Homework #6 - EE 482 due 2/18/11

1. Consider an abrupt (step) silicon diode whose parameters are:

| $N_d = 10^{19} \mathrm{cm}^{-3}$ | $W_n = 200 \mu \mathrm{m}$ |
|----------------------------------|----------------------------|
| $N_a = 10^{17} \mathrm{cm}^{-3}$ | $W_p = 0.2 \mu \mathrm{m}$ |

- (a) Calculate the breakdown voltage at 300K. Consider all three possible breakdown mechanisms. Use breakdown fields from plot in notes (pg. 13).
- (b) Repeat if the acceptor doping is 10^{18} cm⁻³.
- (c) Repeat if the acceptor doping is 10^{19} cm⁻³.
- 2. An ideal silicon long-base diode has an abrupt junction with $N_d \gg N_a = 5 \times 10^{16} \text{cm}^{-3}$ and $\tau_n = \tau_p = 1 \mu \text{s}$. T = 300K.
 - (a) Calculate the excess minority charge per unit area stored in the quasi-neutral p-region if the current density is 50 A/cm^2 .
 - (b) Calculate the charge stored in the depletion region both with 50 A/cm² flowing and in equilibrium $(I = V_A = 0)$.
 - (c) If beginning at time t = 0 a constant current density of 50 A/cm² 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 -50 A/cm² 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 0.5μm. How would the switching times compare to that of the long-base diode (larger or smaller, explain)?
- 3. An abrupt GaAs pn photodiode is doped with $N_a = 10^{18}$ and $N_d = 10^{17} \text{cm}^{-3}$. The width of the undepleted quasi-neutral regions are $W_p = 0.4 \mu \text{m}$ and $W_n = 100 \mu \text{m}$. $\tau_p = \tau_n = 0.01 \mu \text{s}$. $A = 0.25 \text{ cm}^2$.
 - (a) If the diode is used as solar cell illuminated from the p-side, what would be the short-circuit photocurrent I_{ph} at 300K if the reflection coefficient is 0.1 and the incident light power density is 10mW/cm^2 at a wavelength of $0.65\mu\text{m}$. Assume that carriers generated in the narrow quasi-neutral p-region closer to the surface than the depletion region edge recombine at the surface, while carriers generated closer to the depletion region edge are captured by the depletion region.
 - (b) What would the output power be if the load is 100Ω and the series resistance is dominated by the lightly-doped n-region? Would a higher or lower load resistance be better?
 - (c) If the diode is used as an LED, what would be the approximate wavelength of the light generated by the LED?
 - (d) If all recombination within the diode results in photon generation, except recombination at the contact which is nonradiative, what would the total output light flux be if the applied voltage was 0.8V.
- 4. A MOS capacitor is made with a silicon substrate doped with $N_a = 5 \times 10^{17} \text{cm}^{-3}$ of boron, 2nm of silicon dioxide, and an n^+ polysilicon gate doped such that $E_f = E_c + 0.05 \text{ eV}$. Assume there are no significant oxide charges. Determine the charge on the gate, the voltage dropped across the oxide and the voltage dropped across the silicon with the following voltages applied between the gate and the substrate:

(a) $V_{gb} = -1 \text{ V}$; (b) $V_{gb} = 0.0 \text{ V}$; (c) $V_{gb} = 1 \text{ V}$

Sketch the charge densities, electric fields and energy band diagrams in each case. What are the capacitances at low and high frequencies in each of the above cases?