BITS, PILANI – DUBAI
DUBAI INTERNATIONAL ACADEMIC CITY
SEMESTER I 2013-2014

CLASS: EEE/ECE/EIE II Year **Date: 6 Jan 2014**

EEE/ECE/INSTR F214 ELECTRONIC DEVICES Time allowed: 3 hours

Max marks: 80 **COMPREHENSIVE EXAMINATION** Weightage: 40%

Note: Answer ALL questions. All symbols have their usual significance unless otherwise stated

Q1 Define Fermi Dirac distribution function f(E). Show that the probability for an electron to occupy a state of energy E_F is 0.5 at any temperature, where E_F is the Fermi energy. In a p-type Si, the Fermi energy is 0.2 eV above the valence band edge E_V. The band gap of Si is 1.12 eV. What is the probability for an electron to occupy the conduction band edge E_C at 300K?

(8 marks)

Q2. A certain semiconductor is doped simultaneously with donor impurities ($N_D = 3x10^{15}$ cm^{-3}) and acceptor impurities ($N_A = 2x10^{15}$ cm^{-3}). The semiconductor is maintained at a temperature T = 400K. The intrinsic carrier concentration at this temperature is $n_i = 10^{15}$ cm^{-3}. What is the conductivity type of the semiconductor after doping, n-type or p-type? Determine the thermal equilibrium carrier concentrations n_o and p_o for the semiconductor at 400K.

(10 marks)

Q3. A Si p-n junction has its p-side doped with $N_A = 5x10^{17}$ cm^{-3} and the n-side doped with $N_D = 5x10^{16}$ cm^{-3} respectively. The p-n junction is held in thermal equilibrium at 300 K. Calculate:

(a) The contact potential V_o, using the data on the doping densities.
(b) The widths of the depletion region in the n-side (x_{no}) and the p-side (x_{po}), and the total depletion width W.
(c) The peak electric field E_o and the location of the peak electric field.

(10 marks)

Q4. Draw the energy band diagram of an ideal n-channel MOS structure for the following cases: (i) accumulation, (ii) depletion and (iii) inversion. Indicate with appropriate band bending, the onset of strong inversion. If N_A is the doping concentration of the p-type semiconductor in the MOS structure, and ψ_B the semiconductor potential in the bulk, show that

$$\psi_B = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$$

Hence determine the potential ψ_S at the semiconductor oxide interface at the onset of strong inversion. If the acceptor density is increased by a factor of 3, by what amount would ψ_S increase?

(12 marks)

Q5 A solar cell with an active area of 10^{-2} m^2 is uniformly illuminated by light of intensity 800 $W.m^{-2}$. A load is connected across the solar cell such that the solar cell delivers maximum power to the load, with a current I_S through the load, and a voltage V_S across it. The *I-V* characteristics for the solar cell is shown in Figure 1.

(i) From the figure, identify the relevant I-V characteristic and determine the open circuit voltage and short circuit current for the solar cell.

(ii) Determine the fill factor

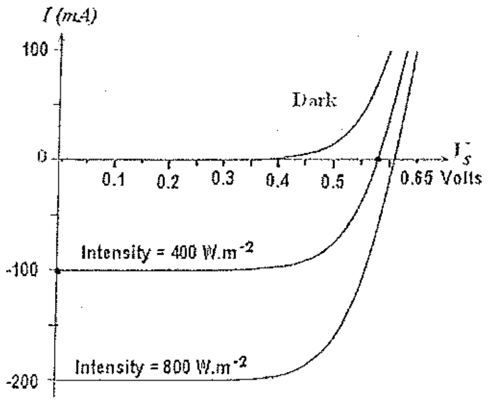

Figure 1

(6 marks)

Q6. A p^{+}-*n*-*p* transistor is biased in the active mode Explain the role of minority carriers in the operation of the transistor. Draw the energy band diagram for the transistor in the active mode. In the diagram, mark the Fermi levels, conduction and valence band edges, applied bias voltages and the energy barriers at the two interfaces for the transistor. Why is the emitter doping in a BJT made very high? For efficient transistor action in the active mode, the base width is made very narrow. Why?

(12 marks)

Q7. Explain Zener breakdown in a p-n junction with the help of appropriate band diagram,

(4 marks)

Q8. Explain the terms pinch-off and saturation with reference to the operation of a JFET

(4 marks)

Q9. Explain with the help of a band diagram, tunneling phenomenon in a p-n junction. Hence draw the I-V characteristics of a tunnel diode. Why does it exhibit negative resistance characteristics?

