Homework #5 - EE 482

due 2/11/10

1. When aluminum is deposited on p-type silicon a Schottky barrier diode with $\phi_B = 0.38\,\text{V}$ 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^{-6} A, how should the metal be biased for the contact to pass 1 mA with the semiconductor grounded (ignore changes in Schottky barrier lowering)? Assume ideality factor of 1.05.
   (c) Assuming the barrier height is unchanged as the doping is increased, calculate the doping concentration necessary to reduce the depletion region width to 2.5nm in equilibrium (narrow enough to allow tunnelling).

2. Consider two Si *pn* junctions. They both have a *p*-type region with $N_a = 5 \times 10^{17}\text{cm}^{-3}$ and an *n*-type region with $N_d = 10^{19}\text{cm}^{-3}$. The "step" junction has these two regions in direct contact. The "pin" junction has an additional region of width 100 nm in between these two regions doped with $N_d = 10^{16}\text{cm}^{-3}$ (also called a $p\nu n$ junction).
   (a) Find and sketch the charge density, built-in field and potential for each of these junction at zero bias. Indicate the length of each depletion region.
   (b) Compare the maximum field in the *pin* diode to that in the step junction without the lightly doped *n* region, but with the same dopant concentrations in the other regions. Why are they different?
   (c) Discuss how the depletion capacitance for the *pin* structure varies with voltage, comparing it as in part (b) to the basic step junction with the same doping (but no lightly-doped *n*-region). Sketch capacitance C versus applied bias, using a single set of axes for both plots.

3. In an abrupt **silicon** p-n junction at 300K, $N_a = 5 \times 10^{18}\text{cm}^{-3}$, $N_d = 2 \times 10^{17}\text{cm}^{-3}$, $\tau_n = \tau_p = 0.02\mu\text{s}$ in heavily-doped *p*-region and $\tau_n = \tau_p = 0.5\mu\text{s}$ in *n*-region, $W_p = 100\,\text{nm}$ and $W_n = 700\mu\text{m}$.
   (a) If the p-region is biased at +0.7V relative to the n-region, sketch the current densities as functions of position and calculate (neglecting recombination in the depletion region):
      i. The hole current density in the n-region at the edge of the depletion region.
      ii. The hole current density in the p-region at the edge of the depletion region.
      iii. The electron current density at the contact to the p-region.
      iv. The electron current density at the contact to the n-region.
   (b) Repeat (a)-(d) for $V_A = 0.3\,\text{V}$ **including** recombination in the depletion region. Assume $x'_d = x_d/10$ and that region of peak recombination is on lightly-doped side of depletion region.