VIKAS SINGH

Semiconductor Materials :-

The best conductor (silver, copper and gold) have one valence electron, whereas the best insulator have eight valance electrons. A semiconductor is an element with electrical properties between those of a conductor and those of an insulator.

Germanium → Germanium is an example of a semiconductor. It has electrons in the valance orbit. Many years ago germanium was the only material suitable for making semiconductor devices. But Ge has a drawback as its high reverse saturation current that can not be overcome.

Silicon → Silicon (Si) is most abundant element on the earth. Its reverse saturation current is less than Ge. So Si is very important for the construction of electronics devices.

The conductivity is proportional to the concentration n of free electrons. For a good conductor n is very large ($\sim 10^{28}$ electrons/m^3); for an insulator n is very small ($\sim 10^7$ electrons/m^3); and for a semiconductor n lies between these two values. Conductivity of semiconductor increases as temprature increases. There are two types of semiconductors.

Intrinsic Semiconductors → It is a pure semiconductor. A silicon crystal is an intrinsic semiconductor if every atom in a ~~so~~ crystal is a silicon atom. At room temprature silicon crystal acts like an insulator because it has only a few electrons and holes produced by thermal energy.

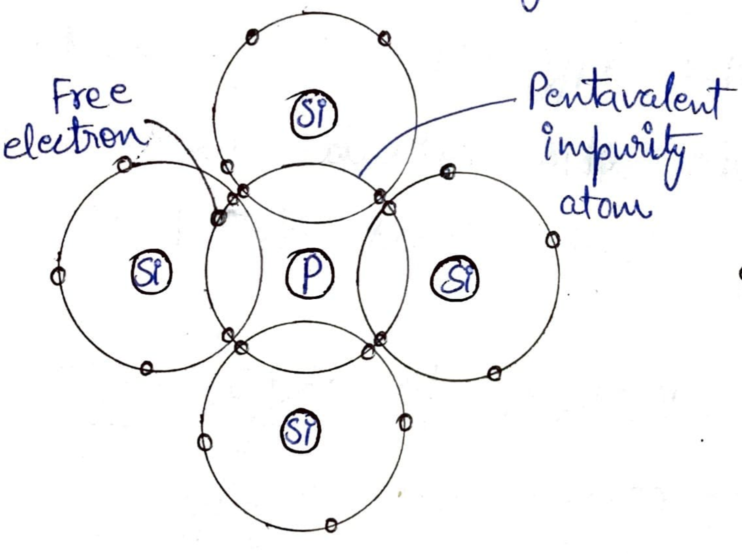
Doping a Semiconductor:-

One way to increase conductivity of a semiconductor is by doping. This means adding impurity atoms to an intrinsic crystal to alter the electrical conductivity. A doped semiconductor is called an extrinsic semiconductor.

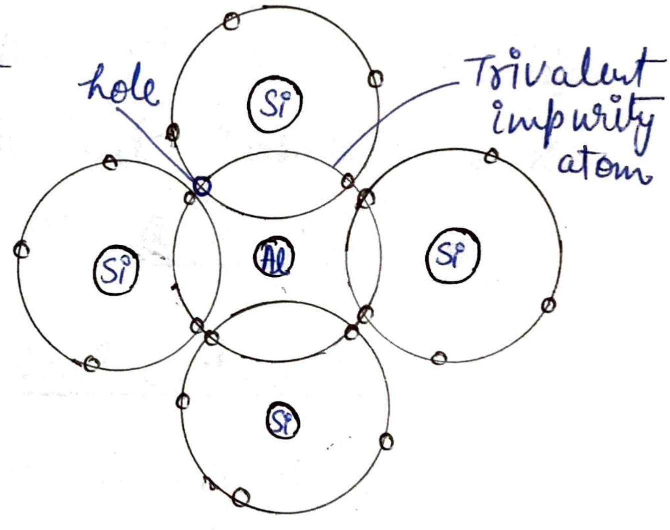
There are two types of impurities that can be added to a semiconductor, pentavalent atom and trivalent impurity.

