④ ⓐ According to Band theory of solids, the energy spectrum of e- consists of a large number of energy bands and is separated by forbidden regions. The band gap is the difference in the energy between the lowest point of conduction band (C.B) and highest point of valence band (V B).

⇒ Based on the structure of energy bands and type of energy emission, semiconductors are classified into two types

① Direct Band Gap Semiconductor.

② Indirect band Gap Semiconductor.

⇒ Direct Band Gap S-C

① These are made from compound (mixed) element.

② These are made from III and V [or] II and VI elements.

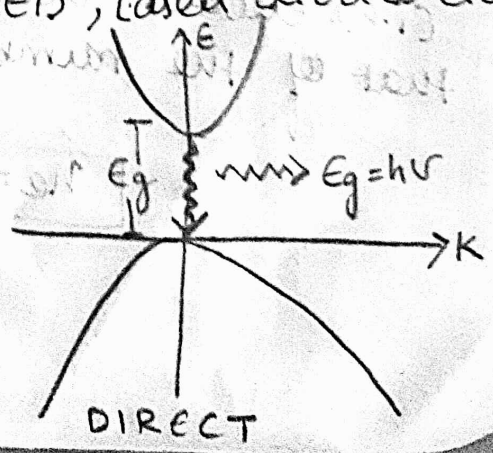
③ These are called as Direct band gap SC because electron-hole recombination takes place directly.

④ Photons are emitted during recombination

⑤ Life time of charge carrier is less due to direct combination.

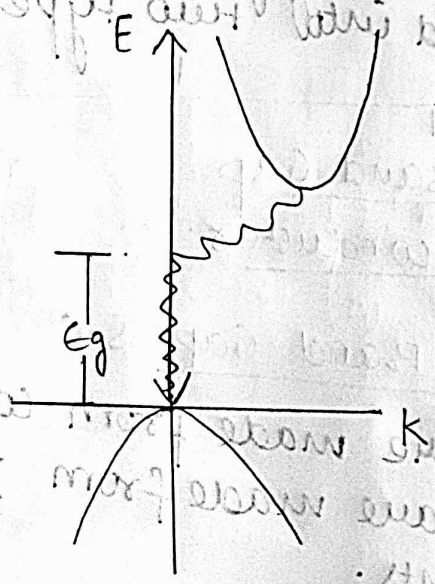
⑥ These are used for making LED, Laser diodes etc.

⑦ Ex: GaAs, GaP, CdS, MgO



INDIRECT BAND GAP semiconductor

1. These are made from single element.
2. These are made from IV group and VI group elements.
3. These are called as Indirect band S.C. because electron-hole takes place through traps)
4. Heat is produced in the recombination.
5. Life time of charge carriers is more due to indirect recombination.
6. These are used for making diodes, transistors etc.
7. Example : Ge, Si



Indirect

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4 5 Fermi Level in an Intrinsic semiconductor

⇒ For an intrinsic semiconductor no. of e^- (i.e) electron density will be the same as that of the number of holes (i.e) hole density.

$$\boxed{n_e = n_h} \quad \text{—— (1)}$$

$$\Rightarrow 2\left(\frac{2\pi m_e^* k_B T}{h^2}\right)^{3/2} e^{(E_F - E_c)/k_B T} = 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{3/2} e^{(E_v - E_F)/k_B T}$$

$$\Rightarrow (m_e^*)^{3/2} e^{(E_F - E_c)/k_B T} = (m_h^*)^{3/2} e^{(E_v - E_F)/k_B T}$$

$$\Rightarrow \left(\frac{m_h^*}{m_e^*}\right)^{3/2} = \frac{e^{[E_F - E_c]/k_B T}}{e^{(E_v - E_F)/k_B T}}$$

$$\Rightarrow \left(\frac{m_h^*}{m_e^*}\right)^{3/2} = e^{(E_F - E_c - E_v + E_F)/k_B T}$$

$$\Rightarrow \left(\frac{m_h^*}{m_e^*}\right)^{3/2} = e^{[2E_F - (E_c + E_v)]/k_B T}$$

$\Rightarrow$ Taking log on both sides.

$$\Rightarrow \frac{3}{2}\log\left(\frac{m_h^*}{m_e^*}\right) = \frac{[2E_F - (E_c + E_v)]}{k_B T}$$

$$\Rightarrow \frac{3}{2} k_B T \log\left(\frac{m_h^*}{m_e^*}\right) = [2E_F - (E_c + E_v)]$$

$$\Rightarrow \boxed{E_F = \frac{E_c + E_v}{2} + \frac{3}{4} k_B T \log\left(\frac{m_h^*}{m_e^*}\right)}$$

