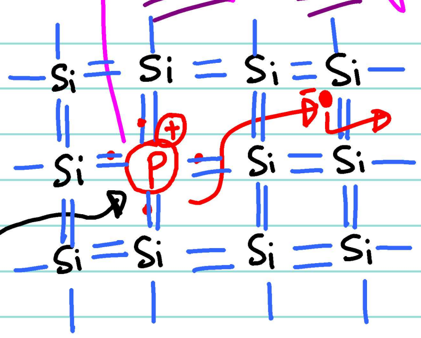
Lec-3

Si

Extrinsic Semiconductors → Semiconductors with impurities

for Si, Gr-III or Gr-V

Donor impurity.



Phosphorus (P), Arsenic

Valence electrons = 5

Carrier → electrons (−)

→ n-type Semiconductor.

Acceptor conc.

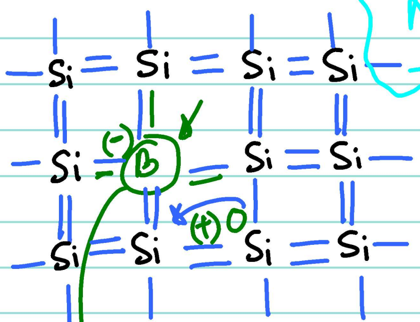
Process → doping

$\frac{N_A}{N_a}$ $\frac{N_D}{N_d}$ Donor conc.

$n_i \to 2n_i$

Group-III

(B)



carrier → holes (+)

p-type Semiconductor.

$10^{15} - 10^{18}$

cm^{-3}

Acceptor impurity.

→ ✓ $n_o p_o = n_i^2$ n_i = intrinsic carrier conc.

hole conc. at th. eq.

electron conc. at thermal equilibrium.

'p' → $5\times10^{5}\ cm^{-3}$ → (e) 'p' → $5\times10^{15}\ cm^{-3}$ ✓ → n_o, p_o = ?

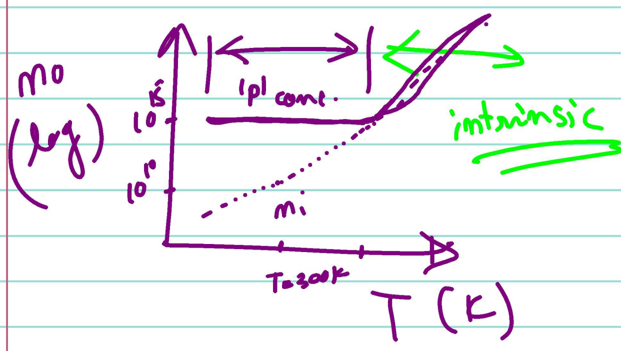
$p \gg n_i$ $\boxed{\text{Si}}$ T = 300K, n_o = $n_i = 1.5\times10^{10}\ cm^{-3}$

T = 300K ↑, 'p' → $5\times10^{15}\ cm^{-3}$

$n_o = 5\times10^{15}\ cm^{-3}$

n_i ↑

T_1 $n_i >$ 'p' conc



10^{18}

10^{15}

$\frac{1}{10^{7}}$ Si $\frac{10^{15}}{10^{22}}$ Si $\frac{1}{10^{4}}$

Drift and Diffusion Current:

Carriers → electrons (●)
→ holes (O)

Drift and Diffusion → due to concentration gradient.

Drift → Caused by electric field

Drift

$\vec{E}$ e ● v_{dn} ←   → J_n

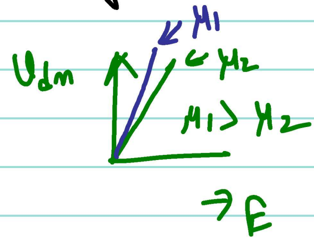
$\vec{E}$ h O → v_{dp} → J_p

E = electric field

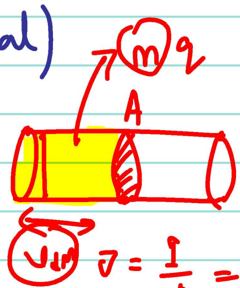
✓ $v_{dn} \propto E$; v_{dn} = drift velocity of electron

$v_{dn} = -\mu_n E$ (V/cm)

(cm/s) μ_n → mobility electron → cm²/V-s.



