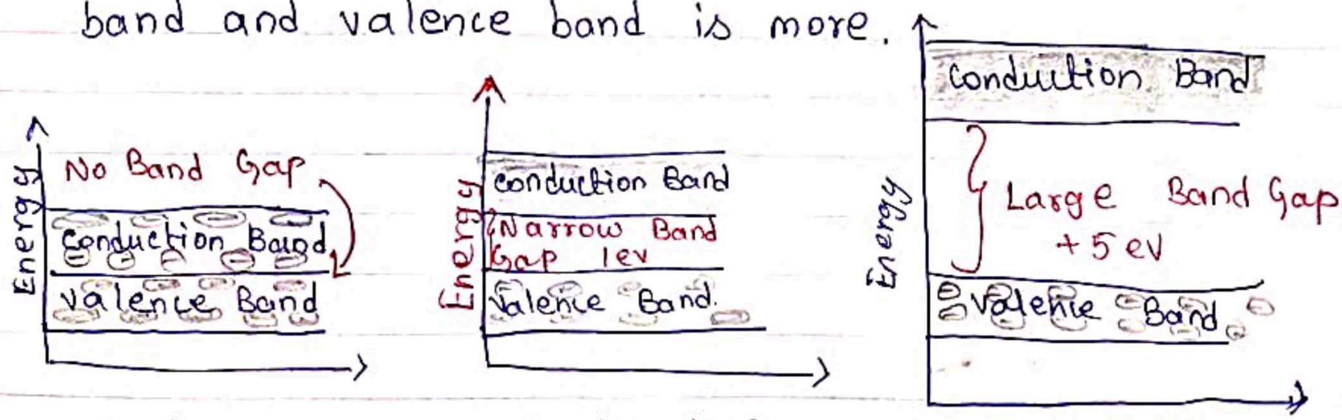
-> Insulators are as important as any other electrical component, the entire reliability of the electrical installation depends on them.

-> 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. ($M\Omega$)

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 I.S: 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 upgraded 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, teflon 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
-> Possess 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.

A. Solid Inorganic Insulator:

2. Ceramic Products

Ex: Porcelain Insulator

Preparation

• Porcelain is the most commonly used material for overhead insulators in the present day. The porcelain is aluminum silicate.

• The aluminum silicate is mixed with plastic kaolin, feldspar, and quartz to obtain final hard and glazed porcelain insulator material. Thus, the surface of the insulator should be glazed enough so that water should not be traced on it.

• The porcelain can also be called as ceramic.

Properties

The properties of the porcelain insulator are

- **Dielectric Strength:** The approximate value of dielectric strength is 60 kV/cm.
- **Compressive Strength:** The approximate value of compressive strength is 70,000 Kg/cm².
- **Tensile Strength:** The approximate value of tensile strength is 500 Kg/cm².
- Porcelain also should be free from porosity since porosity is the main cause of deterioration of its dielectric property. It must also be free from any impurity and air bubble inside the material which may affect the insulator properties.

Advantages

The advantages of the porcelain insulator are

- Compared to glass insulator the mechanical strength of porcelain insulator is very high
- Leakage current is low
- It is less affected by temperature
- Long life
- Easy to maintain
- Highly Flexible
- Highly reliable
-

Disadvantages

The weak in tension and poor shock resistance is the disadvantages of a porcelain insulator.

Applications

The applications of this insulator are distribution and transmission lines, isolators, transformer bushings, fuse units, plugs, and sockets.

B. Solid Organic Insulator: Epoxy Resins
Ex: Resins (polymers)

Resins are-organic substances with a very high molecular weight. They are available in nature as well as artificially made. For an electrical insulating purpose, the natural resins these days have been replaced by synthetic resins. Synthetic resins are synthetic polymers sometimes called plastics and form an important group of insulating materials.
Resins can be classified on the basis of their behavior under heat, as *thermoplastic resins* and *thermosetting resins*.

