4.8 DRIFT AND DIFFUSION CURRENTS

The flow of charge, i.e current, through a semiconductor material are of two types, namely drift and diffusion. The net current that flows through a PN junction diode also has two components, viz. (i) drift current and (ii) diffusion current.

Drift current When an electric field is applied across the semiconductor material, the charge carriers attain a certain drift velocity v_d, which is equal to the product of the mobility of the charge carriers and the applied electric field intensity, E. The holes move towards the negative terminal of the battery and electrons move towards the positive terminal. This combined effect of movement of the charge carriers constitutes a current known as the *drift current*. Thus the drift current is defined as the flow of electric current due to the motion of the charge carriers under the influence of an external electric field. The drift current density due to the charge carriers such as free electrons and holes are the current passing through a square centimeter perpendicular to the direction of flow. The equation for the drift current density, J_n, due to free electrons is given by

$$J_n = qn\mu_n E \text{ A/cm}^2$$

and the drift current density, J_p, due to holes is given by

$$J_p = qp\mu_p E \text{ A/cm}^2$$

where n = number of free electrons per cubic centimetre
p = number of holes per cubic centimetre
μ_n = mobility of electrons in $\text{cm}^2/\text{V-s}$
μ_p = mobility of holes in $\text{cm}^2/\text{V-s}$
E = applied electric field intensity in V/cm
q = charge of an electron = 1.6×10^{-19} coulomb.

Diffusion current It is possible for an electric current to flow in a semiconductor even in the absence of the applied voltage provided a concentration gradient exists in the material. A concentration gradient exists if the number of either electrons or holes is greater in one region of a semiconductor as compared to the rest of the region. In a semiconductor material, the charge carriers have the tendency to move from the region of higher concentration to that of lower concentration of the same type of charge carriers. Thus, the movement of charge carriers takes place resulting in a current called *diffusion current*. The diffusion current depends on the material of the semiconductor, type of charge carriers and the concentration gradient.

As indicated in Fig. 4.6(a), the hole concentration $p(x)$ in a semiconductor bar varies from a high value to a low value along the x-axis and is constant in the y- and z-directions.

Diffusion current density due to holes, J_p, is given by

$$J_p = -qD_p \frac{dp}{dx} \text{ A/cm}^2$$

Since the hole density $p(x)$ decreases with increasing x as shown in Fig. 4.6(b), dp/dx is negative and the minus sign in the above equation is needed in order that J_p has a positive sign in the positive x-direction.

Diffusion current density due to the free electrons, J_n, is given by

$$J_n = qD_n \frac{dn}{dx} \text{ A/cm}^2$$

where dn/dx and dp/dx are the concentration gradients for electrons and holes respectively, in the x-direction and D_n and D_p are the diffusion coefficients expressed in cm^2/s for electrons and holes, respectively.

Total current The total current in a semiconductor is the sum of drift current and diffusion current. Therefore, for a P-type semiconductor, the total current per unit area, i.e. the total current density is given by

$$J_p = qp\mu_p E - qD_p \frac{dp}{dx}$$

Similarly, the total current density for an N-type semiconductor is given by

$$J_n = qn\,\mu_n\,E + qD_n \frac{dn}{dx}$$