'Si' $\mu_n = 1350$ cm²/V-s.   (typical)



$J = \frac{I}{A} = \frac{q n v_{dn}}{A}$

$J_n = -q n v_{dn}$

$= -q n(-\mu_n E)$

$J_n = q n \mu_n E$

$J_p = q p \mu_p E$ → mobility of holes.

for Si, $\mu_p = 480$ cm²/V-s

→ $J = J_n + J_p = q n \mu_n E + q p \mu_p E$

$J = (q n \mu_n + q p \mu_p) E = \sigma E = \frac{1}{\rho} E$

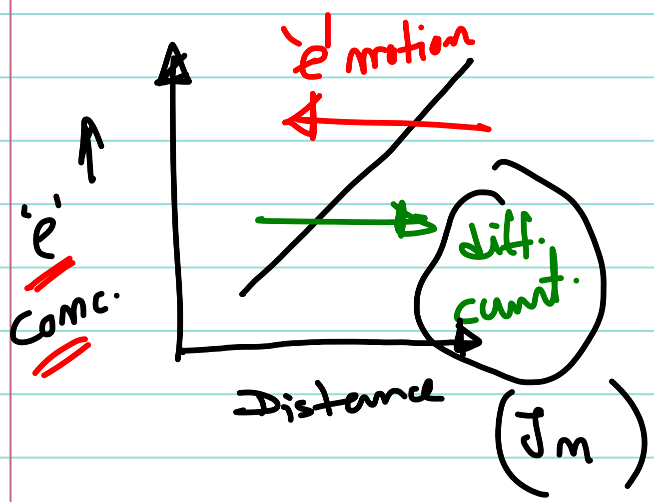
→ $\sigma = q n \mu_n + q p \mu_p = \frac{1}{\rho}$ → Resistivity.

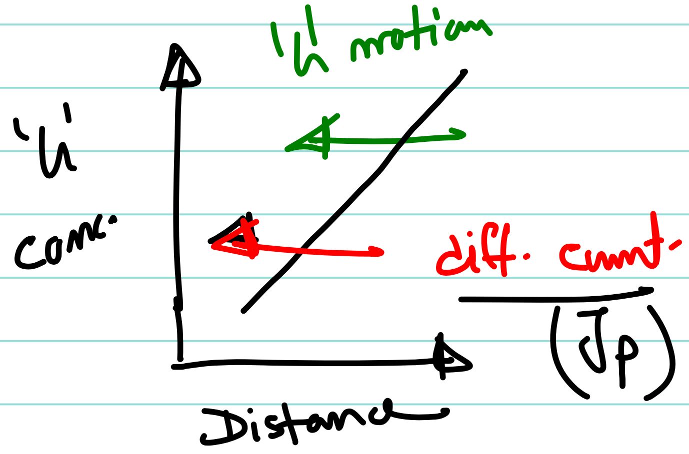
σ → conductivity $(\Omega\text{-cm})^{-1}$

$10^{10} - 10^{18}$ cm^{-3}

$\sigma = n q \mu_n = N_D q \mu_n$

Diffusion





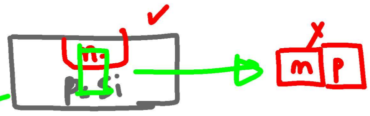
$$J_n = q\, D_n \frac{dn}{dx}$$; D_n = electron diffusion coefficient

$$J_p = -q\, D_p \frac{dp}{dx}$$; D_p = hole " "

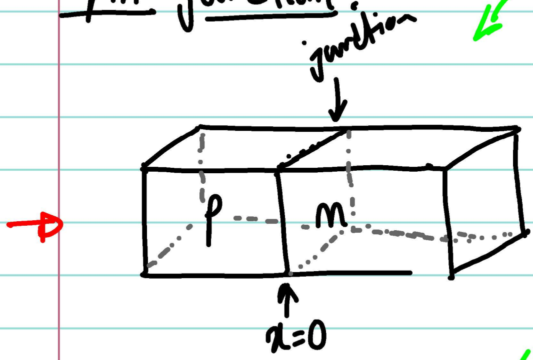
Einstein Relation

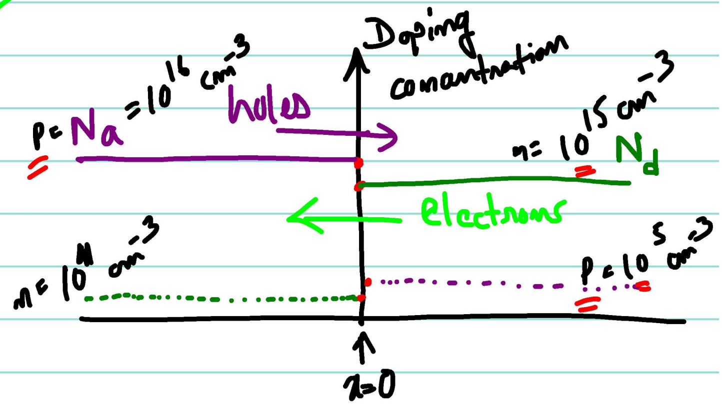
$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{KT}{q} = V_T = 0.026\ V \text{ at } 300K$$