The different resins are

- Natural resins
- Polyethylene, Polystyrene, Polyvinyl chloride (P.V.C)
- The Acrylic Resins (Polymethyl methacrylate)
- Polytetrafluoroethylene (Teflon), Polyamide Resins (Nylons)

- Resins derived from Cellulose
- Polyester Resins
- **Epoxy Resins**
- Phenolic Resins
- Silicon Resins

Epoxy Resin Preparation

Epoxy resins belong to the group of **thermosetting** insulating materials. Typical epoxy resins are obtained from the alkaline condensation of epichlorohydrin with dioxydiphenyl propane. Such polymers contain the reactive epoxy group. The commercial epoxy resins include Araldite, Debeckote, Epikot, etc.

Properties

- They possess excellent electrical and mechanical properties.
- Dielectric constant and loss tangents of such materials are 2.5-3.8 and 0.003-0.03, respectively, a typical value of resistivity being 10^{13}ohm-cm.

Advantages

The advantages of the polymer insulator are

- Compare to porcelain and glass insulator the polymer insulator is very lightweight
- Installation cost is low
- Tensile strength is higher than porcelain
- Better performance

Disadvantages

The disadvantage of the polymer insulator is if there is any unwanted gap between weather shed and core their moisture may enter.

Applications

- They are ideally suitable for casting of insulators, bushings etc for high voltages.
- They are also used to produce laminated and insulating varnishes.
- Epoxy resins are surely superior to all other plastics and resins. There is hardly any industry in which these resins are not used. They find applications in electrical and electronic devices, in space satellites, in supersonic aircraft, in oil wells, stained glass window, on roads and bridges and in computers.
- In switchgear, they are fully incorporated in the 5-30 kV range. In bushings, they are used above 15 kV. They are also used in transformers and busbars.

B. Liquid Insulator: Transformer Oil

Transformer oil is used in oil-filled electrical power transformers to insulate, stop arcing and corona discharge, and to dissipate the heat of the transformer (i.e. act as a coolant).

- **Transformer oil** (also known as insulating oil) is a special type of oil which has excellent electrical insulating properties and is stable at high temperatures.

- Transformer oil is also used to preserve the transformer's core and windings – as these are fully immersed inside the oil.
- Another important property of the insulating oil is its ability to prevent oxidation of the cellulose-made paper insulation. The transformer oil acts as a barrier between the atmospheric oxygen and the cellulose – avoiding direct contact and hence minimizing oxidation.
- The level of transformer oil is typically measured using a MOG (Magnetic Oil level Guage).

Production of Transformer Oil

- Transformer oil is normally obtained by fractional distillation and followed through crude petroleum.
- Transformer oil is hydrocarbon product, mainly oil contains napthanic, parrafinic and aromatics.
- The crude oil which is burried from earth crust subjected in to the following sequence of operations. Distillation-Acid treatment-Neutralization-Water wash-Hot air blowing.
- After the hot filtration operation, transformer oil is ready for filling the transformers.

Transformer Oil Types

There are two main **types of transformer oil** used in transformers

1. Paraffin based transformer oil
2. Naphtha based transformer oil

- Naphtha oil is more easily oxidized than paraffin oil. But the product of oxidation – i.e. sludge – in the naphtha oil is more soluble than the sludge from the paraffin oil. Thus sludge of naphtha-based oil is not precipitated in the bottom of the transformer. Hence it does not obstruct convection circulation of the oil, means it does not disturb the transformer cooling system.
- Although Paraffin oil has a lower oxidation rate than Naphtha oil, the oxidation product (sludge) is insoluble and precipitated at the bottom of the tank. This sludge acts as an obstruction to the transformer cooling system.
- Another problem with paraffin-based oil that the dissolved waxes inside of it can lead to a high pour point. Although this is not an issue in warmer climate conditions (such as India).

Despite the disadvantages mentioned above, paraffin-based oil is still commonly used in many countries (such as India) due to its high availability.

Transformer oil requirements

- Chemically stable to ensure minimum oxidation at higher operating temperatures.
- Low water Content to keep its dielectric strength
- High specific heat
- High thermal conductivity

- Low Density
- Non Toxic / Non PCB to avoid pollution problems.
- Good Arc quenching properties
- Simple to produce and cost is reasonable

Functions of Transformer Oil

To provide dielectric strength of the transformer insulation system.

- To provide efficient cooling.
- To protect the transformer core and coil assembly from chemical attack.
- To prevent the build up of sludge in the transformer.

