pielectric Breakdown



Dielectric Breakdown of Gases

Average velocity of the charge carrier in a gas

where

 μ = Mobility of the charge carrier

E = Applied electric field

Condition of Ionization

$$E.\lambda = V_i$$

where

 $V_i = Ionization potential$

 λ = Mean free path

Electron ionization coefficient (Townsend breakdown process)

$$\alpha = \frac{1}{\lambda} e^{-(V_i/\Xi \lambda)}$$

where.

 α = Townsend's first ionization coefficient or ionization coefficient of electrons

λ « Pressureat constant temperature

$$n_{d} = n_{o} e^{\alpha d}$$

n_d = Number of electrons striking the anode per second

Secondary ionization coefficient

$$n = \frac{n_0 e^{nd}}{1 - \gamma \left(e^{nd} - 1\right)}$$

where.

n = Total number of electrons arriving at the anode

 n_0 = Number of primary photoelectrons per second emitted from cathode

d = Distance between anode and cathode

γ = Townsend's second ionization coefficient

Townsend criterion for spark breakdown

$$\gamma \left(e^{\alpha d} - 1 \right) = 1$$

Note:

The avalanche breakdown develops over relatively long period of time over 1 μs and does not generally occur with impulse voltage.

Dielectric Breakdown of Liquids

Colloidal theory

$$\frac{\epsilon - \epsilon'}{\epsilon + 2 \epsilon'} \cdot r^3 E^2 \ge \frac{kT}{4}$$

where

r = Radius of insulating particle

∈ = Permittivity of insulating material

∈' = Permittivity of oil
E = Field strength

k = Boltzmann's constant

T = Absolute temperature

Bubble theory

$$E_i = \frac{3 \in E_0}{2 \in +1}$$

where

 $\mathsf{E}_\mathsf{i} = \mathsf{Electric}$ field in a gas bubble which is immersed in a liquid

∈ = Permittivity of liquid

 E_0 = Electric field in the liquid in absence of the bubble

· Break down due to liquid globules

where

E = Critical field at which the globule looses its stability

∈₁ = Permittivity of the liquid medium

 σ = Pressure due to surface tension, dyne/cm

R = Radius of globule

Dielectric Breakdown of Solids

Theory of Von Hippel

$$E_c = \frac{2\pi^2 vem}{h} \left[\frac{1}{n_w^2} - \frac{3}{e} \right] V/m$$

where

E_o = Critical field at which the breakdown occurs

v = Optical frequency of lattice

n_ = The index of refraction for infinite wave length

∈ = Dielectric constant

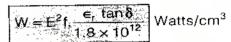
m = Effective mass of electron

e = Electron charge

h = Plank's constant

Thermal breakdown

· Heat generated per unit volume in unit time



where

E = Uniform electric field

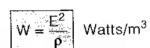
f = Frequency of applied voltage

 δ = Loss angle

€, = Relative permittivity

For direct voltage

Power dissipated per volume is given by



where p = Resistivity of the insulation, ohm-m

Power loss



where $\in tan\delta = Loss$ factor of the dielectric at a temperature

 ϵ' tan δ' = Loss factor of the dielectric at the initial temperature

T'

c = Coefficient depending on the properties concerned