Exam #2 — EE 482

Winter 2011

This is a take-home exam. All work should be your own. Do not discuss the exam with anyone else. You are welcome to use notes and texts from this course or online or library, but do not use any analysis/modeling software (beyond that in standard calculator).

Show all work. Be sure to state all assumptions made and **check** them when possible.

Please use separate page for each problem, and put your name on each. All questions should be asked on GoPost. Exam is due back under door of my office (EEB 218) or sent as email attachment to dunham@ee.washinton.edu by 10am Friday 3/4/11. Please do not spend more than 5 hours actively working on the exam.

1. A metal-semiconductor contact is made between platinum ($\phi_m = 5.4$eV) and silicon doped with 10^{20}cm^{-3} of boron. There is a large density of surface states which pins the Fermi level near the surface of the semiconductor at 0.4 eV above the valence band.

   (a) Is the contact ohmic or rectifying? Explain.

   (b) Draw the band diagram for the contact in equilibrium. Calculate and label all barriers between the semiconductor and the metal.

2. A silicon *p*-*n* junction has a doping density given by $N_d - N_a = 10^{17}\left[1 - \exp\left(-x/50\text{nm}\right)\right]\text{cm}^{-3}$. The junction is biased such that $x_n = 100\,\text{nm}$ (distance between metallurgical junction and edge of depleted portion of n-region).

   (a) Sketch the charge density, electric field and voltage as functions of x.

   (b) Determine the junction capacitance, maximum electric field and the applied bias. ($T =$ 300K)

3. A *pn* silicon diode is operated at 300K. The diode has a neutral p region with $W_p = 20\mu$m, doped with $N_a = 10^{16}$cm^{-3} and a neutral n region with $W_n = 0.5\mu$m and $N_d = 10^{18}$cm^{-3}. Assume traps at midgap and $x' = x_d/10$. $\tau_p = 2\tau_n = 10^{-5}$s in p-region, and $\tau_p = 2\tau_n = 10^{-6}$s in n-region. The junction is operated in forward bias with $V_a = 0.3\,$V.

   (a) Sketch the minority carrier densities and the hole and electron currents as functions of distance, assuming there is significant recombination in the depletion region. Show at least relative magnitudes of the concentrations and currents.

   (b) Calculate the hole current at x_n and the electron current at the contact to the n-region.

   (c) Calculate the ratio of excess stored minority charge in the p region to that in the n region.

   (d) If photons with energy larger than the bandgap were absorbed within this diode, how would the magnitude of the current change (increase, decrease, no change)?

4. In a silicon MOS capacitor with an n-type substrate and an p^+ polysilicon gate ($E_f = E_v$), the substrate doping is uniform with $N_d = 2 \times 10^{18}$cm^{-3}. The oxide thickness is 3nm. There is a p^+ channel contact biased at -1V relative to the substrate. The voltage drop across the oxide is $V_{ox} = -0.6\,$V.

   (a) Determine the state of the channel region (accumulation, flat-band, depletion, strong inversion, etc.).

   (b) Determine the applied gate voltage.

   (c) Sketch the charge density, electric field and energy band diagram for the system.

   (d) What gate capacitance would be measured at (i) high and (ii) low frequencies under these bias conditions.