If $m_e^* = m_h^*$; $\log\left(\frac{m_h^*}{m_e^*}\right) = 0$; then

$$\boxed{E_F = \frac{E_v + E_c}{2}}$$

(Q.17)

=) Conc. or Density of electrons in the conduction Band:

Density of e- in a conduction band:-

$$\left[n_e = \int_{E_c}^{\infty} Z(E)\, F(E)\, dE \right] \quad \text{—— (1)}$$

The density of states expression for available states in conduction band is written as

$$\left[Z(E)\, dE = \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} E^{1/2}\, dE \right] \quad \text{—— (2)}$$

Considering minimum energy of a conduction band as E_c and maximum energy as ∞, we can write eq (2)

$$\left[Z(E)\, dE = \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} [E - E_c]^{1/2}\, dE \right] \quad \text{—— (3)}$$

From Fermi-Dirac distribution function, the probability of finding e- in a given energy state can be written as;

$$\left[F(E) = \frac{1}{1 + e^{(E - E_F)/k_B T}} \right] \quad \text{—— (4)}$$

Substituting eq (3) and eq (4) in Eq (1); the density of electrons in a conduction band within limits E_c to ∞ can be written as:

$$\left[n_e = \int_{E_c}^{\infty} \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} [E - E_c]^{1/2} \cdot \frac{1}{1 + e^{[E - E_F]/k_B T}}\, dE \right] \quad \text{—— (5)}$$

To move electron from valence band to conduction band; the energy required is greater than $4 k_B T$

i.e $\quad E - E_F >> k_B T$

$$\frac{E - E_F}{k_B T} >> 1.$$

$$e^{(E - E_F)/k_B T} >> 1$$

$$1 + e^{(E - E_F)/k_B T} = e^{[E - E_F]/k_B T}$$

Now; Eq (5) becomes;

$$\left[n_e = \int_{E_c}^{\infty} \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} (E - E_c)^{1/2} \frac{1}{e^{[E - E_F]/k_B T}} dE \right]$$

$$\left[n_e = \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} \int_{E_c}^{\infty} (E - E_c)^{1/2} e^{-[E - E_F]/k_B T} dE \right]$$

$$\left[n_e = \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} \int_{E_c}^{\infty} (E - E_c)^{1/2} e^{(E_F - E)/k_B T} dE \right]$$

Let us assume that;

$$E - E_c = x k_B T$$

$$E = E_c + x k_B T$$

Differentiating; we get; $\left[dE = k_B T dx \right.$

If we define limits; $\left[\begin{array}{ll} \text{when } E = E_c & x = 0 \\ \text{when } E = \infty & x = \infty \end{array} \right]$

Eq (6) can be written as;

$$\left[n_e = \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} \int_0^{\infty} (x k_B T)^{1/2} e^{(E_F - E_c - x k_B T)/k_B T} k_B T dx \right]$$

$$\left[n_e = \frac{\pi}{2} \left(\frac{8 m_e^*}{h^2} \right)^{3/2} (k_B T)^{3/2} \int_0^{\infty} x^{1/2} e^{(E_F - E_c)/k_B T} \cdot e^{-x} dx \right]$$

$$\left[n_e = \frac{\pi}{2} \left(\frac{8 m_e^* k_B T}{h^2} \right)^{3/2} e^{[E_F - E_c]/k_B T} \int_0^{\infty} x^{1/2} e^{-x} dx \right]$$

$$\left[\int_0^{\infty} x^{1/2} e^{-x} dx = \frac{\sqrt{\pi}}{2} \right]$$

$$\left[n_e = \frac{\pi}{2} \left(\frac{8 m_e^* k_B T}{h^2} \right)^{3/2} e^{[E_F - E_c]/k_B T} \frac{\sqrt{\pi}}{2} \right]$$

$$\left[n_e = \frac{1}{4} \left(\frac{8 \pi m_e^* k_B T}{h^2} \right)^{3/2} e^{[E_F - E_c]/k_B T} \right]$$

⇒ Density of e- or conc. of e- in a conduction band is:-

$$\boxed{n_e = 2 \left(\frac{2 \pi m_e^* k_B T}{h^2} \right)^{3/2} e^{[E_F - E_c]/k_B T}} \quad \text{—— (7)}$$

* Concentration of holes in the valence Band

⇒ we know $F(E)$ represents the probability of filled states
⇒ As the maximum probability is 1, the probability of unfulfilled states will be $[1 - F(E)]$

