ENERGY BAND DIAGRAM

The region on the left is p-type with an acceptor density Na, while the region on the right is n-type with a donor density Nd. The dopants are assumed to be shallow, so that the electron (hole) density in the n-type (p-type) region is approximately equal to the donor (acceptor) density.

Thermal equilibrium

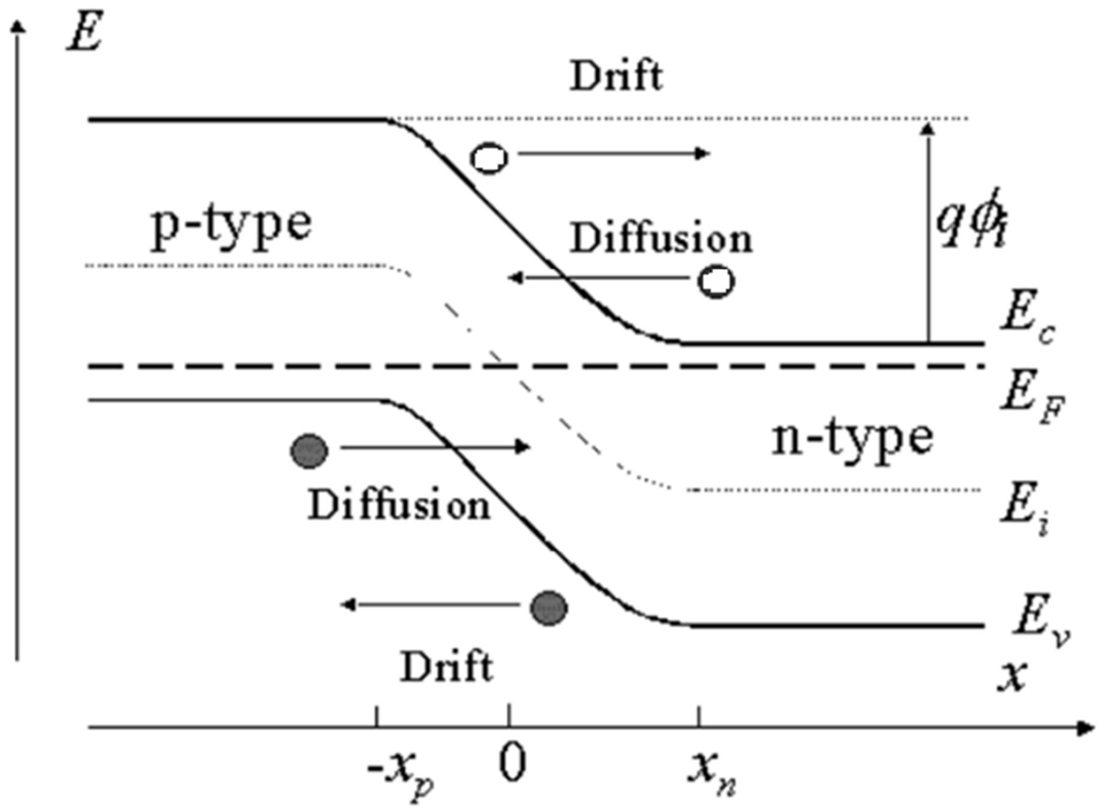

Fig:1.2.1 PN Diode Energy Band Diagram

(Source :https://ecee.colorado.edu)

To reach thermal equilibrium, electrons/holes close to the metallurgical junction diffuse across the junction into the p-type/n-type region where hardly any electrons/holes are present. This process leaves the ionized donors (acceptors) behind, creating a region around the junction, which is depleted of mobile carriers. This region the depletion region, extending from x = -xp to x = xn. The charge due to the ionized donors and acceptors causes an electric field, which in turn causes a drift of carriers in the opposite direction. The diffusion of carriers continues until the drift current balances the diffusion current, thereby reaching thermal equilibrium as indicated by a constant Fermi energy.

While in thermal equilibrium no external voltage is applied between the n-type and p-type material, there is an internal potential, which is caused by the work function difference between the n-type and p-type semiconductors.

