EFFECT OF APPLIED POTENTIAL ON DEPLETION REGION OR BARRIER POTENTIAL IN A P-N JUNCTION

When a p-type semiconductor is brought in close contact with n-type semiconductor, resulting there is depletion region formed as shown below.

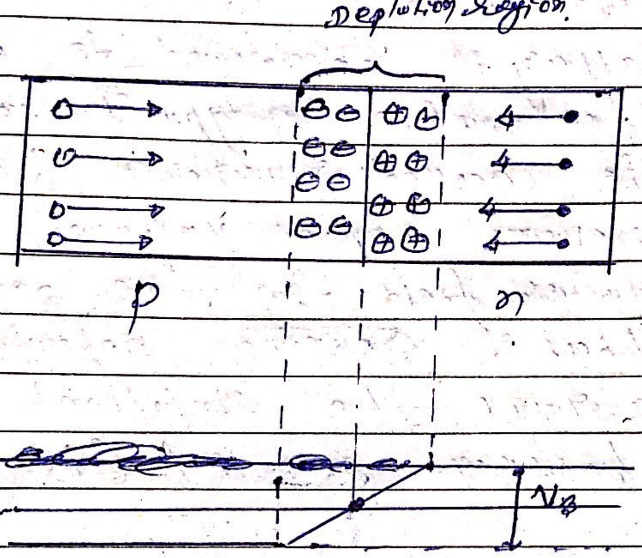

Fig: Barrier potential

The depletion layer contains only immobile +ve and -ve ~~charge~~ charge ions. Due to these immobile positive and negative ions an electric potential barrier is created (developed) across the p-n junction. This is called potential barrier. ~~is called~~
The value of potential barrier is 0.3V for Ge and 0.7V for silicon.

Forward biasing:- When p-type is connected to +ve terminal of battery and -ve terminal to the n-type of semiconductor, this is called the forward biasing. The forward biasing establishes an electric field which acts against barrier that reduces it.

and hence the resistance of the diode is reduce to zero; that setup a current through the diode

II> Reverse Biasing: When the +ve terminal of battery is connected to ~~p~~ n-type and -ve terminal to n-type of semiconductor, then, that is called reversing biasing. In the case reverse applied voltage establishes an electric field in the same direction as that of reverse potential barrier. As a result the resultant field strengthen and barrier potential (VB) increasing.

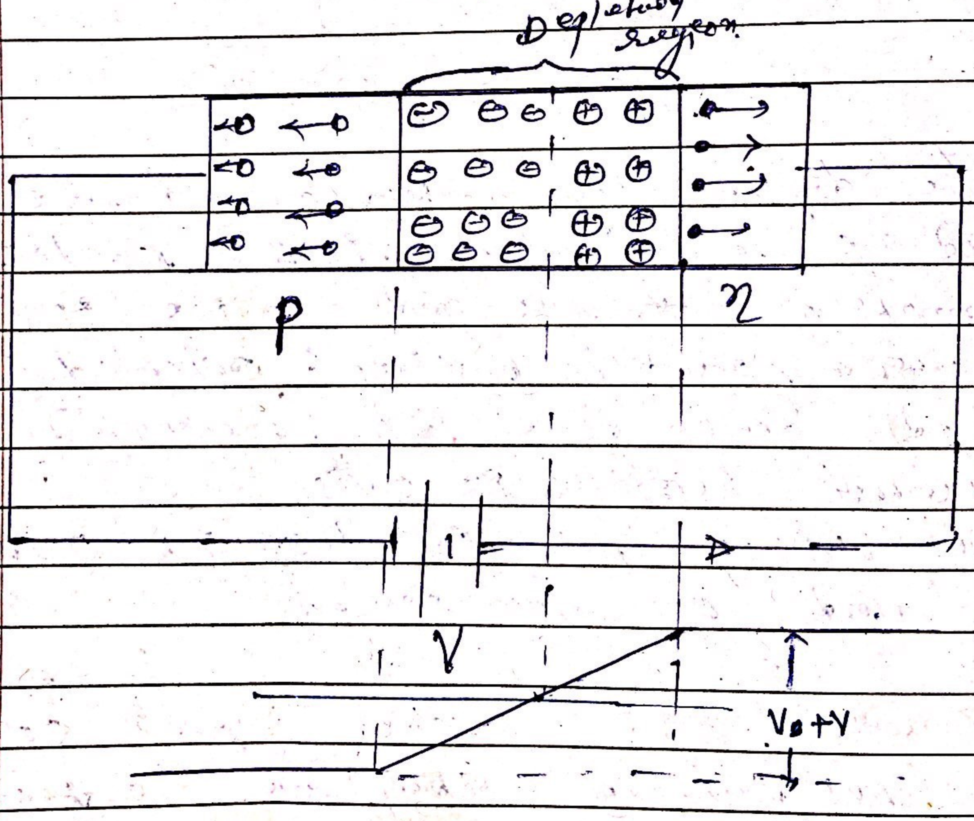

Fig Barrier potential

This barrier potential prevent the flow of the charge carriers across the junctions.

