UNIT-II

UNIT-2

1. Valence bond is partially filled overlapping with the conduction bond. Due to this Reason the valence electrons can move in conduction band very easily.

ex:- Non-metal $1s^2 2s^2 2p^6 3s^1 3p^0$.

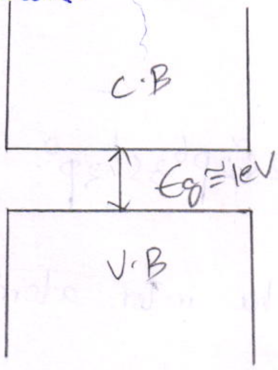
case (ii) In this case the inter atomic spacing is such that complitely filled valency bond overlaps with the empty or partially filled condution bond.

ex:- Mg, Zn Mg: $1s^2 2s^2 2p^6 3s^2 3p^0$

SEMICONDUCTORS:-

In some materials the inter atomic spacing is such that there is a gap called bond gap(Eg) between the complitely filled valence bond and completely empty conduction bond depending on the magnitude of gap we can classify the materials as Semiconductors and insulators.

If the bond gap is $\simeq 1eV$ those materials are called Semiconductors.



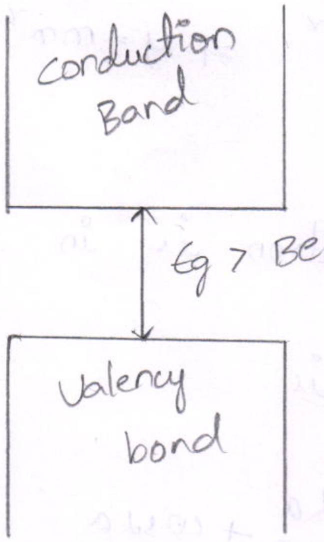
for Si → $E_g = 1.1eV$ and for Ge → $E_g = 0.7eV$

INSULATORS:-

In some materials the forbidden energy gap is wide. Those materials are called Insulators.

Eg:- for glass $E_g = 3.3eV$

for diamond $E_g = 5.4\ eV$



E-k CURVE / (BRILLOUIN ZONES)

When the electron is in free state. The energy value of electron is $E = \frac{1}{2} mv^2 = \frac{p^2}{2m}$.

Brillouin Zone is a Representation of peremissive values of 'k' (wave number) of the electrons in 1D, 2D & 3D.

① The energy value of electron in free state is $E = \frac{1}{2} mv^2 = \frac{p^2}{2m}$. but $P = \hbar k$

$$E = \frac{(\hbar k)^2}{2m}$$

$E = ck^2 \Rightarrow y = mx^2$ (parabolic)

