LECTURE 25/9/2020

BARRIER POTENTIAL

Near the junction on one side there are many +ve charges and on the other side there are many -ve charges.

According to ~~coulo~~ coulomb's law there exist a force between these opposite charges. And this force produces an electric field between these opposite charges. The direction of electric field is from +ve charge towards -ve charge.

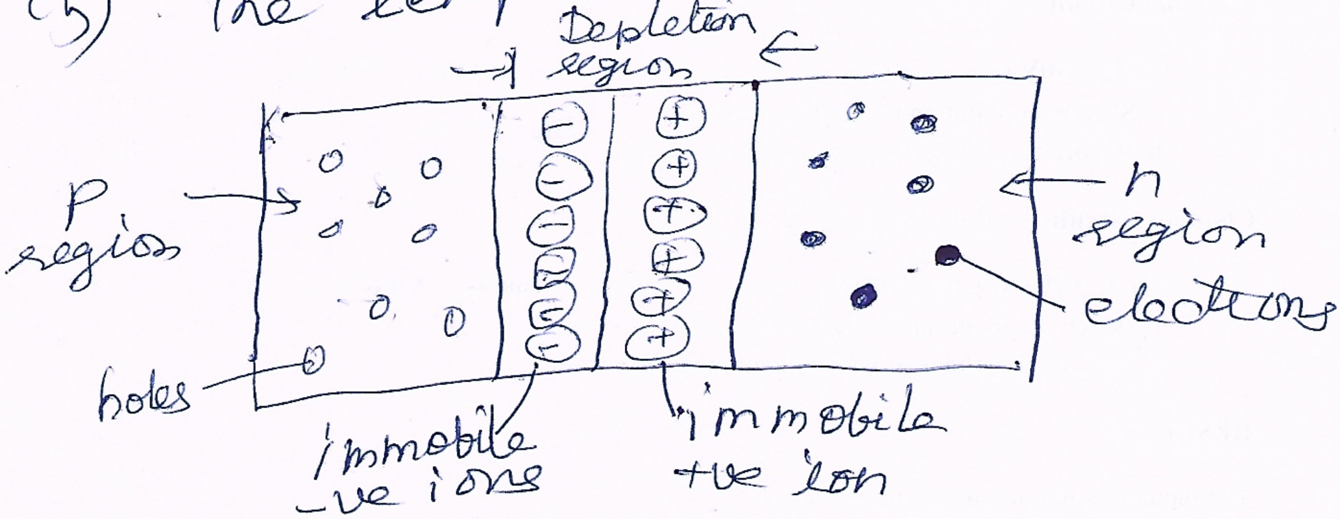
This electric field is responsible to produce a potential difference across the junction. This p.d. has a fixed polarity and it acts as a barrier to the flow of holes and electrons across the junction. Hence this potential is called barrier potential / junction potential / built in potential barrier of p-n junction.

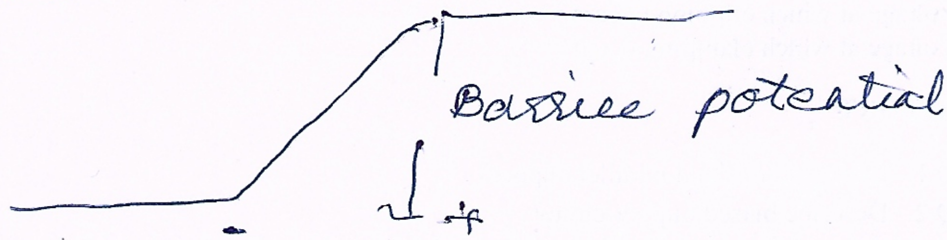
The barrier potential is expressed in volts. Its value is called the height of the barrier.

Barrier potential indicates the amount of voltage with proper polarity to be applied across the p-n junction to restart the flow of electrons & holes across the junction.