Therefore; density of holes in valence band n_h is given by

$$\left[n_h = \int_{-\infty}^{E_v} Z(E)\,[1 - F(E)]\,dE \right] \quad \text{—— (1)}$$

The density of states expression for available states in valence band is written as

$$\left[Z(E)\,dE = \frac{\pi}{2}\left(\frac{8m^*_h}{h^2}\right)^{3/2} E^{1/2}\,dE \right] \quad \text{—— (2)}$$

~~The den~~ Considering minimum energy of a valence band as $-\infty$ and maximum energy as E_v, we can write eq (2) as

$$\left[Z(E)\,dE = \frac{\pi}{2}\left(\frac{8m^*_h}{h^2}\right)^{3/2} [E_v - E]^{1/2}\,dE \right] \quad \text{—— (3)}$$

From Fermi-Dirac distribution function;

$$1 - F(E) = 1 - \frac{1}{1 + e^{[E - E_F]/k_BT}}$$

$$1 - F(E) = \frac{e^{(E - E_F)/k_BT}}{1 + e^{(E - E_F)/k_BT}}$$

Here;

$$\left[\begin{array}{l} E - E_F << k_BT \\ \dfrac{E - E_F}{k_BT} << 1 \\ 1 + e^{(E - E_F)/k_BT} = 1 \\ 1 - F(E) = e^{(E - E_F)/k_BT} \end{array} \right] \quad \text{—— (4)}$$

Substituting eq (4) and eq (3) in eq (1); the density of holes in valence bands within limits $-\infty$ to E_v can be written as;

$$\left[n_h = \int_{-\infty}^{E_v} \frac{\pi}{2}\left(\frac{8m^*_h}{h^2}\right)^{3/2} [E_v - E]^{1/2} e^{[E - E_F]/k_BT}\,dE \right] \quad \text{—— (5)}$$

let us assume that; $(E_V - E = x k_B T)$

diff. we get; $[dE = -k_B T\, dx]$

if we define the limits; $\left[\begin{array}{l} \text{when } E = E_V;\ x = 0 \\ \text{when } E = -\infty;\ x = \infty \end{array}\right]$

Eq (6) can be written as;

$$\left[n_h = \int_{\infty}^{0} \frac{\pi}{2}\left(\frac{8m_h^*}{h^2}\right)^{3/2}(x k_B T)^{1/2} e^{[E_V - x k_B T - E_F]/k_B T}(-k_B T)\,dx\right]$$

To exclude the negative sign; the limits can be interchanged!!

$$\left[n_h = \int_{0}^{\infty} \frac{\pi}{2}\left(\frac{8m_h^*}{h^2}\right)^{3/2}(x k_B T)^{1/2} e^{[E_V - x k_B T - E_F]/k_B T}(k_B T)\,dx\right]$$

$$\left[n_h = \frac{\pi}{2}\left(\frac{8m_h^* k_B T}{h^2}\right)^{3/2} \int_{0}^{\infty} x^{1/2} \cdot e^{-x} \cdot e^{(E_V - E_F)/k_B T}\,dx\right]$$

$$\left[n_h = \frac{\pi}{2}\left(\frac{8m_h^* k_B T}{h^2}\right)^{3/2} e^{(E_V - E_F)/k_B T} \int_{0}^{\infty} x^{1/2} \cdot e^{-x}\,dx\right]$$

$$\left[n_h = \frac{\pi}{2}\left(\frac{8m_h^* k_B T}{h^2}\right)^{3/2} e^{(E_V - E_F)/k_B T} \frac{\sqrt{\pi}}{2}\right] \qquad \left[\int_{0}^{\infty} x^{1/2} e^{-x}\,dx = \frac{\sqrt{\pi}}{2}\right]$$

$$\left[n_h = \frac{1}{4}\left(\frac{8\pi m_h^* k_B T}{h^2}\right)^{3/2} e^{(E_V - E_F)/k_B T}\right]$$

The density of holes or conc. of holes in a valence band is;

$$\left[n_h = 2\left(\frac{2\pi m_h^* k_B T}{h^2}\right)^{3/2} e^{(E_V - E_F)/k_B T}\right] \quad \text{—— (7)}$$

* Carrier concentration in an intrinsic semi conductor

In an intrinsic semiconductor; the conc. of e^- in the conduction band is equal to the conc. of holes in the valence band.