② When the electron is in periodic potential energy equation is

$$\cos ka = \frac{P \sin \alpha a}{\alpha} + \cos \alpha a$$

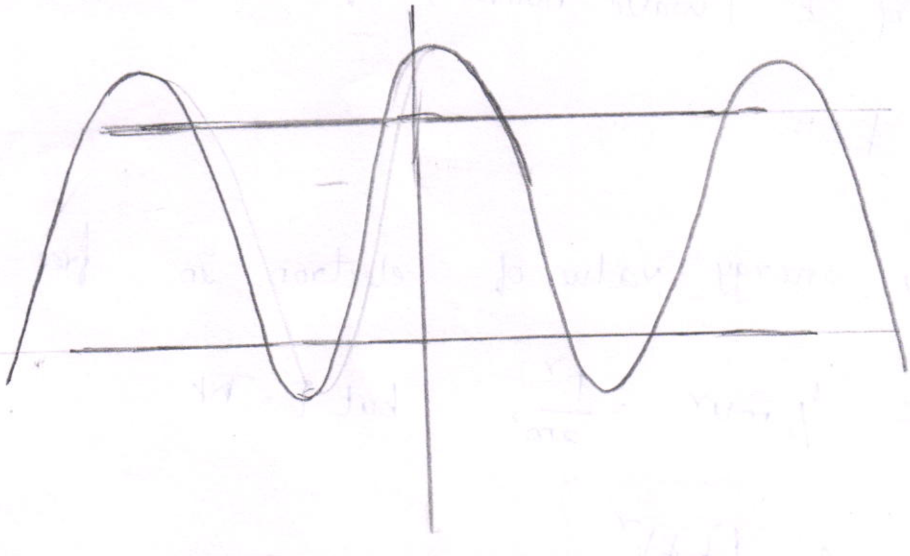
$$\cos ka = -1$$

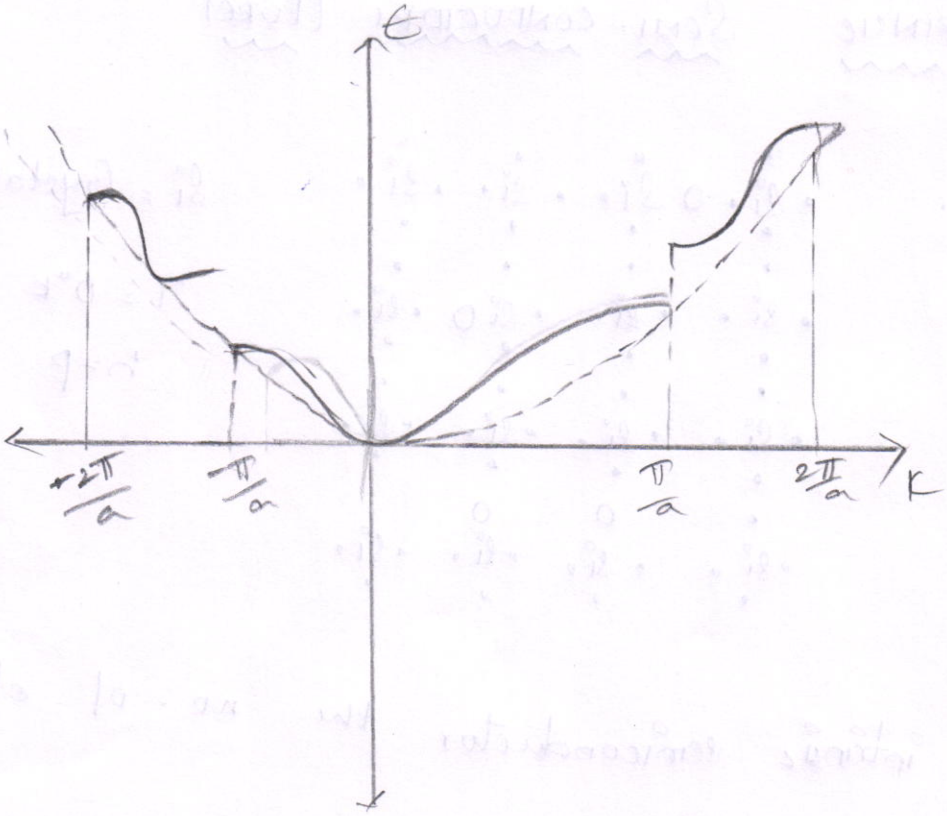
$$ka = +n\pi$$

$$k = \frac{n\pi}{a}$$

for $n = 1 \quad k = \frac{\pi}{a}$

$n = 2 \quad k = \frac{2\pi}{a}$



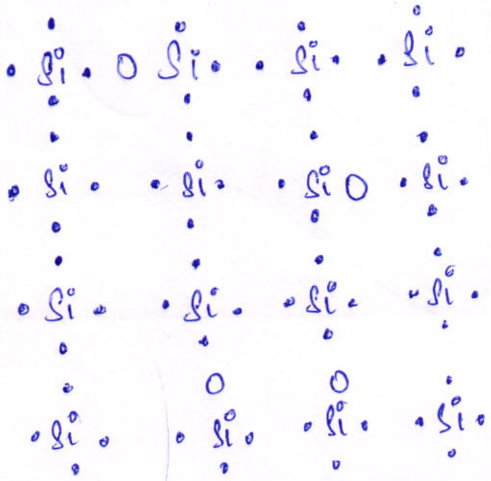


first billounin Zone = $\frac{-\pi}{a}$ to $\frac{\pi}{a}$

second billounin Zone = $\frac{\pi}{a}$ to $\frac{2\pi}{a}$ & $\frac{-\pi}{a}$ to $\frac{-2\pi}{a}$

Third billounin Zone = $\frac{2\pi}{a}$ to $\frac{3\pi}{a}$ & $\frac{-2\pi}{a}$ to $\frac{-3\pi}{a}$

INTRINSIC SEMI-CONDUCTORS (PURE)



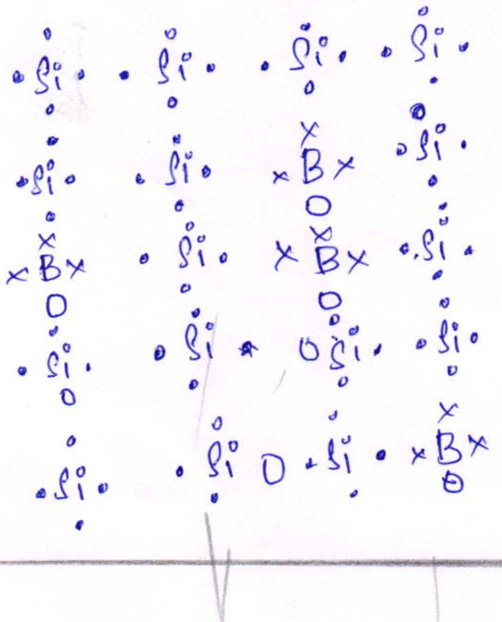
Si = Crystal

$T = 0°K$

$n = p$

In intrinsic semiconductor the no. of electrons must be equal to no. of vacancies.

<u>P-type</u> <u>semiconductor</u>:- If you add III group elements to pure semiconductors we get p-type.



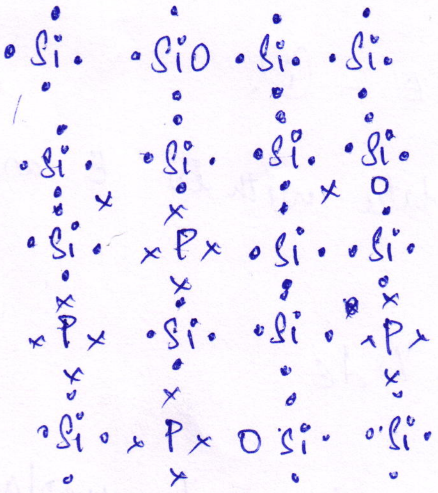
Here Vacancies are more in number then free electrons

$\therefore P > n$

majority carriers : Vacancies

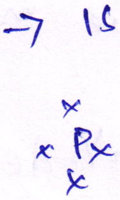
minority carriers : electrons

<u>N</u> - <u>type</u> <u>Semiconductor</u> :- V Group elements



N, P, As

$P(15) \rightarrow 1s^2 2s^2 2p^6 \underline{3s^2 3p^3}$.



