BARRIER VOLTAGE OR CONTACT POTENTIAL ACROSS THE PN JUNCTION

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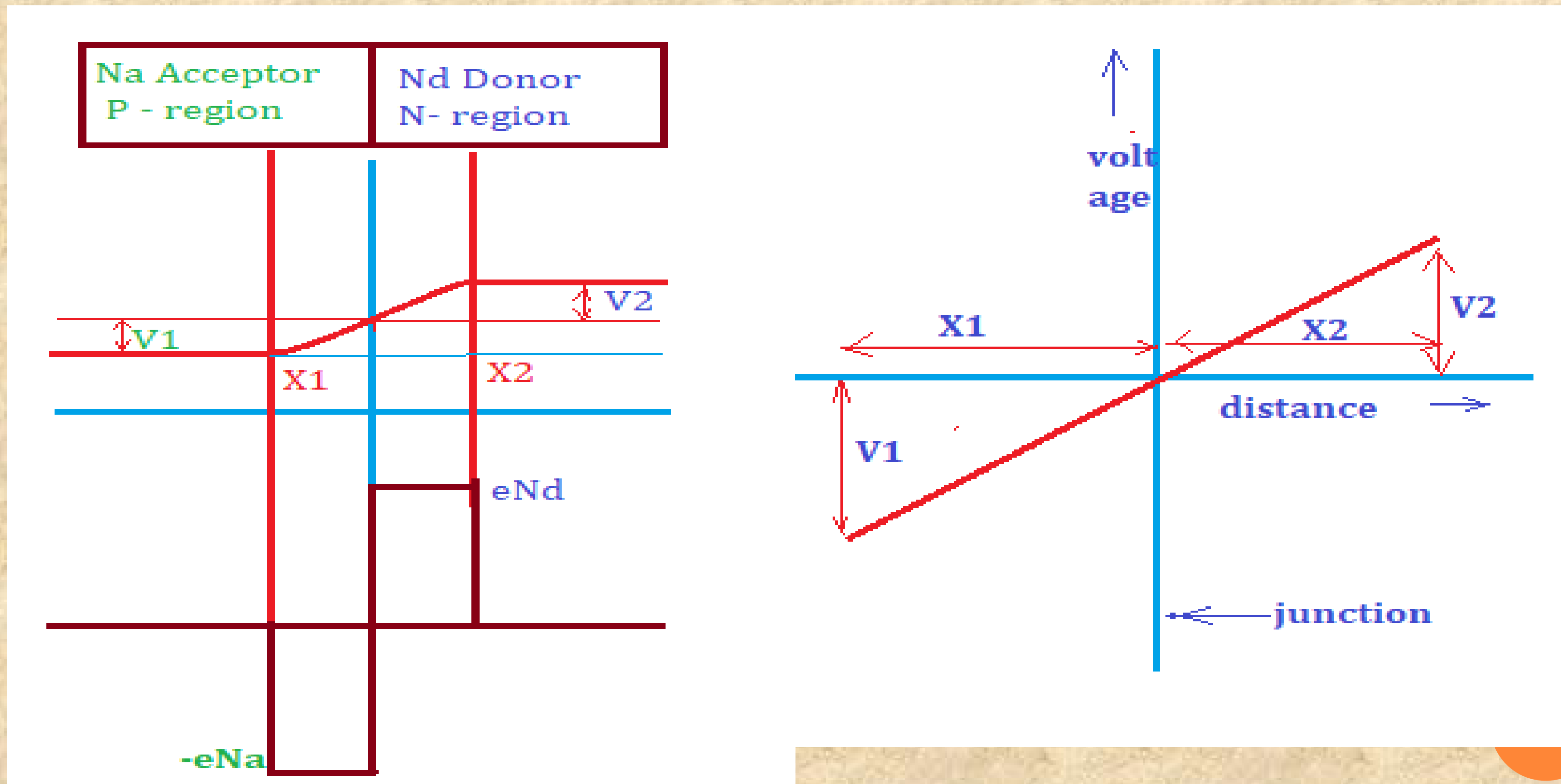
BARRIER VOLTAGE

Near the PN junction there exists a space charge region due to the positively charged region on n type side and negatively charged region on p type side.



The barrier potential $V_B = |V_1| + |V_2|$

And total width of the space charge region $X = X_1 + X_2$

To find the distribution of barrier potential in the space charge region, we proceed with the Poisson's equation

$$\frac{d^2V}{dx^2} = -\frac{\rho}{\epsilon}$$

Where ρ is the volume density of charge and ε is the permittivity of the medium.

The potential variation in P side region is

$$\frac{d^2V}{dx^2} = \frac{eN_a}{\epsilon}$$

here N_a is the density of the negatively charged (ionized) acceptor atoms.

