Quasi-Fermi-Energy Levels & Currents.

8/9/2014

$$J_p = q\mu_p p \mathcal{E} - qD_p \frac{dp}{dx}$$

$$= q\mu_p p \mathcal{E} - \frac{qD_p}{kT} p \frac{d}{dx} E_I \quad \mu_p \quad q\mathcal{E}$$

$$+ \frac{qD_p}{kT} p \frac{d}{dx} E_{fp} \quad \mu_p$$

$$= \frac{qD_p}{kT} p \cdot \frac{d}{dx} E_{fp}$$

$$= p \mu_p \frac{d}{dx} E_{fp}$$

$$p = n_i \exp\left(\frac{E_I - E_{fp}}{kT}\right)$$

$$\frac{dp}{dx} = \frac{p}{kT} \frac{d}{dx} \left[E_I - E_{fp}\right]$$

$$E = -qV$$

$$\frac{dE}{dx} = -q\frac{dV}{dx} = q\mathcal{E}$$

$$J_p = p\,\mu_p \frac{dE_{fp}}{dx}$$

$$= q\,p\,\mu_p \frac{d}{dx}\left(E_{fp}/q\right) = \sigma_p \frac{d}{dx}\left(E_{fp}/q\right)$$

$$= - \sigma_p \frac{d}{dx}\left(V_{fp}\right)$$

$V_{fp} \rightarrow$ quasi-fermi potential of hole

$$\boxed{J_p = \sigma_p \mathcal{E}_{fp}}$$