$n > p$ (N-type)

electrons > vacancies

majority carriers → electrons

minority carriers → vacancies

Carriers Concentration in Intrinsic Semiconductors:-

calculation of density of electrons in conduction band. If 'dn' is the number of electrons in the conduction with in E and E+dE

$$dn = Z(E) \cdot F(E) \cdot dE \quad — (i).$$

Z(E) → density of energy states with in E and E + dE

$$Z(E) = \frac{4\pi}{h^3} (2m)^{3/2} E^{1/2} dE$$

In case of Conduction band we have to replace m with m_e^* (m_e^* → effective mass of $e^{\ominus}$)

$$Z(E) = \frac{4\pi}{h^3} (2m_e^*)^{3/2} E^{1/2} dE \quad — (2).$$

Here $E = E - E_c$

$F(\epsilon)$ is called feemi distribution function

$$F(\epsilon) = \left[\frac{1}{1+\exp\left(\frac{\epsilon-\epsilon_F}{k_T}\right)}\right]$$

$$F(\epsilon) = \left(1+\exp\left(\frac{\epsilon-\epsilon_F}{k_T}\right)\right)^{-1}$$

$$F(\epsilon) = \exp\left(\frac{\epsilon-\epsilon_F}{k_T}\right)^{-1}$$

$$F(\epsilon) = \exp\left(\frac{\epsilon_F-\epsilon}{k_T}\right) \text{ --- ③}$$

Such ③ in ①

$$d_n = \frac{4\pi}{h^3}(2m_e^*)^{3/2}\ (\epsilon-\epsilon_c)^{1/2}\, d\epsilon \cdot \exp\left(\frac{\epsilon_F-\epsilon}{k_T}\right)$$

The total number of electrons in conduction band

$$n = \int_{\epsilon_c}^{\infty} d_n = \int_{\epsilon_c}^{\infty}\frac{4\pi}{h^3}(2m_e^*)^{3/2}\cdot(\epsilon-\epsilon_c)^{1/2}\exp\left(\frac{\epsilon_F-\epsilon}{k_T}\right)d\epsilon$$

$$n = \frac{4\pi}{h^3}(2m_e^*)^{3/2}\exp\left(\frac{\epsilon_F}{k_T}\right)\int_{\epsilon_c}^{\infty}(\epsilon-\epsilon_c)^{1/2}\exp\left(\frac{-\epsilon}{k_T}\right)$$

Put $\epsilon-\epsilon_c = x$ $\quad d\epsilon = dx$

$\therefore\ \epsilon = x+\epsilon_c$

∵ Lower limit ∴ $E_c = -E_c$ $x = 0$

Upper limit : $x = \infty$ & $E_c = \infty$

$$∵\ n = \frac{4\pi}{h^3}(2m_e^*)^{3/2}\exp\left(\frac{E_F}{kT}\right)\int_0^\infty x^{1/2}\exp\left(\frac{-(x+E_c)}{kT}\right)dx$$

$$n = \frac{4\pi}{h^3}(2m_e^*)^{3/2}\exp.\left(\frac{E_F}{kT}\right)\exp\left[\frac{-E}{kT}\right]\cdot\int_0^\infty x^{1/2}.\exp\left(\frac{-x}{kT}\right)dx$$

$$= \frac{4\pi}{h^3}(2m_e^*)^{3/2}\exp\left(\frac{E_F}{kT}-\frac{E_c}{kT}\right)\cdot\int_0^\infty x^{1/2}.\exp\left(\frac{-x}{kT}\right)dx$$

$$= \frac{\overset{2}{\cancel{4}}\pi}{h^3}(2m_e^*)^{3/2}\exp\left(\frac{E_F}{kT}-\frac{E_c}{kT}\right)\cdot\frac{(kT)^{3/2}.\pi^{1/2}}{\cancel{2}}$$

$$= \frac{2\pi}{h^3}(2m_e^*)^{3/2}\exp\left(\frac{E_F-E_c}{kT}\right)\times(kT)^{3/2}.\pi^{1/2}$$

$$= 2\pi^{3/2}\left(\frac{2m_e^* kT}{h^2}\right)^{3/2}\exp\left(\frac{E_F-E_c}{kT}\right)$$

$$n = 2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}\exp\left(\frac{E_F-E_c}{kT}\right)$$

Calculation of density of Vacancies in Intrinsic semiconductor

If 'dp' is the number of vacancies in the valence band with E and $E+dE$

$$d_p = Z(E)\,[1-F(E)]\,dE \text{ — ①}$$

$$Z(E) = \frac{4\pi}{h^3}(2m)^{3/2}E^{1/2}dE \text{ — ②}$$

$Z(E) \rightarrow$ density of energy states with in E and $E+dE$

In this cases the vacancies are present in Periodic potential. Hence replace 'm' with m_h^*

effective mass of vacancy $= m_h^*$

$$E \rightarrow E_v - E$$

$$Z(E) = \frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v - E)^{1/2}dE$$

where $(1-F(E))$ is the probability function

for Vacancy Occupancy

$$[1-F(E)] = \left[1 - \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)}\right]$$

$$= \left[1 - \left\{1 + emp\left(\frac{E - E_F}{kT}\right)\right\}^{-1}\right]$$

$$= \left[emp\left[-\frac{E_F + E}{kT}\right]\right]$$

$$= \left[1 - \left\{1 - emp\left(\frac{E - E_F}{kT}\right)\right\}\right]$$

$$[1 - F(E)] = emp\left(\frac{E - E_F}{kT}\right) \text{ — ④}$$

Sub ③ & ④ in ①

$$dp = \frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v - E)^{1/2}d.E\left[emp\left(\frac{E - E_F}{kT}\right)\right]$$