(6 marks)

Q10. Using a two transistor analogy for a *p-n-p-n* structure, show how the structure can function as a rectifier. Draw typical $I - V$ characteristics for the device and identify the reverse blocking, forward blocking and forward conducting states. Name one application of the device.

(8 marks)

END OF PAPER

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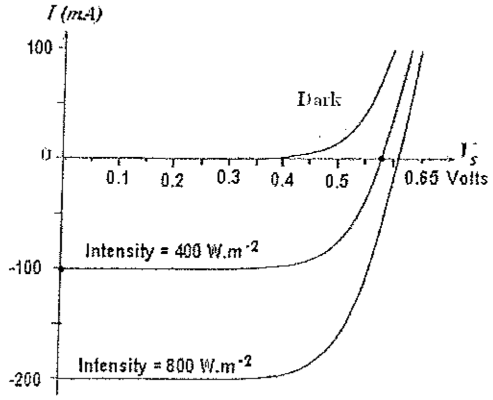

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END OF PAPER

LIST OF SELECTED FORMULAE AND PHYSICAL CONSTANTS

$$p_p = N_v e^{-(E_F - E_v)/(kT)}$$

$$n_n = N_c e^{-(E_c - E_F)/(kT)}$$

$$V_o = \frac{kT}{q} \ln\left(\frac{N_a N_d}{n_i^2}\right)$$

$$W = \sqrt{\frac{2\varepsilon_s}{q}\left[\frac{1}{N_a} + \frac{1}{N_d}\right](V_o - V)}$$

$$N_c = 2\left(\frac{2\pi m_n^* kT}{h^2}\right)^{3/2}$$

$$N_v = 2\left(\frac{2\pi m_p^* kT}{h^2}\right)^{3/2}$$

$$W_m(forMOS) = \sqrt{\frac{2\varepsilon_s}{q}\left[\frac{1}{N_a}\right](2\phi_B)}$$

TABLE OF SELECTED CONSTANTS

Parameter	Symbol	Value	Units
Electronic Charge	q	1.6×10^{-19}	C
Boltzmann's constant	k or k_B	1.38×10^{-23} 8.625×10^{-5}	J/K eV/K
Permittivity of free space	ε_o	8.85×10^{-14}	F/cm
Dielectric constant of Si (ε_r)	ε_{Si}	11.7	-
Dielectric constant of SiO_2 (ε_{ox})	ε_{SiO2}	3.9	-
Intrinsic carrier concentration in Si at 300K	n_i	1×10^{10}	cm^{-3}
Bandgap of Si	E_g	1.12	eV

BITS PILANI DUBAI CAMPUS
EEE/ECE/INSTR F214 –ELECTRONIC DEVICES - Test 2

Sem I, 2013- 2014 | OPEN BOOK | Time Allowed: 50 mins
Total Marks : 40 | Date: 31 October 2013 | Weightage: 20%

INSTRUCTIONS: This paper contains **FIVE** (5) questions in **TWO** (2) pages. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

Use the following constants wherever applicable:

Bandgap of Si = 1.12 eV .
Relative permittivity of Si = 11.8.
Electronic Charge = 1.6×10^{-19} Coul.
Intrinsic carrier concentration n_i for Si at 300 K = 10^{10} cm^{-3}.
Permittivity of free space = 8.85×10^{-14} Farad / cm.
Boltzmann's constant = 1.38×10^{-23} J/K

Q1. A Si p-n junction is in thermal equilibrium at 300 K. The n-side is uniformly doped with donor impurities, $N_D = 10^{17}$ cm^{-3} and the p-side with acceptor impurities, $N_A = 10^{15}$ cm^{-3}. (i) Calculate the contact potential V_o across the junction. (ii) Hence determine the total depletion width and the space charge width on either side of the junction.

(3 + 3 = 6 marks)

Q2. A Si p-n junction at 300 K with $N_A = N_D = 10^{17}$ cm^{-3} is subjected to a reverse bias voltage V_R (in volts). The peak electric field at the junction in the presence of the reverse bias is 5×10^5 V/cm. Calculate V_R. The effect of the contact potential V_o is not neglected.

