DRIFT AND DIFFUSION CURRENTS

→ The flow of charge (ie) current through a semiconductor material are of two types namely drift & diffusion.

→ (ie) The net current that flows through a (PN junction diode) semiconductor material has two components

(i) Drift current
(ii) Diffusion current

DRIFT CURRENT

→ When an electric field is applied across the semiconductor material, the charge carriers attain a certain drift velocity V_d , which is equal to the product of the mobility of the charge carriers and the applied Electric Field intensity E ;

Drift velocity V_d = mobility of the charge carriers X Applied Electric field intensity.

→ Holes move towards the negative terminal of the battery and electrons move towards the positive terminal of the battery. This combined effect of movement of the charge carriers constitutes a current known as ― the drift current ― .

→ Thus the drift current is defined as the flow of electric current due to the motion of the charge carriers under the influence of an external electric field.

→ Drift current due to the charge carriers such as free electrons and holes are the current passing through a square centimeter perpendicular to the direction of flow.

(i) Drift current density J_n , due to free electrons is given by

$$J_n = q\, n\, \mu_n\, E \text{ A / cm}^2$$

(ii) Drift current density J_P, due to holes is given by

$$J_P = q\, p\, \mu_p\, E \text{ A / cm}^2$$

Where, n - Number of free electrons per cubic centimeter.

P - Number of holes per cubic centimeter

μ_n – Mobility of electrons in cm^2 / Vs

μ_p – Mobility of holes in cm^2 / Vs

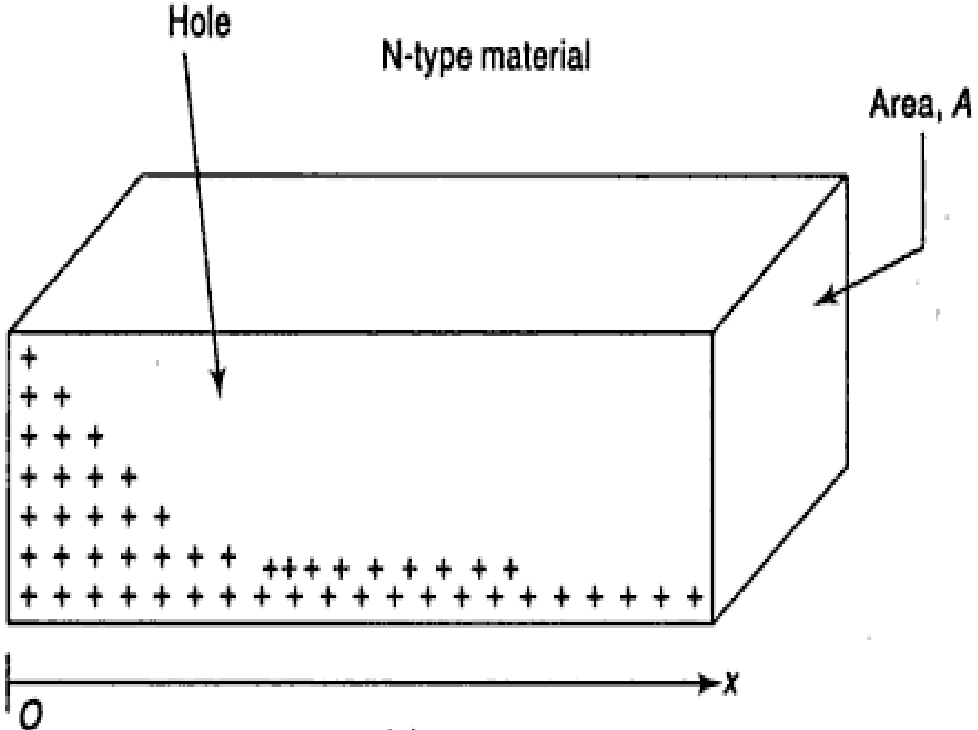
E – Applied Electric filed Intensity in V /cm

q – Charge of an electron = 1.6×10^{-19} coulomb.

