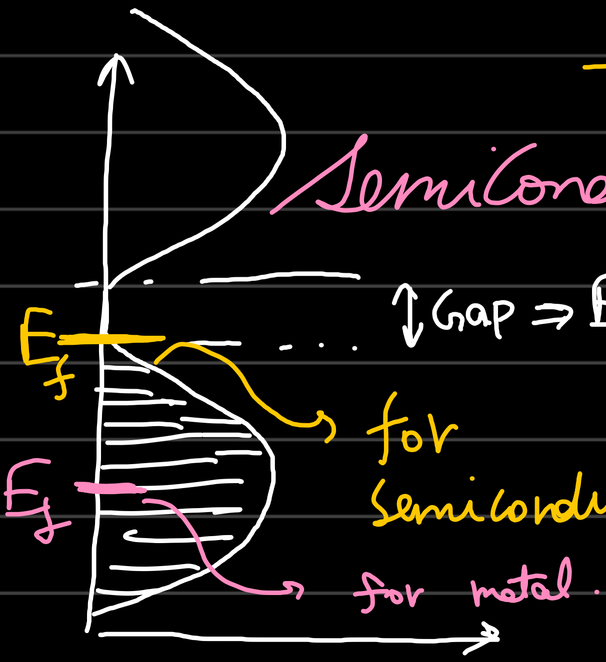
Lecture 16

Semiconductor Band Theory:



$\updownarrow$ Gap $\Rightarrow E_g$ {Band gap}

→ Valence band
largely bonding orbitals

→ Conduction band
largely anti-bonding orbitals

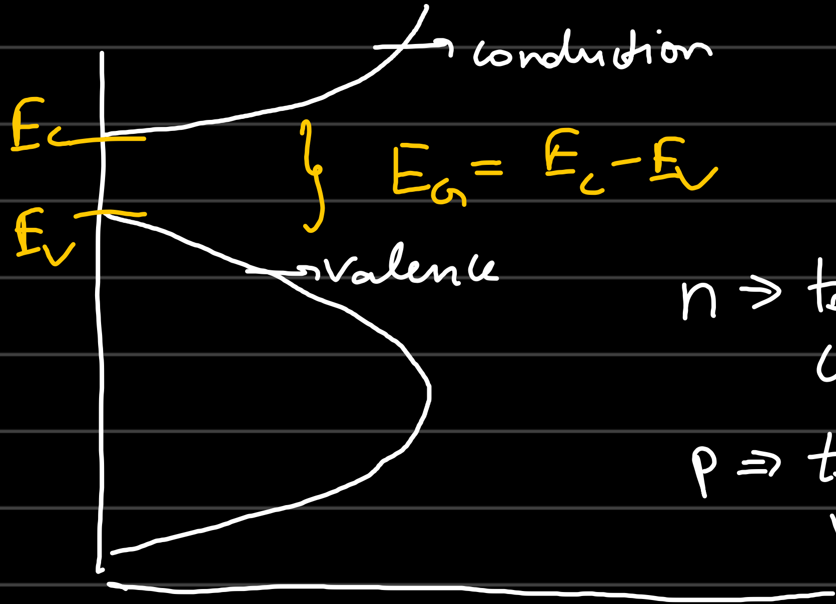
→ Electron-hole pairs generated:

→ Probability of an electron occupation at energy E : ... $P(E) = \dfrac{1}{1+e^{\beta(E-E_f)}}$

$$P(E_f) = \frac{1}{2} \Big|_{at\ T \neq 0}$$

→ Intrinsic Semiconductor:

Intrinsic: n_i → Thermally generated carrier density is dominant!



$n \Rightarrow$ total no. of electrons in conduction band

$p \Rightarrow$ total no. of holes in valence band

@ 0K $\Rightarrow n = p = 0$

@ $T \neq 0 \Rightarrow n = p = n_i = \int_{E_c}^{\infty} \rho(E)\, D(E)\, dE$

$\hookrightarrow cm^{-3} eV^{-1}$

$\approx 10^{11} - 10^{16}\ cm^{-3}$

$\rightarrow \boxed{D(E) = C \cdot \sqrt{E}}$

$$n = c \int_{E_c}^{\infty} \frac{\sqrt{E}}{1 + e^{\beta(E - E_f)}}\, dE$$

$$n = N_c\, e^{-(E_c - E_f)\beta}$$

$$p = N_v\, e^{-(E_f - E_v)\beta}$$

effective density of states

→ In an intrinsic semiconductor, $E_f = \frac{E_g}{2}$

$$n \ast p = N_c N_v e^{-(E_c - E_v)\beta} = N_c N_v e^{-E_g \beta}$$

$$\boxed{n \times p = n_i^2}$$ Law of Mass Action

Conductivity in semiconductors:

$$\boxed{\sigma = n e \mu_e + p e \mu_h}$$

Extrinsic Semiconductor:

↳ dopants added to Silicon lattice.

