ECE609 Spring06

# HOMEWORK 5 - SOLUTIONS

Two-Terminal Devices

## 1 P-N junctions (25pts)

1. - $$qVi = E_g + k_BT\ln\left(\frac{N_AN_D}{N_CN_V}\right) = 1.14eV$$
   - $W = 1\mu m$
   - $E = 1.14/10^{-4} = 11400V/cm$
2. - The thermal equilibrium densities are: -In the p-type region: $p = Na = 2 * 10^{16}cm^{-3}$ and $n = n_i^2/p = 10^{20}/2 * 10^{16} = 5x10^3cm^{-3}$.
     -In the n-type region: $n = Nd - Na = 9 * 10^{16}cm-^3$ and $p = n_i^2/n = 10^{20}/(1 * 10^{16}) = 1.11 * 10^3cm^{-3}$.
   - The built-in potential is obtained from:
     $$Vi = k_BT/q\ln\left(\frac{n_np_p}{n_i^2}\right) = 0.79V$$
   - $Vi = 0.63V$
3. $Vi = 0.76V$
   $$W = 2(\epsilon(N_a + N_d)(Vi - Va)/(qN_aN_d))^{1/2}$$
   since $W = l_n + l_p$,and $l_nN_d = l_pN_a$ it comes: $l_n = WN_a/(N_a + N_d)$.

|  | $V_a = 0V$ | $V_a = 0.5V$ | $V_a = -2.5V$ |
|---|---|---|---|
| $x_d$ | $0.315\mu m$ | $0.143\mu m$ | $0.703\mu m$ |
| $E$ | $40kV/cm$ | $18kV/cm$ | $89kV/cm$ |
| $V_n$ | $0.105V$ | $0.0216V$ | $0.522V$ |

4. $Vi = 0.83V$ so at zero bias $W = 0.33\mu m$, and then $C = 3.17pF$.
5. $$I = qA\left(\frac{D_nn_{p0}}{L_n} + \frac{D_pp_{n0}}{w_n}\right) * (\exp(q\beta V_a) - 1)$$
   - $Dn = 1000 * 0.0258 = 25.8cm^2/Vs$
   - $Dp = 300 * 0.0258 = 7.75cm^2/Vs$
   - $n^{p0} = n_i^2/Na = 10^{20}/10^{16} = 10^4cm^{-3}$
   - $p_{n0} = n_i^2/Nd = 10^{20}/4x1016 = 2.5 * 10^3cm^{-3}$
   - $L_n = 161\mu m$
   - $I = 40.7mA$

## 2 Metal-Semiconductor Junctions (15pts)

1. $V_B = V_M - \Xi = 0.45V$, we know that the built-in potential is given by:

   $$Vi = V_B - (k_B T/q)\ln(Nc/N_d) = 0.30V.$$

   For the p-type structure:

   $$V_B = \xi + Eg/q - V_M = 0.67V$$

   and

   $$Vi = V_B - (k_B T/q)\ln(Nv/N_a) = 0.53V.$$

2. The depletion layer width equals: $W = 0.26\mu m$, $E = 4.0 * 10^5 V/cm$, $V = 5.3V$, $C = 40nF/cm^2$.