$$\boxed{J_n = \sigma_n \mathcal{E}_{fn}}$$

$\mathcal{E}_{fp} \rightarrow$ quasi-Fermi field of hole

$$(n, p) = n_i \exp\left(f\left(E_{fn}, E_{fp}, E_I, T\right)\right)$$

E_c

E_{fn} — $-$ve slope

E_f

$$J_n = n \mu_n \frac{d}{dx} E_{fn}$$

$+$ve slope

E_I

E_{fp}

$n_0 = 10^{16}/cm^3$

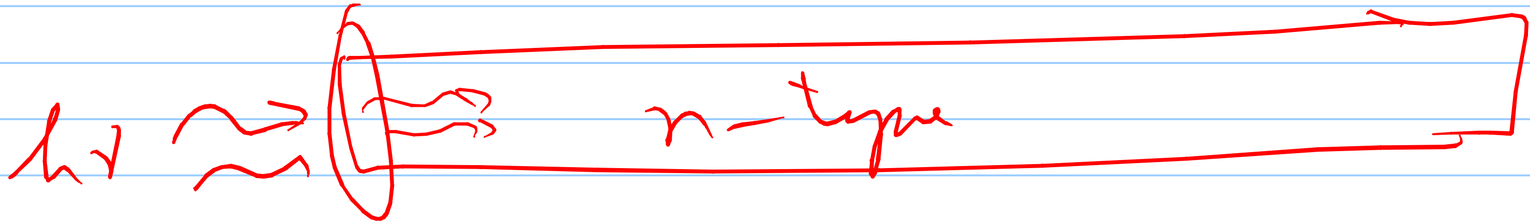
$p_0 = 10^4/cm^3$

$\delta n = \delta p = 10^{14}/cm^3$

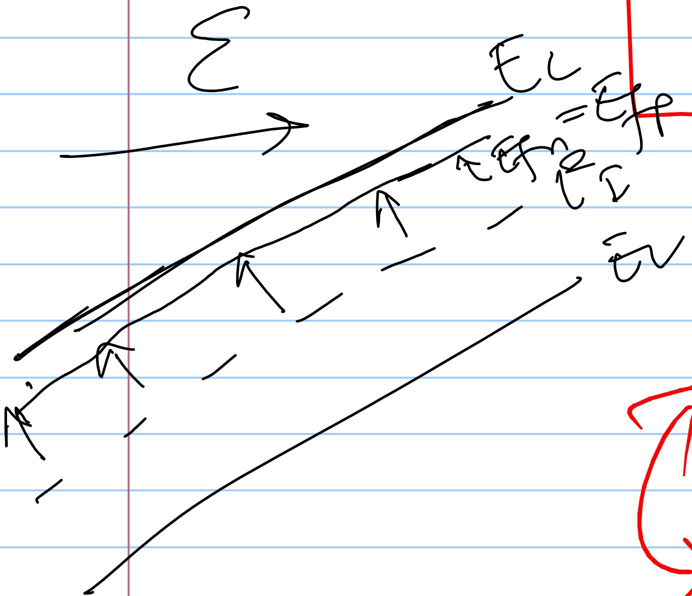
$$J_p = p \mu_p \frac{d}{dx} E_{fp}$$

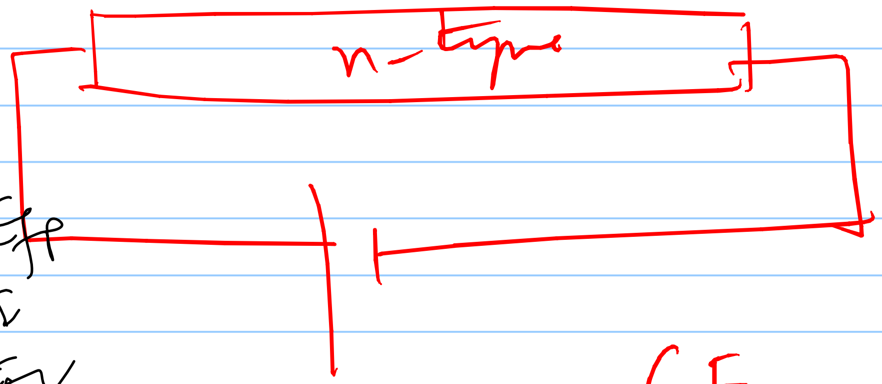
$\left.\begin{aligned} J_n &= 0 \\ J_p &= 0 \end{aligned}\right\}$ TE process

E_v

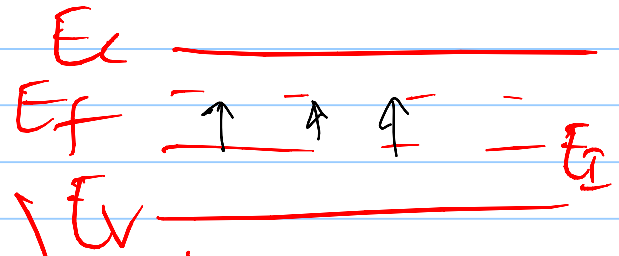


$$J_n = n\,\mu_n \frac{dE_{fn}}{dx}$$





$n_0,\ p_0$



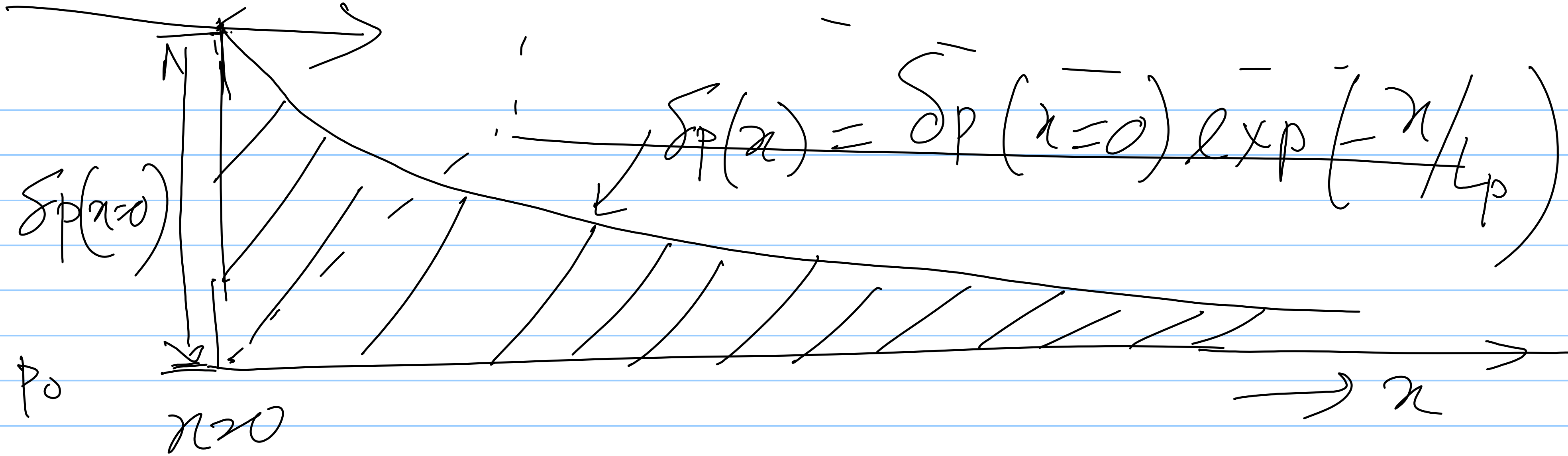
$$n_0 = n_i \exp\left(\frac{E_{fn} - E_I}{kT}\right)$$

