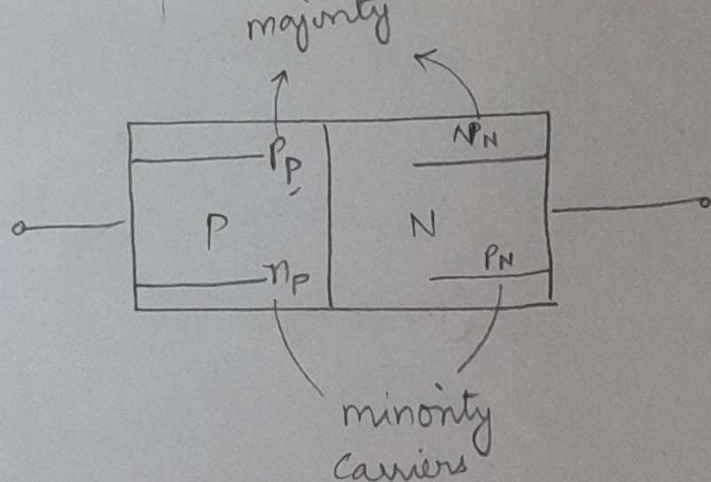
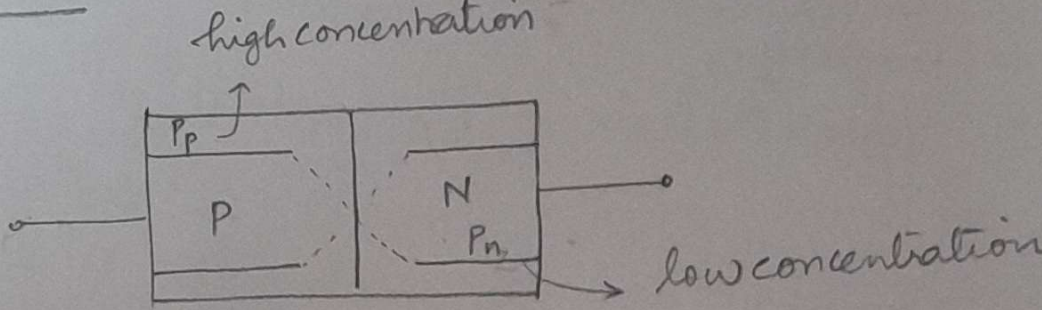
videolecture
youtube
= nGMjmA7Hem8

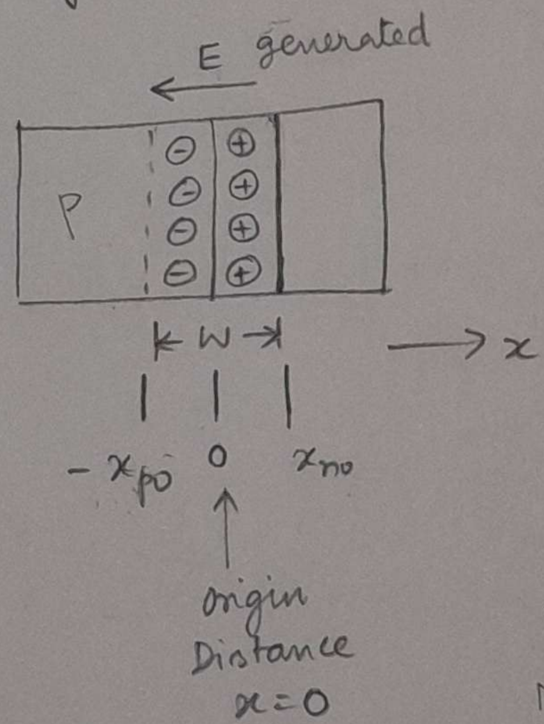


Suffix - type of SC

Diffusion



When they diffuse they leave behind ions.

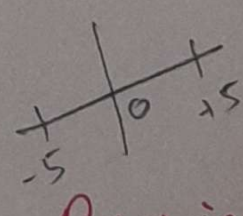


Whenever there is an internal field 'E' there is a built in potential 'V_B'

$$V_B = V_T \ln\left[\frac{N_A N_D}{n_i^2}\right]$$

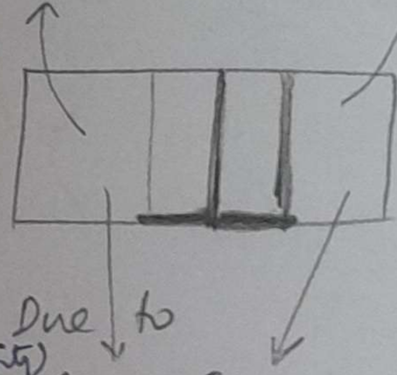
N_A = acceptor concentration
N_D = Donor concentration
n_i = intrinsic carrier concentration

$$W = x_{no} + x_{po}$$



Derivation for Barrier Potential

Contact potential / Built in potential / Barrier potential



<u>At $x = -x_{p_0}$</u>

hole conceptration = P_P (majority)

e^- = N_P

<u>At $x = -x_{n0}$</u>

e^- concentration = N_n (majority)