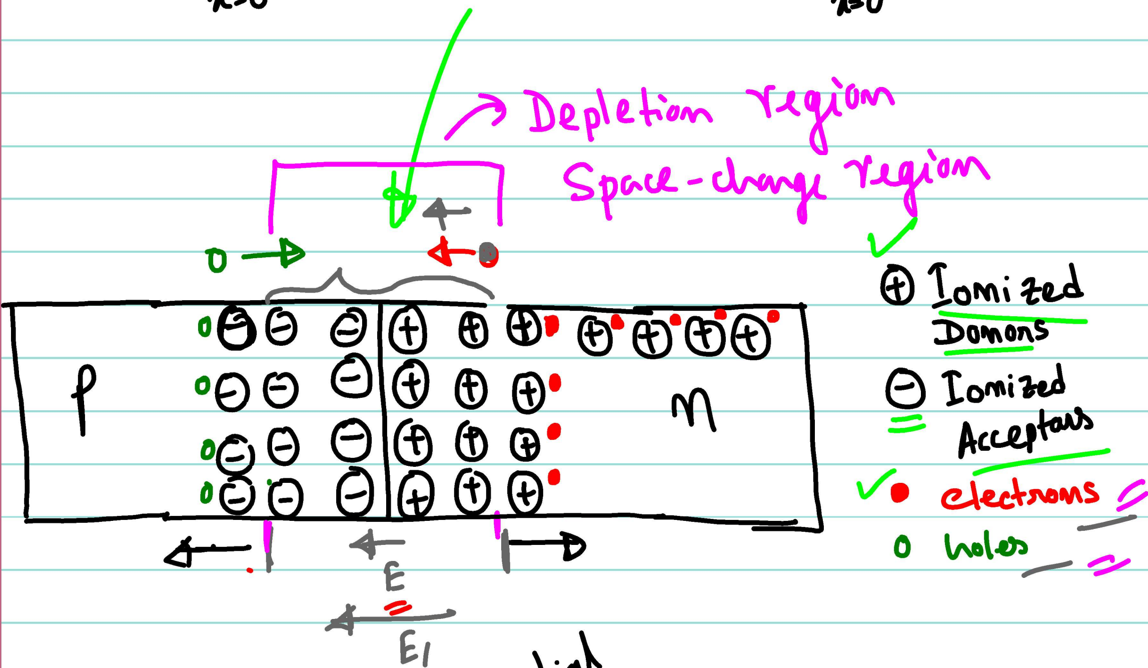
Lec-4

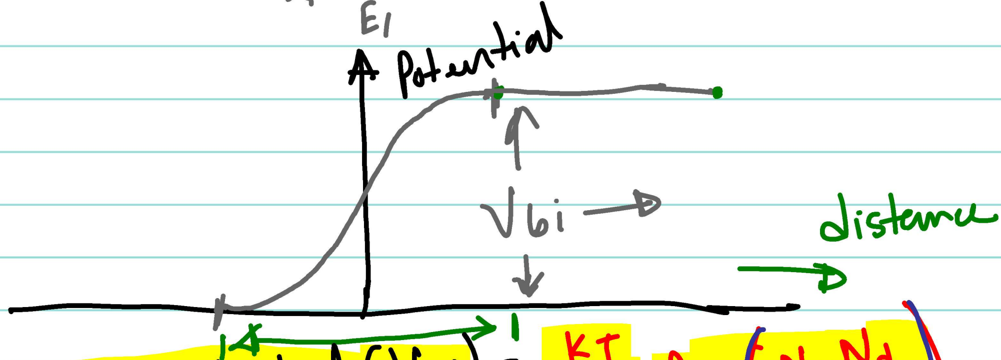


pn junction:









Built-in potential (V_{bi}) $= \dfrac{kT}{q} \ln\left(\dfrac{N_a N_d}{n_i^2}\right)$

$= V_T \ln\left(\dfrac{N_a N_d}{n_i^2}\right)$

V_T: 0.026 V at 300K

Doubt

$n_0 p_0 = n_i^2$

$N_d p_0 = n_i^2$

$n_0 N_a = n_i^2$

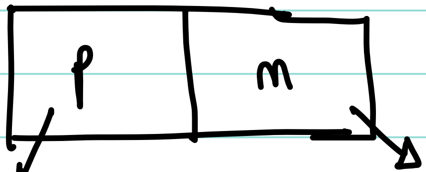
$n_0 = \dfrac{n_i^2}{N_a}$

$\cancel{N_a N_d = n_i^2}$

Built-in potential:

