* semiconductor and superconductivity:
(chapter-10)

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* Semi-conductor:

The substance whose conductivity lies between those of conductor and insulator are called semi-conductors. For example Germinium and silican are the semi-conductors. They conduct electricity when an electric field is applied. The distinguishing feature about a semi-conductor is that conductivity increases as the temperature is increased.

* valence band -

The range of energy of valence electron is called valence band.

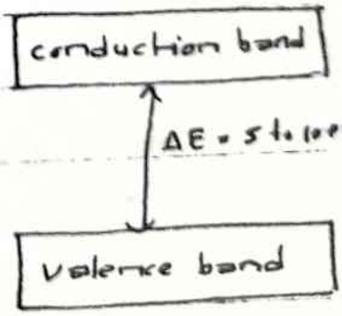
* conduction band:

when the electron in valence band get sufficient energy to become free from the atom, It reaches the higher band as conduction band. Therefore the range of energy of conduction electrons (free electrons) is called conduction band.

The valence band is separated by the conduction band by a certain energy gap called forbidden energy gap denoted by $\Delta E$.

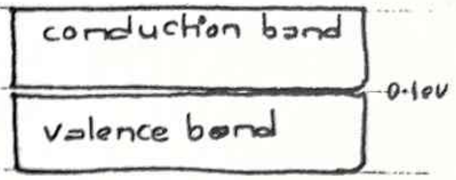
* Insulator, conductor and semi-conductor interms of band theory:

* Insulator: In case of insulator valence band is completely full and conduction band is completkly empty. And there is a large energy gap of an order of 5-10 ev between them.



Insulator.

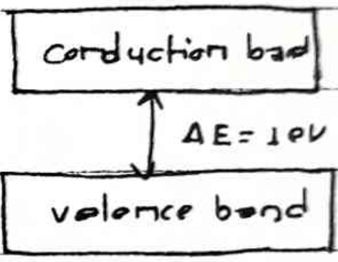
* conductor:




* conductor

In case of conductor there is overlaping between valence band and conduction band. The energy gap is very small of an order of 0.1 ev. Therefore the electron in the valence band can easily jump to the conduction band and the conductivity is very high.

* Semi-conductor:




semi-conductor.

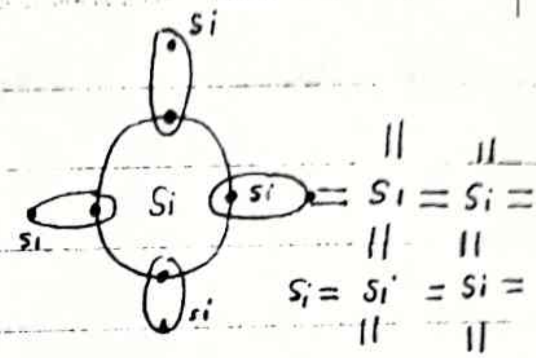
In case of semi-conductor, the valence band is completely full and conduction band is completely empty. There is small energy gap of 1ev between the valence band and conduction band. Thus at 0°k temperature semi-conductor behaves as an insulator. At room temperature, 1 ev energy becomes available from the atmosphere so that electrons from valence band jump to the conduction band and conductivity of the semi-conductor increases.

* Types of semi-conductor:

(1) Intrinsic semi-conductor:

Intrinsic semi-conductor is pure semi-conductor of four valence electron system. The valence electrons of an atom form covalent bonds with the four neighbouring atoms so as to seek eight electrons in the valence shell.

In this way all the valence electrons are located in the covalent bonds and no electrons is set free. As a




result, the valence band is completely full and conduction band is completely empty.

At room temperature the valence band is completely full and conduction band is completely empty. There is a forbidden gap of 1eV. This energy becomes available from the surroundings. Therefore some of the electrons from the covalent bond may comeout from thermal agitation and reach to the conduction band. A ~~e~~ vacancy is thus created in the valence band. This vacancy is called hole. The moment of hole is opposite to that of electron. Therefore the hole is called positive charge carrier. The conduction of electricity is due to both free electrons and the holes.

As the temperature increased, the valence electrons becomes free in more numbers and conductivity of the semi-conductor increases accordingly. Also as the crystal is neutral, the number of free electron is equal to the number of free holes.