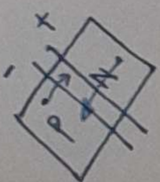
h = P_n.

Carriers type

$$J_p(\text{diff}) + J_p(\text{drift}) = 0 \longrightarrow$$

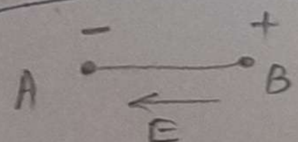
$V_B - V_A$.

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



$$\cancel{p}\cancel{q}\mu E = + \cancel{q} D_p \frac{dp}{dx}$$

$$\boxed{V = -\int E dx}$$



$$+ E \cdot dx = \frac{D_p}{P} \cdot \frac{dp}{\mu p}$$

From, Einstein relation, $\frac{D}{\mu} = V_T$ (Thermal voltage)

$$= \frac{T}{11,600} \ (V)$$

$$-\int_{-x_{p0}}^{x_{n0}} E \cdot dx = \int_{P_P}^{P_n} \frac{V_T \cdot dp}{P}$$

$$\int_{-x_{p0}}^{0}$$

$$-\left[V(x_{n0}) - V(-x_{p0})\right] = V_T \left[\ln(P)\right]_{P_P}^{P_n}$$

$$-V_B = V_T \ln\left[P_n / P_P\right]$$

ries
ntial

$$V_B = -V_T \ln\left[{P_n}/{P_P}\right]$$

$$\boxed{V_B = V_T \ln\left[{P_P}/{P_n}\right]} \quad — ①$$

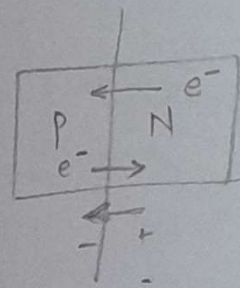
when $N_A \ggg n_i$

WKT

$$P_P = N_A$$

$$P_n = \frac{n_i^2}{N_D}$$

$$\underbrace{N_n}_{N_D} \cdot P_n = n_i^2$$



Acc = holes

$n_p \cdot P_n = n_i^2$

$$\therefore V_B = V_T \ln\left[\frac{N_A}{\frac{n_i^2}{N_D}}\right]$$

$$\boxed{V_B = V_T \ln\left[\frac{N_A N_D}{n_i^2}\right]} \quad — ②$$

$$\left(\frac{N_n \cdot P_P}{n_i^2}\right)$$

$$\frac{P_P}{P_n} = e^{\frac{V_B}{V_T}} \quad — \text{from ①}$$

$$\boxed{V_T = \frac{KT}{q}}$$

Voltage produced within the PN Jn due to the action of temperature

(26 mV at room temperature)

$$\Rightarrow P_P = P_n e^{\left(\frac{V_B}{V_T}\right)}$$

$$= P_n e^{\left(\frac{V_B}{KT/q}\right)}$$

$$\boxed{P_P = P_n e^{\left(\frac{V_B q}{KT}\right)}}$$

$$\boxed{N_n = N_P e^{\frac{V_B q}{KT}}}$$

Note :

$$n_n = n_p e^{V_0/V_T} \quad — \quad \mathrm{I}$$

$$P_p = P_n e^{V_0/V_T} \quad — \quad \mathrm{II}$$

$$\frac{\mathrm{I}}{\mathrm{II}} = \frac{n_n}{P_p} = \frac{n_p \cancel{e^{V_0/V_T}}}{P_n \cancel{e^{V_0/V_T}}}$$