This increases the resistance of the p-n junction. When the junction is reversed biased, the electron in the n-type and the hole in the p-type semiconductor attracted away from the junction. Since there is no recombination of electron holes take places so, there is negligibly small current.

Diode equation

The net current density across the p-n junction has following four components.

1) ~~The~~ I_1 = This is due to flow of minority electrons in the conduction band of p-type to the conduction band of n-type and the direction is from n to p side. ($n \to p$)

2) I_2 = Due to flow of majority electrons in the C.B of n-type to the C.B of p-type and hence direction will be from p to n.

3) I_3 = Due to flow of majority holes in the V.B of holes in p-type to V.B of n-types so, the direction is from $p \to n$.

4) I_4 = Due to flow of minority holes ~~from~~ in V.B of n-type to V.B of p-type so, direction is from n to p. ($n \to p$).

Therefore The net current flow is

$$I = -I_1 - I_4 + I_2 + I_3$$
$$= I_2 + I_3 - (I_1 + I_4). \quad \text{—①}$$

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The minority current of electron from p-side to n-type is not affected by the application of forward or reverse bias.

The majority current of electrons from n-side to p-side is very sensitive to the applied voltage. Since the electrons in n-type material face barrier which may be raised or lowered by the applied voltage. Thus

~~The~~ for forward biasing, The current density for majority electron flow is

$$I_a = C_1 \exp[-e(V_a - V)/k_B T]$$

where C_1 is constant.

$\rightarrow$ (II)

Similarly,

The current density for majority holes flow from p-side to n-side is given by.

$$I_B = C_2 \exp[-e(V_B - V)/k_B T] \quad \text{—— (III)}$$

where

C_2 = another constant.

At equilibrium,

When no voltage is applied across the junction, ~~then~~.

i.e $V = 0$

then, ~~$I_a = I_1$~~ $I_a = I_1$

and ~~$I_B = I_2$~~ $I_B = I_2$

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$I_2 = I_2 = C_1 \exp[-e(V_B - V)/k_BT]$

$\therefore$ ~~$I_1 = C_1 \exp(-eV_B/k_BT)$~~. $[\because V = 0.]$

$\therefore C_1 = I_1 \cdot \exp(eV_B/k_BT)$

On substituting the values of C_1 in eqn ② we get

$$I_2 = I_1 \exp(eV_B/k_BT) \exp[-e(V_B - V)/k_BT]$$

$$= \frac{I_1 \cancel{\exp.(eV_B/k_BT)} \times \exp(eV/k_BT)}{\cancel{\exp(eV_B/k_BT)}}$$

$$I_2 = I_1 \exp(eV/k_BT) \quad \text{——} \quad ⓐ$$

Similarly, $\therefore I_3 = I_4 = C_2 \exp[-e(V_B - V)/k_BT]$

$\therefore C_2 = I_4 \cdot \exp[e(V_B - V)/k_BT]$

On substituting the values of C_2 in eqn (III) we get

$$I_3 = I_4 \exp.[-e(V_B - V)/k_BT] . \exp[e(V_B - V)/k_BT]$$

$$= I_4 . \exp . \cancel{\frac{-eV_B}{k_BT}} . \exp(eV/k_BT) . \exp \cancel{\frac{eV_B}{k_BT}} .. \exp \frac{eV}{k_BT}$$

$$= I_4 \exp\left(\frac{eV}{k_BT}\right) . \quad \text{——} \quad ⓑ$$

On putting the values of eqⁿ ② and eqⁿ ③ in eqⁿ ① we get

$$I = I_2 + I_3 - (I_1 + I_4)$$

$$= I_1 \exp(eV/K_BT) + I_4 \exp\left(\frac{eV}{K_BT}\right) - (I_1 + I_4)$$

$$= \cancel{\exp^{eV/K_BT}\left[(I_1 + I_4) - (I_1 + I_4)\right]}$$

$$= \exp(eV/K_BT)(I_1 + I_4) - (I_1 + I_4)$$

$$= (I_1 + I_4)\left[\exp^{eV/K_BT} - 1\right]$$

put $I_1 + I_4 = I_0$

$$\boxed{\therefore \quad I = I_0\left[\exp^{eV/K_BT} - 1\right]}$$

The above equation is called forward biased diode current which increases exponentially.