

Mobility and Electrical conductivity of Intrinsic

Semiconductors:-

The electrical conductivity (σ) of an intrinsic semiconductor is,

$$\sigma_i = n_i e (\mu_e + \mu_h) \quad \text{--- (1)}$$

n_i \rightarrow intrinsic carrier concentration,

e \rightarrow charge of the electron

μ_e \rightarrow mobility of electrons

μ_h \rightarrow mobility of holes

\therefore Substitute the value of n_i in (1):

$$\sigma_i = 2e \left(\frac{2\pi k_B T}{h^2} \right)^{3/2} (m_h^* m_e^*)^{3/4} e^{-E_g/2k_B T} (\mu_e + \mu_h)$$

Electrical conductivity depends on the band gap and mobility of charge carriers.

But $(\mu_e + \mu_h)$ has a temperature dependence and it will cancel with $T^{3/2}$ term.

$$\text{So, } \sigma_i = C e^{-E_g/2k_B T} \quad \text{--- (2)}$$

Taking log on both sides,

$$\log \sigma_i = \log C - (E_g/2k_B T)$$

If a plot is made

between $\log \sigma_i$ and $1/T$

we get straight line here

σ_i increases with temperature.



Determination of band gap energy:-

We know, $\sigma_i = C e^{-E_g/2k_B T}$ — (1)

We know resistivity $\rho_i = \frac{1}{\text{Conductivity } (\sigma_i)}$

$$\therefore \rho_i = \frac{1}{C} e^{E_g/2k_B T} \quad \text{--- (2)}$$

We know resistance per unit area per unit length,

$$\text{(i.e.) } \rho_i = \frac{R_i a}{l} \quad \text{--- (3)}$$

$R_i \rightarrow$ resistance

$a \rightarrow$ cross sectional area

$l \rightarrow$ Length

Equating ^{equation} (2) and (3), we get,

$$\frac{R_i a}{l} = \frac{1}{C} e^{E_g/2k_B T}$$

$$R_i = \frac{l}{aC} e^{E_g/2k_B T}$$

$$R_i = C_1 e^{E_g/2k_B T} \quad \text{where } C_1 = \frac{l}{aC}$$

Taking \log on both sides,

$$\log R_i = \log C_1 + \frac{E_g}{2k_B T}$$

$$\text{In general, } \frac{\log R_i}{1/T} = \frac{E_g}{2k_B}$$

The resistance can be found using meter bridge or Carey foster bridge.

If a graph is plotted between $1/T$ and $\log R_i$, a straight line is obtained (in figure) with a slope,

$$\frac{dy}{dx} = \frac{E_g}{2k_B}$$

We can calculate band gap E_g ,

$$E_g = 2k_B \left(\frac{dy}{dx} \right) \text{ Joules}$$