(2) Extrinsic semi-conductor:

When some impurity atoms are mixed with a pure semi-conductor crystal, we get extrinsic semi-conductor. The process of adding impurity atoms is called dopping. The dopping agents are of two types (I) Donar agent and (II) Acceptor agents. Donar agents provide free electrons and is pentavalent atoms like As, Sb and acceptor agents provide free holes and is trivalent atoms like Indium (In) or Gallium (Ga).

According to the nature of impurity atoms the extrinsic semi-conductor is of two types-

* N-type extrinsic semi-conductor:

The four valence electrons of pentavalent impurity atom form co-valent bond with four neighbouring host atom. The fifth valence electron of the impurity atom does not take part in co-valent bonding and it thus almost free. This electron can be conveyed to the conduction band merely by small energy. The number of free electrons in the conduction band thus depends on the number of impurity atoms added. Also there are some free holes and free electrons formed by the thermal agitation. In all, the free electrons are in majority and free holes are in minority. Therefore it is called N-type semi-conductor.

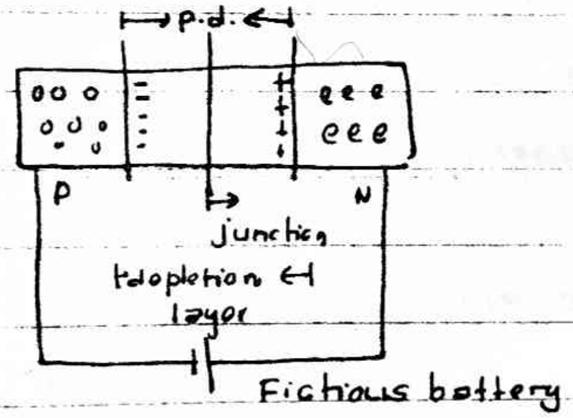
* P-type extrinsic semi-conductor:

The valence electron of trivalent impurity atom for covalent bond with the neighbouring atoms. In this way three bonds are formed by shearing equal electrons. However in the fourth bond electron is sheared by the host atom only and so this bond is devoid of an electron. This bond is filled by an electron from other covalent bond. The bond which releases electron acquires a free hole. In this way for each impurity atom one hole is created in the valence band. However, there are some free electrons in conduction band and equal numbers of free holes in valence band produced by thermal agitation. In all, holes are majority and free electrons are in minority. Therefore it is called p-type semi-conductor.

* P-N junction:

when a p-type semi-conductor is kept in contact with N-type semi-conductor so as to form a single piece of crystal, It is called P-N junction or junction diode. The surface which separates two types of semi-conductor is called junction.

when the crystal is formed electrons from N-type diffuse into p-type and recombine the holes. Therefore, round the junction there is certain region which contains no free charge carriers. (no electrons in N side and no holes in p side) This is called depletion layer.



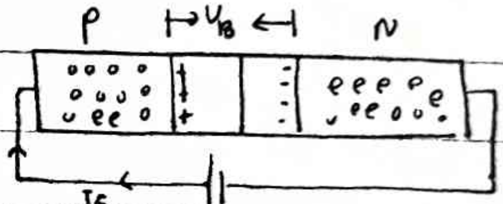

The p-type region has positive holes as majority carriers and N-type region has negative electrons are as majority carriers. In addition there are few minority charge carriers in each region. Thus at the junction there is decreasing hole concentration from left to right which makes hole to diffuse from p-side to N-side. similarly electrons diffuse from right to left across the junction. Holes leaving and electrons entering the p-side make, it negative. similarly holes entering and electrons leaving the N-region makes it positive. Thus there is net negative and net positive charges on the p-side of the junction charge on the N-side. This produces an electric field across the junction. The potential difference increases with the electrons diffuse into p-side and hole diffuse into N-side. For a certain potential difference across the junction, the flow of electrons stops. This is called barrier potential. ($V_B$)

