BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE PILANI, RAJASTHAN
I SEMESTER (2023-24), Comprehensive Examination
ELECTRONIC DEVICES (EEE F214/INSTR F214/ ECE F214)

Date: 13-12-2023, Wednesday
Time: 3 hr **(CLOSED BOOK)** **MM: 120**

Note: Attempt all parts of particular question together. Take constants mentioned below:

List of Constants; at 300K (*symbols have their usual meaning*)**:**
$kT/q = 0.0259$ V E_g(Si) = 1.12 eV ε(Si) = 11.8 ε_o $\varepsilon(SiO_2) = 3.9\ \varepsilon_o$ n_i (Si) = 1.5 x 10^{10} cm^{-3}
$\varepsilon_o = 8.85 \times 10^{-14}$ F/cm

1. The total current in a semiconductor is constant and is composed of electron drift current and hole diffusion current. The electron concentration is constant and is equal to 10^{16} cm^{-3}. The hole concentration is given by

$$p(x) = 10^{15} e^{(-x/L)}\ cm^{-3}$$

where L = 12 μm and $x \geq 0$. The hole diffusion coefficient is D_p = 12 cm^2/s and the electron mobility is μ_n = 1000 cm^2/V-s. The total current density is J = 4.8 A/cm^2. Calculate:

(i) the hole diffusion current density versus *x*,

(ii) the electron drift current density versus *x*,

(iii) plot the electron drift current density and hole diffusion current density on a single (J versus *x*) graph.

(iv) the applied electric field versus *x* and its value at $x=0$

(v) plot the graph of electric field versus *x*.

[20 marks]

2. For a n-channel GaAs MESFET, the Schottky barrier height is 0.85 V and semiconductor donor doping density is 10^{16} cm^{-3}. Given that electron mobility is 6000 cm^2/V-s, channel width (Z) and length (L) are 25 μm and 1.0 μm respectively, channel depth (*a*) is 0.5 μm. Assume that effective density of states in the conduction band is 5.0 x 10^{17} cm^{-3} and GaAs permittivity is 13.2 ε_o.

Answer the following:

(i) Calculate the potential barrier from GaAs to metal.

(ii) Is it a depletion mode or enhancement mode device? Justify your answer with proper data.

(iii) Calculate the threshold voltage (V_T)

(iv) V_D (sat) for gate bias of V_{GS} = -1.5 V.

(v) If channel depth reduced to 0.25 μm (from 0.5 μm), will it be a normally ON or normally OFF device? Justify your answer.

[20 marks]

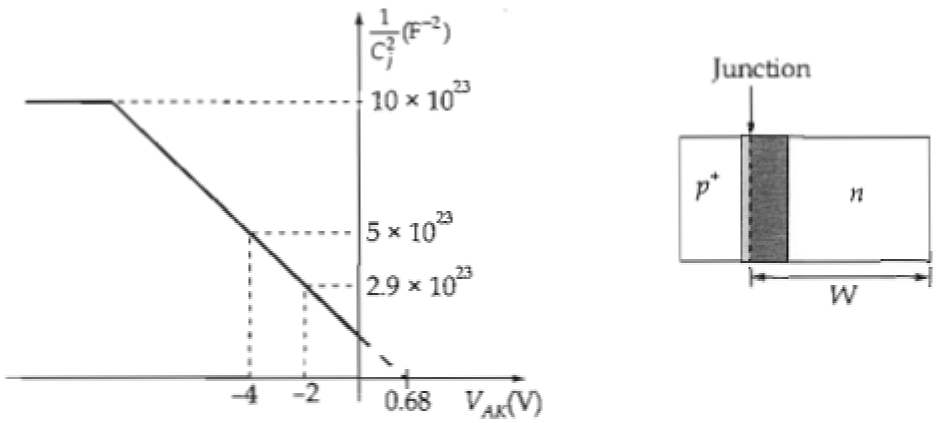
3. Consider a reverse biased p^+-n junction diode. The diode has been biased with a biasing voltage V_{AK}. The graph of $1/C_j^2$ versus V_{AK} is shown in figure below, where C_j is the junction capacitance. The diode has a junction area of 10^{-3} cm^2. Assume that n_i = 1.5 x 10^{10} cm^{-3} and $\varepsilon(Si) = 11.8\ \varepsilon_o$

(i) Determine the value of built-in potential

(ii) Calculate the doping concentrations on both the sides of the junction.

(iii) Calculate the value of width W (in μm) as shown in figure.

(iv) An inductor of 2.2 mH is placed in parallel with the diode. Calculate in resonant frequency (in Hz) of the circuit for reverse bias voltage of -4 V.