The total number of vacancies in the entire Valence bond is

$$p = \int_{-\infty}^{E_v} dp = \int_{-\infty}^{E_v} \frac{4\pi}{h^3}(2m_h^*)^{3/2} \cdot (E_v - E)^{1/2} dE . emp\left(\frac{E - E_F}{kT}\right)$$

$$= \frac{4\pi}{h^3} \times (2m_h^*)^{3/2} . \int_{-\infty}^{E_v} (E_v - E)^{1/2} dE \; emp\left(\frac{E}{kT}\right) . emp\left(-\frac{E_F}{kT}\right)$$

$$= \frac{4\pi}{h^3} \times (2m_h^*)^{3/2} \cdot \exp\left(-\frac{E_F}{kT}\right) \int_{-\infty}^{E_v} \exp\left(\frac{E}{kT}\right)(E_v - E)^{1/2} dE$$

$\Rightarrow$ from ⑤ $\int_{-\infty}^{E_v} \exp\left(\frac{E}{kT}\right) (E_v - E)^{1/2} dE$

$$X_h = \left[(E_v - E)^{1/2} \frac{\exp\left(\frac{E}{kT}\right)}{1/kT} \right]_{-\infty}^{E_v} + \int_{-\infty}^{E_v} \frac{1}{2}(E_v - E)^{-1/2} \frac{\exp\left(\frac{E}{kT}\right)}{1/kT}$$

$$= 0 - 0 + \frac{kT}{2} \int_{-\infty}^{E_v} (E_v - E)^{-1/2} \cdot \exp\left(\frac{E}{kT}\right) dE$$

$$= \frac{kT}{2} \int_{-\infty}^{E_v} (E_v - E)^{-1/2} \cdot \exp\left(\frac{E}{kT}\right) dE$$

Put $E_v - E = x$

$-dE = dx$

$$\Rightarrow -\frac{kT}{2} \int_{\infty}^{0} x^{-1/2} \exp\left(\frac{E_v - x}{kT}\right) dx \} \times$$

Put $E_v - E = x$ (say) $\cdot$ $E = E_v - x$

$\Rightarrow -dE = dx$

$$\Rightarrow -\int_{\infty}^{0} \text{Exp}\cdot\left(\frac{E_v - x}{kT}\right)(x)^{1/2}\cdot dx$$

$$= \int_{0}^{\infty} \exp\left(\frac{E_v - x}{kT}\right) x^{1/2}\, dx$$

$$= \exp\left(\frac{E_v}{kT}\right)\cdot \int_{0}^{\infty} \text{Exp}\left(\frac{-x}{kT}\right)\cdot x^{1/2}\, dx$$

$$= \exp\left(\frac{E_v}{kT}\right) \times \left[\frac{\pi^{1/2}(kT)^{3/2}}{2}\right]$$ subs in ⑤

$$—⑥ \Rightarrow \frac{\overset{2}{\cancel{4}}\pi}{h^3} \times (2m_h^*)^{3/2} \cdot \exp\left(\frac{-E_F}{kT}\right) \cdot \exp\left(\frac{E_v}{kT}\right) \times \frac{\pi^{1/2}(kT)^{3/2}}{\cancel{2}}$$

$$= 2 \times \left(\frac{2m_h^* \times \pi \times kT}{h^2}\right)^{3/2} \cdot \text{Exp}\left(\frac{-E_F + E_v}{kT}\right)$$

INTRINSIC CARRIER CONCENTRATION:-

In Intrinsic Semiconductor the no. of electrons equal to no. of vacancies $n = p = n_i$ (say) where n_i = Intinsic carrier concentration

$$np = n_i . n_i = n_i^2$$

$$n_i^2 = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} . \exp\left(\frac{E_F - E_C}{kT}\right) \times 2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2} \exp\left[\frac{E_V - E_F}{kT}\right]$$

$$n_i^2 = 4\left[\frac{2\pi kT}{h^2}\right]^3 . \exp\left[\frac{E_V - E_C}{kT}\right] (m_e^* . m_h^*)^{3/2}$$

$$n_i^2 = 4\left[\frac{2\pi kT}{h^2}\right]^3 . \exp\left[\frac{-E_g}{kT}\right] (m_e^* m_h^*)^{3/2}$$

$$n_i = 2 . \left(\frac{2\pi kT}{h^2}\right)^{3/2} . (m_e^* m_h^*)^{3/4} . \exp\left(\frac{-E_g}{kT}\right)^{1/2}$$

$$n_i = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2} . (m_e^* m_h^*)^{3/4} \exp\left(\frac{-E_g}{2kT}\right)$$

if $m_e^* = m_h^* = m$ Then,

$$n_i = 2 . \left[\frac{2\pi kTm}{h^2}\right]^{3/2} . \exp\left[\frac{-E_g}{2kT}\right]$$