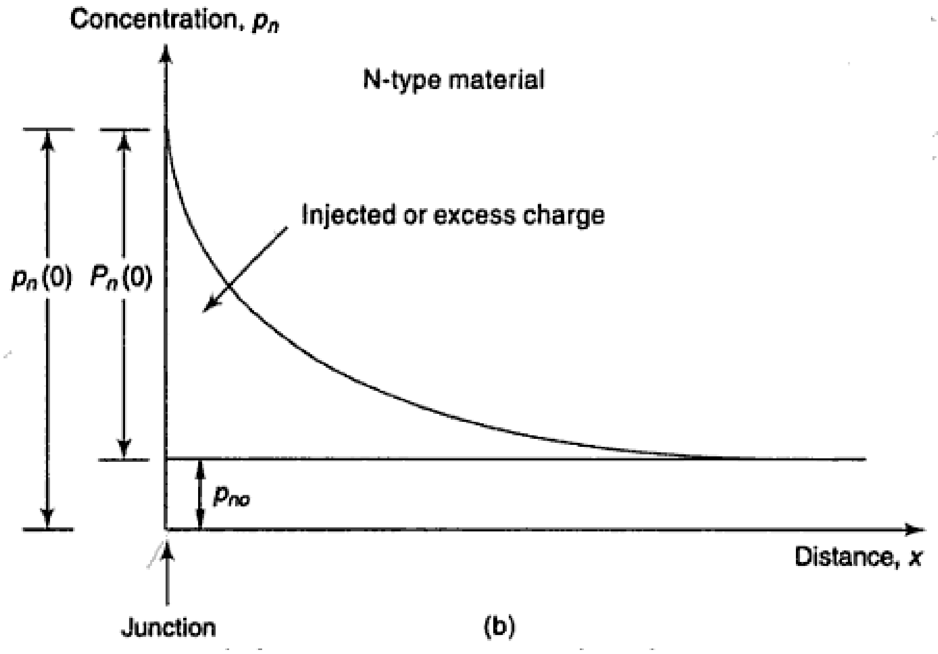
DIFFUSION CURRENT

→ It is possible for an electric current to flow in a semiconductor even in the absence of the applied voltage provided a concentration gradient exists in the material.

→ A concentration gradient exists if the number of either elements or holes is greater in one region of a semiconductor as compared to the rest of the Region.



(a)



(a) Exess hole concentration varying along the axis in an N-type semiconductor bar
(b) The resulting diffusion current

→ In a semiconductor material the change carriers have the tendency to move from the region of higher concentration to that of lower concentration of the same type of charge carriers. Thus the movement of charge carriers takes place resulting in a current called diffusion current.

As indicated in fig a, the hole concentration p(x) in semiconductor bar varies from a high value to a low value along the x-axis and is constant in the y and z directions.

Diffusion current density due to holes J_p is given by

$$J_p = -qD_p \frac{dp}{dx} \text{ A/cm}^2$$

Since the hole density p(x) decreases with increasing x as shown in fig b, dp/dx is negative and the minus sign in equation is needed in order that J_p has positive sign in the positive x direction.

Diffusion current density due to the free electrons is given by

$$J_n = qD_n \frac{dn}{dx} \text{ A/cm}^2$$

Where dn/dx – concentration gradient for electrons

Dp/dx - concentration gradient for holes

D_n and D_p – diffusion coefficient for electrons and holes

Total Current

The total current in a semiconductor is the sum of both drift and diffusion currents that is given by

$$J_p = qp\mu_p E - qD_p \frac{dp}{dx}$$

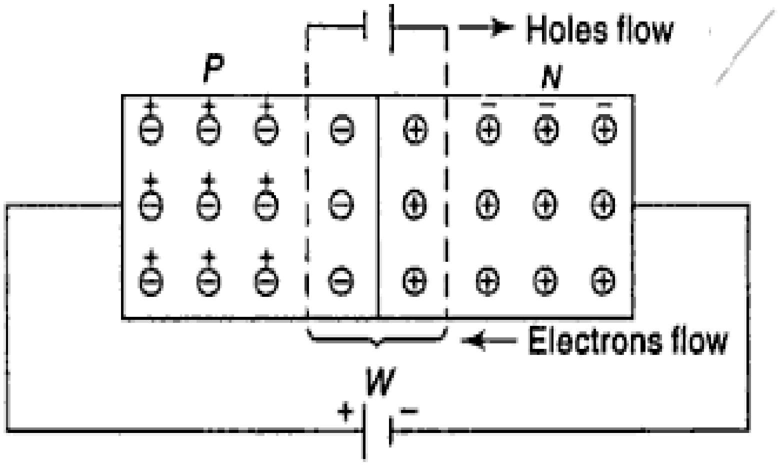
Similarly the total current density for an N type semiconductor is given by

$$J_n = qn\,\mu_n\,E + qD_n \frac{dn}{dx}$$

FORWARD BIAS CONDITION

When positive terminal of the battery is connected to the P-type and negative terminal to N-type of the PN junction diode that is known as forward bias condition.

Operation



The applied potential in external battery acts in opposition to the internal potential barrier which disturbs the equilibrium.