[20 marks]

4. For a pnp transistor, emitter, base, and collector doping are 10^{20} cm^{-3}, 10^{18} cm^{-3}, 10^{17} cm^{-3}, respectively. The base width is 0.5 μm.

(i) Calculate the peak electric field at CB junction at equilibrium.

(ii) Calculate CB junction capacitance per unit area in active mode of operation at V_{CB} = 50V.

(iii) Ignoring EB junction depletion width, what is the neutral base width at V_{CB} = 50V.

(iv) How the output characteristics will be impacted V_{CB} = 50V? What is the name of this effect?

[20 marks]

5. An ideal MOS-Capacitor operated at T = 300 K is having 0.1 μm thick SiO_2 layer and acceptor doping of 2 x 10^{15} cm^{-3}. Assume that the area of cross section of gate is 10^{-3} cm^2. Take n_i (Si) = 10^{10} cm^{-3}

(i) Sketch the general shape of the high frequency (HF) C-V characteristic to be extracted from the given device.

(ii) Determine the C_{MAX} (the maximum HF capacitance) in pF.

(iii) Determine the C_{MIN} (the minimum HF capacitance) in pF.

(iv) If $V_G = V_T$, determine Φs (surface potential) (Give both a symbolic and a numerical answer)

(v) Compute V_T.

(vi) Suppose the gate bias is such that $\Phi s = 3\Phi_F/2$. Draw the MOS-Capacitor energy band diagram corresponding to the specified gate bias. (You need to include the diagrams for all three materials of the MOS-Capacitor, show the proper band bending in both the oxide and semiconductor, and properly position the Fermi level in the metal and semiconductor)

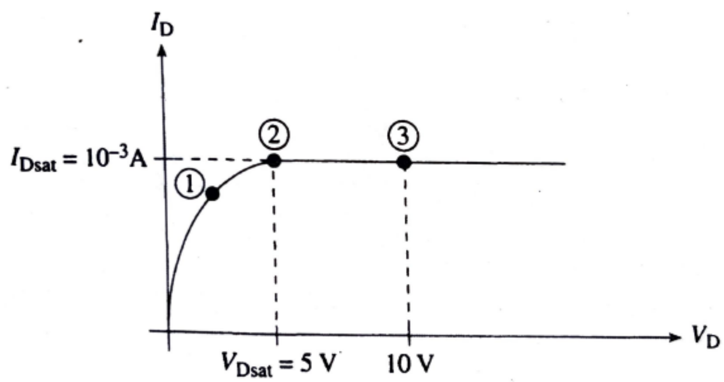
[20 marks]

6. (a) In a MOSFET the voltage applied at the gate is given by:

$$V_G = V_{FB} - \frac{Q_s}{C_i} + \phi_s$$

Where V_{FB} is the flat band voltage, Φs is the surface potential at SiO_2-Si interface and Q_s include the inversion charge and depletion charge. Using this, derive the expression for an ideal drain current for MOSFET showing the dependency in terms of mobility, oxide capacitance and channel length.

Figure below shows the I-V characteristic derived from an ideal MOSFET. Answer the questions based on the information conveyed in the figure.



(i) Given a turn-on voltage of 1 V, what is the gate voltage one must apply to the MOSFET gate to obtain the pictured characteristics?

(ii) Suppose the gate voltage is readjusted so that V_G-V_T = 3 V. Find the new condition, determine I_D if V_D = 4V.

(iii) Determine the channel conductance if the operating point of the MOSFET is point (3) on the pictured characteristic.

(iv) Determine the transconductance if the operating point of the MOSFET is point (3) on the pictured characteristic.

(b) Why photodiodes are used in reverse biased? Draw the I-V characteristic of LEDs of red (R), yellow (Y) and Green (G) colours in the same plot.

[15 + 5 = 20 marks]

**********BEST OF LUCK**********

Make-up question

5. A metal semiconductor junction is formed between platinum (Pt) with a work function of 5.3 eV and a silicon (Si) having donor doping density of 10^{16} cm^{-3} and electron affinity of 4.05 eV. The area of the diode is 10^{-5} cm^2. Assume effective density of states in the conduction band is 2.8 x 10^{19} cm^{-3}

(vi) Sketch the charge density, electric field and potential for the device. For each diagram draw two curves one for equilibrium case and one for 0.4 V applied forward bias. (No numbers or calculations are required)

(vii) Calculate the potential barrier from Pt to Si and Si to Pt.

(viii) Calculate the small signal capacitance C (in pF) at zero bias. (Take T = 300 K).

(ix) Calculate the reverse bias at which the capacitance is reduced by 25% from its zero bias value.

[6 + 6 + 4 + 4 = 20 marks]