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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

TERBUKA

COURSE NAME	:	SEMICONDUCTOR ELECTRONIC AND DEVICES
COURSE CODE	:	BED 20103
PROGRAMME	:	BEJ
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

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Q1 (a) Sketch structure of an n-channel enhancement mode MOSFET with the correct voltage connections. Label source, drain, gate channel, V_{GS}, V_{DS} and the drain current I_D with the correct polarity and directions.

(5 marks)

(b) For $V_{GS} > V_T$, with the aid of diagrams, describe what happen to the channel I_D versus V_{DS} curve as V_{DS} is increased from 0 to greater than $V_{DS(SAT)}$.

(6 marks)

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

$L = 2$ µm $Z = 8$ µm $\varepsilon_o = 8.85418 \times 10^{-14}$ F/cm $N_A = 2 \times 10^{14}$ cm^{-3}

$\mu_n = 600$ cm^2/V-s $C_o = 3.54 \times 10^{-7}$ F/cm^2 $V_T = 0.6$ V

Analyze drain saturation voltage, V_{Dsat} and drain saturation current, I_{Dsat} for $V_G = 5$ V

(6 marks)

(d) Analyze **FOUR (4)** different approaches in order to overcome the problems arising from future scaling of MOSFET.

(8 marks)

Q2 (a) Define asymmetrical abrupt junction.

(2 marks)

(b) Sketch a fully labelled diagram of each of the following distributions for an asymmetrical abrupt p^+n junction:

(i) carrier density (majority and minority)

(1 mark)

(ii) electrostatic potential

(2 marks)

(iii) charge density

(2 marks)

(iv) electric field

(2 marks)

(c) Describe **TWO (2)** physical mechanisms that give rise to the reverse bias breakdown in PN junction.

(4 marks)

(d) For a silicon one-sided abrupt p^+n junction with $N_A = 4 \times 10^{17}$ cm^{-3} and $N_D=3x10^{14}cm^{-3}$ at zero bias, analyze:

(i) built-in potential at 170K

(4 marks)

(ii) depletion layer width (T = 170 K)

(4 marks)

(iii) maximum electric field (T = 170 K)

(4 marks)

Q3 (a) Sketch the energy band diagram for an intrinsic, n-type and p-type semiconductor showing clearly the followings:

(i) Density of state function and Fermi-Dirac function

(ii) Fermi level

(iii) Areas representing electron and hole concentration

(9 marks)

(b) With the aid of suitable figure, explain clearly how Germanium substrate can be tuned to a p-type semiconductor and name the element used in the process.

(5 marks)

(c) A Silicon (Si) sample is doped with 10^{14} boron per cm^3:

(i) Calculate the carrier concentrations in the Si sample at 300K

(2 marks)

(ii) Analyze the carrier concentrations at 550K

(4 marks)

(iii) For each of the conditions above, calculate and sketch the band diagram

(2 marks)

(iv) From the answer in **Q3(c)(i) – (iii)**, point out a simple conclusion based on energy band diagram and carrier concentration

(3 marks)

Q4 (a) Explain clearly how carrier drift, carrier diffusion and carrier concentration can contribute towards total current density.

(5 marks)

(b) With the aid of a diagram, discuss the effect of lattice scattering and impurity scattering, towards mobility as a function of temperature.

(8 marks)

(c) Consider an n-type semiconductor at temperature, T = 300 K, the electron concentration varies linearly from 2 x 10^{18} to 6 x 10^{17}/cm^3 over a distance of 0.2 cm. Given the electron diffusion coefficient is D_n = 25 cm^2/s, calculate the diffusion current density, $J_{n,\ diff}$.

(3 marks)

(d) Two scattering mechanisms exist in semiconductors which are lattice scattering and impurity scattering. If only the first mechanism is present, the mobility will be 200cm^2/V-s. If only the second mechanism is present, the mobility will be 550cm^2/V-s. Calculate the mobility when both scattering mechanisms exist at the same time.

(3 marks)

(e) A p-type semiconductor has a hole concentration of 5 x 10^{16} cm^{-3}. If the hole conductivity is 32 Ω^{-1} cm^{-1}. Analyze the hole drift mobility.

(3 marks)

(f) If the electrons drift mobility of a semiconductor is 2500 $cm^2V^{-1}s^{-1}$ at room temperature (300 K). Analyze the expected electron diffusion coefficient.

(3 marks)

- END OF QUESTIONS -

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Formulae

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

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

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

$$p_n = n_i^2 / n_n$$

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

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

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

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

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

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

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

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

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

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

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

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

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

$$J_N = q\mu_n E$$

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

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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