2. Extrinsic Semi Conductor:-

Impurity Semi conductors in which the charge Carriers are produced by doping of the impurity atoms into intrinsic (or) pure semiconductors.

Extrinsic Semi Conductors are produced by doping of trivalent (or) Pentavalent impurity atoms into intrinsic semiconductors.

2) Difference between Intrinsic and Extrinsic Semi Conductor.

Intrinsic Semi Conductor	Extrinsic Semi Conductor.
(i) Pure Semiconductor	Doped with impurity is called Extrinsic
(ii) The charge Carriers are Produced only due to thermal agitation.	Charge Carriers are Produced due to impurities and to produce thermal agitation.
(iii) low electrical Conductivity	high electrical Conductivity
(iv) low operating Temp.	high operating temp.
(v) At T=0K, fermi level exactly lies between E_c and E_v	At T=0K, Fermi level ~~is~~ closer to Conduction band in n-type, closer to Valence band in p-type
(vi) Ex:- Si and Ge	Ex:- Ph and Ar

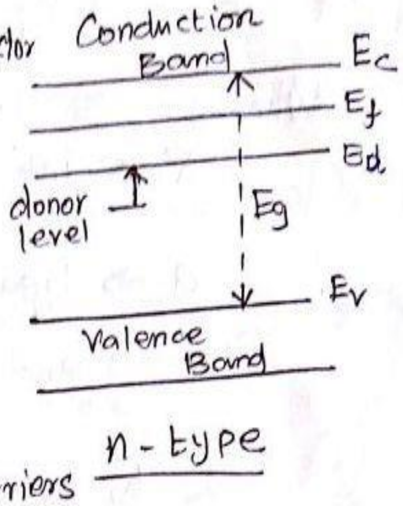
3) Difference between n-type and P-type Semi

n-type	P-type
(i) Doping an intrinsic Semi Conductor with Pentavalent impurity.	Add in trivalent impu
(ii) e^-s are majority Carriers and holes are minority Carriers.	holes are majority Car and e^- are minority Ca
(iii) Donor energy level Closer to Conduction band.	Acceptor energy level Valance band
(iv) When Temp. is increased, these semi conductors Can easily donate an e^- from doner energy level to the Conduction band.	When Temp is increased Semi Conductors Can ea accept an e^- from Valen to acceptor energy level

Impurity added, they are classified.

(i) n-type Semi Conductor :-

Doping an intrinsic Semiconductor with the pentavalent (five e^-s in Valence band)



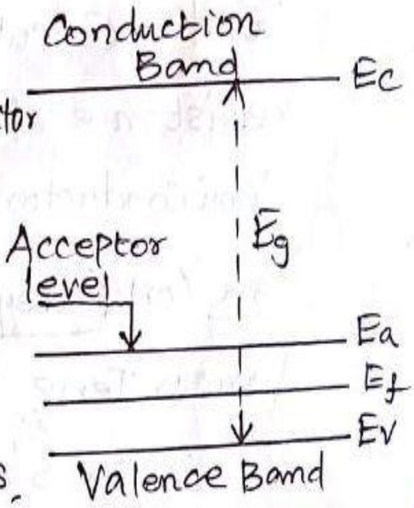
Ex :- Phosphorous, arsenic, antimony

* e^-s are majority charge carriers
* holes are mainority charge carriers.

The energy level of the doneted e^-s are called donor energy level (E_d).

(ii) P-type SemiConductor :-

Doping an intrinsic SemiConductor with the trivalent (3 e^-s in valence band).



Ex :- Boron, Indium etc.

* holes are majority charge carriers.
* e^- are minority charge carriers.

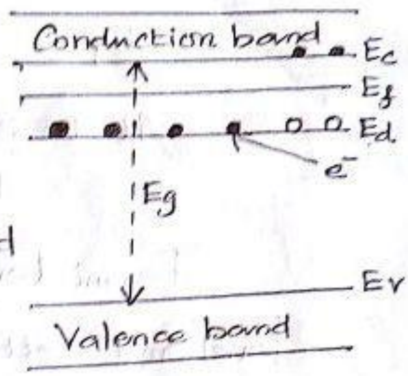
The energy level of the accept e^-s are called Accepted energy level (E_A).

2.1 Carrier Concentration and fermi level Calculation in n-type Semiconductor:-

2.1 (a) Fermi Energy level

At 0K, E_f will lie exactly between E_c and E_d, but even at low temp. Some electrons may go from E_d to E_c. Let us assume that $E_c - E_f > 4KT$. The density of e^- in Conduction band,

$$n = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2} \exp\left[\frac{E_f - E_c}{kT}\right] \rightarrow (1)$$



$E_c \Rightarrow$ Bottom energy level in Conduction band

$E_f \Rightarrow$ Fermi energy level

$E_d \Rightarrow$ Donor energy level

$E_v \Rightarrow$ Top energy level in Valence band

Density of ionized donor

$$= N_d\left[1 - F(E)\right]$$

$$= N_d\left[1 - \frac{1}{1+\exp\frac{E_d - E_f}{kT}}\right]$$

$$= N_d\left[\frac{1+\exp\frac{E_d-E_f}{kT} - 1}{1+\exp\frac{E_d-E_f}{kT}}\right]$$

$$= \frac{N_d \exp\frac{E_d-E_f}{kT}}{1+\exp\frac{E_d-E_f}{kT}}$$

$\left[\because e^{E_d - E_f/kT} \text{ is small Value} \quad 1 + e^{E_d - E_f/kT} \approx 1\right.$

$$= \frac{N_d}{1+\exp\frac{E_f - E_d}{kT}} \rightarrow (2)$$

E_f is lies more than a few kT above the donor level.

$$\therefore N_d\left[1 - F(E)\right] \approx N_d \exp\frac{E_d - E_f}{kT} \rightarrow (3)$$

At Very low Temp.

