Chapter - 3

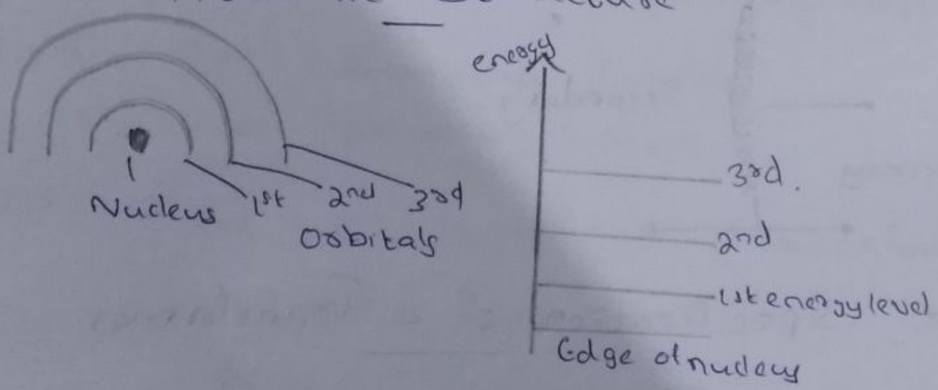
SOLID STATE - FUNDAMENTALS

- Atomic Structure
- Band Theory

  Valence band, conduction band, forbidden energy gap.
- Classification of Solids

  Conductors, Semi conductors, insulators.
- Types of Semi-conductor
  - Intrinsic
  - Extrinsic - P type & N type

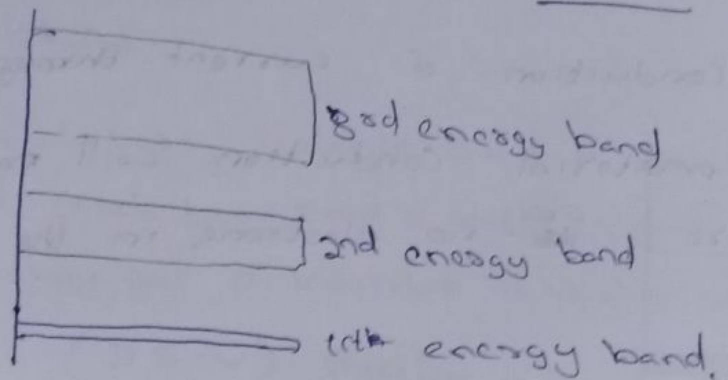
Atomic Structure



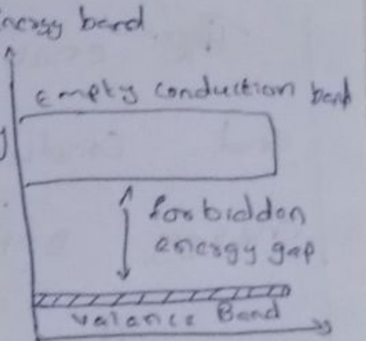
In an atom the electrons revolve around the nucleus in different orbits. Each orbits has fixed amount of energy. The larger the orbit, ~~the~~ greater the energy

Thus the outer orbit posses more energy than inner orbit.

The electrons in the same shell or orbit have a range of energies rather than a single energy. This range of energy is called Energy Band



Valence band



Valance Band in a solid is the energy band possessed by Valance electrons under normal condition. It has the highest energy. Depending upon the material, this band may be filled completly or partially

Conduction band

The energy ~~po~~ band possessed by the conduction electrones in a solid. in metals the valance electrons are loosly bonded to nucleus, they can move freely in the solid. These electrons are called free electrons or conduction electrons. They are responsible for conduction of current through a solid. material. Conduction will not occur if there ~~is~~ are no electrons in the conduction band.

Forbidden energy gap

The energy gap b/w the valence band and conduction band is called forbidden energy gap.

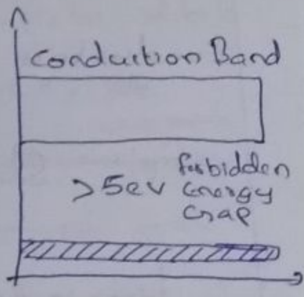
The width of forbiddon energy gap represents bondage of valance electrons to the nucleus. ~~gr~~ Greater the F.E.G more tightly the valance electrons are bonded to the nucleus. To make valance electrons free, an extional energy must be supplied.