Pentavelent impurity added more electrons.

Trivalent impurity added more holes.



Doping to get a Free Electron



Doping to get a Hole

A pentavalent atom is in the center ~~so~~ surrounded by Four silicon atoms. The neighbouring atom share an electron with the central atom, but there is an extra electron left over. because 8 electrons can be fit into the valance orbit. It is a free electron.

Each pentavalent or donor atom in a silicon crystal produces one free electron.

The trivalent impurity have only three valance electrons. It is surrounded by four silicon atoms There are only 7 electrons in the valance orbit. This means that hole exists in the valance orbit of each trivalent atom. A trivalent atom is also called as an acceptor atom because each hole can accept a free electron during recombination.

Ex. of Pentavalent impurity - arsenic, antimony, phosphorus

Ex. of Trivalent impurity - aluminium, boron, gallium

Semiconductor with pentavalent impurity is Known as N-type semiconductor or doNar type.

Semiconductor with trivalent impurity is Known as P-type semiconductor or AccePtor type

Two types of Extrinsic Semiconductor

n-type Semiconductor → Si with pentavalent impurity is called an n-type semiconductor. In n-type semiconductor electrons are called the majority carrier and the holes are called the minority carriers.

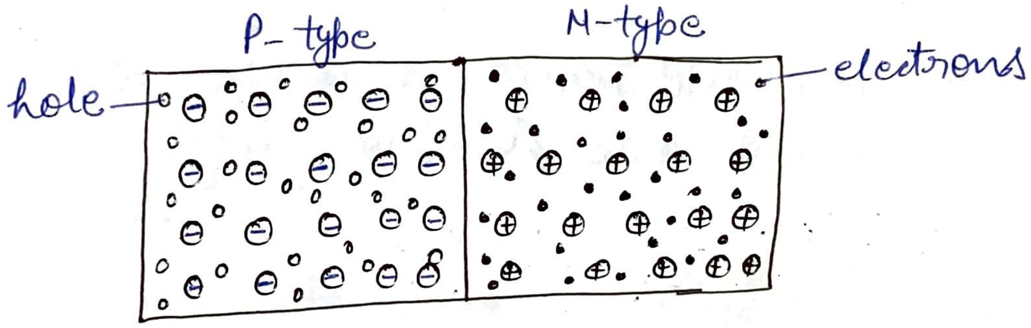
p-type Semiconductor → Si with trivalent impurity is called p-type semiconductor. In p-type semiconductor holes are called majority carrier and electrons are called the minority carrier.

The Unbiased diode :-

When a Silicon or germanium crystal so that one half of it is p-type and the other half is n-type, something new comes into existence.

The border between p-type and n-type is called the pn junction. It is also known as diode. The P-region has holes and negatively charged impurity ions. N-region has free electrons and positively charged impurity ions.

Holes and electrons are mobile charge and ions are immobile.



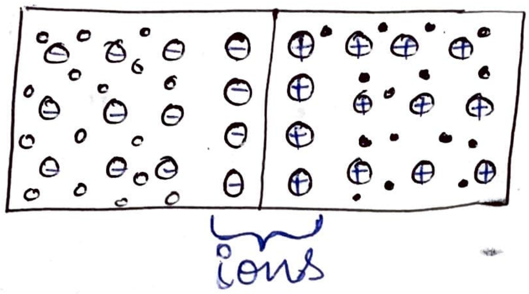
Unbiased PN-junction

* Due to opposite charge holes from p-region diffuse into n-region and electrons from n-region diffuse into p-region. These are diffused due to the difference in concentration.

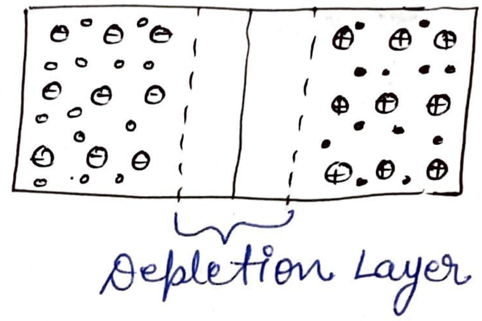
* Each time an electron diffuses across a junction it creates a pair of ions. When an electron leaves the n-side it leaves one negative charge it becomes a positive ion. and when a ~~hole~~ migrating electron falls into hole on p-side it makes a negative ion.