(6 marks)

Q3. A JFET has p-regions doped with 10^{18} cm^{-3} and an n-channel with 10^{16} cm^{-3} and is operated at room temperature. The channel half width 'a' is 1 μm. The source is grounded, drain connected to a potential V_D and the gate tied to a potential V_G. With $V_G = 0$ volts, the drain current is found to saturate at 10 mA. (a) Calculate the pinch-off voltage V_P. (b) How much will be the saturation drain current if V_G is changed to -2 volts? What will be the corresponding drain potential at which the drain current begins to saturate?

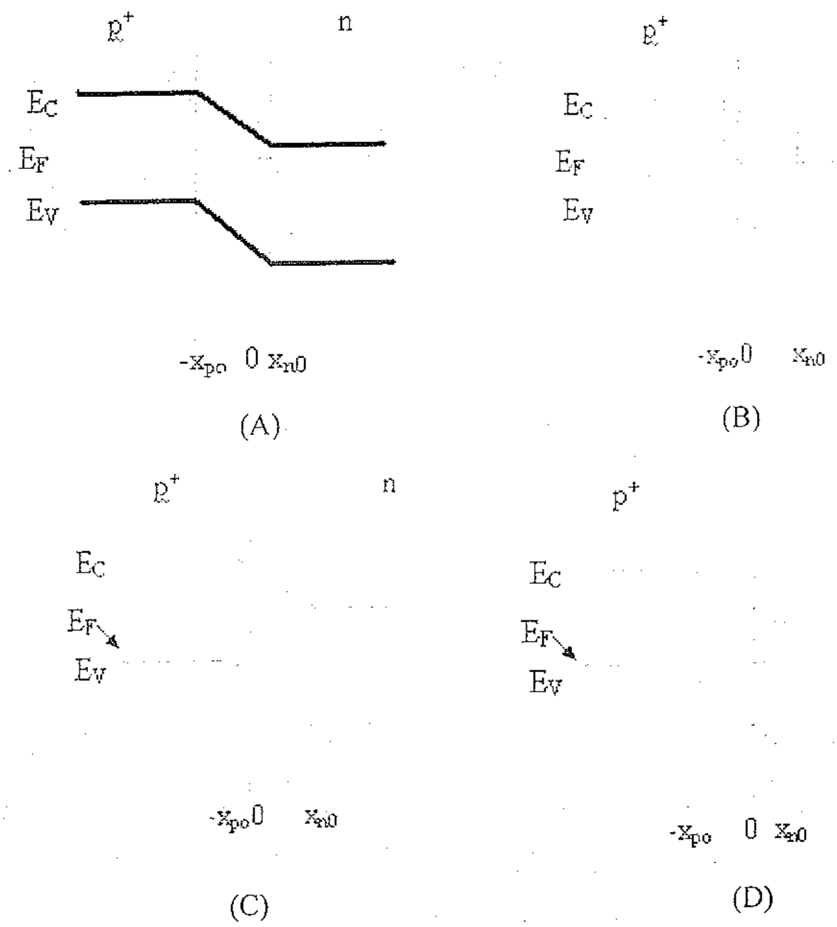
(8 marks)

PTO

Q4. The p-n junction as described in Q1 above, is operated with an unknown reverse bias V_R. The junction is found to exhibit a depletion capacitance C_1. When the reverse bias is doubled to $2V_R$, the depletion capacitance is found to be $0.8C_1$. Calculate V_R and C_1. Area of junction is 0.001 cm^2.

(10 marks)

Q5. Which one of the options shown in Figure below more closely represents the energy band diagram for the p-n junction described in Q1 above? Why?



(a) How far is the equilibrium Fermi energy from the conduction band edges for the p- and n- sides respectively?

(b) Redraw the band diagram when the p-n junction is heated to a high temperature. Mark Fermi energy, conduction and valence band edges.

(10 marks)

----END OF PAPER -----

BITS PILANI DUBAI CAMPUS
EEE/ECE/INSTR F214 –ELECTRONIC DEVICES - Test 1

Sem1, 2013- 2014 CLOSED BOOK Time Allowed: 50 mins

Total Marks : 50 Weightage: 25%

Date : 7-10-13

INSTRUCTIONS: This paper contains **SIX (6)** questions. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings.

Use the following constants wherever applicable:

Bandgap of Si = 1.12 eV . Intrinsic carrier concentration n_i for Si at 300 K = 10^{10} cm^{-3}.

Relative permittivity of Si = 11.8. Permittivity of free space = 8.85 x 10^{-14} Farad / cm.

