① # Dielectric properties of solid.

~~Polarization~~ :>

Dielectric Medium

Dielectric are non-metallic materials of high specific resistance ρ. negative temperature coefficient of resistance $(-\alpha)$, Large insulation resistance

Such dielectric materials are electrically non-conducting materials such as glass, ebonite, mica, wood and paper. Thus all dielectric materials are insulating materials.
But the main difference between dielectric and an insulator lies in their applications.

So if the main function of non-conducting material is to provide insulation (electrical) then they are called as insulator

On other hand if the main function of non conducting material is to store electrical charges they are called as dielectrics

Fundamental properties of dielectrics.

1. Generally the dielectrics are non-metallic materials of high resistivity
2. They have a very large energy gap (more than 7 eV)
3. All the electrons in a dielectric are tightly bound to their parent nucleus.

Dipole moment ($\vec{P}$)

1. The product of the magnitude of the charge (q) and distance between two charges (d) is called as dipole moment
2. Dipole moment $P = qd$ (Coulomb-metre)

Permittivity (ε)

1. The permittivity represents the dielectric property of a medium. It indicates easily polarizable nature of materials. Its unit is farad/metre.

Dielectric constant (ε_r).

1. A dielectric characteristic of a material is determined by its dielectric constant. It is a measure of polarisation of the dielectric.

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Some Definitions:

It is the ratio between absolute permitivity of the medium (ε) and permitivity of free space. (ε_0).

Dielectric Constant = $\dfrac{\text{Absolute permitivity } (\varepsilon)}{\text{Permitivity of free space } (\varepsilon_0)}$

$$\varepsilon_r = \varepsilon/\varepsilon_0$$

Polarization

① The process of producing electric dipoles inside inside the dielectric by the application of an external electrical field is called polarization in dielectrics

Polarisability (α).

It is found that the average dipole moment field (E)

$\mu = \alpha E$

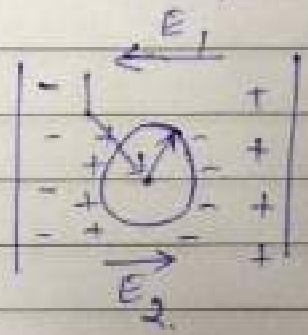
where $\alpha = \dfrac{\mu}{E}$

Polarisability is defined as the ratio of average dipole moment to the electrical field applied. Its unit is farad m^2

Local field in a Dielectric:

The interaction of one dipole with the other dipole is concerned. The interaction of one dipole with the other dipoles lying inside the cavity is however to be treated microscopically, which is necessarily since the nature of the medium very close to the dipole should be taken into account.

$$E_{Loc} = E_0 + E_1 + E_2 + E_3$$



E_0 is the external field. E_1 is the depolarization field, that is the field due to polarisation charges lying on the surface of the Lorentz sphere.

E_3 is field due to field due to other dipoles lying within the sphere

Lorentz field E_2

$$E_2 = \frac{4\pi}{3} P$$

$E_3 = 0$ If all the atoms may be replaced by point dipoles parallel to each other

(5)

Thus $E_{local} = E_0 + E_1 + \frac{4\pi P}{3}$

$$E_{total} = E + \frac{4\pi P}{3} \quad \text{— (1)}$$

called Lorentz relation

6 Clausius Mossotti equation relation

Polarization, $P = N(\alpha_o + \alpha_i + \alpha_e)E_i$

$P = N\alpha_e \vec{E_i}$

E_i = Local field.

$= \left(\vec{E} + \frac{\vec{P}}{3\epsilon_0}\right)$

$\vec{E}$ → externally applying field.

$\vec{P} = N\alpha_e\left(\vec{E} + \frac{\vec{P}}{3\epsilon_0}\right)$

$\vec{P} = N\alpha_e E + N\alpha_e \frac{\vec{P}}{3\epsilon_0}$

$P\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right) = N\alpha_e E$

we know displacement vector

$\vec{D} = \epsilon_0\vec{E} + \vec{P}$

$\vec{P} = \vec{D} - \epsilon_0\vec{E}$

$= \epsilon_0\epsilon_r\vec{E} - \epsilon_0\vec{E}$

$\vec{P} = \epsilon_0(\epsilon_r - 1)\vec{E}$

$\vec{P} = \frac{N\alpha_e\vec{E}}{\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right)}$

$\epsilon_0(\epsilon_r - 1)\vec{E} = \frac{N\alpha_e\vec{E}}{\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right)}$

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$$\epsilon_0(\epsilon_r - 1) = \frac{N\alpha_e}{\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right)} \quad \longleftarrow (1)$$

Adding $3\epsilon_0$ b/s

$$\epsilon_0(\epsilon_r - 1) + 3\epsilon_0 = \frac{N\alpha_e}{\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right)} + 3\epsilon_0$$

$$\epsilon_0(\epsilon_r + 2) = \frac{\cancel{N\alpha_e} + 3\epsilon_0 - \cancel{N\alpha_e}}{\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right)}$$

$$\epsilon_0(\epsilon_r + 2) = \frac{3\epsilon_0}{\left(1 - \frac{N\alpha_e}{3\epsilon_0}\right)} \quad \longrightarrow (2)$$

$$\frac{\epsilon_0(\epsilon_r - 1)}{\epsilon_0(\epsilon_r + 2)} = \frac{\frac{N\alpha_e}{\cancel{1 - \frac{N\alpha_e}{3\epsilon_0}}}}{\frac{3\epsilon_0}{\left(\cancel{1 - \frac{N\alpha_e}{3\epsilon_0}}\right)}} = \frac{N\alpha_e}{3\epsilon_0}$$

$$\Rightarrow \frac{\epsilon_r - 1}{\epsilon_r + 2} = \left(\frac{N\alpha_e}{3\epsilon_0}\right)$$

C-M- equation

For multiple dielectric medium C-M equation changes to

$$\frac{\epsilon_r - 1}{\epsilon_r + 2} = \sum_i \frac{N_i(\alpha_e)_i}{3\epsilon_0} \quad \text{for multiple dielectric}$$

Reference books:

1. Solid state physics by R.K. Puri & V.K. Babbar
2. Rudiments of materials by S.O. Pillai and Mrs Sivakami Pallai (author)
3. Solid state physics by Rita John
4. Introduction to solid state physics by C. Kittel