Homework #5 - EE 482

due 11/13/02

1. Repeat Problem 4 of Homework #4 **including** recombination in the depletion region for $V_A = 0.6\text{V}$ and $V_A = 0.3\text{V}$. Assume $x'_d = x_d/10$.

2. An ideal silicon long-base diode has an abrupt junction with $N_d \gg N_a = 10^{17}\text{cm}^{-3}$ and $\tau_n = \tau_p = 1\mu\text{s}$. $T = 300\text{K}$.

   (a) Calculate the charge per unit area stored in the quasi-neutral p-region if the current density is 100 A/cm^2.

   (b) Calculate the charge stored in the depletion region both with 100 A/cm^2 flowing and in equilibrium ($I = V_A = 0$).

   (c) If beginning at time $t = 0$ a constant current density of 100 A/cm^2 is applied to the diode which was previously at equilibrium, estimate how long will it take for the diode to turn on if turn-on is defined as

      i. The diffusion charge (and thus associated steady-state current) reaches 63% of its final value; or

      ii. The diode voltage becomes within 0.1V of its final value?

   Roughly sketch the changes in depletion charge, diffusion charge and diode voltage using a common time axis.

   (d) What would be the storage time if later a reverse current of -100 A/cm^2 was applied? Again roughly sketch the changes in stored charge and diode voltage during turn-off.

   (e) Repeat (a) and (b) for an ideal short-base diode with the same doping and area in which the width of the p-region between the junction and the contact at which virtually all the recombination takes place is $0.5\mu\text{m}$. How would the switching times compare to that of the long-base diode (larger or smaller, explain)?

3. Aluminum (work function 4.1eV) is in contact with silicon (electron affinity 4.05eV) doped with 10^{17}cm^{-3} of phosphorus at room temperature.

   (a) Ignoring surface states, calculate the work function of the silicon ϕ_s, the metal-semiconductor barrier height ϕ_B and the built-in voltage ϕ_i and draw the theoretical equilibrium energy-band diagram. Is this contact blocking or ohmic? Explain.

   (b) Repeat (a) assuming that a very large number of surface states (both donors and acceptors) exist centered 0.35eV above the valence band. Assume that the interface layer is thin enough to allow easy tunnelling and can be ignored in calculating the barriers.

   (c) Sketch the band diagram for these two contacts assuming that there is +0.3V bias on the semiconductor relative to the metal.

4. When gold is deposited on p-type silicon a Schottky barrier diode with $\phi_B = 0.4\,\text{V}$ is formed.

   (a) If the doping in the silicon is 10^{17}cm^{-3}, what is the barrier presented to holes in the silicon?

   (b) If in reverse bias at 300K, this contact passes 10^{-8} A, how should the metal be biased for the contact to pass 0.1 mA with the semiconductor grounded (ignore changes in Schottky barrier lowering)?

   (c) Assuming the barrier height is unchanged as the doping is increased, calculate the doping concentration necessary to reduce the depletion region width to 4nm in equilibrium (narrow enough to allow tunnelling).