The forbidden energy gap is usually expressed in terms of electron volts (eV).

Energy Bands of Conductors, Insulators & Semi-Conductors

Insulators

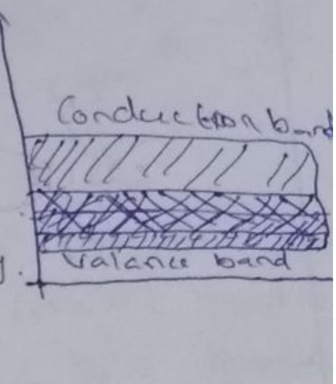
In insulators, valence band is full and conduction band is empty. The energy gap of insulators is very large (>5eV). Therefore a very large electric field is required to lift the ~~Valata~~ Valance e^- to conduction band



Eg! Air, Plastic, Rubber.

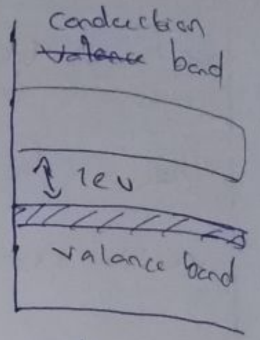
Conductors

In Conductors there is no F.E.G. b/w valance band and conduction band. The two bands actually overlap. So, conduction will occur easily.



Eg! All metals

Semi-Conductors



In Semi-Conductors Valance band is almost filled and Conduction band is empty. But the F.E.G is very small (1ev). Therefore a smaller energy ~~*~~ is required to make a semi-conductor conduct electricity (As compared to insulator).

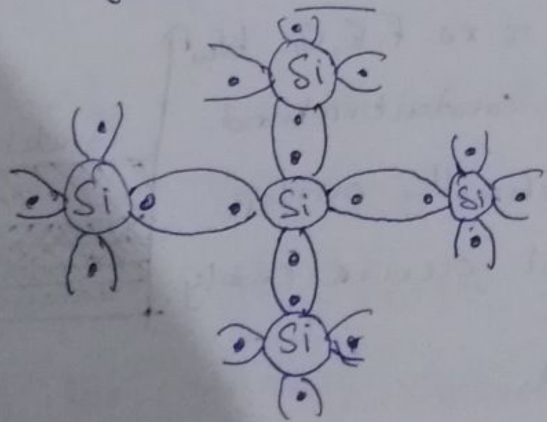
So, conductivity of semi-conductor lies b/w conductors and ~~semi-conductors~~ insulators

Eg:- Silicon, Germanium, Carbon, selenium etc.

Intrinsic Semi-conductors

A semi-conductor in the purest form is known as intrinsic semi-conductors.

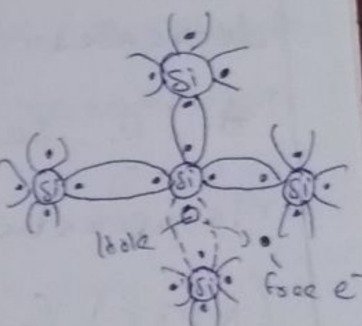
Crystal structure



~~to form~~ In molecules, the atoms are held together by ~~to~~ the bonding action of valance e^-s. Each atom has a tendency to fill it's outermost shell by complete ~~eight~~ eight e^-s to attain stability.

Intrinsic semi-conductors are formed by atoms of element having 4 valence e^-s. These atoms forms ~~cov~~ single bonded covalent bonds to attain complete octet and form a crystal lattice. ~~&~~ each ~~atom~~ ~~semiconductors~~ ~~Ge~~ in a crystal ~~.~~ are covered by ~~4 At~~ four neighbouring ~~semi~~ atoms. This structure is ~~a~~ known as crystal.

Hole & Free Electrons



At room temperature ~~some~~ some of the crystal bonds will be broken. then e^- will ~~have~~ be free to move in the crystal. These electrons are known as free e^-s. The absence of electrons in covalent bond is represented by a small 'circle'. It is known a

Hole. $\bar{e}$'s have −ve charge and Holes have +ve charge

Effects of Temperature

At room temperature, some of the covalent bonds will get broken and $\bar{e}$'s ~~at~~ become free to move in the solid structure. So, ~~tt~~ if a ~~vol~~ V/g is applied at room temp., ~~these~~ these $\bar{e}$'s will contribute small electric current. If the temp. is increased again, more electrons get freed to the conduction band and more current will flow. This shows that Resistance of a semi-conductor decreases with rise in temp.

i.e, semi-conductors have Negative Temperature Coefficient of Resistance (NTC) (means Temp $\propto \frac{1}{R}$)

Generation & Recombination of electrons & Holes

Due to thermal agitation, covalent bond ~~with~~ inside an Intrinsic Semi-conductor produce free $\bar{e}$s. & holes. This process is known as Electron Hole pair Generation.

