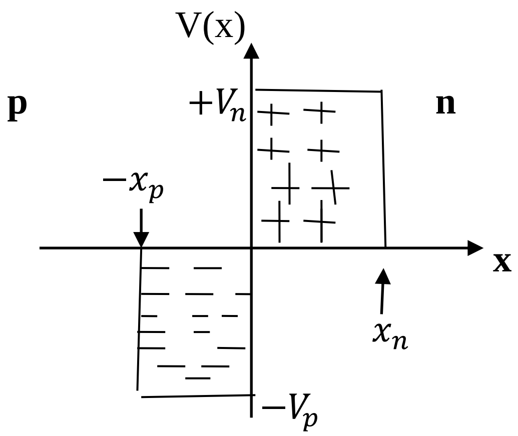
Semester-IV

Unit - CC10

Dr. Bidyut Samanta

Online-1

Height of Potential Barrier across a p-n junction



Due to diffusion of electrons from n-side to p- side and that of holes from p-side to n- side space charge is produced near the junction. Because of space charge variation near the junction an intrinsic potential barrier develops across the junction.

In an open circuited p-n junction net electron current and hole current must be zero separately.

Considering the hole current density in only,

$$J_p = qp\mu_p E - qD_p \frac{dp}{dx} = 0$$

Where E is the built in electric field, μ_p and D_p are mobility and diffusivity of the holes.

Now using Einstein relation : $\frac{D_p}{\mu_p} = \frac{kT}{q}$

We get : $\frac{dp}{dx} = \frac{\mu_p}{D_p} pE = \frac{qE}{kT} p = -\frac{qp}{kT} \frac{dV}{dx}$

Integrating in the space charge region from p-region to n-region ($i.e., from\ -x_p$ to x_n),

$$\int_{p_p}^{p_n} \frac{dp}{p} = -\frac{q}{kT} \int_{-x_p}^{x_n} dV$$

p_p & p_n are hole concentration in the p-side and n-side respectively.

$$\therefore\ ln \frac{p_n}{p_p} = -\frac{q}{kT}(V_n - (-V_p))$$

$$\boxed{\boldsymbol{ln \frac{p_n}{p_p} = -\frac{q}{kT}\left(V_n + V_p\right) = -\frac{q}{kT} V_b} \quad \textbf{....... (1)}}$$

Where V_b is the contact potential barrier or difference.

$$\therefore p_n = p_p e^{-qV_b/kT}$$

At moderate temperatures, practically all the impurity atoms are ionised and equilibrium conc. of holes in the p-side is $p_p = p_{po} = N_a$

$p_{po}\ and\ N_a$ are the equilibrium hole concentration in the p-side and acceptor concentration respectively.

And for electrons in the n-side : $n_n = n_{no} = N_d$

$n_{no} and\ N_d$ are the equilibrium electron concentration in the n-side and donor concentration respectively.

Concentration of minority carrier holes in the n-side is given the mass action law: $p_n = \frac{n_i^2}{n_n} = \frac{n_i^2}{N_d}$

$\therefore$ from equation (1):

$$\boxed{\boldsymbol{V_b = \frac{kT}{q} ln \frac{p_p}{p_n} = \frac{kT}{q} ln \frac{N_a N_d}{n_i^2}} \qquad \textbf{(2)}}$$

The value of $\boldsymbol{V_b}$ for Ge & Si is often in the range 0.5V to 0.7V. It increases with the increase of donor and acceptor impurity concentration.

Now the question is can we measure the potential barrier height at the p-n junction using a voltmeter?

We can’t measure it, because in order to show the reading a small current must flow through the junction which produces Joule heating. Since there is no external source of energy, this heating must cause a simultaneous cooling of the junction. But from the principle of thermodynamics, it is not possible to derive work by cooling a body below its equilibrium temperature. Thus no current can pass through the circuit and voltmeter shows zero reading.