UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME : FUNDAMENTAL OF SEMICONDUCTOR

COURSE CODE : BEJ 33103

PROGRAMME CODE : BEJ

EXAMINATION DATE : JULY/ AUGUST 2023

DURATION : 3 HOURS

INSTRUCTION : 1. ANSWER ALL QUESTIONS

2.THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.**

3.STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

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Q1 (a) Sketch the lattice structure corresponding to simple cubic (SC), Body-Centered Cubic (BCC) and Face-Centered Cubic (FCC).

(4 marks)

(b) Discuss the variation of the Fermi level with doping concentration and temperature.

(6 marks)

(c) A Gallium Arsenide (GaAs) sample is doped with 8.65 x 10^{15} indium per cm^3.

(i) Calculate the carrier concentrations and the Fermi level position with respect to the intrinsic Fermi level at T = 300 K.

(4 marks)

(ii) Calculate the carrier concentrations and the Fermi level position with respect to the intrinsic Fermi level at T = 200 K and 550 K.

(8 marks)

(iii) From the answer in part **Q1(c)(i) – (ii)**, point out a simple conclusion on the energy band diagram and carrier concentration.

(3 marks)

Q2 (a) Sketch the plot of average drift velocity as a function of applied electric field for electrons and holes in silicon.

(2 marks)

(b) Based on the plot in part **Q2(a),** determine the step to obtain mobility.

(2 marks)

(c) Explain the change in carrier mobility as a function of ionized impurity concentration. Show the related graph in your explanation.

(4 marks)

(d) Describe the Hall effect measurement.

(5 marks)

(e) A GaAs semiconductor at T = 300 K is doped with multiple implants, which are 5.23 x 10^{14} antimony atoms/cm^3, 8.67 x 10^{16} gallium atoms/cm^3, 3.34 x 10^{14} phosphorus atoms/cm^3 and 4.56 x 10^{16} boron atoms/cm^3. Find the:

(i) carrier mobilities

(6 marks)

(ii) conductivity and resistivity of the semiconductor.

(6 marks)

Q3 (a) A P-N junction has an asymmetrical depletion width and the electric field, E created is shown in **Figure Q3(a)**.

(i) Identify the region with higher doping. State the reason.

(3 marks)

(ii) Compare the electric field parameter in **Figure Q3(a)** with electric field parameter in standard P-N junction

(3 marks)

(iii) Sketch **TWO (2)** other parameters for P-N junction in **Figure Q3(a)**

(3 marks)

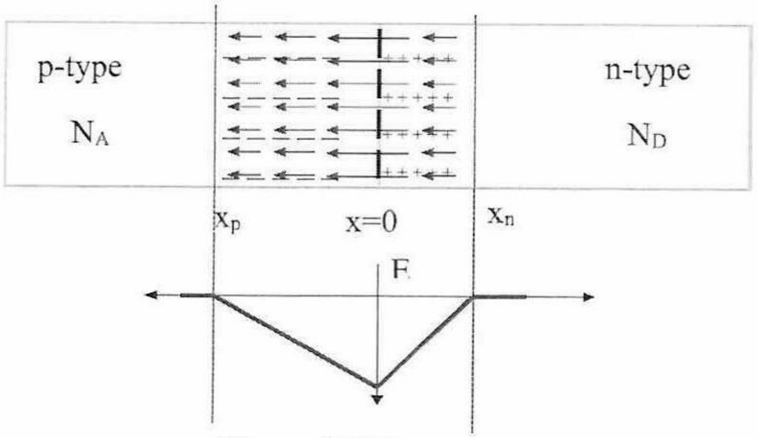

Figure Q3(a)

(b) For a silicon one-sided abrupt P^+N junction with $N_A = 4.34 \times 10^{18}$ cm^{-3} and $N_D = 3.27 \times 10^{13}$ cm^{-3} at zero bias and T = 250 K, calculate:

(i) built-in potential

(4 marks)

(ii) depletion layer width

(3 marks)

(iii) maximum electric field

(3 marks)

(c) Sketch the energy band diagram and circuit of a P-N junction for the following condition:

(i) Thermal equilibrium condition

(2 marks)

(ii) Forward bias condition

(2 marks)

(iii) Reverse bias condition

(2 marks)

Q4 (a) Sketch the energy-band diagram through a MOS diode with a p-type substrate and polysilicon gate under zero bias.

