Electrical Properties of Polymers:-

Response of polymers to electric field. applied is them

- Insulators or dielectrics
  Generally backbone chain Saturated polymers
  PVC, PE, PS
- Electronic conductors
  polymers having conjugated π-bonds [alternative double and single bonds] in their backbone chain
- Ionic conductors (polymer salt complexes)
  Inorganic salt dissolved in a polymer host.

Dielectrics / ~~Insulator~~ :-

Electrical insulator

Dielectric :- A type of insulator that can be polarized by an electric field.

Polarization (charge separation) :-

When an electric field is applied, electron cloud displacement occur in molecules, leading to separation of positive and negative charges. Thus molecules behave like electric dipoles. ~~These are three modes~~ This is called polarization.

These are three modes of polarization:-

Electronic polarization :- → slight displacement of electrons with respect to the nucleus.

Atomic polarization :- → distortion of atomic position in a molecule or lattice. (less significant in polymers)

Orientation polarization :- → In ~~orientation polar~~ polar molecules the permanent dipoles tend to be aligned by the electric field.

A high field, about 10^5 V/mm is required to produce significant orientation of dipoles. Thus in most polymers, orientation polarization is not significant

The ability to polarize under an applied field or the extent to which a material concentrates electric flux is termed as permittivity.

Dielectric constant:-

The relative permittivity of a material under an applied electric field i.e, ratio of permittivity in the material to permittivity in vacuum is called as dielectric constant.

Dielectric strength or dielectric breakdown strength :-

The maximum electric field that a material can withstand without losing its insulating behaviour i.e., the maximum voltage required to produce dielectric breakdown. (Unit is Volts per unit thickness). Most polymer dielectrics have Dielectric strength around 100 kV/cm

Polymer dielectrics:-

Polymeric dielectrics with low and high dielectric constant are essential in electronic industries.

* Polar polymers (high diectric constant) :-

They are used for energy storing applications as in capacitors.

Insulating polymers with low dielectric constant :-

Used for electrical insulations. In electronics, elochical insulations are provided by adhesives as encapsulation materials.

For power transmission, the cable materials are made using insulating polymers. The polymers are, cross linked polyethylenes. Polymers used as insulation should have high dielectric breakdown strength, especially in the case of high voltage direct current power transmission cables.

Dielectric breakdown mechanisms in insulating polymers.

The most important breakdown mechanisms for polymers are avalanche, thermal and electromechanical breakdown.

Avalanche breakdown is divided into three classes, namely fast avalanches, erosion breakdown or electrical treeing, and water treeing..

(1) Avalanee breakdown:-

When electric field is applied, the accelerated electrons can cause ionization in the insulating material during impact and generate more free electrons. The generated electrons also may get accelerated and cause impact ionization. Thus the polymer will undergo rapid breakdown due to an increased amount of highly energetic and mobile electrons. This rapid formation of a conduction path through the insulator is called avalanche breakdown.

At high electric field fast avalanche breakdown occurs.

The breakdown occurs in the polymer in less dense regions or regions that contain voids.

(a) Gas discharge or partial discharge

If these are voids filled with gases in the polymer, ionization of the gases can occur even at lower voltages and initiate an avalanche of energetic electrons.

(b) Electrical treeing or erosion breakdown:-

Partial discharges damage the polymer locally and the degradation of the polymer occurs at low electric fields and grows slowly over time creating conduction paths just like growing trees. This is called electrical treeing.

Electric tree.

degradation in polymer leading to dielectric breakdown.

(c) Water treeing :-

Water can degrade insulation materials under high electric field conditions. This is pronounced in cables that are used under ground. Water diffuses into the amorphous regions of the polymer and creates defects.

At high electric fields the avalanche breakdown occurs degrading the the polymer at the regions where water diffuses. This degradation occurs very slowly. leading to dielectric breakdown.

(2) thermal breakdown :-

This occurs when thermal losses cannot be dissipated fast enough and causes elevated temperatures that damages the polymer, creating defects for breakdown to occur.

(3) Electromechanical breakdown :-

Electromechanical breakdown depends on the mechanical strength of the polymer. and is responsible for the lower dielectric strength at elevated temperatures. When a voltage is applied between electrodes, the polymer can be compressed by the electrostatic force. This compressive stress may degrade the polymer creating defects which may lead to dielectric breakdown.