$V_B = 0.3V$ for Ge

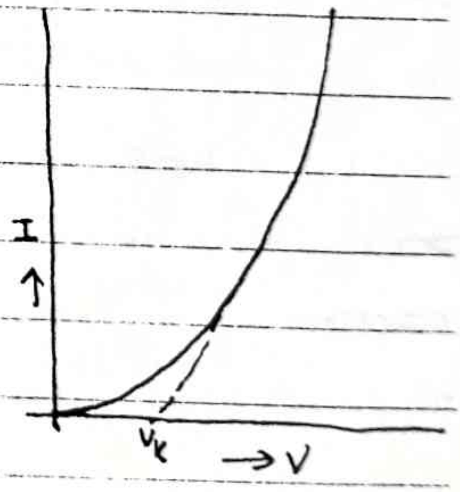
$V_B = 0.7V$ for Si

* Forward biasing:

when p-type of semiconductor is connected to the positive terminal and N-type is connected to the negative terminal of battery, the junction diode is called forward biased.




when applied voltage exceeds barrier potential the majority charge carriers starts crossing the junction and forward current increases i.e junction diode provides low resistance to the majority charge carriers.

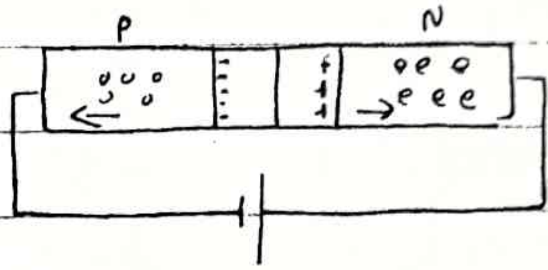



when applied voltage is zero, forward current is zero. when the forward voltage is increased the forward current increases gradually. At certain voltage current increases rapidly. The voltage which separates the forward high current and forward low current is called knee voltage ($V_K$)

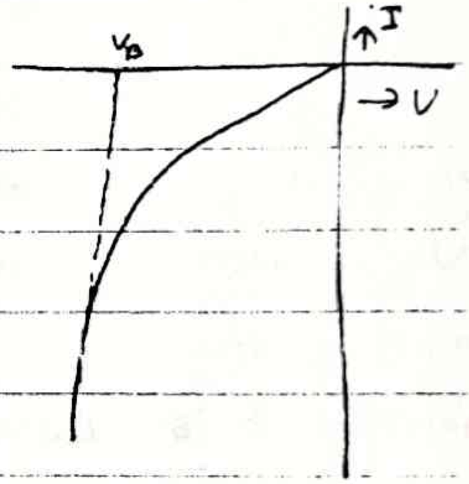
The knee voltage is nearly equal to barrier voltage.

* Reverse biasing:

when p-type of junction diode is connected to the negative terminal and N-type of junction is connected to the positive terminal of the battery then the junction diode is called reversed biased.




when applied voltage is increased, the majority charge carriers are pulled away from the junction so the thickness of the depletion layer increases. It means the junction diode provides high resistance to the majority charge carriers.




when reverse voltage is zero, there is no current in the circuit. when the reverse voltage is zero increased there is small current in the reverse direction. This is due to the minority charge carriers.

when the reverse biasing goes on increasing the current in the circuit increases in large amount at once. This is called junction breakdown.

* Metal semi-conductor junction: -

To overcome the difficulties face in PN-junction diode a new diode is introduced, which is metal semi-conductor junction. In PN junction there generates a barrier potential which delay to conduct electricity in forward biased i.e applied voltage should be greater than the barrier potential, the least current flow in reverse biased condition due to minority charge carriers.

When two materials come into contact the energies at their surface are initially equal. The energy difference between the fermi level and surface (vacuum level) is called work function $\phi$. If an electron is at fermi-level, the work function is the energy required to completely remove the electron from the material.

Consider a metal, workfunction $\phi_m$ in contact with an N-type semi-conductor with work function $\phi_s$.

Let $\phi_m > \phi_s$

The fermi level of the semi-conductor is higher than the fermi-level of the metal. The electrons will flow from the conduction band of the semi-conductor to the metal and the metal will become negatively charged. There is no potential barrier between the metal and semi-conductor i.e will not delay the electricity.

* superconductivity:

The electrical resistivity of some metals and alloys drops suddenly to zero when the speciemen is cooled to a sufficient low temperature. This phenomenon is called superconductivity. And the substances which shows that phenomenon called superconductors. At a certain temperature called the critical

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temperature, the specimen undergoes a phase transition from a state of normal electrical resistivity to a super conducting state.

For example for below a temperature of about 4K, mercury suddenly lost all resistivity and becomes a perfect conductor called superconductor.