* These ions are fixed in the crystal structure and can not be move. Due to these ions near the

junction make a carrier less region. This charge empty region is called as Depletion layer.



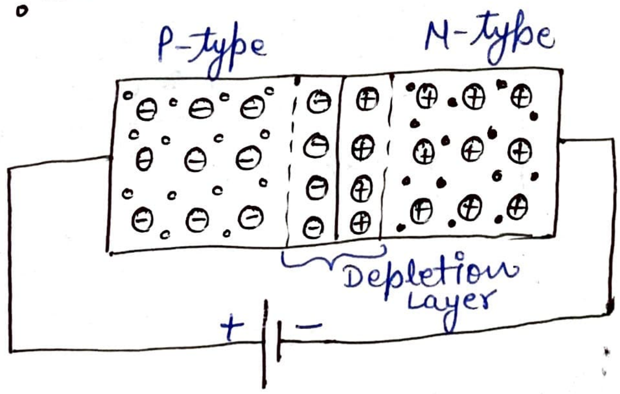
creation of ions



creation of Depletion Layer

* Depletion region has immobile ions which are electrically charged so it is also known as Space charge region.
* The electric field between the acceptor and donor ion is called a Barrier or Barrier potential.

Forward Bias :-



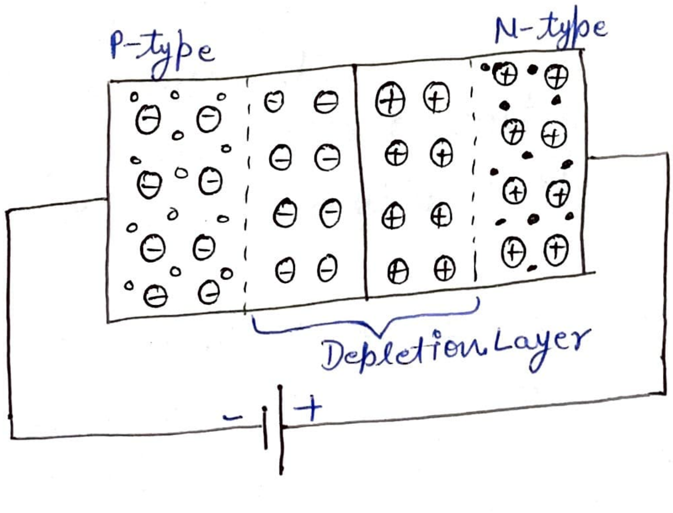
PN-junction showing Forward Bias

When we connect a battery to a PN-junction such that positive terminal of battery is connected to p-side and negative ~~termind~~ terminal to n-side, this condition is said to be forward bias.

The battery pushes holes and electrons towards the junction. If the battery voltage is greater than 0.7 V the free electron has enough energy to get across the depletion layer. Soon after the free electron has entered the p-region, it recombines ~~wt~~ with a hole.

The free electron becomes a valance electron. As a valance electron it continues to travel to left, passing from on hole to the next until it reaches the left end of the diode. When it leaves the left end of the diode, a new hole appears and the process begins again. Since there are so many electrons taking the same journey so a current through diode flows continuously.

Reverse Bias :-

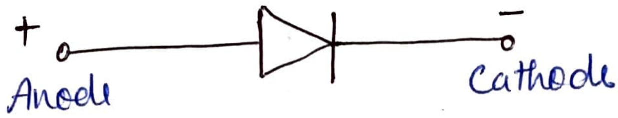


PN junction sowing Reverse Bias

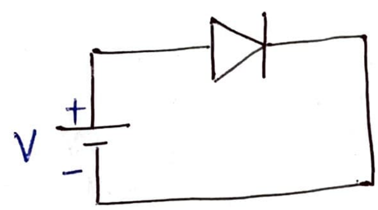
If the negative terminal of battery is connected to p-type and positive terminal to n-type pn-junction then it is known as Reverse Bias PN-junction.

