Fermi Level in Intrinsic - Semiconductors

In Intrinsic Semi conductors

$n_e = n_h$ → Resp. concentration of electrons & holes.

$$\frac{4\sqrt{2}}{h^3}\left(\pi m_e^* KT\right)^{3/2} e^{\frac{(E_F - E_g)}{KT}} = \frac{4\sqrt{2}}{h^3}\left(\pi m_h^* KT\right)^{3/2} e^{(-E_F/KT)}$$

after cancellation,

$$\left(m_e^*\right)^{3/2} e^{\frac{(E_F - E_g)}{KT}} = \left(m_h^*\right)^{3/2} e^{(-E_F/KT)}$$

$$\frac{e^{(E_F - E_g)/KT}}{e^{-(E_F/KT)}} = \left(\frac{m_h^*}{m_e^*}\right)^{3/2}$$

{ m_h^* & m_e^* is the effective mass of holes & electrons }

$$e^{\left(\frac{2E_F - E_g}{KT}\right)} = \left(\frac{m_h^*}{m_e^*}\right)^{3/2}$$

Taking natural log on both sides.

$$\frac{2E_F - E_g}{KT} = \frac{3}{2}\ln\left(\frac{m_h^*}{m_e^*}\right)$$

$$2E_F - E_g = \frac{3}{2}\ln\left(\frac{m_h^*}{m_e^*}\right)KT$$

$$2E_F = \left[\frac{3}{2}\ln\left(\frac{m_h^*}{m_e^*}\right)KT\right] + E_g$$

as $m_h^* = m_e^*$ $\quad (\because \ln 1 = 0)$

$$2E_F = E_g$$

$$\boxed{E_F = E_g/2}$$

Charge carrier density or carrier concentration, denotes the number of charge carrier in per volume

Carrier Concentration in Intrinsic Semiconductor

Inside a semiconductor, $\bar{e}$ & holes are generated with thermal energy. The electron & hole concentration at temperature T k. in intrinsic semiconductor $n = p = n_i$, where n_i is called intrinsic semiconductor.

Also the product $np = n_i^2$ —— (1)

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

$$p = n_v = 2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2} e^{-(E_F - E_v)/kT}$$

$$n = N_c\, e^{-(E_c - E_F)/kT} \quad , \quad p = N_v\, e^{-(E_F - E_v)/kT}$$

on substituting n & p in Eq^n (1).

$$n_i^2 = (N_v N_c)\, e^{-(E_F - E_v)/kT} \cdot e^{-(E_c - E_F)/kT}$$

$$n_i^2 = (N_v N_c)\, e^{-(\cancel{E_F} - E_v + E_c - \cancel{E_F})/kT}$$

$$n_i^2 = (N_v N_c)\, e^{-[E_c - E_v]/kT}$$

$$n_i^2 = [N_v N_c]\, e^{-[E_g]/kT}$$

or $n_i = [N_c N_v]^{1/2} e^{-E_g/2kT}$

Substituting N_v & N_c

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

If $m_e^* = m_h^* = m$ is the rest mass of $\bar{e}$. the Eq^n becomes

$$n_i = 2\left(\frac{2\pi kT \cdot m}{h^2}\right]^{3/2} \cdot e^{-E_g/2kT}$$

$$\Rightarrow n_i = 2\left(\frac{2\pi mk}{h^2}\right)^{3/2} T^{3/2} e^{-E_g/2kT}$$

$$n_i = 2\left(\frac{2\pi m K}{h^2}\right)^{3/2} T^{3/2} e^{-E_g/2KT}$$

$$\boxed{n_i = C\, T^{3/2}\, e^{-E_g/2KT}}$$

$$C = 2\left(\frac{2\pi m k}{h^2}\right)^{3/2} = 4.83 \times 10^{21}$$

Carrier Concentration [Extrinsic Semiconductors]

As in pair production $n = p = n_i$

Also the product $np = n_i^2$ —— (1)

n_i - intrinsic concentration.

Suppose N_D & N_A are concentration of donor atom in in n-type semiconductor and concentration of acceptor atom in p-type semiconductor.

n-type : Since in n-type semiconductor, majority charge carriers are electrons. The hole concentration will be less as comparison to e concentration. & Electron concentration is equal to donor atoms concentration. i.e

$n = N_D$

substituting in (1)

$$p = \frac{n_i^2}{n}$$

p-type - majority charge carrier are holes. The electron concentration 'n' in comparison to holes is less. Hole concentration is equal to of acceptor atoms. in p-type

$p = N_A$.

Substituting in (1)

$$n = \frac{n_i^2}{p}$$. —— x —— x ——