UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2018/2019

COURSE NAME	:	SEMICONDUCTOR ELECTRONIC AND DEVICES
COURSE CODE	:	BED 20103
PROGRAMME	:	BEJ
EXAMINATION DATE	:	DECEMBER 2018 / JANUARY 2019
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

Q1 (a) With the aid of energy band diagram, explain the MOS diode operation with p-type substrate in accumulation, depletion & inversion modes.

(6 marks)

(b) For $V_{GS} > V_T$, sketch the channel I_D versus V_{DS} curve as V_{DS} is increased in the following condition:

(i) A small V_{DS} value.

(2 marks)

(ii) Value of V_{DS} equal to $V_{DS\,(SAT)}$

(2 marks)

(iii) Value of V_{DS} greater than $V_{DS\,(SAT)}$

(2 marks)

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

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

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

(5 marks)

(d) Analyse **TWO (2)** solutions to overcome the problems arising from the scaling of MOSFET.

(8 marks)

Q2 (a) Define the built-in potential voltage and describe how it maintains thermal equilibrium in PN junction.

(4 marks)

(b) For a PN junction structure,

(i) Analyse the existence of an electric field formed in the space charge region.

(5 marks)

(ii) Analyse the size of space charge region width in one-sided PN junction.

(5 marks)

(iii) Analyse the existence of junction capacitance in PN junction.

(5 marks)

(c) For a silicon one-sided abrupt P^+N junction with $N_A = 4.34 \times 10^{14}\ cm^{-3}$ and $N_D = 3.27 \times 10^{18}\ cm^{-3}$ at zero bias and T = 300 K, calculate:

(i) built-in potential

(2 marks)

(ii) depletion layer width

(2 marks)

(iii) maximum electric field

(2 marks)

Q3 (a) List two elemental semiconductor materials and two compound semiconductor materials.

(4 marks)

(b) Illustrate the schematic energy band diagrams correspond to conductor, semiconductor and insulator.

(3 marks)

(c) Analyze the electrical conductivities of the materials based on the illustrated diagram in **Q3(b)**.

(6 marks)

(d) A Gallium Arsenide (GaAs) sample is doped with 8.65×10^{15} boron 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) Analyze the carrier concentrations and the Fermi level position with respect to the intrinsic Fermi level at T = 184 K and 575 K

(8 marks)

Q4 (a) Sketch the plot of average drift velocity as a function of applied electric field for electron and hole in silicon.

(5 marks)

(b) From the plot in **Q4(a)**, determine the step to obtain mobility.

(4 marks)

(c) Another technique for determining the conductivity type of a semiconductor is called the hot probe method. It consists of two probes and an ammeter that indicates the direction of the current. One probe is heated and the other is at room temperature. No voltage is applied, but a current will exist when the probes touch the semiconductor. With the aid of a diagram, analyze the operation of the hot probe technique and relate it with carrier transport phenomena.

(6 marks)

(d) With the aid of a diagram, describe the operation of Hall Effect measurement.

(6 marks)

(e) Analyze the step to obtain the semiconductor parameters from the experiment in **Q4(d)**

(4 marks)

-END OF QUESTIONS-

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Formulae

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

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

$$n = \frac{N_D - N_A}{2} + \left[\left(\frac{N_D - N_A}{2}\right)^2 + n_i^2\right]^{1/2}$$

$$p_n = n_i^2 / n_n$$

$$qV_{bi} = kT \ln\left(\frac{N_A N_D}{n_i^2}\right)$$

$$x_n + x_p = W \equiv \sqrt{\frac{2\varepsilon_S}{q}\left(\frac{1}{N_A} + \frac{1}{N_D}\right)V_{bi}}$$

$$\sigma = q(\mu_n n + \mu_p p)$$

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

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

$$\frac{D}{\mu} = \frac{kT}{q}$$

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

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

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

$$I_D \cong \frac{Z}{L}\mu_n C_o (V_G - V_T)V_D$$ For $V_D << (V_G - V_T)$

$$V_T = \frac{\sqrt{2\varepsilon_s q N_A (2\psi_B)}}{C_o} + 2\psi_B$$

$$g_D \equiv \frac{\partial I_D}{\partial V_D}\Big|_{V_G = cons\tan t} \cong \frac{Z}{L}\mu_n C_o (V_G - V_T)$$

$$g_m \equiv \frac{\partial I_D}{\partial V_G}\Big|_{V_D = cons\tan t} \cong \frac{Z}{L}\mu_n C_o V_D$$

$$J_N = q\mu_n E$$

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

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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, $kT/q = 0.025852$ 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