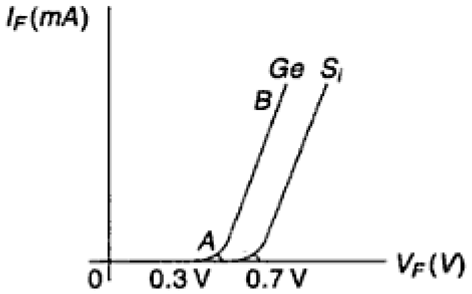
As soon as equilibrium is disturbed by the application of an external voltage, the Fermi level is no longer continuous across the junction.

Under the forward bias condition the applied positive potential repels the holes in P type region so that the holes move towards the junction and the applied positive potential repels the electrons in N type region so that the electrons move towards the junction.

When the applied potential is more than the internal barrier potential the depletion region and internal potential barrier disappear.

V-I Characteristics

As the forward voltage increased for V_F < Vo, the forward current I_F almost zero because the potential barrier prevents the holes from P region and electrons from N region to flow across the depletion region in opposite direction.



For V_F > Vo, the potential barrier at the junction completely disappears and hence, the holes cross the junction from P to N type and electrons cross the junction to opposite direction, resulting large current flow in external circuit.

A feature noted here is the cut in voltage or threshold voltage V_F below which the current is very small.

At this voltage the potential barrier is overcome and the current through the junction starts to increase rapidly.

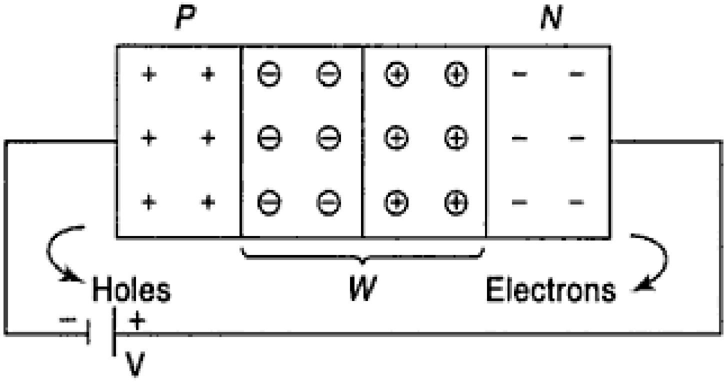
Cut in voltage is 0.3V for germanium and 0.7 for silicon.

UNDER REVERSE BIAS CONDITION

When the negative terminal of the battery is connected to the P-type and positive terminal to N-type of the PN junction diode that is known as forward bias condition.

Operation

The holes from the majority carriers of the P side move towards the negative terminal of the battery and electrons which from the majority carrier of the N side are attracted towards the positive terminal of the battery.

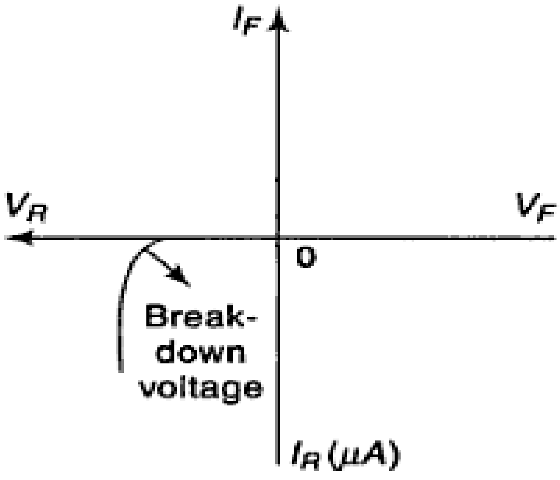


Hence, the width of the depletion region which is depleted of mobile charge carriers increases. Thus, the electric field produced by applied reverse bias, is in the same direction as the electric field of the potential barrier.

Hence the resultant potential barrier is increased which prevents the flow of majority carriers in both directions. The depletion width W is proportional to under reverse bias.

V-I characteristics

Theoretically no current flow in the external circuit. But in practice a very small amount of current of the order of few microamperes flows under reverse bias.



Electrons forming covalent bonds of semiconductor atoms in the P and N type regions may absorb sufficient energy from heat and light to cause breaking covalent bonds. So electron hole pairs continuously produced.

Consequently the minority carriers electrons in the P region and holes in the N region, wander over to the junction and flow towards their majority carrier side giving rise a small reverse current. This current is known as **reverse saturation current Io**.

The magnitude of this current is depends on the temperature because minority carrier is thermally broken covalent bonds.