UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2015/2016

COURSE NAME	:	SEMICONDUCTOR ELECTRONIC AND DEVICES
COURSE CODE	:	BED 20103
PROGRAMME	:	BACHELOR OF ELECTRONIC ENGINEERING WITH HONOURS
EXAMINATION DATE	:	DECEMBER 2015 / JANUARY 2016
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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

Q1 (a) Sketch the energy band diagram for:

(i) Intrinsic semiconductor

(2 marks)

(ii) N-type semiconductor

(4 marks)

(iii) P-type semiconductor

(4 marks)

Include in each of the diagram correctly the density of state function, Fermi-Dirac function, Fermi-level and areas representing electron and hole concentration

(b) Silicon is a group IV element and the electrical conductivity can be tuned whether n-type or p-type.

(i) Name the process to tune the semiconductor electrical conductivity.

(1 mark)

(ii) Draw clearly (100), (110) and (111) plane. Name the usual plane uses for wafer fabrication.

(4 marks)

(c) A silicon device with n-type material is to be operated at T = 550 K. At this temperature, the intrinsic carrier concentration must contribute no more than 5 percent of the total electron concentration.

(i) Find the intrinsic carrier concentration.

(4 marks)

(ii) Analyze the minimum donor concentration required to meet this specification.

(6 marks)

Q2 (a) In a semiconductor, current is caused by electron transport. Explain the following:

(i) The differences between carrier drift and diffusion.

(4 marks)

(ii) The relation between carrier drift and diffusion.

(1 mark)

(iii) **TWO (2)** transport phenomena that affect the current flow indirectly.

(4 marks)

(b) A silicon semiconductor at T=300K is initially doped with donors at a concentration $N_D = 5 \times 10^{13}/cm^3$. The semiconductor resistor is designed to have a resistance of 10kΩ, handle a current density of 50 A/cm^2 and electric field of 100 V/cm.

(i) Analyse the required conductivity of the semiconductor.

(6 marks)

(ii) Prove that by adding $N_A = 1.25 \times 10^{16}/cm^3$, the requirement for the semiconductor conductivity in part **Q2 (b)(i)** can be achieved.

(10 marks)

Q3 (a) Describe the motion of electrons and holes when p- and n-type semiconductors are jointed together. Appropriate diagram may be used to support your answer.

(4 marks)

(b) Define the built-in potential of a p-n junction. Sketch the potential distribution for equilibrium, forward bias and reverse bias conditions in one diagram.

(4 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 $N_D = 4 \times 10^{17}$ cm^{-3} and $N_A=3x10^{14}cm^{-3}$ at zero bias, calculate

(i) built-in potential at 500K

(5 marks)

(ii) depletion layer width (T = 500 K)

(4 marks)

(iii) maximum electric field (T = 500 K)

(4 marks)

Q4 (a) List **TWO (2)** different approaches in order to overcome the problems arising from future scaling of MOSFET.

(2 marks)

(b) An NMOS transistor has the following parameters; L = 1 µm, W = 10 µm, t_{ox}=250Å, $N_A = 5 \times 10^{15}/cm^3$ and applied voltages of 3 V. If the device is to scaled using constant-field scaling, analyse the new devices parameter for scaling factor of k=0.7.

(10 marks)

(c) Sketch the graph of ideal low-frequency capacitance versus gate voltage of an MOS capacitor with a p-type substrate. Include also the individual capacitance components.

(3 marks)

(d) Consider a p-type silicon substrate at T = 300 K doped to $N_A = 10^{16}/cm^3$. The oxide is silicon dioxide with a thickness of 550 Å and the gate is aluminum. Calculate:

(i) Oxide capacitance

(2 marks)

(ii) Minimum capacitance

(4 marks)

(iii) Flat-band capacitance

(4 marks)