$$p_0 = n_i \exp\left(\frac{E_I - E_{fp}}{kT}\right)$$

$$np = n_i^2$$

$$E_{fn} = E_{fp}$$

$$J_p = p\,\mu_p \frac{dE_{fp}}{dx} \approx 0$$



$$\delta p(x) = \delta p(x=0)\exp\left(-x/L_p\right)$$

$L_p \rightarrow$ diffusion length

$$L_p = \sqrt{D_p \tau_p}$$

$A = 10^{-3}\ cm^2$

$\delta p(x=0) = 10^{16}/cm^3$

$L_p = 10^{-3}\ cm$

$\tau_p = 1\mu s$

$Q_p = \delta Q_p =$ Excess hole charge stored

$$= qA \int_0^{\alpha} \delta p(x)\, dx$$

$$= qA \int_0^{\alpha} \delta p(x=0)\, e^{-x/L_p}\, dx$$

$$\boxed{Q_p = qA\, \delta p(x=0)\, L_p.}$$

$$I_p(x=0) = ?$$

$$I_p = A J_p = -A q D_p \frac{d\,\delta p(x)}{dx}$$

$$I_p(x) = \frac{A q D_p}{L_p}\,\delta p(x=0)\, e^{-x/L_p}$$

$$I_p(x=0) = qA\frac{D_p}{L_p}\,\delta p(x=0)$$

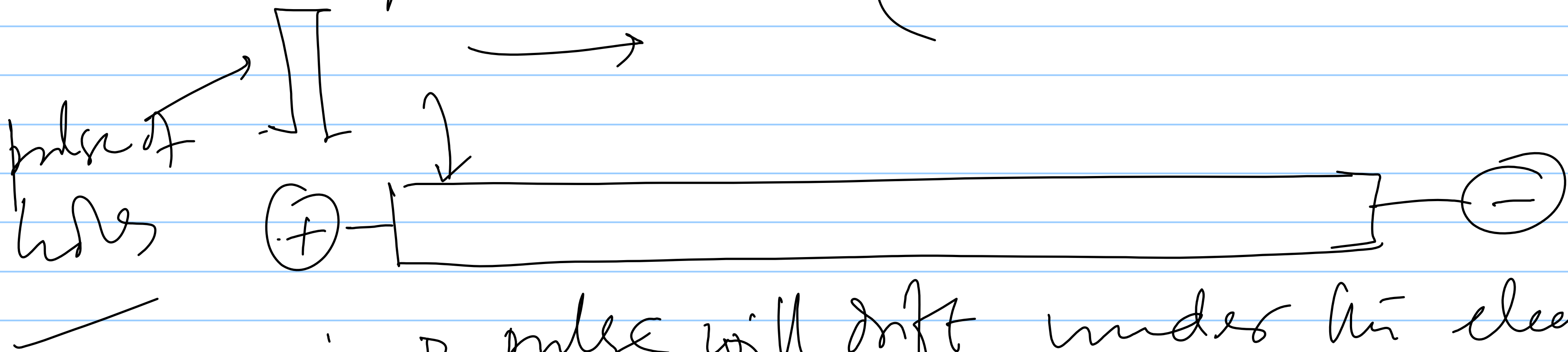
$$Q_p = \tau_p I_p(x=0) = qA\frac{\tau_p D_p}{L_p}\,\delta p(x=0) = qAL_p\,\delta p(x=0)$$

$$\boxed{I_p(x=0) = \frac{Q_p}{\tau_p}} \rightarrow \text{charge control relation}$$