Fermi level in Intrinsic

Semi Conductor

In Intrinsic Semiconductor

the no. of electrons = the no. of vacancies

$$\cancel{2}\left[\frac{\cancel{2\pi}\, m_e^* \cancel{kT}}{\cancel{h^2}}\right]^{3/2} \cdot \exp\left[\frac{E_F - E_C}{kT}\right]$$

$$= \cancel{2}\left(\frac{\cancel{2\pi}\, m_h^* \, kT}{\cancel{h^2}}\right]^{3/2} \cdot \exp\left[\frac{E_V - E_C}{kT}\right]$$

$$\therefore \frac{\exp\left[\frac{E_F - E_C}{kT}\right]}{\exp\left[\frac{E_V - E_F}{kT}\right]} = \left[\frac{m_h^*}{m_e^*}\right]^{3/2}$$

$$\Rightarrow \exp\left[\frac{E_F - E_C - E_V + E_F}{kT}\right] = \left[\frac{m_h^*}{m_e^*}\right]^{3/2}$$

$$\Rightarrow \exp\left[\frac{2E_F - (E_C + E_V)}{kT}\right) = \left(\frac{m_h^*}{m_e^*}\right)^{3/2}$$

Apply 'log' On both sides

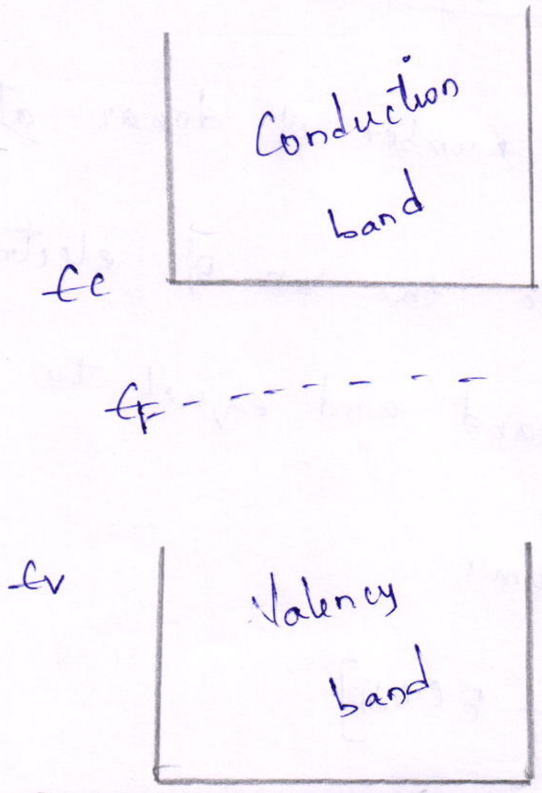
$$\Rightarrow \frac{2E_F - (E_c + E_v)}{kT} = \frac{3}{2}\left[\log m_h^* - \log m_e^*\right]$$

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

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

$$E_F = \frac{3}{4}kT\left[\log\frac{m_h^*}{m_e^*}\right] + \frac{E_c + E_v}{2}$$

at T = 0K $\Rightarrow E_F = \frac{E_c + E_v}{2}$



∴ In Intrinsic Semiconductor the fermi level lies exactly in between Conduction & Valency band

CARRIER CONCENTRATION IN EXTRINSIC SEMICONDUCTOR:-

calculation of dencity of electrons in

N-type Semiconductors:-

If 'N_d' is the number of donar atoms of low temperature the no. of electrons in the conduction band and equal to no. of the Ionised donar atoms.

$$n = N_d[1 - F(Ed)]$$

$$2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2} \cdot \exp\left(\frac{\epsilon_F-\epsilon_c}{kT}\right) = N_d \cdot \exp\left[\frac{\epsilon_d-\epsilon_F}{kT}\right]$$

$$= \frac{\exp\left[\frac{-\epsilon_F-\epsilon_c}{kT}\right]}{\exp\left(\frac{\epsilon_d-\epsilon_F}{kT}\right)} = \frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}}$$

$$= \exp\left[\frac{2\epsilon_F - \epsilon_c - \epsilon_d)}{kT}\right] = \frac{N_d}{2\left[\frac{2\pi m_e^* \times kT}{h^2}\right]^{3/2}}$$

take log on both sides

$$= \frac{2\epsilon_F - (\epsilon_c+\epsilon_d)}{kT} = \log \frac{N_d}{2\left(\frac{2\pi m_e^* \times kT}{h^2}\right)^{3/2}}$$

$$\Rightarrow 2\epsilon_F = kT \log \frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}} + \epsilon_c + \epsilon_D$$

$$\epsilon_F = \frac{kT}{2} \log \frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}} + \frac{\epsilon_c+\epsilon_d}{2} \quad — ④$$

$\therefore$ A+T= 0K $\quad E_F = \frac{E_c + E_d}{2}$

The Density of electrons in the conduction band

$$n = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2} \cdot \exp\left[\frac{E_F - E_c}{kT}\right] \longleftarrow ②$$

Sub ② in ① and put $\frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}} = x$

$$\therefore \exp\left(\frac{E_F - E_c}{kT}\right) = \exp\left(\frac{\frac{kT}{2}\log x + \frac{E_c + E_d}{2}}{kT}\right)$$

$$\exp\left[\frac{E_F - E_c}{kT}\right] = \exp\left[\frac{\frac{kT}{2}\cdot\log x + \frac{E_c + E_d}{2} - E_c}{kT}\right]$$

$$= \exp\left[\frac{kT\log x + E_c + E_d - 2E_c}{2kT}\right]$$

$$= \exp\left[\frac{1}{2}\log x + \frac{E_d - E_c}{2kT}\right]$$

$$= \exp\left[\log x^{1/2} + \frac{E_d - E_c}{2kT}\right]$$

$$= \exp\left[\log x^{1/2}\right] \cdot \exp\left[\frac{E_d - E_c}{2kT}\right]$$

$$= x^{1/2} \cancel{=} \exp\left[\frac{E_d - E_c}{kT}\right] \text{ — ③}$$

$$\therefore n = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2} \exp\left[\frac{E_F - E_c}{kT}\right] \text{ — ②}$$

sub ③ in ②

$$\cancel{x}\ n = 2\left(\frac{2\pi m_e^* \cdot kT}{h^2}\right)^{3/2} \cdot x^{1/2} \cdot \exp\left(\frac{E_d - E_c}{2kT}\right)$$