Generally transformer oil is also known as insulating oil is oil that remains durable even at high temperature. Transformer oil does two major functions that is, it is liquid insulation in electric power transformer and secondly it consumes heat generated by transformer and serves as coolants.

Transformer Oil Properties

Some specific properties of insulating oil should be considered to determine the serviceability of the oil.

The properties (or parameters) of transformer oil are:

1. Electrical properties: Dielectric strength, specific resistance, dielectric dissipation factor.
2. Chemical properties: Water content, acidity, sludge content.
3. Physical properties: Interfacial tension, viscosity, flash point, pour point.

1. Electrical Properties of Transformer Oil:

a. Dielectric Strength of Transformer Oil

- The **dielectric strength of transformer oil** is also known as the breakdown voltage (BDV) of transformer oil. Breakdown voltage is measured by observing at what voltage, sparking strands between two electrodes immersed in the oil, separated by a specific gap.
- A low value of BDV indicates presence of moisture content and conducting substances in the oil. Minimum **breakdown voltage of transformer oil** or **dielectric strength of transformer oil** at which this oil can safely be used in transformer, is considered as 30 KV.

b. Specific Resistance of Transformer Oil

- The Resistivity of the insulating oil must be high at room temperature and also it should have good value at high temperature as well.
- That is why specific resistance or resistivity of transformer oil should get measured at 27^{o}C as well as 90^{o}C. Minimum standard specific resistance of transformer oil at 90^{o}C is 35×10^{12} ohm–cm and at 27^{o}C it is 1500×10^{12} ohm–cm.

c. Dielectric Dissipation Factor of Tan Delta of Transformer Oil

- Dielectric dissipation factor is also known as loss factor or **tan delta of transformer oil**. If the loss angle is small, then the resistive component of the current I_R is small which indicates a high resistive property of the insulating material. High resistive insulation is a good insulator. Hence it is desirable to have loss angle as small as possible. So we should try to keep the value of tanδ as small as possible. The high value of this tanδ is an indication of the presence of contaminants in transformer oil.
- Hence there is a clear relationship between tanδ and resistivity of insulating oil. If the resistivity of the insulating oil gets decreased, the value of tan-delta increases

and vice verse. So both resistivity test and **tan delta test of transformer oil** are generally not required for the same piece of the insulator or insulating oil.

- In one sentence it can be said that tanδ is a measure of the imperfection of dielectric nature of insulation materials like oil.

2. Chemical properties of Transformer Oil:

a. Water Content in Transformer Oil

- Moisture or **water content in transformer oil** is highly undesirable as it affects the dielectric properties of the oil adversely.
- The water content in oil also affects the paper insulation of the core and winding of a transformer. Paper is highly hygroscopic. Paper absorbs the maximum amount of water from oil which affects paper insulation property as well as reduced its life. But in a loaded transformer, oil becomes hotter, hence the solubility of water in oil increases.
- As a result, the paper releases water and increase the **water content in transformer oil**. Thus the temperature of the oil at the time of taking a sample for the test is critical. During oxidation, acids get formed in the oil the acids give rise to the solubility of water in the oil. Acid coupled with water further decompose the oil forming more acid and water. This rate of degradation of oil increases. We measure the water content in oil as ppm (parts per million unit).
- The water content in oil is allowed upto 50 ppm as recommended by IS–335(1993). The accurate measurement of water content at such low levels requires very sophisticated instrument like Coulometric Karl Fisher Titrator.

b. Acidity of Transformer Oil

- Acidic transformer oil is a harmful property.
- If oil becomes acidic, the water content in the oil becomes more soluble in the oil. The acidity of oil deteriorates the insulation property of paper insulation of winding.
- Acidity accelerates the oxidation process in the oil. Acid also includes rusting of iron in the presence of moisture.

