the Drift Current and Diffusion Current

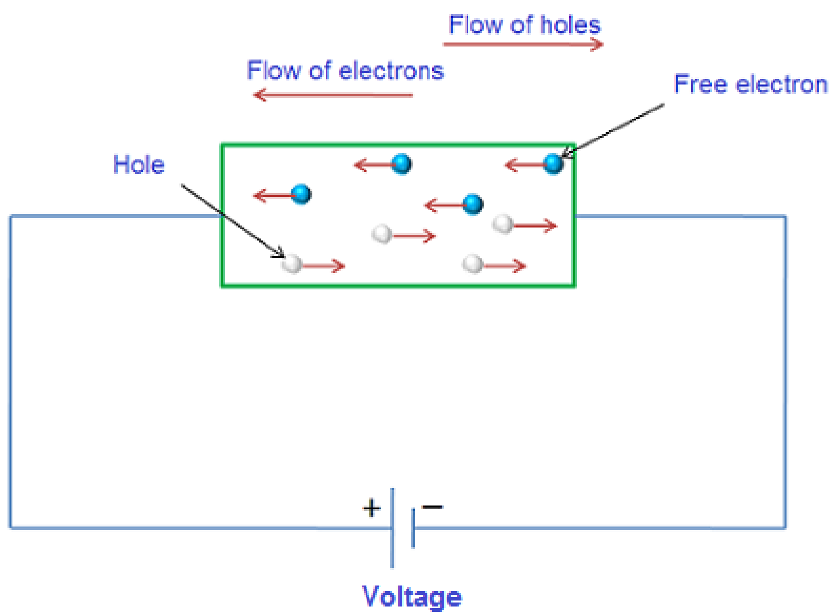
There are two types of current through a semiconducting material – one is drift current and the other is diffusion current. The mechanism of drift current is similar to the flow of charge in a conductor. In case of conductor when a voltage is applied across the material, the electrons are drawn to the positive end. Similar is the case in semiconductor. However, the movement of the charge carriers may be erratic path due to collisions with other atoms, ions and carriers. So, the net result is a drift of carriers to the positive end. In semiconducting material, when a heavy concentration of carrier is introduced to some region, the heavy concentrations of carriers distribute themselves evenly through the material by the process of diffusion. It should be remembered that there is no source of energy as required for drift current. When an electric field is applied across the crystal, every charge carrier experiences a force due to the electric field and hence it will be accelerated in the direction of force. This results in drifting of the charge carriers in the direction of force will cause a net flow of electric current through the crystal.

Drift current

The flow of charge carriers, which is due to the applied voltage or electric field is called drift current.

In a semiconductor, there are two types of charge carriers, they are electrons and holes. When the voltage is applied to a semiconductor, the free electrons move towards the positive terminal of a battery and holes move towards the negative terminal of a battery.

Electrons are the negatively charged particles and [holes]() are the positively charged particles. As we already discussed that like charges repel each other and unlike charges attract each other. Hence, the electrons (negatively charged particle) are attracted towards the positive terminal of a battery and holes (positively charged particle) are attracted towards the negative terminal.



In a semiconductor, the electrons always try to move in a straight line towards the positive terminal of the battery. But, due to continuous collision with the atoms they change the direction of flow. Each time the electron strikes an atom it bounces back in a random direction. The applied voltage does not stop the collision and random motion of electrons, but it causes the electrons to drift towards the positive terminal.

The average velocity that an electron or hole achieved due to the applied voltage or electric field is called drift velocity.

The drift velocity of electrons is given by

$$V_n = \mu_n E$$

The drift velocity of holes is given by

$$V_p = \mu_p E$$

Where v_n = drift velocity of electrons
v_p = drift velocity of holes
μ_n = mobility of electrons
μ_p = mobility of holes
E = applied electric field

The drift current density due to free electrons is given by

$$J_n = e n \mu_n E$$

and the drift current density due to holes is given by

$$J_p = e p \mu_p E$$

Where J_n = drift current density due to electrons
J_p = drift current density due to holes
e = charge of an electron

= 1.602×10^{-19} Coulombs (C).
n = number of electrons
p = number of holes

Then the total drift current density is

$$J = J_n + J_p$$
$$= en\mu_n E + ep\mu_p E$$
$$J = e\,(n\mu_n + p\mu_p)\,E$$

Diffusion Current

Diffusion current is mainly generated in semiconductors. The doping done in the semiconductors is non-uniform. In order to achieve uniformity, the flow of charge carriers takes place from higher concentration area to lower concentration area. It is referred to as diffusion.

This process generally doesn't occur in conductors. Fick's law well describes the diffusion of flux from that the thesis is derived for the diffusion of electrons as well as for holes.

The necessity of the diffusion current in the semiconductor is because of the reason behind the dominating current at the junction. At the equilibrium condition, the net currents are zero because the forward current is balanced by the reverse drift current but inside the depletion region, both drift and diffusion currents are present.

