EC 21103

Introduction to Electronics

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Book: Electronic Circuits – Analysis and Design
(1) by Donald A Neamen (3rd Ed.)

Syllabus:

1. Semiconductor theory
2. Diodes
3. Bipolar Junction Transistors (BJTs)
4. Field Effect Transistors (FETs)
5. Operational Amplifiers
6. Digital Circuits

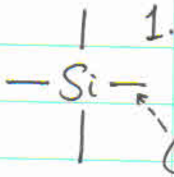
Assessment:

1. Attendance : 5 (De-registration rule)
2. Class Tests : 10
3. Assignments : 5
4. Mid sem exam : 30
5. End sem exam : 50

100 (total)

Semiconductor Theory

Partial



1. Intrinsic semiconductor: Pure semiconductor (s-c)

↳ Valency = 4 (eg. Silicon & Germanium)

(electrons at valence band)

Si ↑ Ge ↑

Crystal Lattice Atomic Structure ↔ Most commonly used.

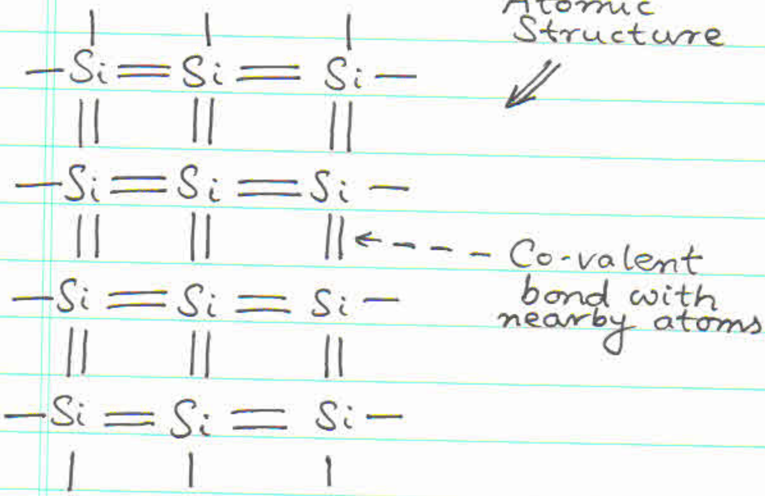


Fig: 2D structure

Charged Carriers

- Electron (e^-)
- Hole (h^+)

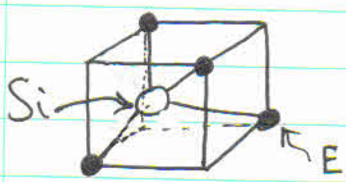
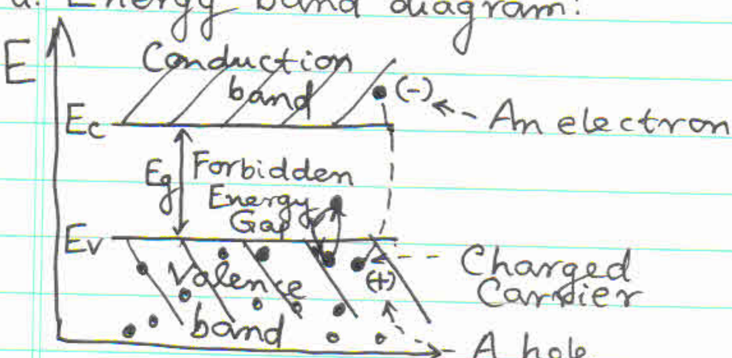
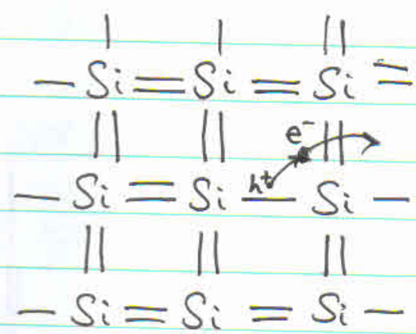


Fig: 3D structure

a. Energy band diagram:



Electron-Volt (eV)



b. Intrinsic carrier concentration

$$n_i = B T^{\frac{3}{2}} e^{\left(\frac{-E_g}{2kT}\right)}$$

where, $B \rightarrow$ Co-efficient/constant

$T \rightarrow$ Absolute temp. (°K)

$E_g \rightarrow$ Bandgap energy (eV)

$k \rightarrow$ Boltzmann's const. (86×10^{-6} eV/K)

Material	E_g (eV)	B ($cm^{-3} K^{-\frac{3}{2}}$)
Si	1.1	5.23×10^{15}
Ge	0.66	1.66×10^{15}

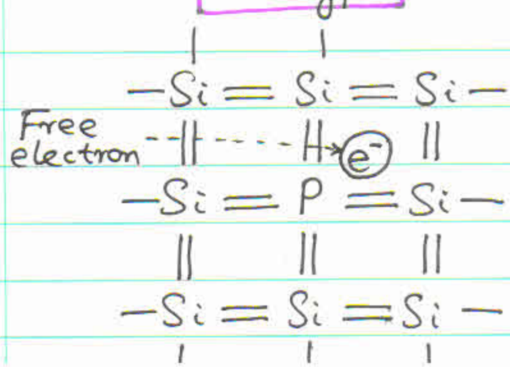
2. Extrinsic Semiconductor: Added impurity

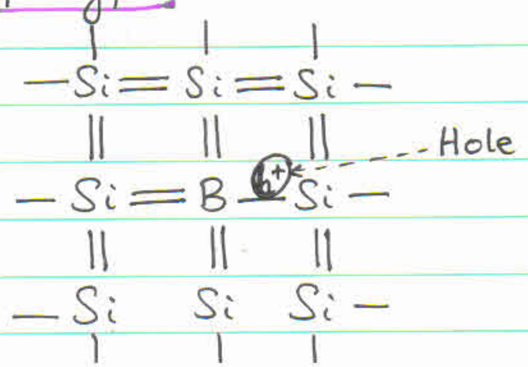
- For increasing e^- & h^+ concentration (conc.)
- Group III & V elements as impurities.

