Energy (eV) $= \frac{12.4}{\lambda(\mu m)}$; $1A^\circ = 10^{-8} cm$

$m_n < m_p$ (effective mass of hole)

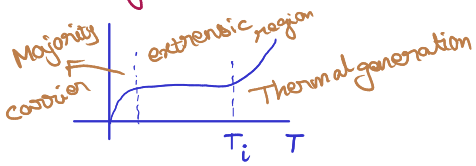
$n_i = N_c\, e^{-\left(\frac{E_c - E_F}{KT}\right)}$; $N_c \propto T^{3/2}$

$n_i \propto T^{3/2}\, e^{-E_g/2KT}$

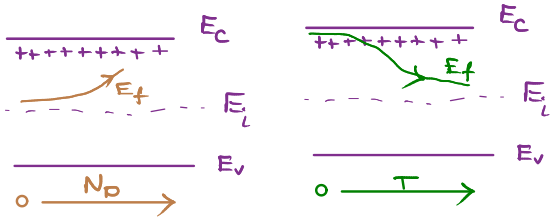
$E_f = \frac{E_c + E_v}{2} - KT \ln\sqrt{\frac{N_c}{N_v}} = E_i$

Dilation approximation:
- No interaction between impurities
- crystal structure unaffected

Charge balance equation $N_D^+ + p_{n_0} = n_{n_0}$



$n_i^2 = n_{n_0} p_{n_0}$

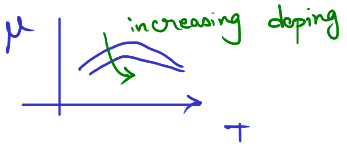


$E_f = E_c - KT \ln \frac{N_c}{N_d}$ → n type

$E_f = E_v + KT \ln \frac{N_v}{N_a}$ → p type

Mobility: $\mu_p = \frac{2\tau_c}{2m_p}$, $D_p = \frac{l_c V_{th}}{2}$

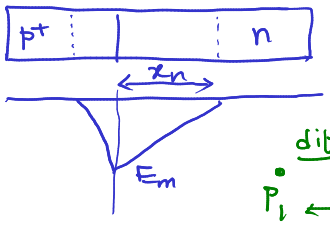
$\frac{D}{\mu} = V_T$; $\mu \propto T^{3/2}$



$\sigma_i = q(\mu_n + \mu_p) n_i$

$J_n = q n \mu_n \mathcal{E} + q D_n \frac{dn}{dx}$ → current density

PN junction diode:



$\frac{x_p}{x_n} = \frac{N_d}{N_a}$

diffusion: $p_1 \rightarrow p_2 (< p_1)$

drift

$\psi_{1,2} = -V_T \ln\left(\frac{p_1}{p_2}\right)$

$E_m = \frac{qN_D x_n}{\epsilon} = \frac{qN_a x_p}{\epsilon} = \sqrt{\frac{2q N_{eq} \psi_0}{\epsilon}}$

$\psi_0 = \frac{1}{2} E_m x_d = V_T \ln\left(\frac{N_A N_D}{n_i^2}\right)$

$x_d = \sqrt{\frac{2\epsilon \psi_0}{q N_{eq}}}$ $\quad N_{eq} = \frac{N_A N_D}{N_A + N_D}$

$|J_{drift}| = |J_{diffusion}| = q \frac{D_p (p_{p_0} - p_{n_0})}{x_d}$ (A/cm^2)

In forward bias: $I = I_0 \left(e^{V/V_T} - 1\right)$ $\quad x_d \propto \sqrt{V_{bias}}$

$I_0 = A q n_i^2 \left(\frac{D_p}{N_D L_p} + \frac{D_n}{N_A L_n}\right)$

$I_0 \propto n_i^2$

I_0 doubles for 10°c

$\psi_0 \downarrow$ 2mV/°c

Reverse bias: $I = -I_0$ for $V > 3V_T$

Small signal analysis:

$C_{dep} = \frac{\epsilon A}{x_d} = \left|q N_a A \frac{dx_p}{dV}\right|$ $\quad C_{diff} = \frac{I\tau}{V_T}$ (F.B) $= 0$ (R.B) $\quad r = \frac{V_T}{I}$

BJT: $\alpha = \frac{I_C}{I_E}$, $\beta = \frac{I_C}{I_B}$

$W_B \uparrow \Rightarrow \alpha \downarrow \Rightarrow$ Base width modulation reduces amplification

$r_e = \frac{V_T}{I_E} = \frac{1}{g_m}$

MOS capacitor:

$V_{Dsat} = V_{GS} - V_T$

$g_m = \frac{dI_{DS}}{dV_{GS}} = \frac{2 I_D}{V_{GS} - V_T}$ (in saturation)

$r_d = \frac{dV_{DS}}{dI_{DS}}$