$\therefore$ The density of donor = density of e^- in Conduction band.

$$N_d\left[1 - F(E)\right] = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2} \exp\left[\frac{E_f - E_c}{kT}\right] \rightarrow (4)$$

Taking logarithms and rearranging,

$$\left[\frac{E_f - E_c}{kT}\right] - \left[\frac{E_d - E_f}{kT}\right] = \log N_d - \log 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}$$

$$2E_f - (E_d + E_c) = kT \log \frac{N_d}{2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}}$$

$$E_f = \frac{E_d + E_c}{2} + \frac{kT}{2} \log \frac{N_d}{2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}} \rightarrow (5)$$

At $T = 0k$,

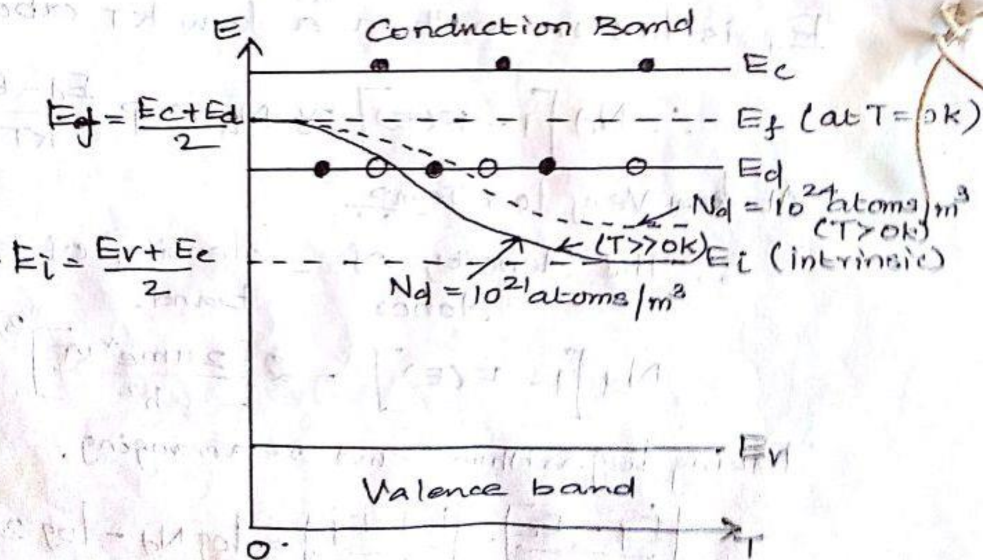
$$E_f = \frac{E_d + E_c}{2} \rightarrow (6)$$

Fermi level lies exactly halfway between donor level and bottom of Conduction band at $T = 0k$.

As the temp. Increases fermi level drops.

The temp. is gradually increase from a low Temp the Contribution of e's to the Conduction band from the Valence band increase and at very high Temp (Ge=500k)

The temp. is increase, the fermi level shifts toward the intrinsic fermi level, But by increasing donor Concentration, the extrinsic behaviour may be maintained even at high Temp.



Variation of fermi level with Temp. and Concentration.

Putting Ef Value into expression of $\frac{E_f - E_c}{kT}$ in equ (1) and Sub the Value of Ef from equ (6).

$$\exp\left[\frac{E_f - E_c}{kT}\right] = \exp\left[\frac{E_d + E_c}{2kT} - \frac{E_c}{kT} + \frac{1}{2}\log\frac{N_d}{2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}}\right]$$

$$\exp\frac{E_f - E_c}{kT} = \exp\left[\frac{E_d - E_c}{2kT} + \frac{1}{2}\log\frac{N_d}{2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}}\right]$$

$$= \exp\frac{E_d - E_c}{2kT}\left[\frac{N_d}{2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}}\right]^{1/2} \rightarrow (7)$$

Substitute equ (7) in equ (1)

$$n = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}\exp\frac{E_d - E_c}{2kT}\left[\frac{N_d}{2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}}\right]^{1/2}$$

$$n = \left[2N_d\right]^{1/2}\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/4}\exp\left[\frac{E_d - E_c}{2kT}\right] \rightarrow (8)$$

The density of e^- (n) in conduction band is Proportional to the square root of donor Concentration(

(c) Electrical Conductivity:-

The electrical Conductivity (σ) in Semiconductor,

$$\sigma = ne(\mu_e + \mu_h) \rightarrow (9)$$

For n-type Semiconductor, the acceptor are almos zero. Therefore the mobility of charge Carriers, holes is zero. ($\mu_h = 0$).

$$\sigma = ne(\mu_e)$$

$$\sigma = \left[2N_d\right]^{1/2}\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/4}\exp\left[\frac{E_d - E_c}{2kT}\right] e(\mu_e) \rightarrow (10)$$