EECS277A Fall 2010 **Midterm Exam #1** Name: Solutions

10/13/2010 11:00 am to 12:20 pm ID no.:

Professor Peter Burke

PROBLEM ONE: (40 points)

NO PARTIAL CREDIT

A p-n junction is biased at 0.1 V forward bias. The p-side is doped at 1018 cm-3. The n-side is doped at 1014 cm-3. Find the following:

A) Electron density on the n-side far from the junction.

$10^{14}\ cm^{-3}$

B) Electron density on the n-side at the edge of the depletion region.

Almost unchanged $\approx 10^{14}\ cm^{-3}$

C) Electron density on the p-side far from the junction.

$n = \frac{n_i^2}{p} = \frac{10^{20}}{10^{18}} cm^{-3} = 10^{2}\ cm^{-3}$

D) Electron density on the p-side at the edge of the depletion region.

$e^{qV_a/kT} \times$ part C) $= e^{0.1/0.026} \times 10^{2}\ cm^{-3} \approx 5\ 10^{3}\ cm^{-3}$

E) Hole density on the n-side far from the junction.

$p = \frac{n_i^2}{n} = \frac{10^{20}}{10^{14}} cm^{-3} = 10^{6}\ cm^{-3}$

F) Hole density on the n-side at the edge of the depletion region.

$e^{qV_a/kT} \times$ part E) $\approx 5\ 10^{7}\ cm^{-3}$

G) Hole density on the p-side far from the junction.

$10^{18}\ cm^{-3}$

H) Hole density on the p-side at the edge of the depletion region.

Almost unchanged $10^{18}\ cm^{-3}$

PROBLEM TWO(60 points):

(NO PARTIAL CREDIT)

Consider an MOS capacitors. The metal has a large work function, of 5 eV. (E.G. nickel). The oxide is SiO_2 with a thickness of 20 nm.

A) The Si is n-doped so that E_c-E_f = 0.25 E_g. Find the voltage needed to be applied to the gate to achieve flat band codition. Assume Q_{ox} = 0.

$$V_{FB} = \phi_m - \phi_s = 5eV - [4.05eV + \frac{1}{4} 1.12eV] = 0.67V$$

B) Calculate the threshold voltage.

$$V_t = V_{FB} - 2\psi_B - \frac{\sqrt{2\epsilon_{Si} q N_a 2\psi_B}}{C_{ox}}$$

$$= 0.67 - 0.56 - 0.054V = +0.056V$$

C) Let Q_{ox} = 10^{10} cm^{-2}. Find the shift in the threshold voltage.

$$\Delta V_g = \frac{Q_{ox}}{C_{ox}} = 10mV$$

$Q_{ox} = 1.6\times10^{-9}$ C/cm² (q missing)

D) The Si is p-doped so that E_f-E_v = 0.25 E_g. Find the voltage needed to be applied to the gate to achieve flat band codition. Assume Q_{ox} = 0.

$$V_{FB} = \phi_m - \phi_s = 5V - [4.05 + \frac{3}{4} 1.12] = 0.11V$$

E) Calculate the threshold voltage.

$$V_t = V_{FB} + 2\psi_B + \frac{\sqrt{2\epsilon_{Si} q N_a 2\psi_B}}{C_{ox}}$$

$$= 0.11 + 0.56 + 0.054V = 0.72V$$

F) Let Q_{ox} = 10^{10} cm^{-2}. Find the shift in the threshold voltage.

As C 10 mV