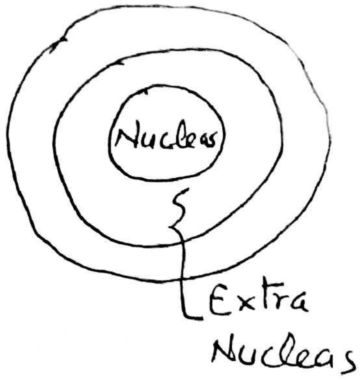
Electrical Engg. Materials (ECE-305)

Atom

- **Nucleas** (Innermost part)
  - ⇒ Contains, Neutrons & Protons
- **Extra Nucleas** (Outer part of atom)
  - ⇒ Contains Electrons only.
  - ⇒ Extra Nucleas also known as Electron Clouds.



⇒ Atomi weight = No. of Neutrons + No. of Protons

⇒ Atomic Number = No. of Protons = No. of Electrons

⇒ charge on Electron = 1.6×10^{-19} Coulomb

⇒ Mass of Electron = 9.1×10^{-31} kg

⇒ Charge on Electron = 1.6×10^{-19} C

⇒ e/m ratio of Electron = 1.7×10^{11} C/kg

⇒ The electrons are distributed in different orbits. These orbits are present in Extra Nucleas part. The No. of electrons in different orbits is given by.–

No. of Electrons in orbit = $2 \times n^2$

where n = No. of orbit

Ist orbit	$= 2 \times 1^2$	$= 2$
IIND "	$= 2 \times 2^2$	$= 8$
IIIrd "	$= 2 \times 2^3$	$= 16$
IVth "	$= 2 \times 2^4$	$= 32$

* But Last orbit can not have more than ~~two~~ Eight electrons.

Energy of Electron:- An electron have basically two energy:-

1). Pottential Energy → Due to charge (+ve) on the Nucleas
2). Kinetic Energy → Due to Revalution Motion around the Nucleas.

Valency Electrons:- The electrons present in the outermost orbit of atom are called valency electrons. The Number of valency electrons can be 8 But not more than 8. The classification of materials according to distribution of valency electrons given as bellow-

1. **Conductors:-** The No. of valency electrons is less than 4. for example.

Sodium (Na) ⟶ 1. valency electrons
Magnesium(Mg) ⟶ 2. " "
Alluminium (Al) ⟶ 3. " "

2. **Insulators:-** The No. of valency electrons more than 4. for Example:-

Nitrogen (N) ⟶ 5. valency electrons
Sulpher (S) ⟶ 6. " "
Neon (Ne) ⟶ 8. " "

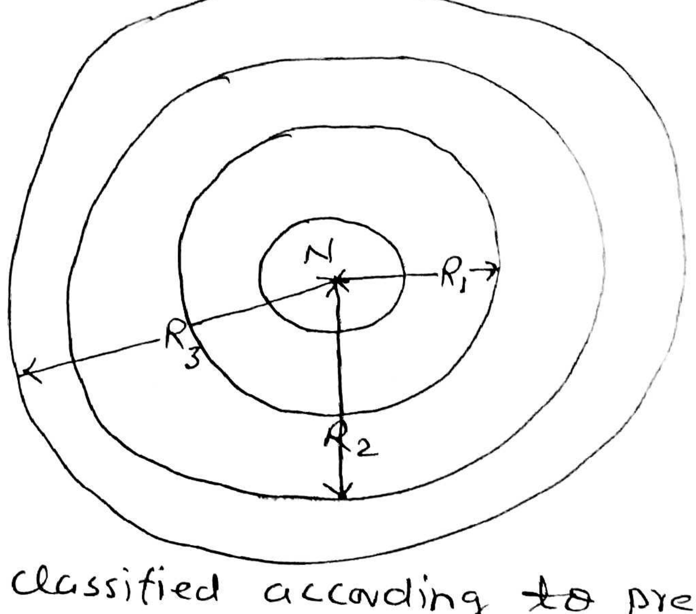
3. **Semiconductors** :- Semiconductors have 4 valency electrons. for example:-

Carbon(C) ⟶ 4. valency electrons
Silicon (Si) ⟶ 4. " "
Germanium (Ge) ⟶ 4. "

⇒ **Free Electrons** :- The valency electrons those are loosely bounded by Nucleus are known as free electrons. The free electrons are very esily removed from orbit by applying a small amount of energy.