a. Doping Impurity (materials other than S-C)

↓

Donor	Acceptor
(Pentavalent) or Group V	(Trivalent) or Group III
eg. P & As	e.g. B & Al & Ga
↓	↓
$\boxed{\text{n-type}}$	$\boxed{\text{p-type}}$





At thermal equilibrium (constant temp.)

$$n_i^2 = n_o \cdot p_o$$

Intrinsic carrier concentration — Thermal equilibrium conc. of free e^- — Thermal equilb. conc. of h^+

At a room temp. each donor (eg. P) atom donates one free e^- in the lattice/crystal structure.

If a donor conc. (N_d) is: $N_d \gg n_i$

$$n_o \cong N_d$$

$$\Rightarrow \frac{n_i^2}{p_o} \cong N_d \qquad (\because n_o \cdot p_o = n_i^2)$$

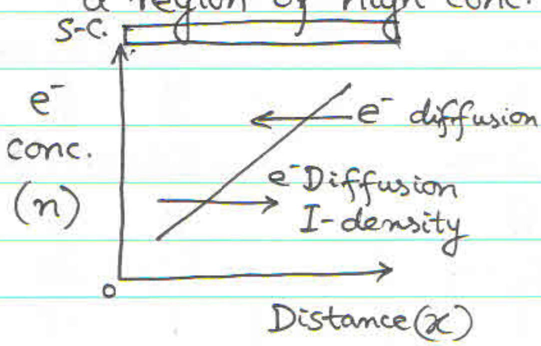
Similarly, $\frac{n_i^2}{n_o} \cong N_a$ ← Acceptor conc.

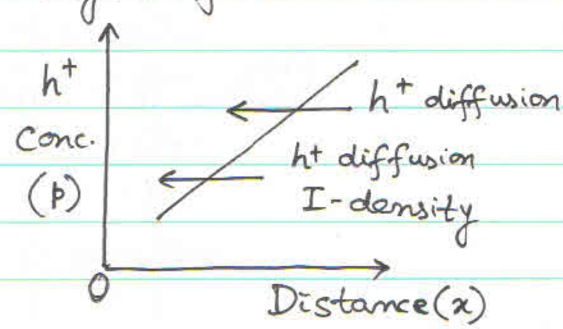
n-type S-C: e^- are majority carriers
h^+ are minority carriers

p-type S-C: h^+ are majority carriers
e^- are minority carriers

b. Transport of carriers: Drift (active) & Diffusion (passive)

Diffusion: Mechanism for carrier/particle flow from a region of high conc. to a region of low conc.





e^- diffusion co-efficient

e^- diffusion I-density: $J_n = e \cdot D_n \cdot \frac{dn}{dx}$ Gradient of e^- conc.

Charge of an e^- (1.6×10^{-19} C)

h^+ diffusion I-density: $J_p = -e \cdot D_p \cdot \frac{dp}{dx}$ Gradient of $h+$ conc.

$h+$ diffusion co-efficient

Drift: Mechanism for carrier/particle flow due to the influence of an external energy/force (e.g. electric field or heat).

<u>n-type</u>

$\longrightarrow \bar{E}$

$\hat{v}_{d_n} \longleftarrow e^-$

$\longrightarrow \hat{J}_n$

<u>p-type</u>

$\longrightarrow \bar{E}$

$h^+ \longrightarrow \hat{v}_{d_p}$

$\longrightarrow \hat{J}_p$

where,

$\hat{v}_{d_n}$: Drift velocity of e^- | $\hat{v}_{d_p}$: Drift velocity of h^+

$\hat{J}_n$: Drift current density of e^- | $\hat{J}_p$: Drift current density of h^+

Mathematically,

$$v_{d_n} = -\mu_n \cdot E$$

e^- mobility ($cm^2/V\text{-}s$) Electric field intensity

$\mu_n \Rightarrow$ A parameter (physical) indicating an ability of an e^- to move/travel inside a solid S-C.

$\mu_p \Rightarrow$ (Same for h^+)

Similarly, $v_{d_p} = +\mu_p . E$

Hole mobility

For lightly doped Si,

$$\mu_n = 1350 \ \ cm^2/V\text{-}s$$
$$\mu_p = 480 \ \ cm^2/V\text{-}s$$

e^- drift I-density: $J_n = -e.n.v_{d_n}$

$= -e.n(-\mu_n.E) = +e.n.\mu_n.E$

h^+ drift I-density: $J_p = +e.p.v_{dp}$

$= +e.p.(+\mu_p.E) = +e.p.\mu_p.E$

S-C contains both e^- & h^+, $\therefore$ total I-density is:

$$J = J_n + J_p$$
$$= e n \mu_n E + e p.\mu_p.E$$
$$= \sigma E \qquad (\sigma = e n \mu_n + e p \mu_p)$$

Conductivity $(\Omega\text{-cm})^{-1}$ Doped carriers

$\therefore$ Doping controls/determines conductivity of S-C.

n-type: $n \gg p$

p-type: $p \gg n$

c. Excess carriers: At thermal non-equilibrium, in the presence of additional energy, valence e^- breaks covalent bonds & become free e^-. Therefore, an e^-h^+ pair is formed, which is known as excess e^- & excess h^+.

$$n = n_o + \delta_n$$
$$p = p_o + \delta_n$$

Total carriers At thermal equilb. Excess carriers