ECE609 Spring07

HOMEWORK 4

Two-Terminal Devices

1 P-N junctions (40pts)

10 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.

10 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 ($n_i = 4.52 * 10^{12}$).

15 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. 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.

	$V_a = 0V$	$V_a = 0.5V$	$V_a = -2.5V$
$W \mu m$			
$E(kV/cm)$			
$V_n(V)$			

5 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 $10^{-4} cm^2$.

2 Metal-Semiconductor Junctions (30pts)

20 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).

10 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 $-5V$.

3 MOS capacitors (30pts)

Calculate the flatband voltage of a silicon nMOS capacitor with a substrate doping $N_a = 10^{16} cm^{-3}$ and an aluminum gate (with a "work function" $V_M = 4.1V$, and an electron affinity $\chi = 4.05V$), assuming there is no fixed charge in the oxide or at the oxide-silicon interface. Repeat for a silicon pMOS capacitor with a substrate doping $N_d = 10^{16} cm^{-3}$. Calculate the threshold voltage of both these silicon nMOS and pMOS capacitors considering a $t_{ox} = 30nm$ thick oxide.