⇒ we can write Intrinsic semiconductor,

$$n_i = n_e = n_h$$

$$\boxed{n_i^2 = n_e n_h} \quad \text{—— (1)}$$

Substituting equations of n_e and n_h in eq (1)

$$n_i^2 = 2\left(\frac{2\pi m^*_e k_B T}{h^2}\right)^{3/2} e^{(E_F - E_C)/k_B T} \times 2\left(\frac{2\pi m^*_h k_B T}{h^2}\right)^{3/2} e^{(E_V - E_F)/k_B T}$$

$$n_i^2 = 4\left(\frac{2\pi k_B T}{h^2}\right)^3 (m^*_e m^*_h)^{3/2} e^{(E_F - E_C + E_V - E_F)/k_B T}$$

$$n_i^2 = 4\left(\frac{2\pi k_B T}{h^2}\right)^3 (m^*_e m^*_h)^{3/2} e^{(E_V - E_C)/k_B T}$$

⇒ ~~n_i^2~~ Here; $(E_C - E_V) = E_g$ is the energy gap / forbidden gap

$$n_i^2 = 4\left(\frac{2\pi k_B T}{h^2}\right)^3 (m^*_e m^*_h)^{3/2} e^{-E_g/k_B T}$$

$$\boxed{n_i = 2\left(\frac{2\pi k_B T}{h^2}\right)^{3/2} (m^*_e m^*_h)^{3/4} e^{-E_g/2k_B T}} \quad \text{—— (2)}$$

⇒ eq (2); gives the intrinsic carrier conc. of pure semiconductor!!

(6) When small quantities of selected impurities are added to intrinsic semiconductor, it becomes an extrinsic semiconductor.

$$\boxed{n_e = N_a \cdot F(E)} \quad \text{--- (1)}$$

[N_a = No. of acceptor ions.
E_a = Acceptor energy level]

$$n_e = N_a \cdot \frac{1}{1 + e^{[E_a - E_F]/kT}}$$

$$\left[\begin{array}{l} (E_a - E_F) >> kT \\ \frac{E_a - E_F}{kT} >> 1 \end{array}\right] \qquad n_e = N_a \cdot \frac{1}{e^{(E_a - E_F)/kT}}$$

$$\boxed{n_e = N_a \cdot e^{-(E_a - E_F)/kT}} \quad \text{--- (2)}$$

$$\boxed{n_h = 2\left(\frac{2\pi m^*_h kT}{h^2}\right)^{3/2} e^{(E_v - E_F)/kT}} \quad \text{--- (3)}$$

Let us say; $N_v = 2\left(\frac{2\pi m^*_h kT}{h^2}\right)^{3/2}$.

At thermal equilibrium;

$$n_e = n_h.$$

$$\Rightarrow N_a \cdot e^{-(E_a - E_F)/kT} = N_v e^{(E_v - E_F)/kT}$$

$$\Rightarrow \frac{N_a}{N_v} = e^{(E_v - E_F + E_a - E_F)/kT}$$

$\Rightarrow$ Applying log on both sides;

$$\Rightarrow \log\left(\frac{N_a}{N_v}\right) = \log e^{(E_v - E_F + E_a - E_F)/kT}$$

$$\Rightarrow \log\left(\frac{N_a}{N_v}\right) = \frac{E_v + E_a - 2E_F}{kT}$$

$$\Rightarrow kT \log\left(\frac{N_a}{N_v}\right) = E_v + E_a - 2E_F$$

$$\Rightarrow \boxed{E_F = \frac{E_v + E_a}{2} - \frac{1}{2} kT \log\left(\frac{N_a}{N_v}\right)} \quad \text{--- (4)}$$

Now substitute the values in eq (3)

$$\Rightarrow n_h = N_v \cdot e^{(E_v - E_F)/kT}$$

$$\Rightarrow n_h = N_v \cdot e^{\left[E_v - \left(\frac{E_v + E_a}{2} - \frac{1}{2} kT \log\left(\frac{N_a}{N_v}\right)\right)\right]/kT}$$

$$\Rightarrow n_h = N_v \cdot e^{\left[\frac{E_v - E_a}{2} + \frac{1}{2} kT \log\left(\frac{N_a}{N_v}\right)\right]/kT}$$

$$\Rightarrow n_h = N_v \cdot e^{\left[\left(\frac{E_v - E_a}{2kT}\right) + \frac{1}{2} \log\left(\frac{N_a}{N_v}\right)\right]}$$

$$\Rightarrow n_h = N_v \cdot e^{(E_v - E_a)/2kT} \cdot e^{\log\left(\frac{N_a}{N_v}\right)^{1/2}}$$

$$\Rightarrow n_h = N_v \cdot e^{(E_v - E_a)/2kT} \cdot \left(\frac{N_a}{N_v}\right)^{1/2}$$