3. Physical Properties of Transformer Oil

a. Inter Facial Tension of Transformer Oil

- Interfacial tension between the water and oil interface is the way to measure the attractive molecular force between water and oil.
- Interfacial tension is exactly useful for determining the presence of polar contaminants and oil decay products.
- Good new oil generally exhibits high interfacial tension. Oil oxidation contaminants lower the IFT.

b. Flash Point of Transformer Oil

- **Flash point of transformer oil** is the temperature at which oil gives enough vapors to produce a flammable mixture with air. This mixture gives momentary flash on the application of flame under standard condition.
- Flashpoint is important because it specifies the chances of fire hazard in the transformer. So it is desirable to have a very high **flash point of transformer oil**. In general it is more than 140^o(>10^o).

c. Pour Point of Transformer Oil

- It is the minimum temperature at which oil starts to flow under standard test condition. Pour point of transformer oil is a valuable property mainly at the places where the climate is icy.
- If the oil temperature falls below the pour point, transformer oil stops convection flowing and obstruct cooling in a transformer. Paraffin-based oil has a higher value

of pour point, compared to Naphtha based oil, but in India like country, it does not affect the use of Paraffin oil due to its warm climate condition.

- Pour Point of transformer oil mainly depends upon wax content in the oil. As Paraffin-based oil has more wax content, it has higher pour point.

d. Viscosity of Transformer Oil

- The **viscosity of transformer oil** can be said that viscosity is the resistance of flow, in normal condition. Resistance to flow of transformer oil means obstruction of convection circulation of oil inside the transformer.
- Good oil should have a low viscosity so that it offers less resistance to the conventional flow of oil thereby not affecting the cooling of a transformer.
- Low **viscosity of transformer oil** is essential, but it is equally important that the viscosity of oil should increase as less as possible with a decrease in temperature. Every liquid becomes more viscous if the temperature decreases.

C. Gas Insulator: SF_6

Introduction

- Sulphur hexafluoride is an inorganic gas made up of sulphur and fluorine.
- Sulphur hexafluoride is one of the most stable gases known.
- Sulphur hexafluoride is a very dense gas so it will mainly reside in the lowest layers of air. Exposure will be primarily occupational.
- Sulphur hexafluoride is a weaker eluent than carbon dioxide and is difficult to obtain in adequate purity.
- It provides high dielectric strength and excellent arc-quenching properties.
- The high heat absorbing ability makes sulphur hexafluoride a strong greenhouse gas with a CO_2 equivalent contribution to the global warming potential.

Manufacturing of SF_6 Gas

- SF6 gas is commercially manufactured by the reaction of fluorine (obtained by electrolysis) with sulfur.

$$S + 3F_2 = SF_6 + 262\ KCal$$

- During process of producing of this gas, other byproducts like SF_4, SF_2, S_2F_2, S_2F_{10} are also produced in small percentages. Not only these byproduct, impurities like air, moisture, and CO_2 are also present in the gas, during production. All these byproducts and impurities are filtered at different stages of purification to get the pure and refined final product.

Properties

SF_6 – an excellent insulating and quenching gas

and it is

- Colourless and odourless
- 5 times heavier than air
- Temperature-resistant up to 500 °C
- Chemically stable
- Non-toxic
- Excellent dielectric properties
- Non-inflammable
- Outstanding arc quenching properties

Applications

- **Indispensable in energy transmission and distribution**

  Because of its dielelectric strength and excellent insulating properties, SF_6 has been used as an insulating gas for medium and high voltage components for many years. Its excellent arc quenching properties (100 times faster than air) has made it suitable as a proven medium in encapsulated medium and high voltage switchgear for decades. Thus, commonly used in electrical switchgear, transformers and substations as an electrical insulation, arc quenching and cooling medium

- **Use in other industry sectors**
  - Moreover, SF_6 gas is also used in other industries such as semi-conductor industry, in display and micro-technology where it mainly serves as etching gas for the production of ultra-fine structures, the so-called "wafers".
  - In medical technology sulphur hexafluoride is for example used for ultrasonic testing and in ophthalmology. SF_6 is also used in X-ray equipment, radar systems, particle accelerators and electron microscopes.

HIGH RESISTIVITY MATERIALS

RESISTANCE

It is the measure of a material that how much current is opposes. The SI unit is Ω (ohm).

$$R = \rho \frac{L}{A}$$

ρ → Resistivity
L → Length
A → Area of cross section.

Resistivity / specific resistance is a properties of a material to oppose current and is fixed for a material. SI unit is ohm metre.

CLASSIFICATION :

* Low Resistivity / High conducting materials
  Eg: Cu, Al, Ag, Au
* High Resistivity
  (or) Low conducting material
  Eg: Nichrome, Tungsten, Carbon etc.

