ELECTRONICS DEVICES AND CIRCUITS

Section A

Conducting Materials

OBJECTIVE

DRIFT VELOCITY, COLLISION TIME, MEAN FREE PATH AND MOBILITY

DRIFT VELOCITY

- The drift velocity is the average velocity that a particle, such as an electron, attains due to an electric field. It can also be referred to as axial drift velocity since particles defined are assumed to be moving along a plane.

- In general, an electron will ‘rattle around’ in a conductor at the Fermi velocity randomly. An applied electric field will give this random motion a small net velocity in one direction.

- In a semiconductor, the two main carrier scattering mechanisms are ionized impurity scattering and lattice scattering.

DRIFT VELOCITY

BECAUSE CURRENT IS PROPORTIONAL TO DRIFT VELOCITY, WHICH IS, IN TURN, PROPORTIONAL TO THE MAGNITUDE OF AN EXTERNAL ELECTRIC FIELD, OHM'S LAW CAN BE EXPLAINED IN TERMS OF **DRIFT VELOCITY.**

Microscopic understanding of mobility?

❖How long does a carrier move in time before collision ?

The average time taken between collisions is called as relaxation time, τ (or mean free time)

❖How far does a carrier move in space (distance) before a collision?

The average distance taken between collisions is called as mean free path, l .

Calculation

Drift velocity=Acceleration x Mean free time

$$V_d = \frac{F}{m^*} \times \tau$$

Force is due to the applied field, F=qE

$$V_d = \frac{F}{m^*} \times \tau = \frac{qE}{m^*}\tau$$

$$V_d = \mu E \Rightarrow \mu = \frac{q\tau}{m^*}$$

Calculation

- Calculate the mean free time and mean free path for electrons in a piece of n-type silicon and for holes in a piece of p-type silicon.

$$\tau = ? \qquad l = ? \qquad m_e^* = 1.18\, m_o \qquad m_h^* = 0.59 m_o$$

$$\mu_e = 0.15\, m^2/(V-s) \qquad \mu_h = 0.0458\, m^2/(V-s)$$

$$\tau_e = \frac{\mu_e m_e^*}{q} = 10^{-12}\sec \qquad \tau_h = \frac{\mu_h m_h^*}{q} = 1.54x10^{-13}\sec$$

$$v_{th_{elec}} = 1.08x10^5\, m/s \qquad v_{th_{hole}} = 1.052x10^5\, m/s$$

$$l_e = v_{th_{elec}}\tau_e = (1.08x10^5\, m/s)(10^{-12}s) = 10^{-7}\, m$$

$$l_h = v_{th_{hole}}\tau_h = (1.052x10^5\, m/s)(1.54x10^{-13}\sec) = 2.34x10^{-8}\, m$$