(6 marks)

(b) Compare the basic operation of the MOSFET enhancement mode and depletion mode for n-channel devices.

(7 marks)

(c) At room temperature, consider a long-channel Silicon MOSFET with the following parameters,

$L = 2.3\ \mu\text{m}$ $\quad Z = 8.6\ \mu\text{m}$ $\quad \varepsilon_o = 8.85418 \times 10^{-14}$ F/cm $\quad N_A = 6.45 \times 10^{14}\ \text{cm}^{-3}$
$\mu_n = 670\ \text{cm}^2/\text{V-s}$ $\quad C_o = 3.54 \times 10^{-7}\ \text{F/cm}^2$ $\quad V_T = 0.6$ V

Calculate the drain saturation voltage, V_{Dsat} and drain saturation current, I_{Dsat} for $V_G = 5.34$ V.

(6 marks)

(d) Discuss **TWO (2)** main approaches to overcome the problems arising from the scaling of MOSFET.

(6 marks)

-END OF QUESTIONS –

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Formulae

$$n = N_C \exp[-(E_C - E_F)/kT]$$

$$V_{Dsat} \cong V_G - 2\Psi_B + K^2\left(1 - \sqrt{1 + {2V_G}/{K^2}} \right)$$

$$p = N_V \exp[-(E_F - E_V)/kT]$$

$$K \equiv \frac{\sqrt{\varepsilon_s q N_A}}{C_o}$$

$$n = \frac{N_\mathrm{D} - N_\mathrm{A}}{2} + \left[\left(\frac{N_\mathrm{D} - N_\mathrm{A}}{2} \right)^2 + n_\mathrm{i}^2 \right]^{1/2}$$

$$I_{Dsat} \cong \left(\frac{Z\mu_n C_o}{2L} \right)(V_G - V_T)^2$$

$$p_n = n_i^{\,2} / n_n$$

$$E_\mathrm{F} = E_\mathrm{i} + kT \ln\left(\frac{n}{n_\mathrm{i}} \right)$$

$$qV_\mathrm{bi} = kT \ln\left(\frac{N_\mathrm{A} N_\mathrm{D}}{n_\mathrm{i}^2} \right)$$

$$E_\mathrm{F} = E_\mathrm{i} - kT \ln\left(\frac{p}{n_\mathrm{i}} \right)$$

$$x_\mathrm{n} + x_\mathrm{p} = W \equiv \sqrt{\frac{2\varepsilon_\mathrm{S}}{q}\left(\frac{1}{N_\mathrm{A}} + \frac{1}{N_\mathrm{D}} \right) V_\mathrm{bi}}$$

$$\sigma = q(\mu_\mathrm{n} n + \mu_\mathrm{p} p)$$

$$ni^2 = N_C N_V \left(\frac{T}{300}\right)^3 exp\left(\frac{-E_g}{kT\left(\frac{T}{300}\right)} \right)$$¶

$$\frac{1}{\mu} = \frac{1}{\mu_L} + \frac{1}{\mu_I}$$

$$E_{MAX} = \frac{qNW}{\varepsilon_S}$$

$$J_N = qD_n \frac{dn}{dx}$$

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Physical constant

Boltzmann constant, $k = 8.6173324 \times 10^{-5}$ eV/K or 1.38066×10^{-23} J/K

Thermal voltage at 300 K, $kT/q = 0.0259$ V

Permittivity in vacuum, $\varepsilon_o = 8.85418 \times 10^{-14}$ F/cm

Elementary charge, $q = 1.60218 \times 10^{-19}$ C

Properties of Si and GaAs at 300 K

Properties	**Si**	**GaAs**
Effective density of states in conduction band, N_C (cm^{-3})	2.86×10^{19}	4.7×10^{17}
Effective density of states in valence band, N_V (cm^{-3})	2.66×10^{19}	7.0×10^{18}
Dielectric constant	11.9	12.4
n_i (cm^{-3})	9.65×10^{9}	2.25×10^{6}
Energy gap (eV)	1.12	1.42
Mobility (cm^2/V-s)		
μ_n (electrons)	1450	9200
μ_p (holes)	505	320

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