Factors Influencing Electrical Resistivity of a material

- → Temperature
- → Alloying
- → Mechanical stressing
- → Age hardnening
- → cold working

Temperature:

The resistivity of the metals increases with increase in Temperature. The change in resistivity of material with temperature is given by

$$\rho_{t_2} = \rho_{t_1} [1 + \alpha (t_2 - t_1)]$$

→ ρ_{t_1} → Resistivity of material at temperature t_1°c (Room temp)

→ ρ_{t_2} → Resistivity of material at temperature t_2°c [Elevated temp]

→ α_1 is the temperature co-efficient of resistance of material at t_1

Metals have +ve temperature co-efficient of resistance. Several metals exhibit zero resistivity at Tc (Critical temp). This phenomenon is called as super conductivity.

The resistivity of semiconductors and insulators decreases with increases in temperature, and hence possess -ve temperature coefficient of resistance.

Alloying:

Mixture of 2 (or) more metals.

Alloying is a solid solution of 2 or more metals. Alloying is done to enhance the properties of metal. The atomic structure of alloy is irregular when compared to pure metals.

The electrical resistivity increases with increase of alloy content. Even the impurity of low resistivity material will increases the resistivity of pure metal.

For eg: The impurity of silver added to copper will increase the resistivity of copper drastically.

Mechanical Stressing

It develops localized strains in the crystal structure of the material and hence creates hindrance to flow of electrons/current, which results in an increase in the resistivity of the material.

To remove the strain, annealing is done which reduces the resistivity of material.

For eg, the resistivity of hard drawn copper is more as compared to annealed copper.

Age Hardening / Precepitation Hardening :

It is a heat treatment process to increase the hardness of alloy. It also increases the yield strength and permanent deformation by external forces.

In this process alloys are kept at elevated temperature for hours and as a result solid impurities / precipitate is formed

These solid impurities distrubs the flow of electrons and hence resistivity increases.

Cold Working

This process is done to strengthen the metal and improve physical property by changing its shape and size without heating. Here mechanical stress is used to cause a permanent change to metal instead of heat.

Cold working distrubs the crystal structure which interupts the flow of electrons and hence resistivity increases.

HIGH RESISTIVITY MATERIALS :

CONSTANTAN :

Constantan is an alloy of copper and Nickel. Constantan is the oldest and still the most widely used alloy. It is also called as Eureka, Advance and Ferry.

It has a low thermal variation of its resistivity, which is constant over a wide range of temperatures.

Composition

Cu (copper) - 55%

Ni (Nickel) - 45%

Characteristics :

It is known as the most versatile because of its special characteristics some of them are

-> High specific heat resistance
-> Negligible temperature co-efficient
-> Highly ductile
-> Resistant to corrosion
-> Easily soldered and moulded.

Properties :

Appearance - Silver white Malleable alloy
Solubility in water - Insoluble
Odour - Odourless
Density - 8.89 g/cm^3

Electrical resistivity - 4.9×10^{-7} Ωcm
Tensile Strength - 455 to 860 mpa
Maximum working temp: 400 - 450°C

APPLICATIONS :

Temperature Measurement :

It develops high thermal EMF. when coupled with metals such as copper, iron and chromel and hence, It is used for formation of ~~temperature~~. thermocouple.

Heavy duty Industrial Rheostats :

It has high specific heat resistance and good ductility and hence used as an alloy for electric motor starter resistance and heavy duty industrial rheostats.

Wire wound precision Resistors :

Owing to its negligible temperature co-efficient & high resistance, it is used in precision resistors, volume control devices and temperature stable potentiometers.

Molybdenum Disilicide [$MoSi_2$]

$MoSi_2$ a refractory metal silicide is mainly used as a heating element. It is a special material that has the properties of both ceramic and metallic materials.

-> It withstands corrosion and oxidation, like ceramic material and has a low thermal expansion. And it also has good thermal and electrical conductivity like matallic material.

-> It is a high density material consisting of Molybdenum disilicide and self-forming glaze of silicide dioxide [corrosion resistance].

-> Thermal shock doesnot have any effect on the element and it can withstand many years of service because of its strength.

-> $MoSi_2$ are prepared through pressure assisted sintering methods.

-> Hot extrusion and hot pressing creats basic shapes and are compairitively cheaper.