Basic Idea of Diode :—

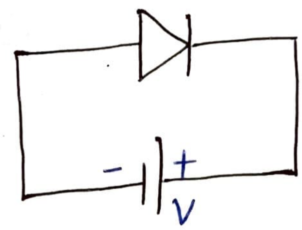
The pn junction forms a semiconductor device called pn-junction diode.



Symbol of Diode



Forward Bias Diode Circuit



Reverse Bias Diode Circuit

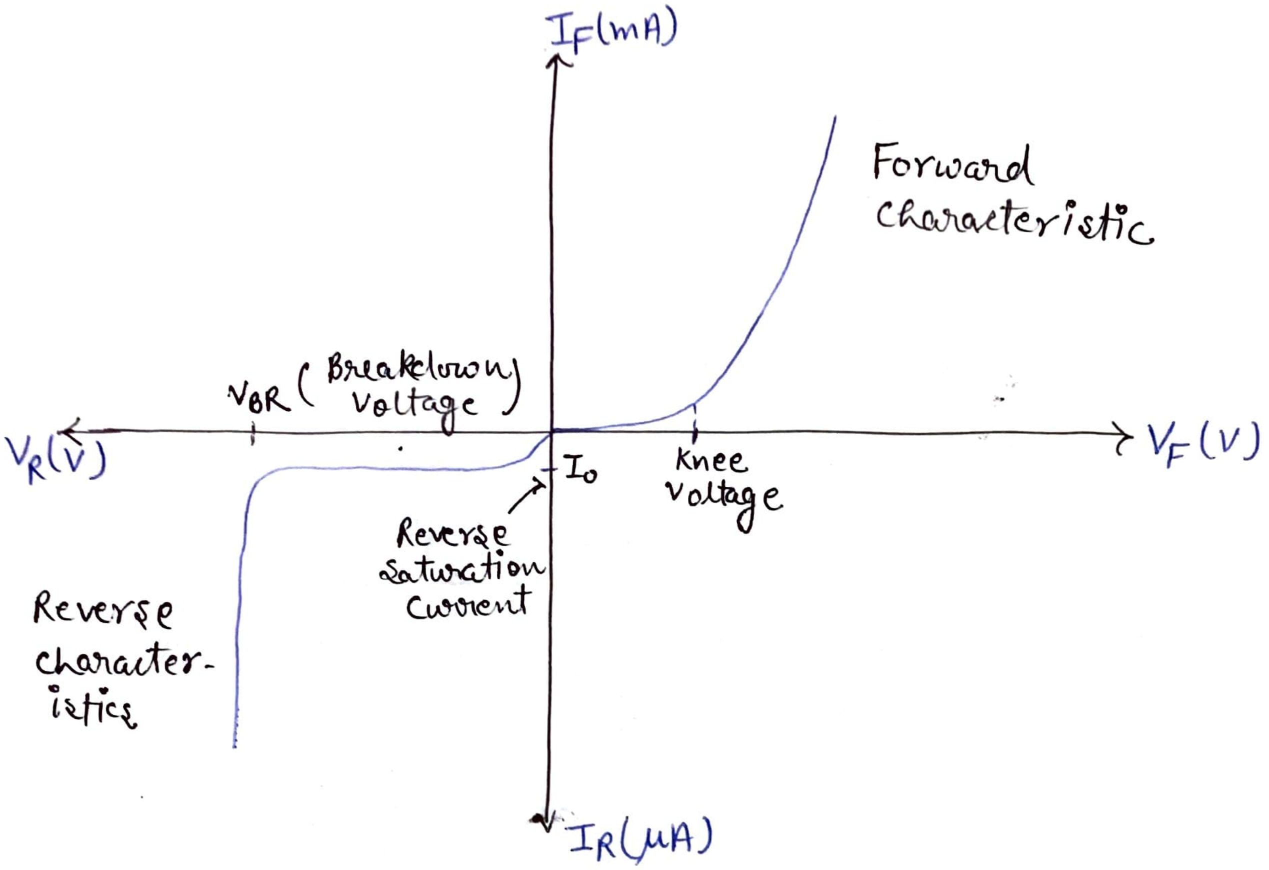
In forward bias conditions +ve terminal of battery is connected to Anode and −ve terminal of battery is connected to cathode.

