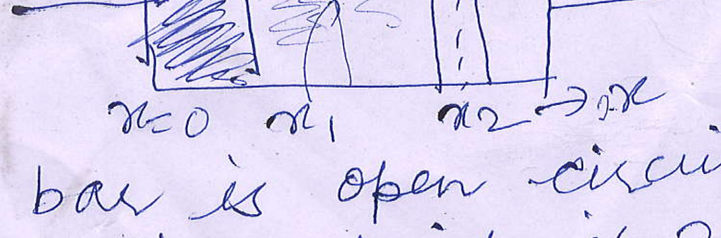
UNIT2 21/9/2020 1

Introduction:
n and p type semiconductors are combined with a special fabrication techniques to form a p-n junction. Such a p-n junction forms a popular electronic device called diode.
Diode is a basic element of a number of electronic circuits ∴ study of diode is important.

POTENTIAL VARIATION IN A CONTINUOUSLY GRADED SEMICONDUCTOR

Consider a p type continuously graded bar i.e. non-uniformly doped. No external voltage is applied ∴ the bar is open circuited and the net current is zero.
But due to non-uniform doping there exists a diffusion current as holes move from high concentration to low concentration. Hence there exists a diffusion current density of J_p

$$J_p = -q D_p \frac{dp}{dx}$$



As bar is open circuited the net current through it is zero. This means there exists one more internal current which is equal to diffusion current but opposite direction to it. This is a drift current flowing in opposite direction to that of diffusion current.

The current density of this current is $J_p = p q \mu_p E$

But drift current cannot exist without a potential difference and the applied voltage to the bar is zero, So externally $E = 0$. This indicates that E required for the circulation of drift current gets generated internally.

This indicates that non-uniform doping of the bar results in the induced voltage

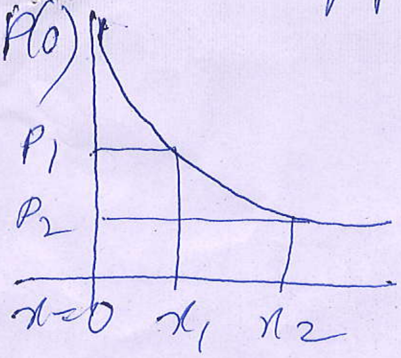
$$-q D_p \frac{dp}{dx} + p q \mu_p E = 0$$

EXPRESSION FOR POTENTIAL DIFFERENCE

To derive the expression for the potential difference between any 2 points of a non-uniformly doped bar consider 2 points at a distance of $x = x_1$ and $x = x_2$.

Let the concentration of holes at $x = x_1$ is $p = P_1$ & concentration at $x = x_2$ is $p = P_2$

There exists a potential difference between x_1 and x_2 which is responsible to circulate drift current equal and opposite to diffusion current



Potential at $x_1 = V_1$ & potential at $x_2 = V_2$

As net current through the bar is zero.

$$\therefore p q \mu_p E = q D_p \frac{dp}{dx}$$

$$\therefore p E = \frac{D_p}{\mu_p} \frac{dp}{dx} \quad \ldots (1)$$

According to Einstein's relation

$$\frac{D_p}{\mu_p} = V_T$$

$$\therefore p E = V_T \frac{dp}{dx}$$

$$\therefore E = \frac{V_T}{p} \frac{dp}{dx} \quad \ldots (2)$$

As $E = -\frac{dV}{dx} \quad \ldots (3)$

$\therefore$ Combining (2) & (3)

$$-\frac{dV}{dx} = \frac{V_T}{p} \frac{dp}{dx}$$

$$dV = -\frac{V_T}{p} dp$$

$$\int_{V_1}^{V_2} dV = -V_T \int_{p_1}^{p_2} \frac{1}{p} dp$$

$$\therefore V_2 - V_1 = -V_T \left[\ln p\right]_{p_1}^{p_2}$$

$$\therefore V_2 - V_1 = -V_T \ln \frac{p_2}{p_1}$$

$$\therefore V_{21} = V_T \ln \frac{P_1}{P_2} \quad \cdots (4)$$

V_{21} is the potential difference between concentration P_1 and P_2

$\therefore$ Potential difference depends on the concentration and not distance between x_1 and x_2.

$$\ln \frac{P_1}{P_2} = \frac{V_{21}}{V_T}$$

$$\therefore \frac{P_1}{P_2} = e^{\frac{V_{21}}{V_T}}$$

$$\left.\begin{aligned} P_1 &= P_2 e^{\frac{V_{21}}{V_T}} \\ P_2 &= P_1 e^{-\frac{V_{21}}{V_T}} \end{aligned}\right\} \text{for p type Semiconductor}$$

Similarly for n type semiconductor bar.

$$\left.\begin{aligned} n_1 &= n_2 e^{-\frac{V_{21}}{V_T}} \\ n_2 &= n_1 e^{\frac{V_{21}}{V_T}} \end{aligned}\right\} n \text{ type.}$$

$$\therefore \cancel{P_2} \, P_1 n_1 = P_2 e^{\frac{V_{21}}{V_T}} \times n_2 e^{-\frac{V_{21}}{V_T}}$$

$$\therefore n_1 P_1 = n_2 P_2$$

The product of the concentration of electrons & holes is always constant. This proves the law of mass action