Haynes-Shockley Experiment

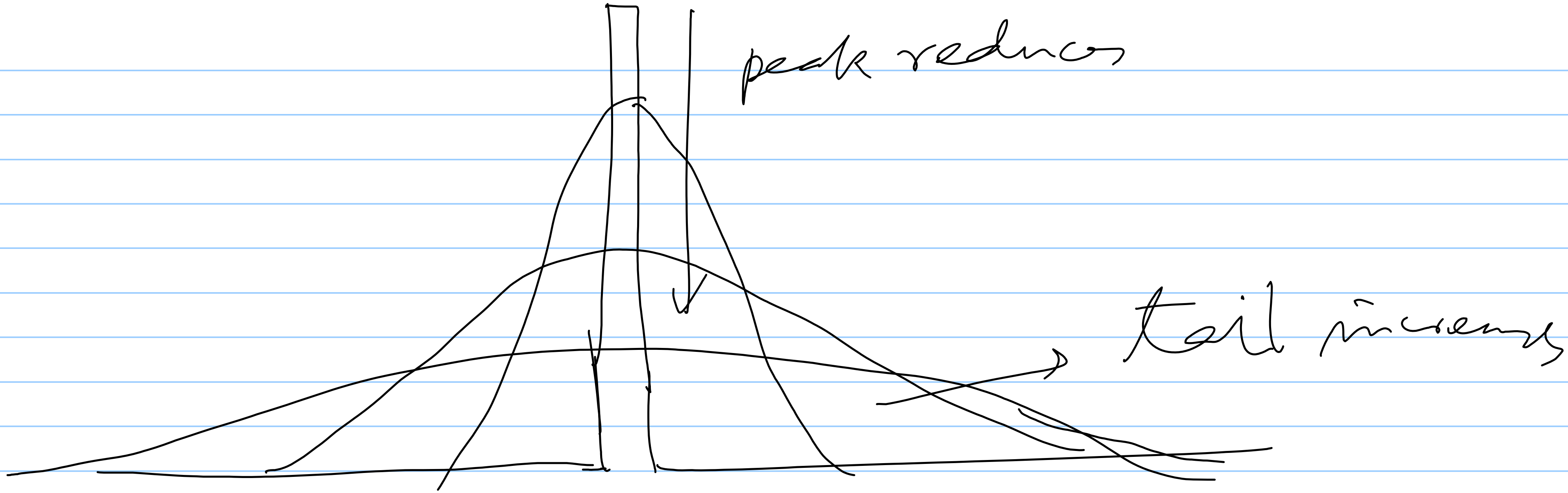
Minority carrier mobility and diffusivity

n-type bar $\longrightarrow$ $(\mu_p, \; D_p)$



→ pulse will drift under the electric field

→ pulse will spread under diffusion effect


peak reduces
tail increases

$$v_d = \frac{L}{t_d} = \mu_p \cdot \mathcal{E}$$

$$\mu_p = \frac{v_d}{\mathcal{E}}$$

$$\frac{\partial \delta p(x,t)}{\partial t} = -\frac{1}{q}\nabla \cdot J_p - \frac{\delta p}{\tau_p}$$

$$\boxed{\frac{\partial}{\partial t}\delta p(x,t) = D_p \frac{\partial^2}{\partial x^2}\delta p(x,t)}$$

$$-\frac{1}{q}\nabla\cdot J_p = \frac{d}{dx}\left(+\frac{q}{q}D_p\frac{d}{dx}p\right) = +D_p\frac{d^2\delta p(x,t)}{dx^2}$$

Continuity Eqn.

$$\frac{\partial \rho}{\partial t} = -\nabla\cdot J = q\frac{\partial p}{\partial t}$$

$$\Rightarrow \frac{\partial \delta p(x,t)}{\partial t} = -\frac{1}{q}\nabla\cdot J_p = D_p\frac{\partial^2}{\partial x^2}\delta p(x,t)$$