R_1, R_2, R_3 = Orbital Radius

* Higher kinetic energy and Lower Potential energy of Last orbit.



The materials are also classified according to presence of free electrons :-

1. **Conductors** :- In solid stage conductors are contains a large No. of free electrons.

2. **Insulators** :- In solid stage insulators have no free electrons.

3. **Semiconductors** :- In solid stage Semiconductors have few free electrons.

The Last orbit divided in two parts named as-

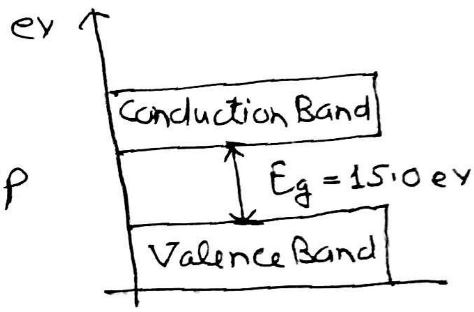
1. Valence band ⟶ Contains valency electrons
2. Conduction band ⟶ Contains free electrons.

Classification of Materials According to Energy bands :-

1. Insulators
2. Conductor
3. Semiconductors

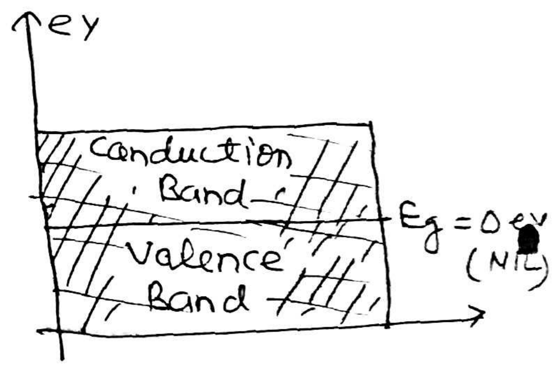
1. Insulators :-

Conduction Band = Fully Empty
Valence Band = fully filledup
Energy Band Gap = 15 ev



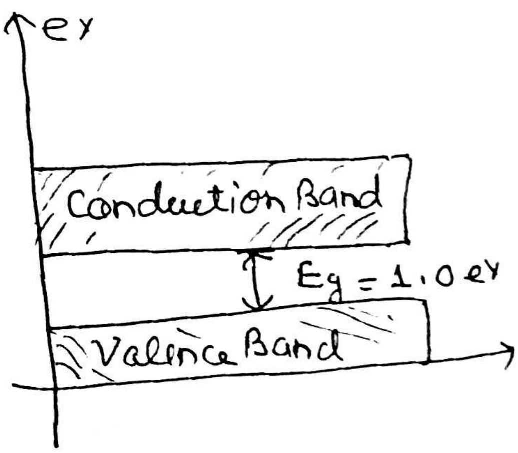
2. Conductors :-

Conduction Band = Fully filledup
Valence Band = fully Empty
Energy Band gap = 0 ev. (NIL)



3. Semiconductors :-

Conduction Band = Almost Empty
Valence Band = Almost filledup
Energy Band gap ≃ 1.0 ev



** Eg (Energy Band gap) = Seperation between Conduction Band & Valence Band.

Semiconductors

The element of IV^{th} group of periodic table are known as semiconductor materials. The conductivity of semiconductors lies b/n conductors and insulators.

Carbon (6) = 2, 4

Silicon (14) = 2, 8, 4

Germanium (32) = 2, 8, 18, 4

Properties:- 1) The resistivity of a semiconductor is less than a insulator but more than conductor.

2) Semiconductors have negative temperature coefficient of resistance. The resistance of semiconductor material decreases with increasing the temperature.

$$\text{Resistance} \propto \frac{1}{\text{Temperature}}$$

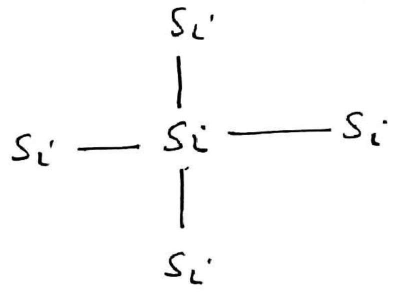
3) when suitable type metallic impurity is added to a semiconductor material then it's current - conducting properties are changed very highly. This process is known as dopping or diffusion. The dopping or diffusion process must satisfied following two conditions :-

a) The process must be substitutional dopping.

