Announcements

- HW #1 due Friday in class.
- If you want comments on Lab 0, turn it in to your TA.

Minority Carrier Continuity Equations

$$\mathbf{j}_n^{\text{tot}} = qn\mu_n\mathbf{E} + qD_n\boldsymbol{\nabla}n$$

$$\mathbf{j}_p^{\text{tot}} = qp\mu_p\mathbf{E} - qD_p\boldsymbol{\nabla}\mathrm{p}$$

$$\frac{\partial n}{\partial t} = -\frac{1}{-q}\boldsymbol{\nabla}\cdot\mathbf{j}_n^{\text{tot}} + \mathrm{G} - \mathrm{R}$$ (G is generation,

$$\frac{\partial p}{\partial t} = -\frac{1}{q}\boldsymbol{\nabla}\cdot\mathbf{j}_p^{\text{tot}} + \mathrm{G} - \mathrm{R}$$ R is recombination)

For **minority carriers**, in low level injection (p<<n): $\mathrm{G} - \mathrm{R} \cong$

$$\frac{(p_0 - p)}{\tau_p} = -\frac{\Delta p}{\tau_p}$$

$\mathbf{j}_p^{\text{tot}} \cong \mathbf{j}_p^{\text{diff}}$ (neglect drift since p small)

Minority Carrier Continuity Equations

$$j_p^{tot} = qp\mu_p E_x - qD_p \frac{dp}{dx} \cong -qD_p \frac{dp}{dx}$$

$$\frac{\partial p}{\partial t} = -\frac{1}{q}\frac{d}{dx}\left(-qD_p \frac{dp}{dx}\right) - \frac{\Delta p}{\tau_p}$$

$$= D_p \frac{d^2 p}{dx^2} - \frac{\Delta p}{\tau_p}$$

Similarly in p-type material under low level injection (1D):

$$\frac{\partial n}{\partial t} = D_n \frac{d^2 n}{dx^2} - \frac{\Delta n}{\tau_n}$$

p-n Junction – Minority carrier injection

$$\varphi_j - v_d = \frac{kT}{q} \ln \frac{p(-x_p)}{p(x_n)} = \frac{kT}{q} \ln \frac{n(x_n)}{n(-x_p)}$$

$$p(x_n) = p(-x_p) \exp\left[-\frac{q(\varphi_j - v_d)}{kT}\right]$$

$$= N_A \frac{{n_i}^2}{N_A N_D} \exp\left[-\frac{q(-v_d)}{kT}\right] = \frac{{n_i}^2}{N_D} \exp\left[\frac{qv_d}{kT}\right]$$

$$n(-x_n) = \frac{{n_i}^2}{N_A} \exp\left[\frac{qv_d}{kT}\right]$$

Diode reverse leakage current

Short base $W_p \ll L_n$, $W_n \ll L_p$:

$$I_s = qAn_i^2\left[\frac{D_n}{N_A W_p} + \frac{D_p}{N_D W_n}\right]$$

Long base $W_p \gg L_n$, $W_n \gg L_p$:

$$I_s = qAn_i^2\left[\frac{D_n}{N_A L_n} + \frac{D_p}{N_D L_p}\right]$$

Current dominated by minority carrier injection into the lightly-doped and/or narrower side.

Minority carrier diffusion length: $L_n = \sqrt{D_n \tau_n}, L_p = \sqrt{D_p \tau_p}$

Diffusion charge (forward bias)

Short base W_p<<L_n, W_n<<L_p:

$$Q_D = qA{n_i}^2\left[\frac{W_p}{2N_A} + \frac{W_n}{2N_D}\right]\left(e^{qv_d/kT} - 1\right)$$

Long base W_p>>L_n, W_n>>L_p:

$$Q_D = qA{n_i}^2\left[\frac{L_n}{N_A} + \frac{L_p}{N_D}\right]\left(e^{qv_d/kT} - 1\right)$$

Stored charge dominated by minority carrier injection into the lightly-doped and/or **wider** side.