-> Hot isotatic pressing creates intricate shapes with even density and grain structures but the process is expensive.

PROPERTIES:

Appearance - Grey metallic with tetragonal crystal structure.

Solubility - Insoluble in most acids and alkali but soluble in Nitric acid and hydrofluoric acid.

Density - 6.23 - 6.31 g/cm^3

Electrical Resistivity - 3.5×10^{-7} Ω cm

Tensile strength - 185 MPa

High Melting point - ($\simeq$ 2030°C)

-> It posses high temperature oxidation resistance as it forms a thin coherent adherent and protective silica layer.

-> Pure $MoSi_2$ has no phase change before it reaches the melting point and has good thermal stability.

-> High thermal conductivity and small thermal expansion co-efficient helps to increase the thermal shock resistance of their products.

-> $MoSi_2$ is not only stable in oxidizing medium but also can be used at high temperature in reducing, neutral, inert and strong corrosive atmosphere such as N_2, CO_2, SO_2 etc.

Limitations :

-> It is brittle at low temperature [low toughness <1000°C]
-> Poor creep resistance at temperature over 1200°C.

Applications :

-> $MoSi_2$ is widely used in electric heating elements and can be applied in high temperature structural parts, thermocouple protection tubes.
-> It is also used as a protective coating on the surface of metal substrate against high temperature and corrosion.
-> It can be used for temperature upto 1800°c in electrical furnaces for production of glass, steel, ceramics.
-> High oxidation resistance and high temperature elasticity makes it a promising material for high temperature applications such as jet engine combustion chambers, missile combustic chambers, gas turbine parts etc.

3. NICHROME

Nichrome is an alloy mainly composed of nickel and chromium. Its most common form consists of 80% Nickel and 20% Chromium. It is chemically called as NiCr. Other types of nichrome contain varying concentration of the two elements. Iron is also a component of this alloy although it is a very small part in the total concentration. The chemical formula in this case becomes NiFeCr.

Nichrome Coil

Some peculiar properties of nichrome are listed below.

- Nichrome is consistently silvery-gray in colour
- It is corrosion-resistant. Upon heating at high temperature the outer layer forms a covering of chromium oxide which acts as a shield to the inner layers and prevents

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 ~~polagi-~~ polarization is independent of the frequency and temperature.

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

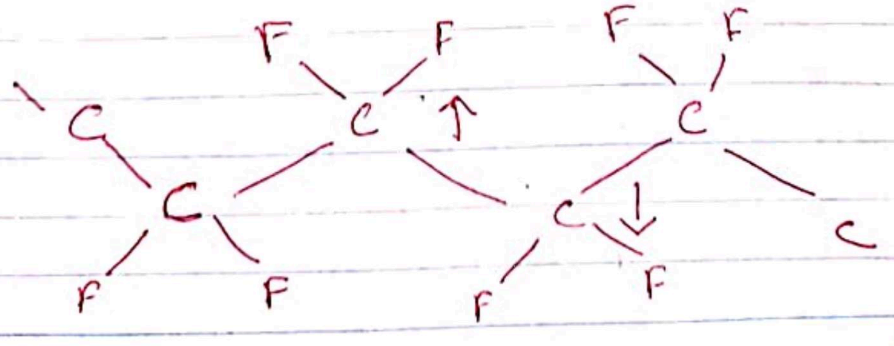
→ For example: Aromatic rings, sulfur, bromine and Phenol increase the relative permittivity because they are highly polarizable.

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

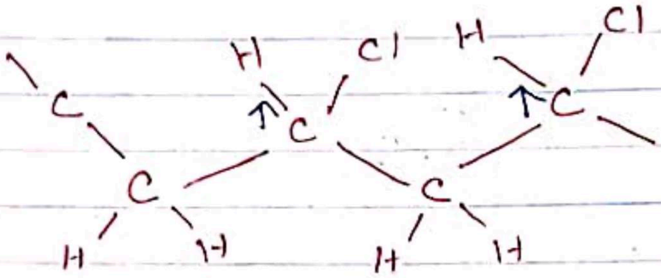
→ Chain geomentry determines whether a polymer is polar (or) non-polar.

→ 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 cancelldeach 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 slighly 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