- END OF QUESTION -

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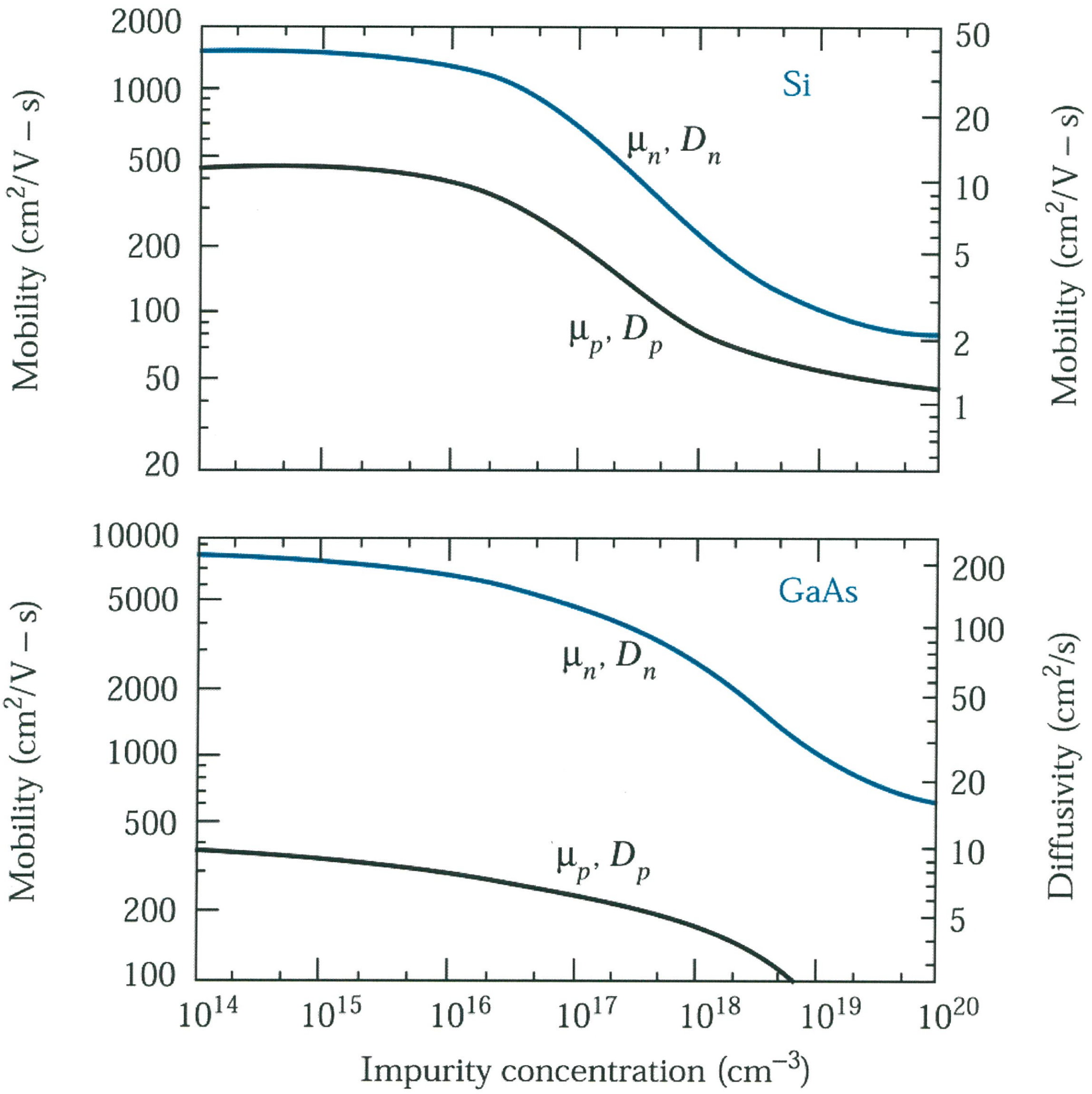
Appendix



A1. Mobilities and diffusivities in Si and GaAs at 300 K as a function of impurity concentration.

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Formulae

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

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

$$n_n = \frac{1}{2}[N_D - N_A + \sqrt{(N_D - N_A)^2 + 4n_i^2}]$$

$$p_n = n_i^2 / n_n$$

$$\sigma = nq\mu_n + pq\mu_p \,.$$

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

$$C' = \frac{\epsilon_{ox}}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s}\right)\sqrt{\left(\frac{kT}{e}\right)\left(\frac{\epsilon_s}{eN_a}\right)}}$$

$$C' = \frac{\epsilon_{ox}}{t_{ox} + \left(\frac{\epsilon_{ox}}{\epsilon_s}\right) x_{dT}}$$

$$W = \sqrt{\frac{2\varepsilon V_{bi}}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)}$$

$$E_{max} = \frac{qN_d x_n}{\varepsilon_S} = \frac{qN_a x_p}{\varepsilon_S}$$

$$C_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$$

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Formulae

$$x_{dT} = \left(\frac{4\epsilon_s \phi_{fp}}{eN_a}\right)^{1/2}$$

$$\phi_{fp} = V_t \ln\left(\frac{N_a}{n_i}\right)$$

Physical constant

Boltazmann 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, $\varepsilon_0 = 8.85418 \times 10^{-14}$ 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