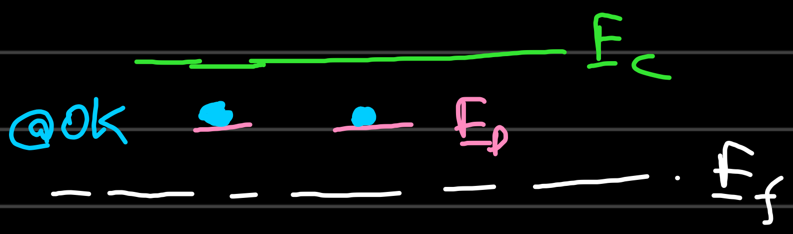
i) n-type
→ excess electrons
→ pentavalent (M^{+5}) dopant

ii) p-type
→ excess holes
→ trivalent (M^{+3}) dopant.

→ In intrinsic semiconductors: $n \approx p$; $N_c \approx N_v$

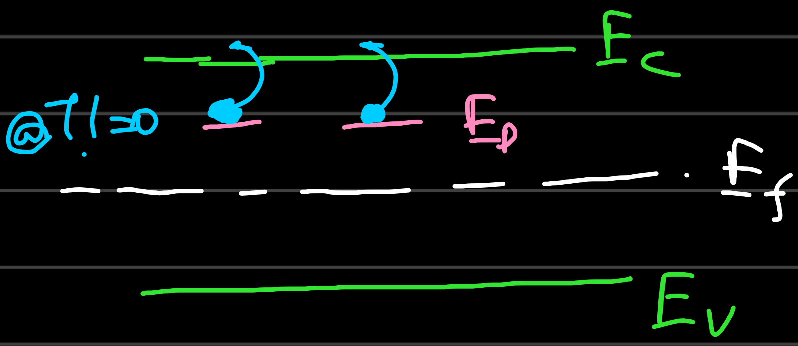
→ In extrinsic semiconductor

↳ defect level introduced. → N_D donor atoms



→ Donor Ionization.

$n > n_i$ @ $T \neq 0$

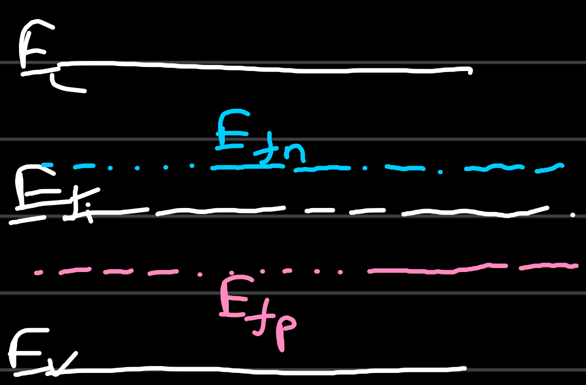


→ If all donors are ionized

$n \approx N_D$

$p = n_i^2/N_D$

$p < n_i$



$$n = \gamma e^{-(E_c - E_f)\beta}$$

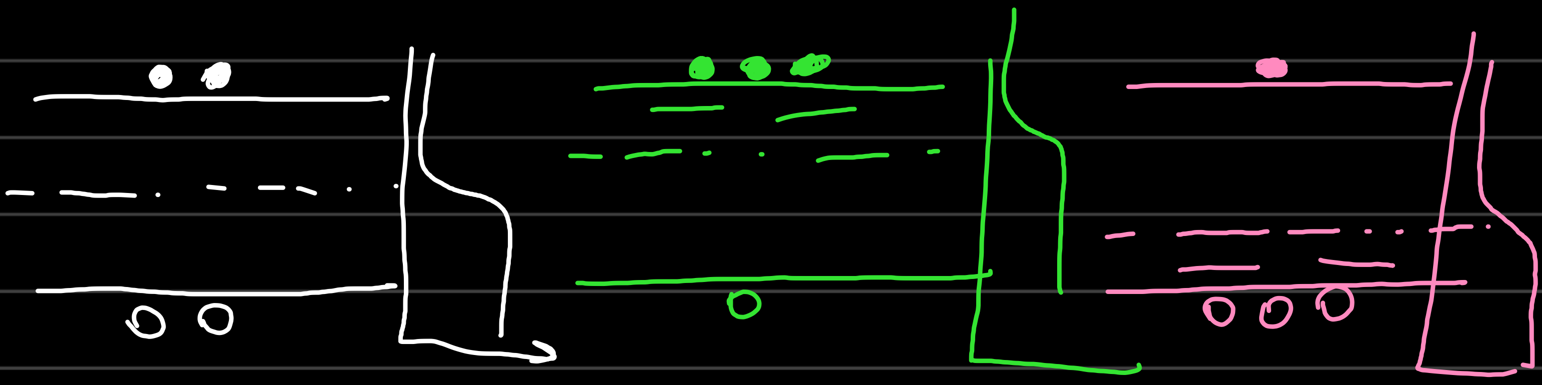
$$p = \gamma e^{-(E_f - E_v)\beta}$$

when $N_D \neq 0$ {n-type} {Doping}

↳ $n > n_i \Rightarrow p < n_i$ $\boxed{np = n_i^2}$

If n ↑sing $\Rightarrow$ E_f must rise. {($E_c - E_f$) ↓ses}

If p ↑sing $\Rightarrow$ E_f must fall {($E_f - E_v$) ↓ses}



Always: $\boxed{n + N_A^- = p + N_D^-}$

Electrical neutrality.