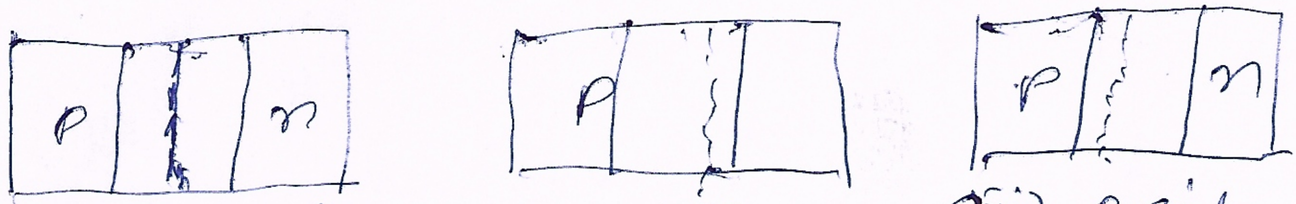
Barrier potential 0.7V = Si, 0.3V = Ge

Barrier potential depends on
(1) Type of semiconductor
(2) Concentration of donor impurity on n side
(3) Concentration of acceptor impurity on p side
(4) The intrinsic concentration of basic semiconductor
(5) The temperature.





Depletion region:
The width of the depletion region depends on the amount of doping on n side and p side
(i) Equally doped: ~~Depletion~~ Depletion region is equal on both the sides
(ii) n side heavily doped: Depletion region is more on p side
(iii) p side heavily doped - Depletion region is more on n side.



(i) Both sides equally doped (ii) n side heavily doped (iii) p side heavily doped

Depletion layer penetrates more on the lightly doped side.

EXPRESSION FOR BARRIER POTENTIAL

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

Let V_B = Barrier potential

At the junction there is an abrupt change in concentration of holes from P_p to P_n

So $P_1 = P_p = N_A$ & $P_2 = P_n$

$$\therefore V_B = V_T \ln \left[\frac{N_A}{P_n} \right]$$

but $n_n \times P_n = n_i^2$

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

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

but $n_n = N_D$

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

The Barrier potential V_B depends on volt equivalent of temperature V_T and the amount of doping on n side and p side i.e N_D & N_A respectively

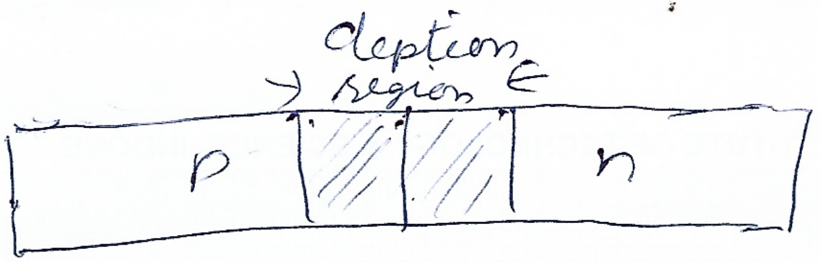
ENERGY BAND STRUCTURE OF OPEN-CIRCUITED P-N JUNCTION

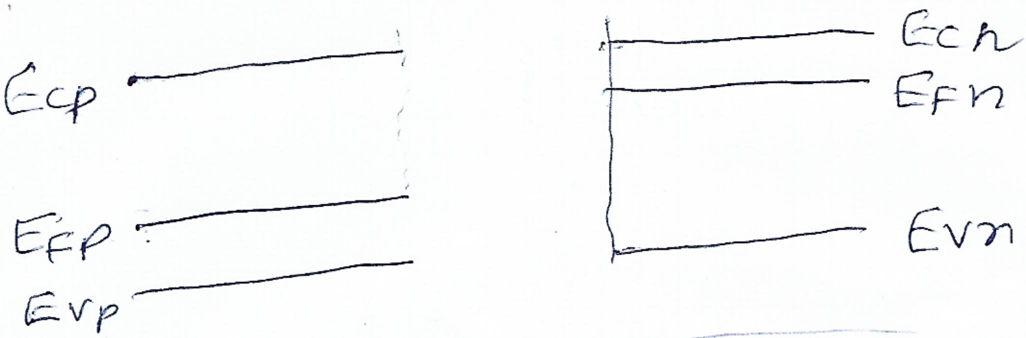
Fermi-level in n type material lies just below the conduction band while in p type material it lies just above the valence band