The no: of free $\bar{e}$s is equal to no: of holes These free $\bar{e}$s and holes are generated and ~~propagated~~ located in random manner.

~~Once~~ [If a free $\bar{e}$ and a hole meets again they will combine ~~to nullify the~~ and becomes a bonded $\bar{e}$. This process is known as Electron Hole Recombination].

The ~~Aver~~ average time ~~an~~ a free electron or a hole will exist befor recombination is called Mean Life Time of $\bar{e}$ and hole.

Extrinsic Semi-conductor

Pure or Intrinsic semi-conductor is not used in construction of semi-conductor devices, because of it poor conductivity. To Increase the conductivity of intrinsic semi-conductor, we add a certain amount of impurities.

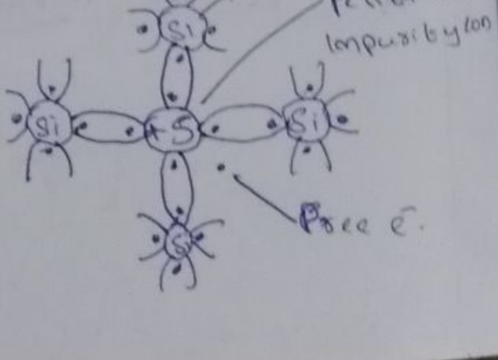
The process of adding impurities to a pure semi-conductor is called **Doping**. The doped semi-conductor is then called Extrinsic (impure) Semiconductor.

Depending on dopent used, the extrinsic Semi-conductors are divided into

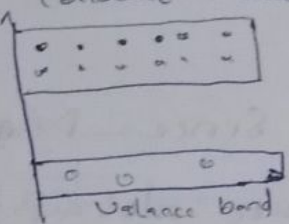
* N-type Semi-conductors
* P-type Semi-conductors

N-type Semi-conductor

N-type Semi-conductor doped with a pentavalent impurity like Antimony, Arsenic Phosphorous etc.



when a Silicon (Si) is doped with pentavalent impurity. ~~four e's~~ four valance e's of silicon make covalant bond with four e of the pentavalent impurity and one electron will be left ~~unbond~~ unbonded. This will be a free e and it can move freely in the crystal structure. Each impurity atom will provide one free e to the crystal. So a small amount of impurity will provide a huge no: of free e's. The fifth e in the pentavalent impurity is known as ~~DON~~ DONORS.



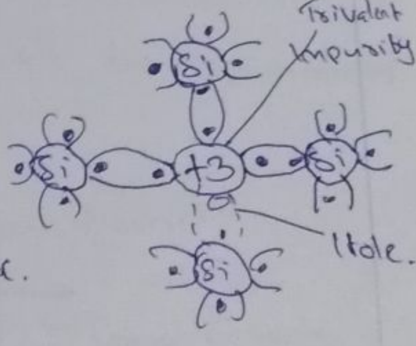
Energy band diagram

Majority carriers - Electrons
Minority carriers - Holes

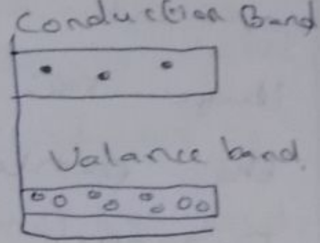
P-type Semi-conductors

~~Impurit Trivalent.~~

Trivalent impurity is the dopant
eg:- Gallium, Indium, Boron etc.



When a Trivalent impurity is added to the Silicon crystal, ~~there~~ three e^-s of Si bonds with the 3 e^-s of the impurity. And there will be ~~a~~ lack of one e^-. This vaccant space is known as Hole. And the Trivalent impurity is called Acceptor. Large no. of holes are produced by adding a small amount of Trivalent impurity.



Majority carriers - holes

Minority carriers

Since Majority and minority carriers are always of opposite electric charges they carry current in opposite direction.