Electronic Charge = 1.6 x 10^{-19} Coul. Boltzmann's constant = 1.38 x 10^{-23} J/K

Q1. A Si sample is in thermal equilibrium at 300 K. The sample is doped with donor impurities such that $N_D = 2x10^{10}$ cm^{-3}.

(i) Calculate the thermal equilibrium electron and hole concentrations, n_0 and p_0 respectively. Is it justified to assume N_D to be the same as n_0?

(ii) Determine the position of the Fermi energy E_F with respect to E_i for the semiconductor.

(5 + 3 = 8 marks)

Q2. A certain semiconductor has its electron mobility twice that of hole mobility. The semiconductor is initially undoped and the intrinsic carrier concentration $n_i = 10^{10}$ cm^{-3}.

(i) Write down the expression for the conductivity of the undoped semiconductor (σ_i) in terms of carrier mobilities

The semiconductor is now doped with a certain type of impurity. The conductivity of the doped semiconductor (σ_d) is found to be the same as the undoped conductivity(σ_i).

(ii) Determine the thermal equilibrium electron and hole concentrations (n_0 and p_0) in the doped semiconductor

(iii) What type of impurity has the semiconductor been doped with, donor or acceptor? Explain.

(4+4+2=10 marks)

Q3. A piece of p-type silicon sample in the form of a cylindrical disc has a radius which is ten times its length. The doping concentration in the sample is $1x10^{18}$ cm^{-3}. The sample is held at 300 K. The hole mobility at 300 K is 150 cm^2/V-s. A dc voltage of 1.5 Volts applied across its flat ends results in a current of 150 mA. Determine the sample dimensions.

(8 marks)

Q4. Explain the terms: (i) absorption coefficient, (ii) photoluminescence.

(2x2 = 4 marks)

Q5. A n-type Si rod uniformly doped with $N_D = 10^{17}$ cm^{-3}, is irradiated with a steady light source such that a steady generation of excess electrons and holes of $\Delta n = \Delta p = 10^{15}$ cm^{-3} is produced. The sample is held at 300 K.

(i) Determine the new steady state electron and hole concentrations, n and p respectively for the sample, in the presence of irradiated light.

(ii) The position of the quasi Fermi energy F_n and F_p, relative to E_i for the sample.

(4+6 = 10 marks)

Q6. Describe Haynes Shockley experiment. What information do we get from such an experiment? Sketch the experimental setup.

(10 marks)

----END OF PAPER -----

NAME: ID. NUMBER

BITS PILANI DUBAI CAMPUS

EEE/EIE/ECE F214 – ELECTRONIC DEVICES - QUIZ 1

Date : 26-9-13

Sem1, 2013- 2014 CLOSED BOOK Time Allowed: 20 mins

Total Marks : 16 Weightage: 8%

INSTRUCTIONS: This paper contains **SIX (6)** questions. Answer **ALL** questions. Unless specifically stated, all symbols have their usual meanings. Make appropriate assumptions wherever applicable.

Q1. A Si sample is in thermal equilibrium at 300 K. The sample is doped with 10^{15} donor impurities

(i) Calculate the thermal equilibrium electron and hole concentrations, n_0 and p_0 respectively.

(ii) If the temperature is raised to 1000 K, explain qualitatively how the values n_o and p_o would change. (2+2 = 4 marks)

Q2. If P_e and P_h represent electron and hole probability for occupying an energy state E respectively, and $P_e = 10P_h$, how far is the energy state E with respect to E_F? Assume T = 300 K. (4 marks)

Q3. Explain Hall Effect. (2 marks)

NAME: ID. NUMBER

Q4. Differentiate between direct and indirect bandgap semiconductors. (2 marks)

Q5. Draw the energy band diagram of an n-type semiconductor, indicating the position of Fermi energy E_F. On this diagram, superimpose the Fermi- Dirac Distribution function (2 marks)

Q6. A Si bar, 0.1 cm long, has a cross sectional area of 100 μm^2. It is doped with $10^{16} cm^{-3}$ phosphorus impurities. Find the resistivity of the sample. Assume $\mu_n = 1000\ cm^2V^{-1}s^{-1}$. (2 marks)

Given: Bandgap of Si = 1.12 eV .
Relative permittivity of Si = 11.8.
Electronic Charge = 1.6 x 10^{-19} Coul.
Intrinsic carrier concentration n_i for Si at 300 K = 10^{10} cm^{-3}.
Permittivity of free space = 8.85 x 10^{-14} Farad / cm.
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