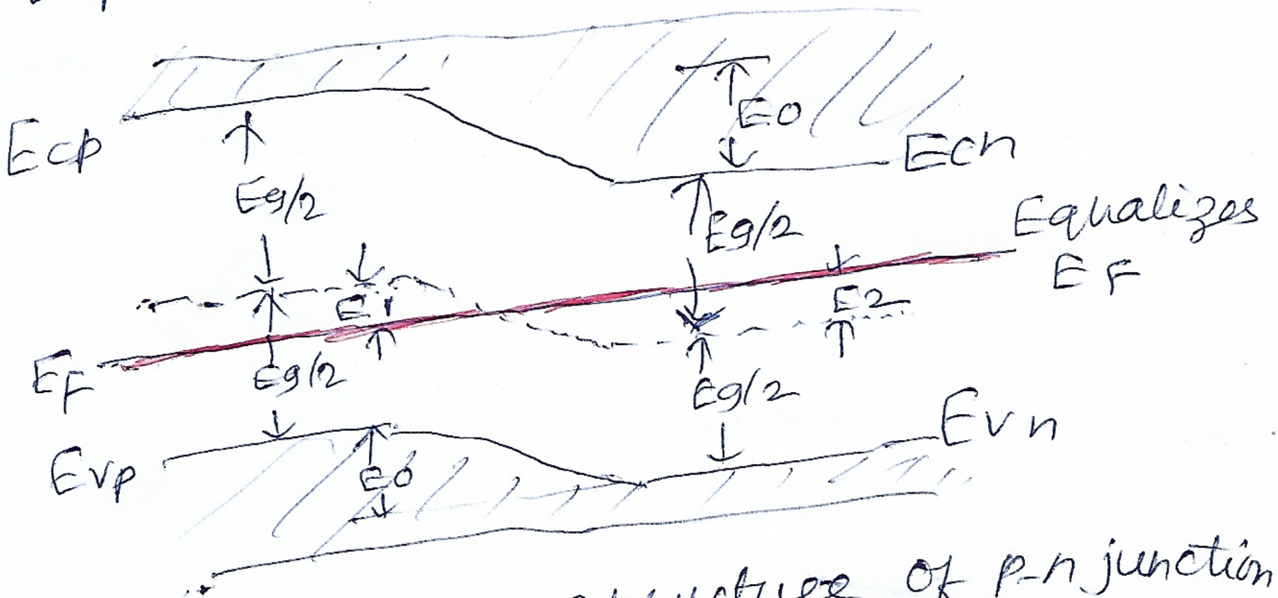
When p-n junction is formed the diffusion starts. The charges get adjusted to equalise the Fermi level in the 2 parts of p-n junction (like adjustments of water levels in 2 tanks of unequal levels connected ~~toget~~ to each other)

Charges flow from p to n & n to p side till the Fermi level on the 2 sides get lined up.

Important to note: The transfer of charges does not disturb the relative position of conduction band, valence band and Fermi-level in any region either p or n







Energy band structure of p-n junction

In p region, EFP is near Evp just above edge of valence band.

In n region EFn is near Ecn just below the edge of the condiction band.

Due to transport of charges the edge of conduction band Ecp in the p type material becomes higher than Ecn. Similarly Evp is higher than Evn. Thus there is a shift of 'E1' in the fermi-level on p side

While there is a shift of 'E_2' in the Fermi level on the n side from their intrinsic levels (centre of E_c & E_v). This adjusts the Fermi level on n side and p side to get equivalent E_F for the p-n junction

The total shift in energy $E_0 = E_1 + E_2$ which is barrier potential / junction potential / contact potential

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

V_B can also be expressed in following expressions

$N_A = P_p$, $N_D = n_n$

$P_n = \frac{n_i^2}{N_D}$, $n_p = \frac{n_i^2}{N_A}$ $\therefore$ $\cancel{N_A = \frac{n_p}{n_i^2}}$

$$\therefore V_B = V_T \ln\left(\frac{P_p \times \frac{n_i^2}{P_n}}{n_i^2}\right)$$

$$= V_T \ln\left(\frac{P_p}{P_n}\right)$$

$$= V_T \ln\left(\frac{P_{p0}}{P_{n0}}\right) = V_T \ln\left(\frac{n_{n0}}{n_{p0}}\right)$$

0 subscript means thermal equilibrium.

& $V_0 = V_B$