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LECTURE-8

EXTRINSIC SEMICONDUCTOR

3 CASES

1) $n_0 > p_0$: n TYPE : $N_a^- < N_d^+$

2) $n_0 < p_0$: p TYPE : $N_a^- > N_d^+$

3) $n_0 = p_0$: INTRINSIC : THERMAL EHP DOMINATES

DOPING FOR COMPOUND SEMICONDUCTORS

COLUMN $\underline{III}$-$\underline{V}$

GaAs

InP

DONORS

$\underline{IV}$ Si $\rightarrow$ Ga ($\underline{III}$)

$\underline{VI}$ O $\rightarrow$ As ($\underline{V}$)

e

1 EXTRA e $\left\{\right.$

COL. $\underline{VI}$ ELEMENTS REPLACE COLUMN $\underline{V}$ ~~EE~~ ELEMENTS

OR

COL. $\underline{IV}$ ELEMENTS REPLACE COLUMN $\underline{III}$ ELEMENTS

ACCEPTORS

$\underline{III}$-$\underline{V}$

1 LESS e $\left\{\right.$

COL. $\underline{II}$ ELEMENTS REPLACE COLUMN $\underline{III}$ ELEMENTS

OR

COL. $\underline{IV}$ ELEMENTS REPLACE " $\underline{V}$ ELEMENTS

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DERIVATION

ROOM TEMPERATURE

Ex. SEMICONDUCTOR IS DOPED WITH BOTH DONOR AND ACCEPTOR IMPURITY, COMPLETE IONIZATION

$$\boxed{N_d^+ > N_a^-} \rightarrow \text{n-TYPE}$$

Ex

$$n_0 + N_a^- = p_0 + N_d^+ \quad \text{----} \quad (1)$$

$$n_0 p_0 = n_i^2 \quad \text{---} \quad (2)$$

* ALWAYS SOLVE FOR MAJORITY CARRIER FIRST!

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$$n_o P_o = n_i^2$$

$$P_o = \frac{n_i^2}{n_o} \quad \cdots \text{(3)}$$

SUBSTITUTE (3) IN (1)

(1) $$n_o + (N_a^- - N_d^+) - P_o = 0$$

$$n_o - (N_d^+ - N_a^-) - P_o = 0$$

$$n_o - (N_d^+ - N_a^-) - \frac{n_i^2}{n_o} = 0$$

$$n_o^2 - (N_d^+ - N_a^-)n_o - n_i^2 = 0$$

$$n_o = \frac{(N_d^+ - N_a^-) \pm \sqrt{(N_d^+ - N_a^-)^2 - 4(-n_i^2)}}{2}$$

$$n_o = \underbrace{\boxed{\frac{(N_d^+ - N_a^-)}{2}}}_{B} \, + \, \cancel{-} \, \underbrace{\boxed{\frac{1}{2}\sqrt{(N_d^+ - N_a^-)^2 + 4n_i^2}}}_{A}$$

(A) > (B)

CHOOSE THE POSITIVE SOLUTION

$$n_o = \left(\frac{N_d^+ - N_a^-}{2}\right) + \frac{1}{2}\sqrt{(N_d^+ - N_a^-)^2 + 4n_i^2}$$

$$P_o = \frac{n_i^2}{n_o}$$

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IF $n_i >> (N_d^+ - N_a^-)$

$$n_o = \frac{N_d^+ - N_a^-}{2} + \frac{1}{2}\sqrt{4n_i^2}$$

$$= \frac{N_d^+ - N_a^-}{2} + n_i$$

$$n_o \approx n_i$$

IF $n_i << (N_d^+ - N_a^-)$

$$n_o \approx N_d^+ - N_a^-$$

Ex

$Si \rightarrow RT$

$Na = 1 \times 10^{12}\ cm^{-3}$ COMPLETE IONIZATION

P-TYPE

$Na = Na^-$ $\quad n_i = 1.5 \times 10^{10}\ cm^{-3}$

$n_o?\quad p_o?$

ONLY ACCEPTOR IMPURITY

$Nd^+ = 0$

$n_o + Na^- = p_o$

$p_o - Na^- - n_o = 0$

$n_o p_o = n_i^2 \Rightarrow n_o = \frac{n_i^2}{p_o}$

$p_o - Na^- - \frac{n_i^2}{p_o} = 0$

$p_o^2 - Na^- p_o - n_i^2 = 0$

$$p_o = \frac{Na^- \pm \sqrt{(Na^-)^2 - 4(-n_i^2)}}{2}$$

$$= \frac{Na^-}{2} \pm \frac{1}{2}\sqrt{(Na^-)^2 + 4n_i^2}$$

$$p_o = \frac{Na^-}{2} + \frac{1}{2}\sqrt{(Na^-)^2 + 4n_i^2}$$

$$= \frac{10^{12}}{} + \frac{1}{}\sqrt{(10^{12})^2 + 4(1.5 \times 10^{10})^2}$$

$$= \frac{10^{12}}{2} + \frac{1}{2}\sqrt{(10^{12})^2 + 4(1.5\times10^{10})^2}$$

$$\left\{\begin{array}{l} p_0 = 1.000225 \times 10^{12}\ cm^{-3} \\ n_0 = \frac{n_i^2}{p_0} = \frac{(1.5\times10^{10})^2}{1.000225\times10^{12}} = 2.25\times10^{8}\ cm^{-3} \end{array}\right.$$

[MAJORITY CARRIER]

[MINORITY]

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OF Si ATOMS PER UNIT VOLUME

$$= \left(8 \text{ ATOMS/CELL}\right) \Big/ \left(0.5431 \times 10^{-7}\,\text{cm}\right)^3$$

$$= 4.99 \times 10^{22}\ \text{cm}^{-3}$$

$$P_0 = 1.000225 \times 10^{12}\ \text{cm}^{-3}$$

OF Si ATOMS PER ACCEPTOR ATOMS

$$= \frac{4.99 \times 10^{22}}{1.000225 \times 10^{12}} = \underline{\underline{4.99 \times 10^{10}\ \text{Si ATOMS}}}$$