ECE609 Spring06

HOMEWORK 5

Two-Terminal Devices

1 P-N junctions (70pts)

1. Consider a p-n junction diode in GaAs doped with $1.6 * 10^{15} cm^{-3}$ acceptors on the p-type side and $1 * 10^{17} cm^{-3}$ donors on the n-type side at a temperature of $300K$. Assume that GaAs has an energy gap of $Eg = 1.4eV$, a relative dielectric constant of 13, and effective band-edge densities of states of $Nc = 5 * 10^{17} cm^{-3}$ and $Nv = 7 * 10^{18} cm^{-3}$. (a) Calculate the built-in voltage of the device (derive first an expression for Vi, in function of the inputs of the problem), (b) the depletion width, (c) the average electric field in the depletion region.

2. An abrupt silicon p-n junction consists of a p-type region containing $2 * 10^{16} cm^{-3}$ acceptors and an n-type region containing also $10^{16} cm^{-3}$ acceptors in addition to $10^{17} cm^{-3}$ donors. We consider that the intrinsic concentration is $n_i = 10^{10} cm^{-3}$ at $T = 300K$. Calculate the thermal equilibrium density of electrons and holes in the p-type region as well as both densities in the n-type region. Calculate the built-in potential of the p-n junction at 300K, Calculate the built-in potential of the p-n junction at 400 K ($n_i = 4.52 * 10^{12}$).

3. An abrupt silicon ($n_i = 10^{10} cm^{-3}$) p-n junction consists of a p-type region containing $10^{16} cm^{-3}$ acceptors and an n-type region containing $5 * 10^{16} cm^{-3}$ donors. Calculate the built-in potential of this p-n junction. Using the neutrality equation in the depletion region (along with the depletion approximation) derive an expression of l_n in function of W (total width). For an applied voltage equals 0, 0.5 and -2.5V, calculate the total width of the depletion region (in μm), calculate maximum electric field in the depletion region (in kV/cm), calculate the potential across the depletion region in the n-type semiconductor (in Volt). We will put these nine results into a summary table.

4. Consider an abrupt p-n diode with $N_a = 10^{18} cm^{-3}$ and $N_d = 10^{16} cm^{-3}$. Calculate the junction capacitance at zero bias if the diode area equals $10^{-4} cm^2$.

5. An abrupt silicon p-n junction ($N_a = 10^{16} cm^{-3}$ and $N_d = 4 * 10^{16} cm^{-3}$) is biased with $V_a = 0.6V$. Calculate the ideal diode current assuming that the n-type region is much smaller than the diffusion length with $w_n = 1mm$ (Note that the hole diffusion current occurs in the "short" n-type region and therefore depends on the quasi-neutral width w_n in that region), and assuming a "long" p-type region. Use $\mu_n = 1000 cm^2/V.s$ and $\mu_p = 300 cm^2/V.s$. The minority carrier lifetime is $10 \mu s$ and the diode area is $100 \mu m$ by $100 \mu m$. We will give the numerical values of all the physical quantities which are necessary to compute the current I (we will give I in mA and we use the fact that $n_i = 10^{10} cm^{-3}$.

2 Metal-Semiconductor Junctions (30pts)

1. Consider a chrome-silicon metal-semiconductor junction with $Nd = 10^{17} cm^{-3}$. Calculate the barrier height and the built-in potential (We give $4.5eV$ for the workfunction of the chrome, $4.05eV$ for the electron affinity in Silicon, the effective density of states $Nc = 2.82 * 10^{19} cm^{-3}$ and $N_v = 1.83 * 10^{19}$, $Eg = 1.12eV$). Repeat for a p-type semiconductor with the same doping density (you will sketch the band diagram for this configuration).

2. Consider a chrome-silicon metal-semiconductor junction with $N_d = 10^{17} cm^{-3}$. Calculate the depletion layer width, the electric field in the silicon at the metal-semiconductor interface, the potential across the semiconductor and the capacitance per unit area (in nF/cm^2) for an applied voltage of $-5V$.