Energy band diagram of a p-n junction under reverse and forward bias

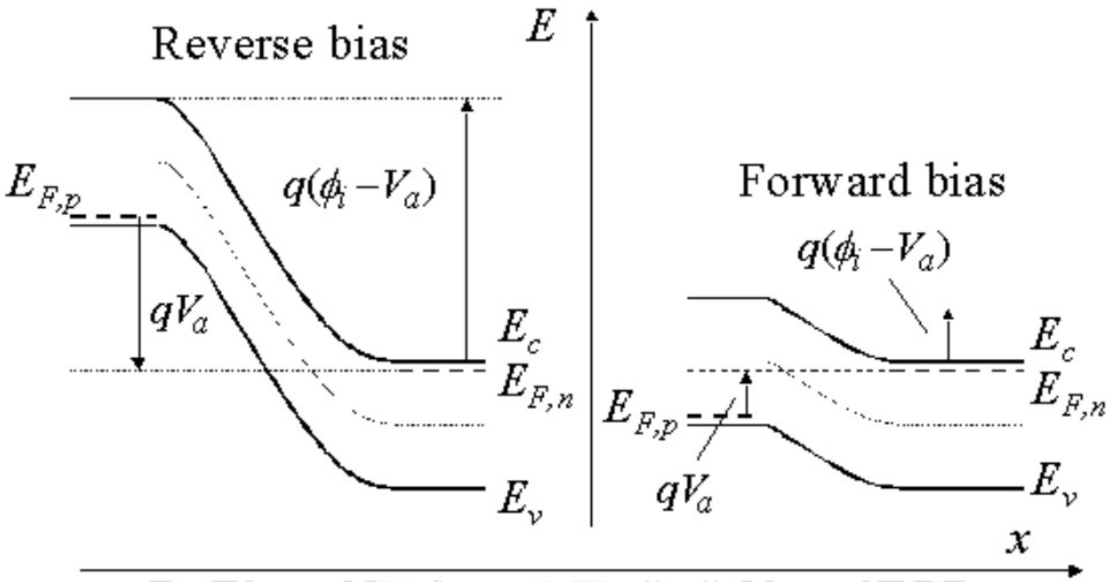

Fig:1.2.2 PN Diode Energy Band Diagram F.B & R.B

(Source :https://ecee.colorado.edu)

P-N diode with an applied bias voltage, Va. A forward bias corresponds to applying a positive voltage to the anode (the p-type region) relative to the cathode (the n-type region). A reverse bias corresponds to a negative voltage applied to the cathode. The applied voltage is proportional to the difference between the Fermi energy in the n-type and p-type quasi-neutral regions.

As a negative voltage is applied, the potential across the semiconductor increases and so does the depletion layer width. As a positive voltage is applied, the potential across the semiconductor decreases and with it the depletion layer width. The total potential across the semiconductor equals the built-in potential minus the applied voltage.

BREAKDOWN IN PN JUNCTION DIODES

When a PN junction is reversed biased it allows very small current to flow through it. This current is due to the movement of minority charge carriers and it is almost independent of the voltage applied.

If reverse bias is made too high, the current through PN junction increases abruptly and the voltage at which this phenomenon occurs is called breakdown voltage.

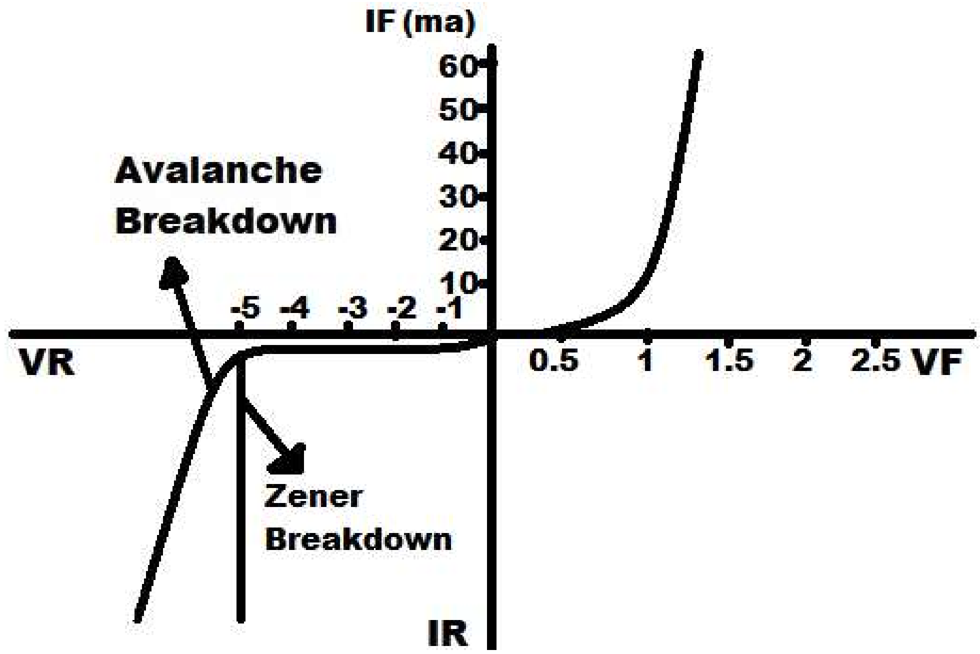

Fig:1.6.1 Avalanche Break down of Diode

At this breakdown voltage, the crystal structure breaks down. This crystal structure returns to the normal state when excess reverse bias is removed, provided that overheating has not permanently damaged the crystal.

There are two processes which causes junction breakdown. One is zener breakdown and another one is avalanche breakdown

Avalanche Breakdown

Avalanche breakdown is increased electric field causes increase in the velocities of the minority carriers. These high energy carriers break covalent bonds, thereby generating more carriers. Again these generated carriers are accelerated by electric field. They break more covalent bonds during their travel. A chain is thus established, creating a large number of carriers. This gives rise to a high reverse current. This mechanism of breakdown is called avalanche breakdown.

Zener Breakdown

When increase the reverse voltage across the pn junction diode, what really happens is that the electric field across the diode junction increases (both internal & external). This results in a force of attraction on the negatively charged electrons at junction. This force frees electrons from its covalent bond and moves those free electrons to conduction band. When the electric field increases (with applied voltage), more and more electrons are freed from its covalent bonds. This results in drifting of electrons across the junction and electron hole recombination occurs. So a net current is developed and it increases rapidly with increase in electric field.

Zener breakdown phenomena occurs in a pn junction diode with heavy doping & thin junction (means depletion layer width is very small). Zener breakdown does not result in damage of diode. Since current is only due to drifting of electrons, there is a limit to the increase in current as well.