$$= n_n P_n = n_p \cdot P_p = n_i^2 \rightarrow \text{Mass action law}$$

$V_B = 0.7V$

$k = 1.381 \times 10^{-23}$

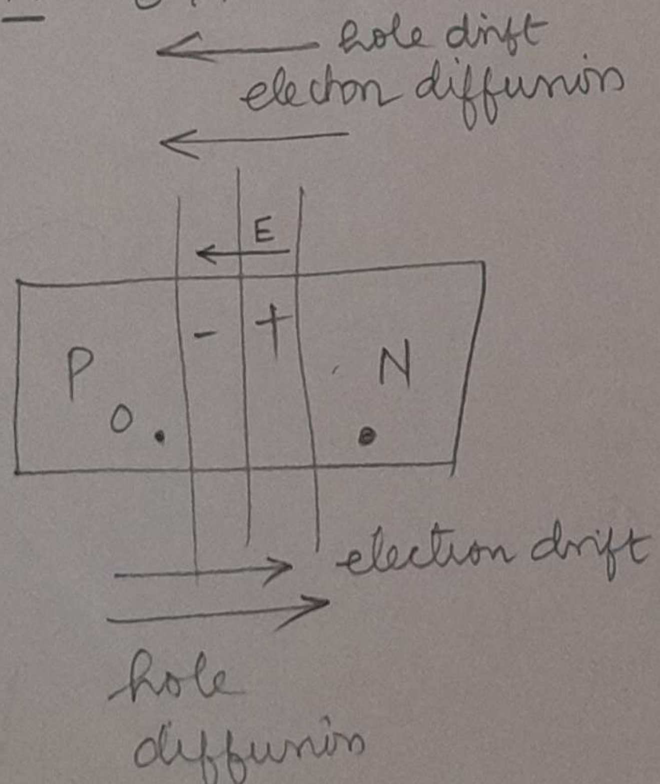
For,

Si $n_i = 1.5 \times 10^{10} / cm^3$

$N_A = N_D = 10^{16} / cm^3$

$V_T = 25\ mV$ (at room temperature)

$V_0 \simeq 697\ mV = 0.7\ V.$



$$V_B = 26 \times 10^{-3} \ln\left[\frac{10^{16} \times 10^{16}}{(1.5 \times 10^{10}) \times (1.5 \times 10^{10})}\right]$$

$$26 \times 10^{-3} \times [26.82]$$

$$= 0.7V$$

1) Calculate the built in potential barrier in a PN junction. Consider a Silicon PN jn at 300K with doping densities

$$N_A = 1 \times 10^{18}\ cm^{-3}\ ;\ N_D = 1 \times 10^{15}\ cm^{-3}.$$

Assume $n_i = 1.5 \times 10^{+10}\ cm^{-3}$

$$V_B = \frac{KT}{q} \ln \left[\frac{1}{\frac{n_i^2}{N_A \times N_D}} \right]$$

$$= 26 \times \ln \left[\frac{1}{\frac{1.5 \times 10^{10} \times 1.5 \times 10^{10}}{10^{18} \times 10^{15}}} \right]$$

$$= 26 \times \ln \left[\frac{10^{33}}{2.25 \times 10^{20}} \right]$$

$$= 26 \times \ln \left[\frac{1}{2.25} \times 10^{13} \right]$$

$$= 26 \times 29 \times 10^{-3}$$

$$V_B = 0.76\ V$$

$$K = 1.3806 \times 10^{-23}$$

$$T = 300$$

$$q = 1.602 \times 10^{-19}$$

$$= 2$$

$$\boxed{\frac{KT}{q} = 25.8\ mV}$$

2) Consider a Si PN junction at 300 K with doping concentration of $N_A = 10^{16}\ cm^{-3}$ and $N_D = 10^{15}\ cm^{-3}$. Assume that $n_i = 1.5 \times 10^{10}\ cm^{-3}$. Calculate width of the space charge region in a PN junction, when a reverse bias voltage $V_R = 5V$ is applied.

$\epsilon_0 = 8.854 \times 10^{-12}$

$\epsilon_r = 12$

N_A

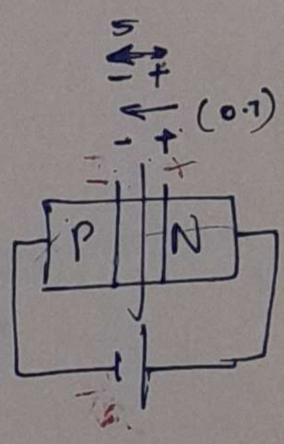
N_D

n_i

V_R

$$W = \frac{2\epsilon_0 \epsilon_r (V_B)}{q}\left[\frac{N_A + N_D}{N_A N_D}\right]$$

$$= \frac{2\epsilon_0 \epsilon_r (V_B + V_R)}{q}\left[\frac{N_A + N_D}{N_A N_D}\right]$$



$\boxed{W = 0.8\ \mu m}$

$8\ \mu m$ $\boxed{2\ mm}$