What do you mean by Diffusion Current?

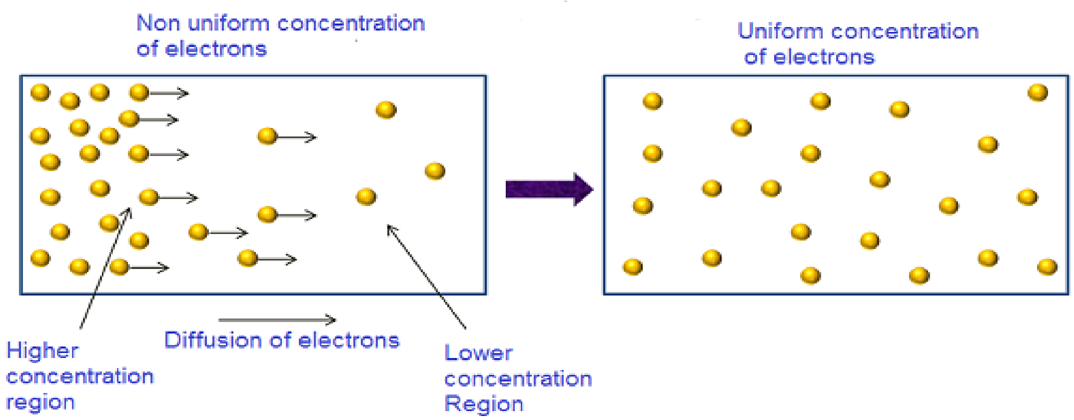
Generally in semiconductors, one can find the movement of charge carriers. This movement of the carriers is termed as Diffusion. The movement of carriers is observed from the higher concentration area to the lower concentration area.

In this process of movement, there is some generation of the current. This type of current is referred to as Diffusion Current for the semiconductors.

Diagram

Diffusion current can occur in the semiconductors that are non-uniformly doped because in non- uniformity only one can find the majority and the minority concentration so that movement can be observed for the carriers from higher concentration to the lower concentration.

Consider an n-type semiconductor that is non-uniformly doped as shown in below figure. Due to the non-uniform doping, more number of electrons is present at left side whereas lesser number of electrons is present at right side of the semiconductor material. The number of electrons present at left side of semiconductor material is more. So, these electrons will experience a repulsive force from each other. The electrons present at left side of the semiconductor material will moves to right side, to reach the uniform concentration of electrons. Thus, the semiconductor material achieves equal concentration of electrons. Electrons that moves from left side to right side will constitute current. This current is called diffusion current.



In p-type semiconductor, the diffusion process occurs in the similar manner.

Both drift and diffusion current occurs in semiconductor devices. Diffusion current occurs without an external voltage or electric field applied. Diffusion current does not occur in a conductor. The direction of diffusion current is same or opposite to that of the drift current.

Concentration gradient

The diffusion current density is directly proportional to the concentration gradient. Concentration gradient is the difference in concentration of electrons or holes in a given area. If the concentration gradient is high, then the diffusion current density is also high. Similarly, if the concentration gradient is low, then the diffusion current density is also low.

The concentration gradient for n-type semiconductor is given by

$$J_n \propto \frac{dn}{dx}$$

The concentration gradient for p-type semiconductor is given by

$$J_p \propto \frac{dp}{dx}$$

Where J_n = diffusion current density due to electrons

J_p = diffusion current density due to holes

The constants it does depend on are D_p and D_n, and $+q$ and $-q$, for holes and electrons respectively. The first constants are called the diffusion coefficients, a proportionality factor

Diffusion current density

The diffusion current density due to electrons is given by

$$J_n = +e\, D_n \frac{dn}{dx}$$

Where D_n is the diffusion coefficent of electrons

The diffusion current density due to holes is given by

$$J_p = -e\, D_p \frac{dp}{dx}$$

Where D_p is the diffusion coefficent of holes

The above equation is for the densities of diffusion densities with respect to electrons and holes but the overall density of the current of respective holes or electrons can be given by the sum of the diffusion current and the drift current.

The overall diffusion density with respect to electrons can be given as

$$J_n = Drift\ current\ + diffusion\ current$$

$$J_n = en\mu_n E + \ eD_n \frac{dn}{dx}$$

The overall diffusion density with respect to holes can be given by the equations for the individual densities of electrons as well as holes. Therefore the overall current density can be given by