$$\Rightarrow n_h = N_v \cdot e^{(E_v - E_a)/2kT}$$

$$\Rightarrow \cancel{n_h = 2\left(\frac{2\pi m^* h kT}{h^2}\right)^{3/2} \cdot (N_a)^{1/2}}$$

$$\Rightarrow n_h = (N_v)(N_a)^{1/2}(N_v)^{-1/2} \cdot e^{(E_v - E_a)/2kT}$$

$$\Rightarrow n_h = (N_v)^{1/2}(N_a)^{1/2} \cdot e^{(E_v - E_a)/2kT}$$

$$\Rightarrow n_h = \left[2\left(\frac{2\pi m^* h kT}{h^2}\right)^{3/2}\right]^{1/2} (N_a)^{1/2} e^{(E_v - E_a)/2kT}$$

$$\Rightarrow n_h = 2^{1/2}\left(\frac{2\pi m^* h kT}{h^2}\right)^{3/4} (N_a)^{1/2} e^{(E_v - E_a)/2kT}$$

$$\Rightarrow \boxed{n_h = (2N_a)^{1/2}\left[\frac{2\pi m^* h kT}{h^2}\right]^{3/4} e^{(E_v - E_a)/2kT}}$$

(7) When small quantities of selected impurities are added to intrinsic semiconductor, it becomes an extrinsic SC.

$$n_h = \cancel{N_d F(E)} = N_d[1 - F(E)] \quad \text{--- (1)}$$

N_d = No. of donor ions.

E_d = Donor energy level.

$$n_h = N_d\left[1 - \frac{1}{1 + e^{(E_d - E_F)/kT}}\right]$$

$$n_h = N_d\left[\frac{e^{(E_d - E_F)/kT}}{1 + e^{(E_d - E_F)/kT}}\right] \quad \left\{\begin{array}{l}(E_d - E_F) << kT \\ \frac{E_d - E_F}{kT} << 1\end{array}\right.$$

$$n_h = N_d \cdot e^{(E_d - E_F)/kT} \quad \text{--- (2)}$$

$$n_e = 2\left(\frac{2\pi m^*_e kT}{h^2}\right)^{3/2} e^{(E_F - E_c)/kT} \quad \text{--- (3)}$$

let us say; $N_c = 2\left(\frac{2\pi m^*_e kT}{h^2}\right)^{3/2}$

At thermal equilibrium,

$n_e = n_h$

$$\Rightarrow N_d \cdot e^{(E_d - E_F)/kT} = N_c \cdot e^{(E_F - E_c)/kT}$$

$$\Rightarrow \frac{N_d}{N_c} = e^{(E_d - E_F - E_F + E_c)/kT}$$

$$\Rightarrow \frac{N_d}{N_c} = e^{(2E_F - (E_c + E_d))/kT}$$

$\Rightarrow$ Applying log on both sides;

$$\Rightarrow \log\left(\frac{N_d}{N_c}\right) = \frac{[2E_F - (E_c + E_d)]}{kT}$$

$$\Rightarrow kT\log\left(\frac{N_d}{N_c}\right) = 2E_F - (E_c + E_d)$$

$$\Rightarrow \boxed{E_F = \frac{E_c + E_d}{2} + \frac{1}{2} KT \log\left(\frac{N_d}{N_c}\right)} \quad \text{--- (4)}$$

Substitute in (3)

$$\cancel{n_e = N_c \cdot e^{[E_F - (}}$$

$$\Rightarrow n_e = N_c \cdot e^{\left[\frac{E_c + E_d}{2} + \frac{1}{2} KT \log \frac{N_d}{N_c} - E_c\right] / KT}$$

$$\Rightarrow n_e = N_c \cdot e^{\left[\frac{E_d - E_c}{2KT} + \frac{1}{2} \log \frac{N_d}{N_c}\right]}$$

$$\Rightarrow n_e = N_c \cdot e^{\left(\frac{E_d - E_c}{2KT}\right)} \cdot e^{\left(\log \frac{N_d}{N_c}\right)^{1/2}}$$

$$\Rightarrow n_e = N_c \cdot e^{\left(\frac{E_d - E_c}{2KT}\right)} \cdot \frac{(N_d)^{1/2}}{(N_c)^{1/2}}$$

$$\Rightarrow n_e = N_c \cdot (N_c)^{-1/2} \cdot (N_d)^{1/2} \cdot e^{\frac{(E_d - E_c)}{2KT}}$$

$$\Rightarrow n_e = (N_c)^{1/2} \cdot (N_d)^{1/2} \cdot e^{\frac{(E_d - E_c)}{2KT}}$$

$$\Rightarrow n_e = 2^{1/2} \left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/4} \cdot (N_d)^{1/2} \, e^{\frac{(E_d - E_c)}{2KT}}$$

$$\Rightarrow \boxed{n_e = (2N_d)^{1/2} \left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/4} e^{\left(\frac{E_d - E_c}{2KT}\right)}}$$

