Announcements

- HW #1 due now; solutions posted after class.
- HW #2 posted this evening.
- If you want comments on Lab 0, turn it in to your TA.
- Keep reading Chapter 3.

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:

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

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

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

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

Diffusion capacitance (forward bias)

- Additional charge stored in the neutral region near edges of spatial charge region.

$$Q_D = i_D \tau_T$$

  - τ_T: transit time of diode (1 fs ~ 1us).
- Diffusion capacitance (forward bias):

$$C_D = \frac{dQ_D}{dv_D} = \frac{(i_D + I_S)\tau_T}{V_T} \cong \frac{i_D \tau_T}{V_T}$$

- Diffusion capacitance proportional to forward current (large at high forward bias)

Diode temperature coefficient

- How does v_D vary with temperature while i_D is fixed?
- Temperature coefficient: $\frac{dv_D}{dT}$
- $v_D = \frac{kT}{q}\ln\left(\frac{i_D}{I_S}+1\right) \cong \frac{kT}{q}\ln\left(\frac{i_D}{I_S}\right)$ → constant
- $\frac{dv_D}{dT} = \frac{k}{q}\ln\left(\frac{i_D}{I_S}\right) - \frac{kT}{q}\frac{1}{I_S}\left(\frac{dI_S}{dT}\right)$
- I_S is proportional to n_i^2. We get

$$n_i^2 = BT^3\exp\left(-\frac{E_G}{kT}\right)$$

$$\frac{dv_D}{dT} = \frac{v_D - \frac{E_G}{q} - 3V_T}{T}$$

Verify this in HW 2

Diode temperature coefficient

$$\frac{dv_D}{dT} = \frac{v_D - \frac{E_G}{q} - 3V_T}{T}$$

- Example: temperature coefficient at RT for a typical Si diode, with $v_D = 0.65\ \mathrm{V}$, $E_G = 1.12\ \mathrm{eV}$
- For a silicon diode, at RT $v_T = 0.0259\ \mathrm{V}$

$$\frac{dv_D}{dT} = \frac{0.65 - 1.12 - 3 \cdot 0.026}{300} \frac{\mathrm{V}}{\mathrm{K}} = -1.82\ \mathrm{mV/K}$$

- If the diode is operating at a constant current at RT, for each °C rise in temperature, v_D falls by about 1.8 mV.