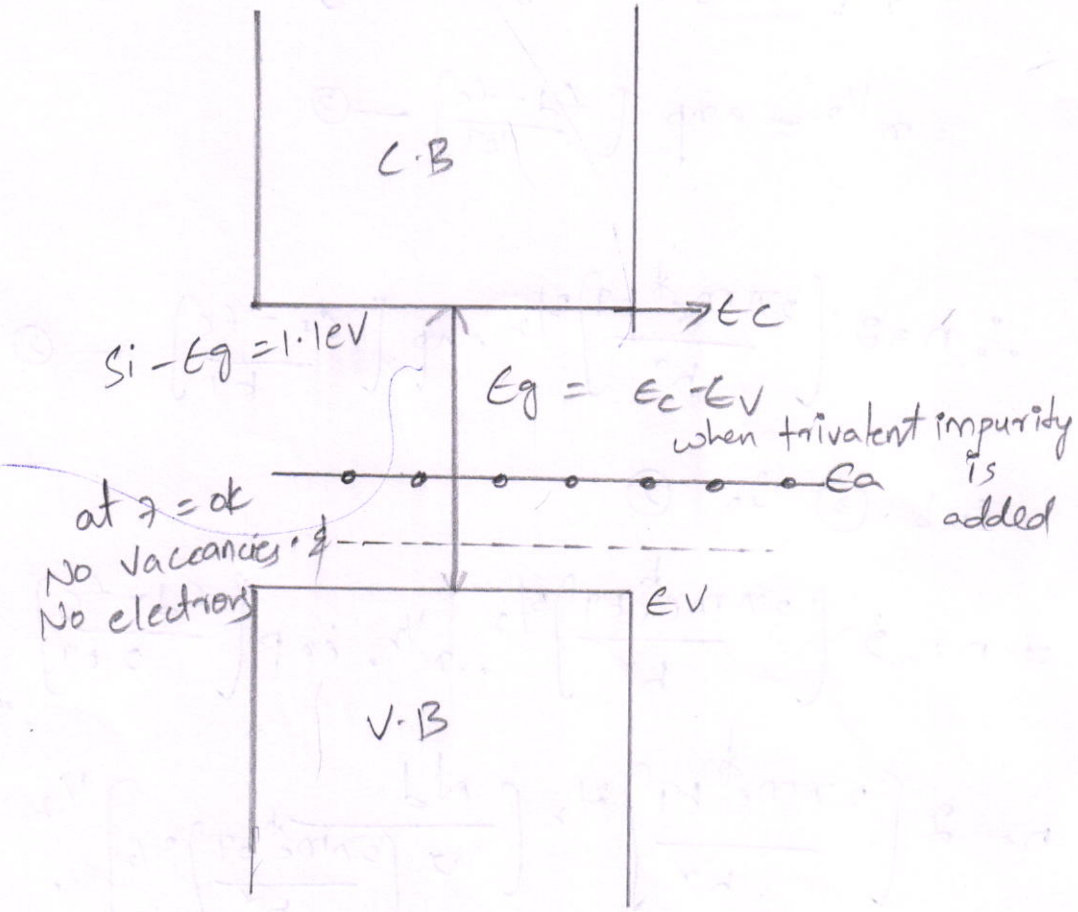
$$n = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}\left[\frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}}\right]^{1/2} \cdot \exp\left[\frac{E_d - E_c}{2kT}\right]$$

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

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

Calculation of density of vacancies in

P-type Semiconductor:-



Na = no. of acceptor atoms added to pure silicon semiconductor

The no. of vacancies in the valence band must be equal to the no. of ionised acceptor atoms in E_a

$$p = N_a\, F(E_a) = \text{———} ①$$

$$\Rightarrow 2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2} \cdot \exp\left[\frac{E_v - E_F}{kT}\right] = N_a \cdot \exp\left[\frac{E_F - E_a}{kT}\right] \text{———} ④$$

where $F(E) = \dfrac{1}{1+\exp\left[\frac{E-E_F}{kT}\right]}$

$$F(E_a) = \frac{1}{1+\exp\left[\frac{E_a-E_F}{kT}\right]}$$

$$= \left[1+\exp\left(\frac{E_a-E_F}{kT}\right)\right]^{-1}$$

$$F(E_a) = \exp\left[\left(\frac{E_F-E_a}{kT}\right)\right]$$

$$\Rightarrow \frac{2\exp\left[\frac{E_v-E_F}{kT}\right]}{\exp\left[\frac{E_F-E_a}{kT}\right]} = \frac{N_a}{2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}}$$

$$\Rightarrow \exp\left(\frac{E_v + E_a - 2E_F}{kT}\right) = \frac{N_a}{2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}}$$

take log on both sides

$$\Rightarrow \log\left(\frac{(E_v + E_a) - 2E_F}{kT}\right) = \log \frac{N_a}{2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2}}$$

$$\Rightarrow E_v + E_a - 2E_F = kT \log \frac{N_a}{2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2}}$$

$$\boxed{E_F = \left(\frac{E_v + E_a}{2}\right) - \frac{kT}{2} \log \frac{N_a}{2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}} \quad — ②}$$

at $T = 0°K$

$$E_F = \frac{E_v + E_a}{2} \quad — ③.$$

Calulation of density in Vacancies in

P- type semiconductors:-

$\exp\left[\frac{E_F - E_a}{kT}\right]$ sub ②.