(8) (a) Hall Effect:

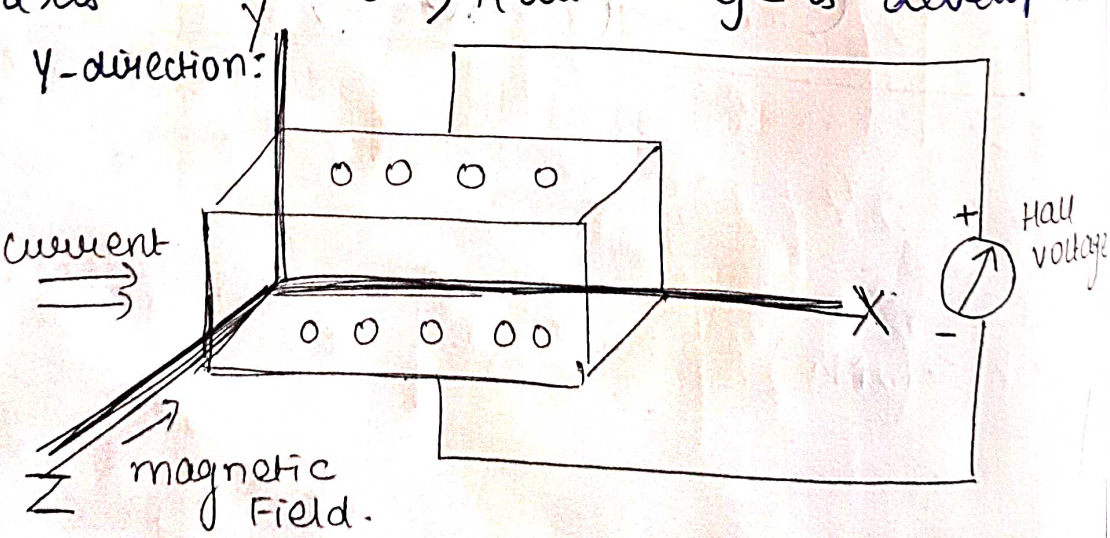
Statement: When a conductor (metal or SC) carrying current (I) is placed perpendicular to a magnetic field (B), a potential difference (electric field) is developed inside the conductor in a direction ⊥r to both current and magnetic field. This phenomenon is known as Hall Effect and the voltage thus generated is called Hall voltage.

Derive the expression for Hall co-efficient:-

⇒ Assume an N-type semiconductor;

⇒ Let I be the current passed along x-axis; the electrons flow opposite to the conventional current direction.

⇒ Let B be the magnetic field applied along z-axis. As a result; Hall voltage is developed along y-direction.



⇒ Due to the magnetic field 'B', there is, a Lorentz force act on each e⁻ given by

$\boxed{BeV}$.

⇒ this makes the electrons deviated in a downward direction along y-axis

⇒ this causes a negative charge to accumulate on the bottom face.

⇒ From Lorentz force formula

$$\boxed{F_B = BeV}$$

where e = charge of e⁻
V = velocity of e⁻
B = magnetic field.

$F_L = q(V_d \times \bar{B})$
$= q V_d B \sin\theta$
$= q V_d B \sin 90°$
$F_L = q V_d B$.
since, there's a use of e⁻, $\boxed{q = e}$
$$\boxed{F_L = BeV}$$

⇒ A potential difference is formed from top to bottom of the specimen.

⇒ The potential difference causes a field E_H to flow along negative y-axis.

⇒ Due to E_H along negative y-direction, a force of E_H acts in upward direction along positive y-axis;

Hence, $\boxed{F_E = e E_H}$

⇒ under equilibrium condition;

⇒ upward force due to E_H = Downward force due to B.

⇒ $F_B = F_E$.