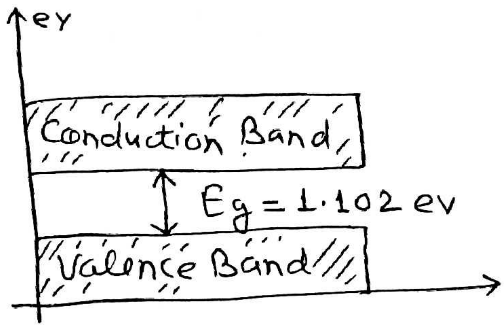
b) The size of impurity atom must be match with size of parent atom.

| P → Si + Al, |
| H → Ge + P |

Intrinsic Semiconductor :- When S/c material is pure means no dopping then known as intrinsic semiconductor. Let us consider example of Si.



Bonding in Si,
Each silicon atom made covalent bonding with four Nieghbour atoms



Energy band diagram of Si,

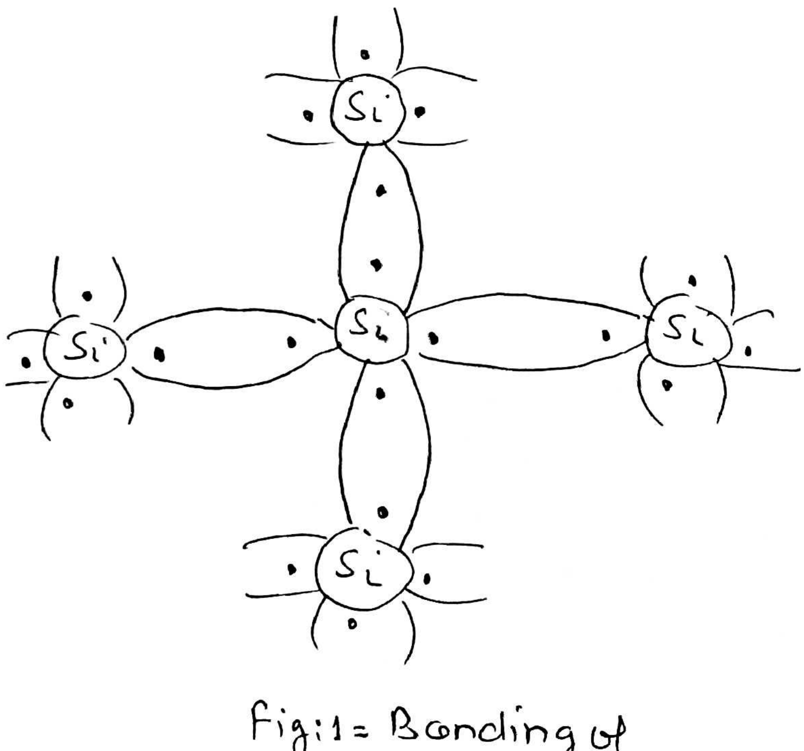


Fig:1 = Bonding of Si.

No free e^- at Normal Temp. (bellaw room temp.)