When diode voltage is less than the barrier potential diode will not conduct as the voltage exceeds the barrier potential diode current increases sharply.

In reverse bias condition +ve terminal of battery is connected to cathode and −ve terminal of battery is connected to anode.

When reverse voltage is increased, reverse current increases initially but after a certain voltage current remains constant equal to reverse saturation current I_0 though reverse current increased.

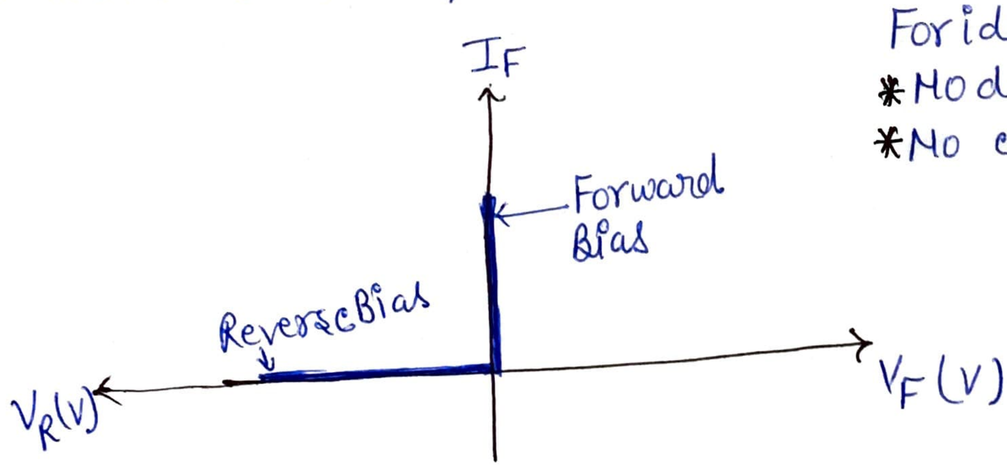
VI Characteristics of a Diode :-



V-I Characteristics of Diode

The Ideal Diode :- An Ideal PN junction diode has good ~~go~~ conduction (no loss) in forward bias and no conduction (act as open switch) in revers bias.

For ideal diode
* No depletion layer
* No cut-in-voltage



VI characteristic of an ideal diode

* Ideal characteristics are also Known as I approxima-tion.

Equivalent circuit for ideal diode

ideal diode

ideal diode
as forward bias
(ON switch)

ideal diode
as reverse
bias
(OFF switch)

Practical Diode (Second Approximation)

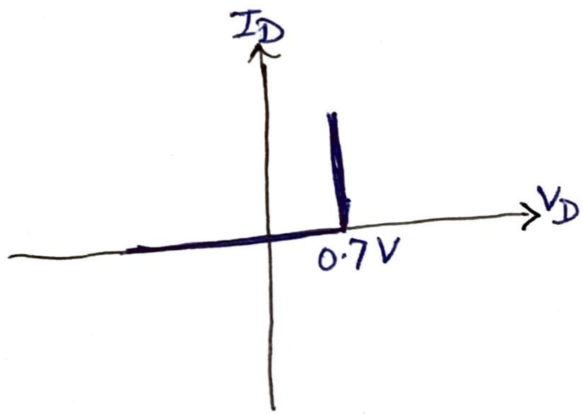
For accurate value of load current and load voltage we use a second approximation.

2nd app.

Reverse Bias

Forward Bias

Equivalent Circuit for Second Approximation



Characteristic for 2nd approximation