⇒ $BeV = eE_H$. {E_H = Hall electric field}

⇒ $$\boxed{V = \frac{E_H}{B}} \quad \text{--- (1)}$$

velocity of e⁻ in presence of E and B is equal to E_H/B

=) If J is the current density; then

$$J = nev$$

$$\boxed{v = \frac{J}{ne}} \quad \text{--- (2)}$$

=) Equating (1) and (2)

$$\frac{E_H}{B} = \frac{J}{ne}.$$

$$\boxed{E_H = \frac{JB}{ne}} \quad \text{--- (3)}$$

$$\boxed{E_H = R_H B J} \quad \text{--- (4)}$$

Hall co-efficient for electrons;

$$\boxed{R_H = \frac{-1}{ne}}$$

where; n = electron density
R_H = Hall coefficient.
B = magnetic field
J = current density

---

(5) Applications of Hall coefficient

1) It is used to determine whether the material is p-type or n-type S.C.
(i.e) if R_H is negative; then the material is N-type
=) if R_H is positive; then the material is p-type

2) It is used to find the carrier concentration.

3) It is used to find the mobility of charge carriers μ_e, μ_h.

(4) It is used to find the sign of the current carrying charges.

(5) It is used to design magnetic flux meters and multipliers on the basis of Hall voltage.

(6) used to find the power flow in an electro-magnetic wave.

(7) used as a magnetic field sensor.

(9) (a) ⇒ P-N Junctions are formed by joining n-type and p-type semiconductor materials.

⇒ Since the n-type region has a high electron conc. and the p-type has a high hole conc, e- diffuse from the ~~n-sid~~ n-type side to the p-type side.

⇒ similarly, holes flow by diffusion from the p-type side to the n-type side.

⇒ in a p-n junction diode, when the e- and hole move to the other side of the junction, they

leave behind. exposed charges on dopant atom sites, which are fixed in the crystal lattice and are unable to move.

=) On the n-type side, positive ion cores are exposed. On the p-type, negative ion cores are exposed.

=) An Electric field E forms between the positive ion cores in the n-type material and negative cores in the p-type material.

=) This region is called "depletion ~~sen~~ region", since the electric field quickly sweeps free carriers out, hence the region is depleted of free carriers. A built in potential V_{bi} is formed at the junction due to E.

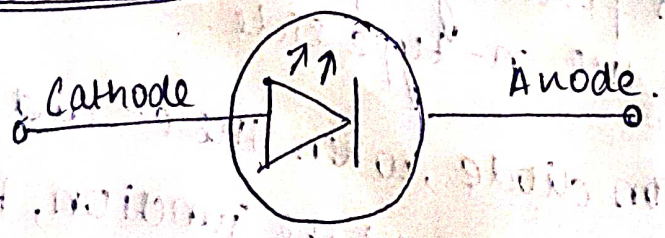
=) In this way, a P-N Junction diode is formed.

(b). LED

=) A light emitting diode is an electric component that emits light when the electric current flows through it.

=) When current passes through the LED, the e- ~~recombine with~~ recombine with holes, emitting light in the process.

=) LED SYMBOL



LED SYMBOL

Construction

① The methods used to construct LED are to deposit three semiconductor layers on the substrate.

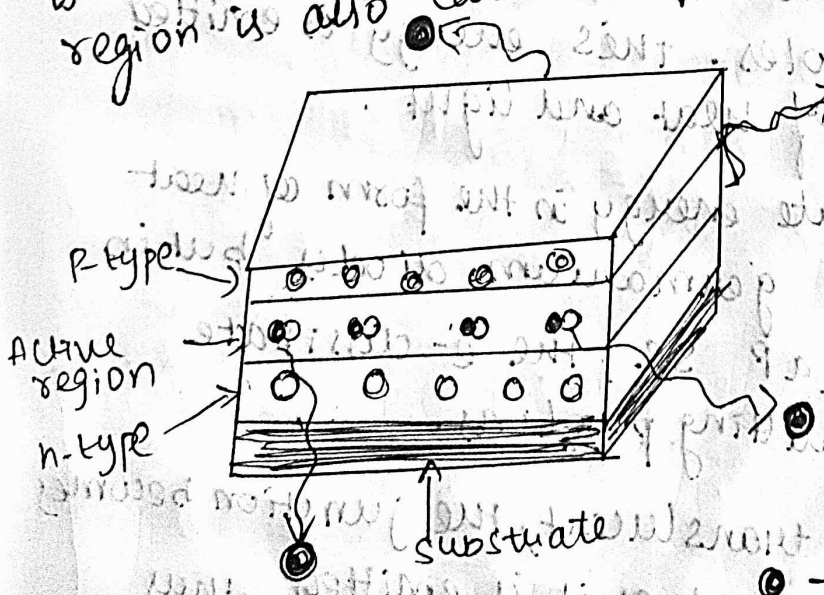
② The three S.C. layers deposited on the substrate are n-type, p-type semiconductor and active region

③ Active region is present in between the n-type and p-type S.C. layers.

