ECE 132 Fall 2017

UNIVERSITY OF CALIFORNIA, SANTA BARBARA
Department of Electrical and Computer Engineering

Homework 4 – due December 1, 2017 by 5:00pm

1. An abrupt Si p^+-n diode has $N_D = 10^{16}$ cm^{-3} on the n side and $N_A = 10^{17}$ cm^{-3} on the p side. For Si at room temperature, E_G = 1.1 eV, N_C = 2.8 x 10^{19} cm^{-3}, and N_V = 1.8 x 10^{19} cm^{-3}. Assume the minority carrier lifetime is 8 μs (for both electrons and holes), the electron mobility is 1400 cm^2/V·s, and the hole mobility is 500 cm^2/V·s.

   (a) Find the depletion region widths under zero bias on the p-side (w_{p0}) and on the n-side (w_{n0}), and the total depletion width $w_{tot,0}$.

   (b) If a forward bias of 0.2 V is applied, find the resulting depletion widths (w_p, w_n, and w_{tot}), the electron current density J_n through the depletion region, the hole current density J_p through the depletion region, and the total current density J_{tot} through the diode.

2. For the diode in Problem 1:

   (a) If the doping on the n-side is increased by a factor of 2, by what percentage do $w_{tot,0}$ and w_{tot} change? How about if instead the doping on the p-side was increased by a factor of 2?

   (b) What is the percent change in the current calculated in Problem 1(b) if the doping on the n-side is increased by a factor of 2? What about if the doping on the p-side is increased by a factor of 2?

   (c) For diodes in which one side is much more heavily doped than the other, what does this tell you about the effects of varying the doping on the heavily doped side versus varying the doping on the lightly doped side?

3. Problem 5.13 in Streetman.

4. Assume that a p^+-n diode is built with a quasi-neutral n region having a width l which is smaller than the hole diffusion length $\left(l < L_p\right)$. This is a so-called *narrow base diode*. Since for this case holes are injected into a short n region under forward bias, we cannot use the boundary condition $\delta p(x_n = \infty) = 0$, as in Eq. 4-35 in Streetman. Instead, our boundary condition becomes $\delta p(x_n = l) = 0$.

   (a) Solve the diffusion equation for this case to obtain: $\delta p(x_n) = \frac{\Delta p_n\left[e^{(l-x_n)/L_p} - e^{-(l-x_n)/L_p}\right]}{e^{l/L_p} - e^{-l/L_p}}$

   (b) If $l \ll L_p$, show that this equation becomes $\delta p(x_n) = \Delta p_n\left(1 - {x_n}/{l}\right)$. [i.e., hole profile is linear]

5. Reading Assignment: *Streetman*: Ch. 5 (sections 5.2 and 5.3)