Integrating,

$$\frac{dV}{dx} = \frac{eN_a x}{\epsilon} + C_1$$

Applying boundary condition: at x $= -X_1, \frac{dV}{dx} = 0$

$$C_1 = \frac{eN_a X_1}{\epsilon}$$

$$\frac{dV}{dx} = \frac{eN_a x}{\epsilon} + \frac{eN_a X_1}{\epsilon}$$

Integrating again, $V = \frac{eN_a x^2}{2\epsilon} + \frac{eN_a X_1 x}{\epsilon} + C_2$

Applying boundary condition, x= 0, V=0, $C_2 = 0$

$$V = \frac{eN_a x^2}{2\,\epsilon} + \frac{eN_a X_1 x}{\epsilon}$$

At $x = -X_1, V = V_1$

$$V_1 = \frac{eN_a X_1^2}{2\,\epsilon} - \frac{eN_a X_1^2}{\epsilon}$$

$$V_1 = -\frac{eN_a X_1^2}{2\,\epsilon}$$

Similarly, for the potential in space charge region on n side

$$\frac{d^2V}{dx^2} = -\frac{eN_d}{\epsilon}$$

Where N_d is the density of the positively ionized donor atoms.

The boundary conditions, x=0, V = 0

And at x=X_2 , $\frac{dV}{dx}$= 0

We get

$$V = -\frac{eN_d x^2}{2\epsilon} + \frac{eN_d X_2 x}{\epsilon}$$

Again, at $x = X_2$, $V = V_2$

$$V_2 = \frac{eN_d X_2^2}{2\epsilon}$$

BARRIER POTENTIAL

Height of the potential barrier across the junction

$$V_B = |V_1| + |V_2|$$

$$= e\left(\frac{N_a X_1^2 + N_d X_2^2}{2\in}\right)$$

Since, the crystal as a hole electrically neutral, from the charge neutrality condition

$$N_a X_1 = N_d X_2$$

$$X_2 = \frac{N_a}{N_d} X_1$$

Putting the value of X_2 in V_B, we get

$$V_B = \frac{e}{2\in}\left(N_a X_1^2 + N_d \frac{N_a^2}{N_d^2} X_1^2\right)$$

$$V_B = \frac{eN_a}{2\in} X_1^2 (1 + \frac{N_a}{N_d})$$

$$X_1 = \left[\frac{2 \in V_B}{eN_a(1+\frac{N_a}{N_d})}\right]^{1/2}$$

$$X_2 = \left[\frac{2 \in V_B}{eN_d(1+\frac{N_d}{N_a})}\right]^{1/2}$$

BARRIER WIDTH

$$X = X_1 + X_2$$

$$= \left(\frac{2 \in V_B}{e}\right)^{1/2}\left[\left\{\frac{\frac{N_d}{N_a}}{N_d+N_a}\right\}^{1/2} + \left\{\frac{\frac{N_a}{N_d}}{N_d+N_a}\right\}^{1/2}\right]$$

$$= \left\{\frac{2\in V_B}{e(N_d+N_a)}\right\}^{1/2}\left[\left\{\frac{N_d}{N_a}\right\}^{1/2}+\left\{\frac{N_a}{N_d}\right\}^{1/2}\right]$$

Consider a typical example,

$N_d = N_a = 10^{21}$ per m^3

$$V_B = 0.5\, volt, \epsilon_0 = 8.85 \times 10^{-12} \frac{farad}{m}$$

$$e = 1.6 \times 10^{-19}\, C, \epsilon = \epsilon_0 \epsilon_r = 16 \times 10^{-12} \times 8.85, \epsilon_r = 16\, for\, Ge$$

We find that the thickness of the barrier is

$$x = 10^{-6}\, m$$

If $N_d > N_a$, then we can neglect N_a in the sum $(N_d + N_a)$ and N_a/N_d approximated to zero. This gives

$$X = \left(\frac{2 \epsilon V_B}{eN_d}\right)^{1/2} \left(\frac{N_d}{N_a}\right)^{1/2} = \left(\frac{2 \epsilon V_B}{eN_a}\right)^{1/2}$$

Which shows that the space charge region decreases as the impurity concentration increases.

We find $\frac{V_1}{V_2} = (\frac{X_1}{X_2})^2 (\frac{N_a}{N_d})$ and $\frac{X_1}{X_2} = \frac{N_d}{N_a}$

Thus $\frac{V_1}{V_2} = \frac{N_d}{N_a}$

When $N_d \gg N_a$, $V_1 \gg V_2$, This implies that the potential charge is confined to the region which has impurity in small amounts i.e. lightly