④ When LED is forward biased, free e- from n-type S.C. and holes from p-type SC are pushed towards the Active Region.

⑤ When free e- from n-side and holes from p-side recombine with the opposite charge carriers. (free e- with holes or holes with free e-) in active region, an invisible or visible light is emitted.

⑥ In LED, most of the charge carriers recombine at active region. Therefore, most of the light is emitted by the active region. The active region is also called depletion region



● → Photon
● → hole
○ → free electron

Working:

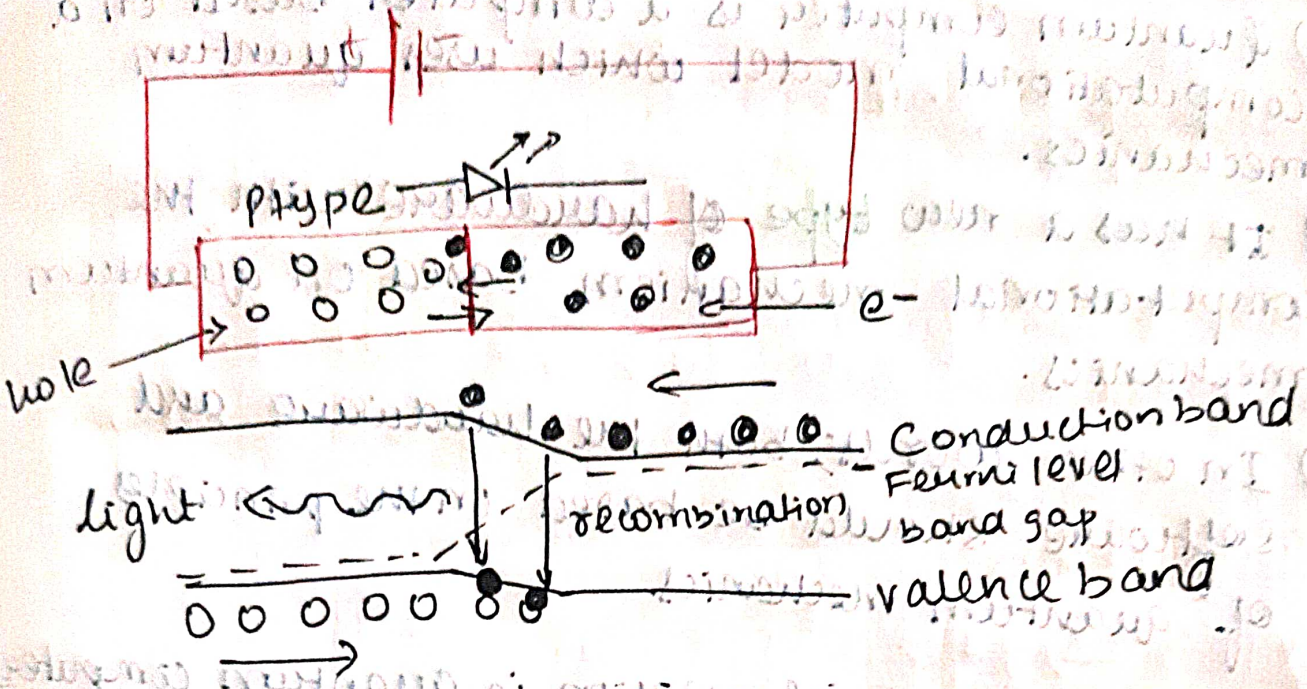
1) A p-n junction can convert absorbed light energy into a proportional electric current. The same process is reversed here (i.e the P-N Junction emits light when electrical energy is applied to it).

2) This phenomenon is generally called Electro-lum inenscene, which can be defined as the emission of light from a semi-conductor under the influence of an electric field.

3) The charge carriers recombine in a forward biased P-N Junction as the electrons cross from the N-region and recombine with the holes existing in the P-region. Free e- are in the conduction band of energy levels, while holes are in the valence band.

4) Thus, energy level of holes < energy level of electrons. Some portion of energy must be dissipated in order to recombine the electrons and holes. This energy is emitted in the form of heat and light.

5) The e- dissipate energy in the form of heat for silicon and germanium diodes but in GaAsP and GaP SC, the e- dissipate energy by emitting photons.

6) If the SC is translucent, the junction becomes the source of light as it is emitted, thus becoming a light emitteg diode; but when the junction is reverse biased no light will be

produced by the LED, on the contrary, the device may be damaged.