* Concentration of atoms = $10^{20}/cm^3$

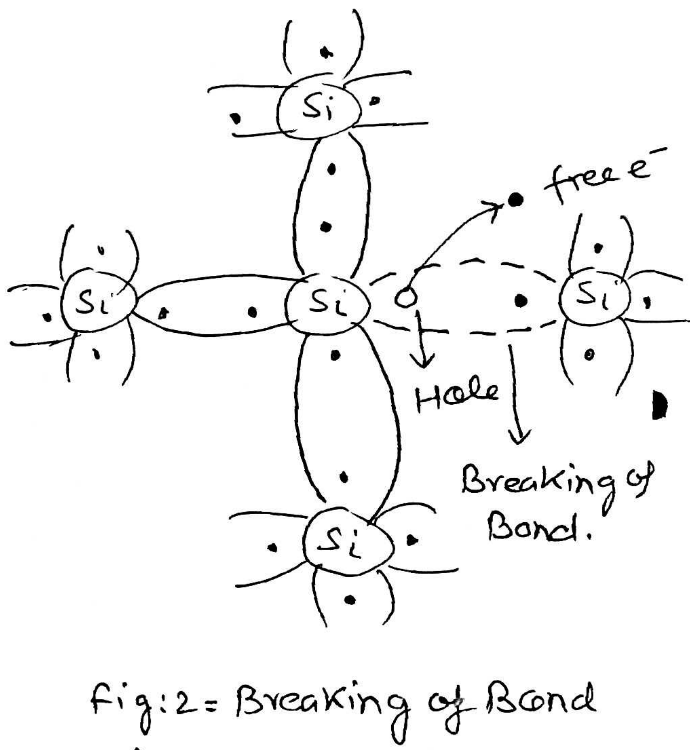


Fig:2 = Breaking of Bond

* When temp. increases covalent Bonds are break. Breaking of bond start at above the room temp.
* When one Co-valent bond break then one hole & one free e^- generate

The phenomenon of breaking of bonds is called EHP Generation. EHP mean's Electron-Hole pair generation. When one Co-valent bond break then on pair of charge carriers (Electron & Hole) generated.

Generation of EHP at roomtemp (in Si) = 10^{10} EHP/cm^3.

n_i = Intrinsic carrier concentration.

$n_i = n_o = P_o$

$n_i^2 = \sqrt{n_o P_o}$

* $n_i \propto T$ (Temp.)

n_o = No. of free $\bar{e}$ due to EHP

P_o = No. of Holes due to EHP.

Extrinsic Semiconductors :- When a suitable type metallic Impurity is added to pure or Intrinsic semiconductors then they are converted in to Extrinsic type semiconductor. There are two types of extrinsic semiconductors :-

1) N-Type S/c

2) P-Type S/c

1) N-Type Semiconductor :- When pentavalent type impurity is added to intrinsic semiconductor material then intrinsic S/c converted into N-Type extrinsic semiconductor material. For example Nitrogen (Phosphorus) is added into Germanium. Then all four atoms of Germanium compelted by shairing of one and one electron of neighbour Nitrogen atom. thier Co-valent bonding.

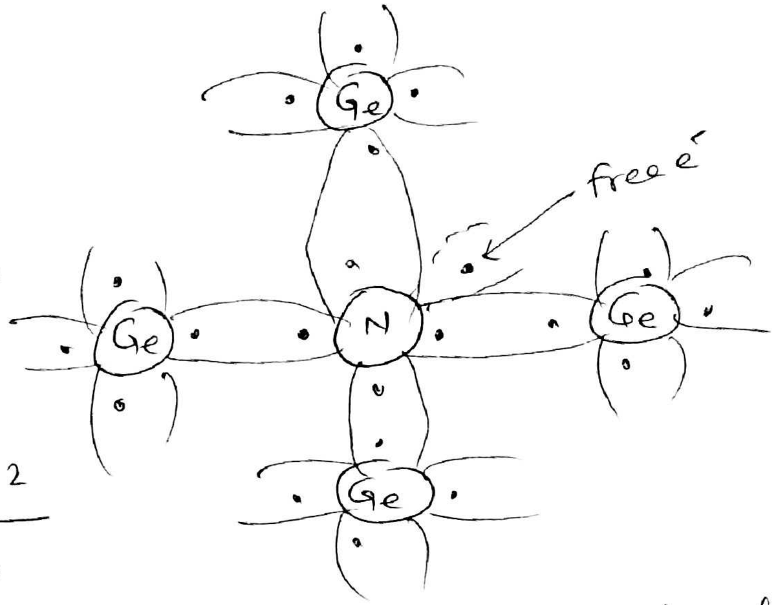
But one electron of nitrogen can not find-out any place in this bonding, this electron is now behaves as free electron.

Each Nitrogen atom provides = one free electron.

in N-Type S/c.

$n >> p$

Here,
Majority of electrons &
Minority of Holes
(Comes from EHP).



N-Type Semiconductor.

Majority Carrier Conc. $n = \frac{n_i^2}{p_o}$

where, n_i = Intrinsic Carrier Concentration.

