UNIT II

SEMICONDUCTING MATERIALS

CONTENTS

2.7.Carrier transport velocity –Electric field relation

Random motion and mobility

In the absence of electric field the free electron move in all random direction. They collide with each other or with positive ion. Hence the net velocity is zero.

When an electric field is applied electron gain drift velocity V_d.

Drift velocity is directly proportional to electric field (E)

$$V_d \propto E \qquad \Rightarrow \qquad V_d = \mu E$$

μ - proportionality constant called mobility of charge carrier

$$\mu = V_d/E$$

Mobility is defined as the drift velocity per unit electric field. Mobility of electron is greater than that of hole. Drift current density Jn due to electron is the charge flowing per unit area per unit time.

$$Jn = ne\, V_d$$

Electrical conductivity due to electron , $\sigma_n = Jn/E$

$$\sigma_n = (ne\, V_d) / E$$

$$\sigma_n = (ne\, \mu_n E) / E$$

$$\sigma_n = ne\, \mu_n$$

Conductivity due to holes $\sigma_p = pe\, \mu_p$

μ_n = mobility of electron, μ_p= mobility of holes

Total conductivity

$$\sigma = \sigma_n + \sigma_p$$

$$= ne\ \mu_n + pe\ \mu_p$$

$$= e\ (n\ \mu_n + p\ \mu_p)$$

For intrinsic semiconductor

$$n = p = n_i$$

$$\therefore\ \sigma_i = e\ (n_i\ \mu_n + n_i\ \mu_p)$$

$$\therefore\ \sigma_i = e\ n_i\ (\mu_n + \mu_p)$$

2.7.1.Drift and diffusion current

Drift current

Electric current produced by the motion of charge carrier on the application of electric field is called drift current.

When an electric field is applied, the charge carriers drifted towards the positive terminal of the battery, this is known as drift motion.

Drift current density due to the electron $Jn = n\ \mu_n eE$

$$Jp = p\ \mu_p eE$$

Total drift current density $J = Jn + Jp$

$$J = n\ \mu_n eE + p\ \mu_p eE$$

$$J = eE\ (n\ \mu_n + p\ \mu_p)$$

For intrinsic

$$Ji = eEn_i\ (\mu_n + \mu_p)$$

2.7.2.Diffusion current

The charge carriers move from the region of higher concentration to region of lower conscentration. This process is known as diffusion. The current produced by diffusion is known as diffusion current.

Consider a semiconductor with concentration gradient dn/dx

Charge carriers diffuse from higher concentration region to lower concentration region.

Rate of flow of electrons / unit area α dn/dx

$$= - D_n \, dn/dx$$

$-D_n$ – proportionality constant known diffusion coefficient,

Current density J= Rate of flow x charge of Electron

$$Jn = - D_n (dn/dx) (-e)$$

$$Jn = + D_n \, e \, (dn/dx)$$

Rate of flow of holes = $- D_p$ (dp/dx)

Current density Jp= $-e \, D_p$ (dp/dx)

2.7.3.Einstein's relation

Definition:

The relation between the mobility and diffusion coefficient of a semi conductor is known as Einsteins relation

We know that the drift current due to electrons = Jn = $n \, \mu_n Ee$

Diffusion current density = Jn= eD_n (dn/dx))

At equilibrium

Drift current = diffusion

$$n \, Ee = eD_n (dn/dx)) / \mu_n$$

Force on the charge carriers due to the internal field

$$F = eD_n (dn/dx)) / \mu_n \text{---------------(1)}$$

From kinetic theory of gases

$$F = kT \; dn/dx \text{---------------(2)}$$

K- Boltzmann constant

T absolute temperature

From (1) & (2)

$$kT \ dn/dx = eD_n \ (dn/dx)) \ / \ \mu_n$$

$$kT = eD_n / \mu_n$$

$$KT/e = D_n / \mu_n$$

For holes

$$kT / e = D_p / \mu_p$$

there fore

$$D_n / \mu_n = D_p / \mu_p$$

$$D_n / D_p = \mu_n / \mu_p$$

This is known as Einstein's relation