$$\Rightarrow \exp\left[\frac{\frac{E_v + E_a}{2} - \frac{kT}{2}\log x - E_a}{kT}\right]$$

$$= \exp\left[\frac{E_v - E_a - kT\log x}{2kT}\right]$$ sub in ④

$$\Rightarrow P = 2\left[\frac{(2\pi m_h^* kT)}{h^2}\right]^{3/2} \cdot \exp\left(\frac{E_v - \left(\frac{E_v + E_a}{2} - \frac{kT}{2}\log x\right)}{kT}\right)$$

$$\Rightarrow P = 2\left(\frac{(2\pi m_h^* kT}{h^2}\right)^{3/2} \exp\left[\frac{+E_v - E_a + kT\log x}{2kT}\right]$$

$$P = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} \exp\left[\frac{-E_a + E_v + kT\log x}{2kT}\right]$$

$$P = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} \exp\left(-\frac{E_a + E_v'}{2kT} + \frac{1}{2}\log x\right)$$

$$P = 2\left[\frac{2\pi m_n^* kT}{h^2}\right]^{3/2} \exp\left[\frac{Ea+Ev}{2kT}\right] \exp\left[+\frac{kT}{2}\log x\right]$$

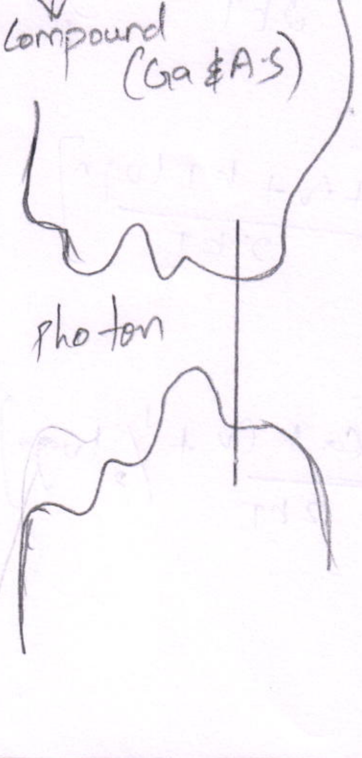
$$P = 2\left[\frac{2\pi m_n^* kT}{h^2}\right]^{3/2} \exp\left[-\frac{Ea+Ev}{2kT}\right] x^{1/2}$$

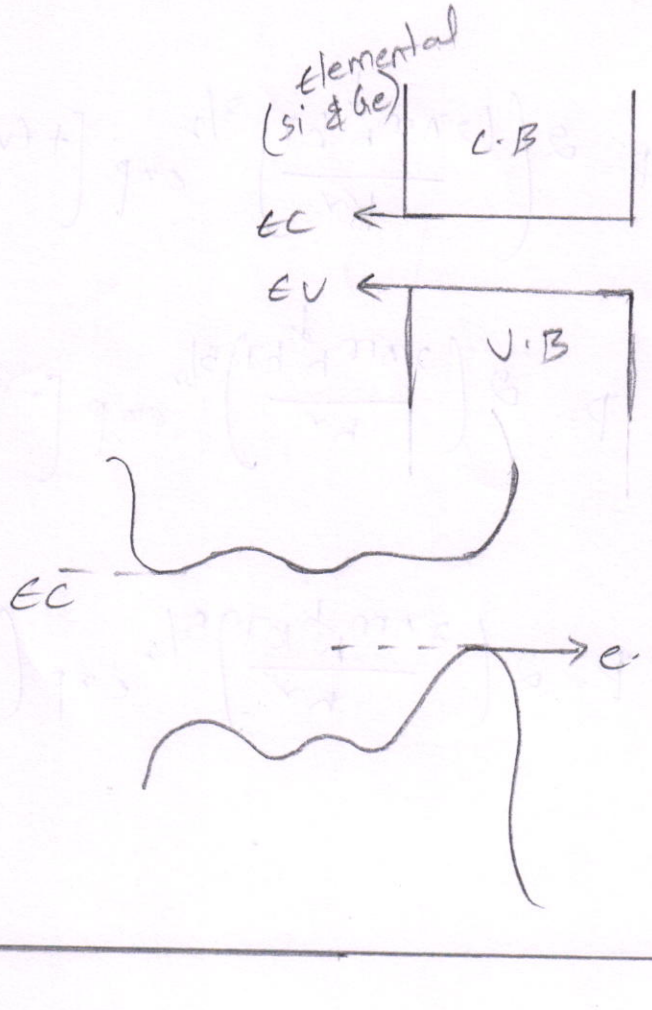
$$P = 2\left[\frac{2\pi m_n^* kT}{h^2}\right]^{3/2} \exp\left(-\frac{Ea+Ev}{2kT}\right) \cdot \frac{Na^{1/2}}{2\left(\frac{2\pi m_n^* kT}{h^2}\right)^{3/4}}$$

$$= (2Na)^{1/2}\left[\frac{2\pi m_n^* kT}{h^2}\right]^{3/4} \cdot \exp\left[\frac{Ev-Ea}{2kT}\right]$$