&

Minority Carrier Conc. $p_o = \frac{n_i^2}{N_D \text{ or } n}$

N_D = No. of added donar atoms

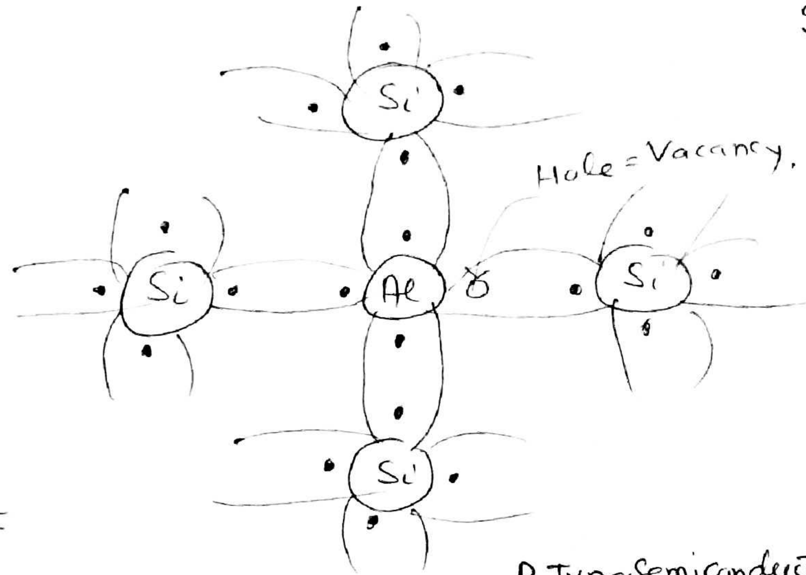
= The pentavalent Impurity is also called Donar Impurity.

Here, in N. Type:
The Aprox. Carrier Conc. ≅ N_D.

2) P. Type Semiconductors :- when a trivalent type suitable metallic impurity is added to a intrinsic S/c material then intrinsic S/c material is converted into P. Type extrinsic S/c material. The trivalent impurity is also called acceptor type impurity, because they have the tendency to accept the electrons and complete their last orbit,
for example: Alluminium (Al)

[P. T. O.]

For example. alluminium is added to Silicon. The Three atoms of Silicon completed Co-valent-bonding with alluminium atom by shairing of one-& one electron. Here a lack of one electron for bonding, so, one covalent bond can-not completed. The lack of this electron is working as a hole.



P Type Semiconductor

* in. P Type Semiconductors ⇒

Majority of Holes &
Minority of electrons (Comes from EHP).

$$\text{Minority Carrier conc. } n_o = \frac{n_i^2}{P} = \frac{n_i^2}{N_A}$$

N_A = No. of Acceptor atoms.

* **Mobility**:- mobility means ability of charge carriers to move - during the application of external field.

Mathematically mobility defined as- " Drift velocity per unit electric field is called mobility. Mobility of charge carrier is reprensted by Symbol μ.

$$\boxed{\mu = \frac{V_d}{E}}$$

$V_d = \mu E$. unit of Mobility is. $cm^2/V\text{-}Sec$.

Drift velocity depends upon applied electric field. for Semiconductor material value of E Lies b/n $10^3 < E < 10^4$ volt/cm.

→ [P.T.O.]

(i) when value of E less than 10^4 volt/cm then mobility is constant.

(ii) when value of E more than 10^4 then.

$$\mu \propto \frac{1}{E}$$

for Silicon:-

Mobility of electron, $\mu_n = 1300 \ cm^2/volt\text{-}sec$
" " Holes. $\mu_p = 500 \ cm^2/volt\text{-}sec$

for Germanium:-

$\mu_n = 3800 \ cm^2/volt\text{-}sec$
$\mu_p = 1800 \ cm^2/volt\text{-}sec$

Current density and Conductivity:- The current density of a conductor can be given by-

$$J = nqV_d \quad \text{------- (i)}$$

n = No. of free electrons.
q = charge on electron
V_d = Drift velocity = $\mu \cdot E$

Replace the value of V_d in Equation (i).

$$J = nq\mu E \quad \text{------- (ii)}$$

But for Semiconductor material (Intrinsic)

$$J_{s/c} = (n\mu_n + p\mu_p) qE$$

$$\sigma_{s/c} = \frac{J}{E}$$

$$\therefore \boxed{\sigma_{s/c} = q(n\mu_n + p\mu_p)}$$

n = No. of free electrons, μ_n = Mobility of electrons.
p = No. of Holes, μ_p = Mobility of Holes.

(P.T.O)