Si → $n_i = 1.5 \times 10^{10}\ cm^{-3}$ at $T = 300\,K$

$V_T = 26\ mV.$



Case I

→ $N_a = 10^{16}\ cm^{-3}$ $\quad$ $N_d = 10^{15}\ cm^{-3}$

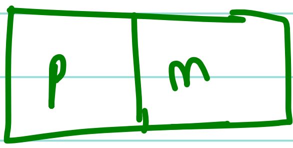
$$V_{bi} = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right) = 0.637\ V.$$

Case II

$N_a = 10^{17}\ cm^{-3}$ $\quad$ $N_d = 10^{16}\ cm^{-3}$

$V_{bi} = 0.757\ V.$

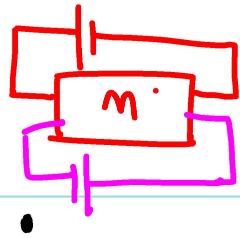
GaAs → "E_g" higher



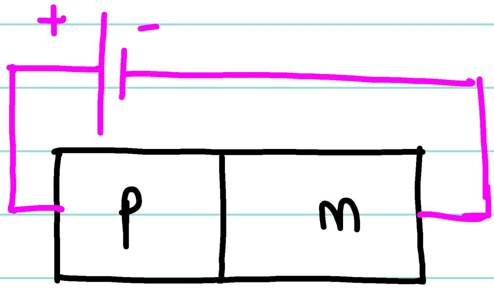
→ $$V_{bi} = V_T \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

$N_a = 10^{16}\ cm^{-3}$ $\quad$ $N_d = 10^{15}\ cm^{-3}$

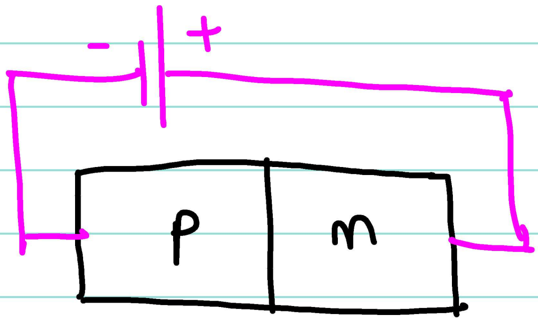
$V_{bi} = 1.107\ V$



A pn junction when it is biased:



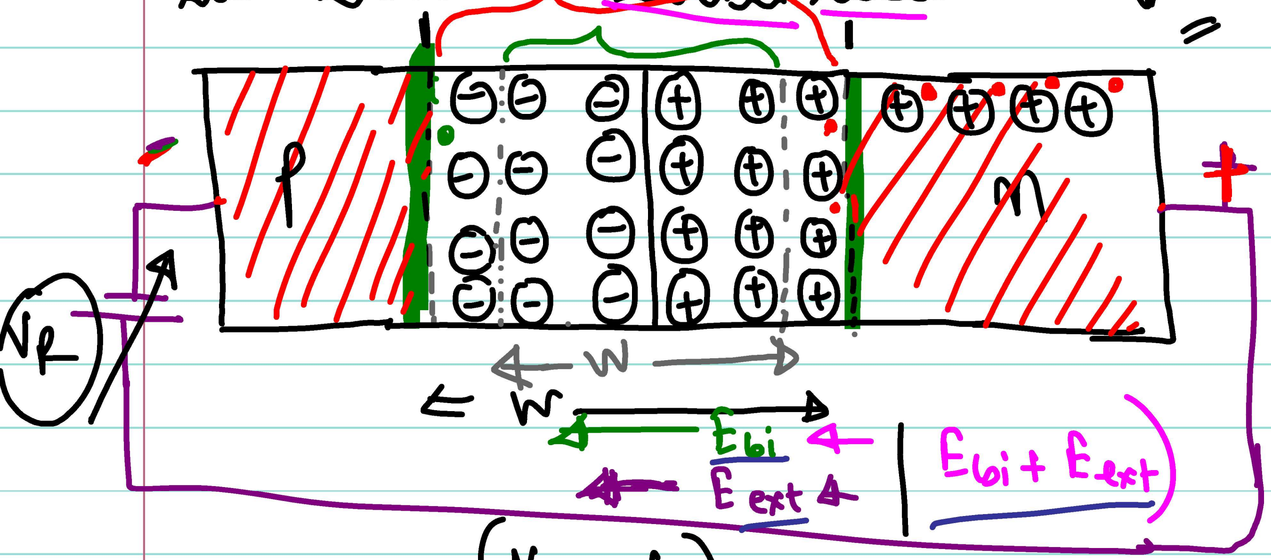
Forward Bias



Reverse Bias

pn junction in Reverse Bias

$$\downarrow C = \frac{\epsilon A}{W}$$



Varactor Diode

$(V = -V_R)$

$$\uparrow \; W = \left[\frac{2\epsilon (V_{bi} - V)}{q} \left(\frac{N_a + N_d}{N_a N_d} \right) \right]^{1/2}$$