Homework 4 – due November 30, 2018 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, $N_C = 2.8 \times 10^{19}$ cm$^{-3}$, and $N_V = 1.8 \times 10^{19}$ cm$^{-3}$. Assume the minority carrier lifetime is 8 $\mu$s (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?


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 ($l < L_p$). 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 $\delta p(x' = \infty) = 0$, as in Eq. 4-35 in Streetman. Instead, our boundary condition becomes $\delta p(x' = l) = 0$. (where $x'$ is the $x$-coordinate having its origin at the depletion edge $x_n$).

(a) Solve the continuity equation for this case to obtain: $\delta p(x') = \frac{\Delta p_n e^{(l-x')/L_p} - e^{-(l-x')/L_p}}{e^{l/L_p} - e^{-l/L_p}}$

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

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