ECE 340 Homework XI Spring 2003

Due: Friday, April 04, 2003

1. For a p^+-n silicon junction, $N_a=10^{17}/cm^3$ in the p-side and $N_d=10^{15}/cm^3$ in the n-side. Determine the depletion capacitance per unit area of cm^2 at –4 V.

2. A Schottky barrier is formed between a metal having a work function of 4.7 eV and n-type Si (electron affinity = 4 eV). The donor doping in the Si is $2x10^{17}/cm^3$. (a) Draw the equilibrium band diagram showing numerical values for qV_o and schottky barrier, $q\phi_n$. (b) Draw the band diagram with 0.5 V forward bias. Repeat for 2V reverse bias. For all three diagrams, determine and show the proper widths of the depletion region.

3. Assume that a p^+-n diode with a uniform cross section area, A, is built with an n region width ℓ smaller than a hole diffusion length ($\ell < L_p$). This is the so-called narrow base diode. Since for this case holes are injected into a short n region under forward bias, we cannot use the assumption $\delta p(x_n = \infty) = 0$ in Eq. 4-35. Instead, we must use as a boundary condition the fact that $\delta p = 0$ at $x_n = \ell$.

   (a) Solve the diffusion equation to obtain

$$dp(x_n) = \frac{\Delta p_n \left[e^{(\ell - x_n)/L_p} - e^{(x_n - \ell)/L_p} \right]}{e^{\ell/L_p} - e^{-\ell/L_p}}$$

   (b) Show that the current in the diode is

$$I = \left(\frac{qAD_p\, p_n}{L_p}\ ctnh \frac{\ell}{L_p} \right) \left(e^{qV/kT} - 1 \right)$$

   (c) If the n-region is relatively short compared to the diffusion length, the excess hole $\delta p(x_n)$ can be approximated as a straight line, i.e. it varies linearly from Δp_n at $x_n=0$ to zero at the ohmic contact ($x_n = \ell$). Find the steady-state **total** excess charges, Q_p in the n-region and determine the percentage of error comparing the **total** excess holes in the n-region obtained from part (a) with that from the straight-line approximation for ℓ/L_p = 0.05, 0.1, 0.5, 1 and 5.

   (d) Calculate the current due to recombination in the n region.