Direct band gap and Indirect band gap

Semiconductors:-



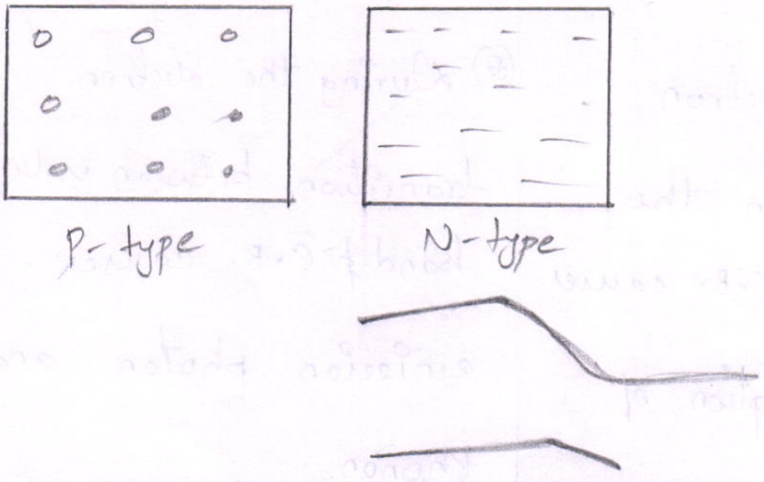


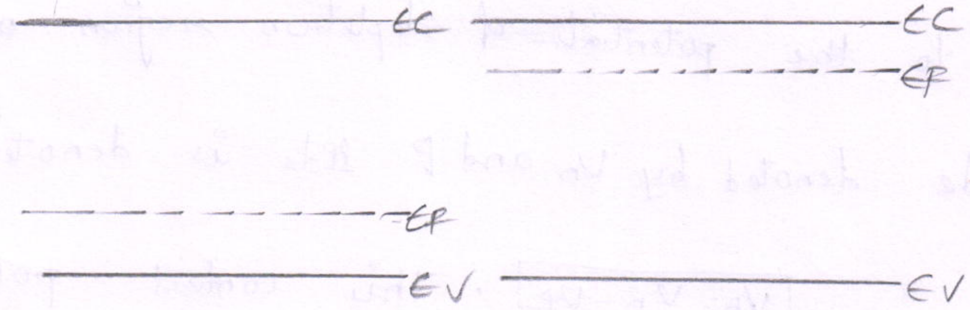
The energy Spectrum of an electron moving the peresence of a periodic potential field is divided into allowed & forbidden band. In real Crystal the E-k-curor relationship is more complicated.

DIRECT BAND GAP	INDIRECT BAND GAP
① In this Semiconductors the maximum of the valence band Occurs at Same value of 'k' as the minimum of the C.B. as shown in fig 1.	① In this Semiconductors the maximum of the valence band does not always occurs at the same 'k' value as the minimum of the C.B. as shown in fig 2
② During the electron transition between the valence band and C.B. causes emission or absorption of Photon.	② During the electron transition between valence band & C.B. causes emission photon and Phonon.

③ Conservation of energy and momentum is Obeyed.	③ Conservation of energy and momentum is not Obeyed.
④ Life time of Charge carries is very less.	④ Life time of Charge carries is more
⑤ These are Used to fabricate diodes and transistors	⑤ L.E.D's and Lasers
⑥ These are mostly from compound semiconductors eg:- Ga, As	⑥ Elemental semiconductors Eg:- Ge, Si

Energy diagram of PN Junction diode :-





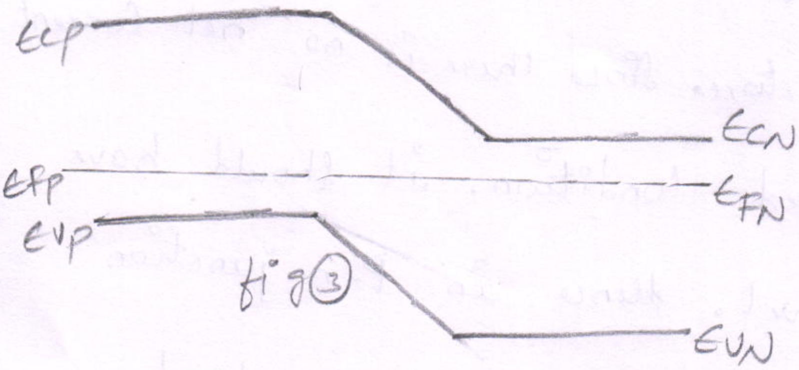
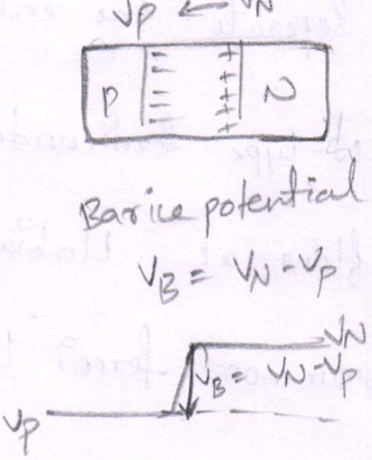


fig ③



The energy levels of V.B, C.B & fermi levels of both p type & N type Semiconductors are shown in fig ① & ②. When P and N Junction is formed the fermi levels become common for both the types as shown in fig ③. The formation of Potential barriers is represented in fig ④. The

Contact potential V_B across the junction is due to the potentials of depletion region on n side denoted by V_n and P side is denoted by V_P i.e., $\boxed{V_B = V_n - V_P}$. This contact potential seperate the energy bands in the P-type and N-type semiconductors. Since there is no-net current flow at Unbiased condition. it should have common fermi level. Hence in P-n junction diode the valency band & conduction band energy levels E_{vp} and E_{cp} of p-type are at higher level compared to the valence and conduction energy levels E_{vn} and E_{cn} of N-type.