Final Exam assignment

EEE 313/EEE 410/ETE 411/ ETE 443: Semiconductor Devices and Technology

Section 2

Fall 2020 semester

Date uploaded: 22/01/2021.

Date Due: 23/01/2021 (By 3:00 pm).

Full Marks: 45

Notice to all students: Please submit with your full name, student ID, Course Name, Course code and Section in the Top sheet. Do not plagiarize. Consult textbook, slides and my notes to solve the problems in the Final examination. Avoid discussion between each other for solving the problems. A scanned pdf version of submission is required. Check for viruses while you save the file and return the answer report in on-line google classroom for EEE 313-EEE 410-ETE 411-ETE 443 section 2.

1 (a) For fixed doping density, why at reduced temperature of operation, the V_{bi} of a semiconductor diode increases? How you will choose the band gap (higher or lower) to decrease the V_{bi} of a p-n junction diode that is operated at low substrate temperature with fixed doping density? [5]

(b) A silicon p-n junction at T = 300 K has the following parameters $N_A = 5.7 \times 10^{15}$ / cm^3 and $N_D = 6.4 \times 10^{16}$ / cm^3, $D_n = 23$ cm^2/s , $D_p = 14.5$ cm^2/s, $\tau_{no} = 7.45 \times 10^{-7}$ s and $\tau_{po} = 3.35 \times 10^{-7}$ s. The cross sectional area is $A = 2.55 \times 10^{-3}$ cm^2 and the forward bias voltage is $V_a = 0.63$ V. Calculate the total current I_{diode} in ampere for this p-n junction diode. Value of n_i at T = 300 K is 1.5×10^{10} / cm^3. [10]

For the equations, look for relevant equations from the textbook.

2. For a p-substrate silicon MOS capacitor at T = 300 K, the substrate doping is $N_A = 3.5 \times 10^{16}$ / cm^3. Value of n_i at T = 300 K is 1.5×10^{10} / cm^3.

(i) What is bulk potential ϕ_B ?

(ii) When the surface is inverted, what is the total surface band bending ϕ_s ?

(iii) For $\varphi_m = 4.25$ eV and $\chi = 4.01$ eV, what is the flat band voltage V_{FB}?

$$\varphi_B = \frac{kT}{q} \ln\left(\frac{N_A}{n_i}\right) \qquad V_{FB} = \varphi_m - \left(\chi + \frac{E_G}{2} + \phi_B\right)$$

(iv) Find the maximum depletion width x_{DT} (μm) when the surface is inverted.

(v) Find the threshold voltage of this device V_T in V if the oxide thickness $t_{ox} = 8.6$ nm. Consider $N_A = 3.5 \times 10^{16}$ / cm^3. Use the V_{FB} as calculated in 2(iii). [5 ×3 =15]

3 (a) For limitations in supply voltage V_{gs} and V_{ds}, comment whether you will choose high V_T or low V_T to increase the saturation drain current of an n-channel MOSFET. How you will choose doping density (higher or lower) and oxide thickness (higher or lower) to achieve this V_T. How the channel mobility will vary (higher and lower) at your selected doping density (higher or lower)? [5]

(b) An ideal n-channel silicon MOSFET has the following parameters V_T = 0.32 V, μ_n = 780 cm^2/V-s, t_{ox} = 8.5 nm, W = 11.8 μm and L = 1.36 μm. Find the drain current I_{ds} for this MOSFET when

(i) V_{gs} = 0.22 V and V_{ds} = 0.16 V,

(ii) V_{gs} = 1.78 V and V_{ds} = 0.72 V,

(iii) V_{gs} = 2.24 V and V_{ds} = 2.55 V. [3+4+3 =10]

<u>Do not use the value of body effect parameter m but the standard drain current equations.</u>

Useful equation:

$$I_{ds} = \mu_n C_{ox} \frac{W}{L} \left\{ \left(V_{gs} - V_T\right) V_{ds} - \frac{{V_{ds}}^2}{2} \right\} \qquad I_{ds} = \mu_n C_{ox} \frac{W}{L} \frac{\left(V_{gs} - V_T\right)^2}{2}$$