$$J_p = Drift\ current\ + diffusion\ current$$

$$J_p = ep\mu_p E - \ eD_p \frac{dp}{dx}$$

$$J = J_n + J_p$$

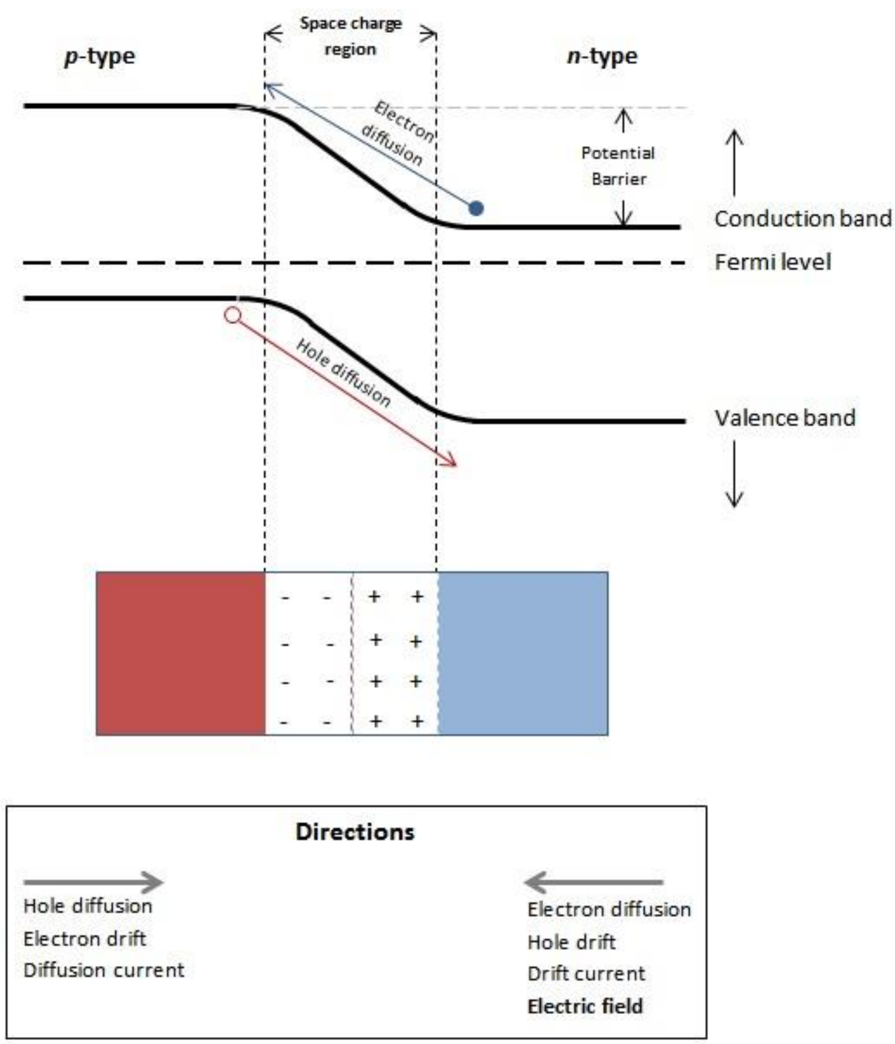
In this way, the equations for the diffusion current densities are described for holes as well as electrons. The diffusion current in the semiconductor has occurred before the application of external supply. It is also termed as the process of recombination in order to achieve uniformity. But have you ever thought why the diffusion doesn't take place in conductors?

Difference between Drift Current and Diffusion Currents

Drift Current	**Diffusion Current**
The movement of charge carriers is because of the applied electric field is known as drift current.	The diffusion current can be occurred because of the diffusion in charge carriers.
It requires electrical energy for the process of drift current.	Some amount of external energy is enough for the process of diffusion current.
THis current obeys Ohm's Law.	This current obeys Fick's Law.
The direction of charge carriers in the semiconductor is reverse to each other.	For charge carriers, the densities of diffusion are reverse in symbol to each other.
The direction of the drift current, as well as the e llllectric field, will be the same.	The direction of this current can be decided by the concentration of the carrier slope.
It depends on the permittivity	It is independent of permittivity

The direction of this current mainly depends on the polarity of the applied electric field.	The direction of this current mainly depends on the charge within the concentrations of carrier

The diffusion current in PN JUNCTION



Einstein Relationship between D, μ

$$\frac{KT}{q} = \frac{\mathrm{Dp}}{\mu \mathbf{p}}$$

In equilibrium there is no net flow of electrons or holes
$J_n = 0$ and $J_p = 0$

The drift and diffusion current components must balance each other exactly. (A built-in electric field exists, such that the drift current exactly cancels out the diffusion current due to the concentration gradient.)

$$J_n = qn\mu_n\mathcal{E} + qD_n\frac{dn}{dx} = 0$$

$$J_p = qp\mu_p\mathcal{E} - qD_p\frac{dp}{dx} = 0$$

$$\mathrm{q}\ \mu_{\mathrm{p}}\ \mathrm{pE} = \mathrm{q}\ \mathrm{D}_{\mathrm{P}}\frac{dp}{dx}$$

$$\frac{KT}{q} = \frac{\mathrm{Dp}}{\mu \mathbf{p}}$$