GIET MAIN CAMPUS AUTONOMOUS GUNUPUR – 765022

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4th Semester Regular Examination-April-May 2019

BECPC4040– SEMICONDUCTOR DEVICES

(Regulations 2017) Common to AEIE/ECE Branches.

Time : 3 Hours Maximum : 100 Marks

Answer ALL Questions

The figures in the right hand margin indicate marks.

PART – A: (Multiple Choice Questions) 10 x 2=20 Mark

Q.1. Answer *All* Questions.

a The forbidden energy gap of silicon is _____ and the forbidden energy gap of germanium is _____. CO1 PO1

a) 0.32 eV, 0.72 eV (b) 0.72eV, 0.32eV c) 0.32eV, 0.32eV d) 0.72eV, 0.72eV

b In an intrinsic semi-conductor the free electron concentration vastly depends upon: CO1 PO1

a) Temperature of the semi-conductor c) Effective mass of electrons only

b) Effective mass of holes only d)Width of the forbidden energy hand of the semiconductor

c The intrinsic carrier density at 300°K is $1.5 \times 10^{10}/cm^3$, in silicon for the case of n-type silicon doped to $2.25 \times 10^{15} atoms/cm^3$, then the equilibrium electron and hole densities are as follows: CO1 PO2

(a) $n = 1.5 \times 10^{15}/cm^3$, $p = 1.5 \times 10^{10}/cm^3$ (b) $n = 1.5 \times 10^{10}/cm^3$, $p = 2.25 \times 10^{15}/cm^3$

(c) $n = 1.5 \times 10^{10}/cm^3$, $p = 1.5 \times 10^{10}/cm^3$ (d) $n = 2.25 \times 10^{15}/cm^3$, $p = 1.0 \times 10^5/cm^3$

d A silicon sample 'A' is doped with 10^{18} atoms/cm^3 of Boron. Another sample 'B' of identical dimensions is doped with 10^{18} atoms/cm^3 of phosphorus. The ratio of Electron to hole mobility is 1/3. Then the ratio conductivity of the sample A to B will become: CO2 PO2

(a) 1/3, (b) 3, (c) 2/3, (d) 3/2

e The static characteristic of an adequately forward biased PN junction is a straight line trait, if the plot is of: CO2 PO1

(a) Log I vs Log V (b) Log I vs V (c) I vs Log V (d) I vs V

f The diffusion capacitance of a PN junction can be characterized as: CO2 PO2

a) Decreases with increasing current and increasing temperature b) Decreases with decreasing current and increasing temperature c) Increases with increasing current and increasing temperature d)Does not depend on current and temperature

g If for Si n–p– n transistor, the base to emitter voltage (V_{BE}) is 0.7V and collector to base voltage (V_{CB}) is 0.2V then the transistor is operating in: CO3 PO1

(a) Normal active mode (b)Saturation mode (c) Inverse active mode (d) Cut-off mode

h For a BJT, the common-base current gain α = 0.98 and the collector base junction reverse bias saturation current, = 0.6 μA. This BJT is connected in the common emitter mode and operated in the active region with a base drive current I_B = 20 μA. The collector current IC for this mode of operation is: CO3 PO2

(a) 0.98 mA (b)0.99 mA (c) 1.0 mA (d)1.01 mA

i In MOSFET devices the N-channel type is better than the P-Channel type in the following ways: (a) It has better immunity (b)It is faster (c) It is TTL compatible (d)It has better drive capability CO4 PO1

j BJT is a _____ device and MOSFET is a _____ device. CO4 PO2

(a) voltage controlled, current controlled (b) current controlled, voltage controlled

(c) current controlled, current controlled (d) voltage controlled, voltage controlled

PART – B: (Short Answer Questions) 10 X2 =20 Marks

Q.2. Answer *ALL* questions

a Where does the maximum electric field occur in free space region? Write the expression for the maximum electric field. CO1 PO1

b Sketch the variation of minority carrier concentration of npn transistor in forward active mode. CO1 PO2

c The difference between the Fermi levels in a p-type and a n-type semiconductor is 0.8eV. What is the built in voltage if these materials create pn junction. CO1 PO1

d What is the meant by high injection. CO2 PO1

e Describe the meaning of degenerate and non-degenerate semiconductors. CO2 PO2

f Describe the three limiting factors in the common base current gain. CO2 PO1

g What is the cutoff frequency of a bipolar transistor? CO3 PO1

h Draw the schematic V-I characteristic of schottttky diode. CO1 PO2

i Which material provides better high frequency performance of depletion type FETs, Si or GaAs? Why? CO4 PO1

j Draw the energy band diagram of MOS structure with p-type substrate under zero bias condition. CO4 PO2

PART – C: (Long Answer Questions) 4 X15=60 Marks

Answer *ALL* questions

Q.3

a What is the significance of Fermi energy level? Under what conditions, the Fermi-Dirac distribution function changes to the Boltzmann distribution. Derive an expression for the concentration of negative charge carriers in intrinsic semiconductor at thermal equilibrium in terms of effective density of states function in conduction band. — 8 — CO1 PO2

b What is the physical meaning of effective density of states function in conduction band and valence band? Consider silicon semiconductor at T=300 K in which $N_a = 10^{16}$ cm^{-3} and $N_d = 3\times10^{15}$ cm^{-3}. Assume that $n_i = 1.5\times10^{10}$ cm^{-3}, determine the thermal equilibrium electrons and hole concentration in a compensated p-type semiconductor. — 7 — CO1 PO2

OR

c Explain the meaning of freeze out condition, complete and partial ionization. Determine the required impurity doping concentration in a semiconductor material. A silicon device with n-type material is to be operated at T= 550K. At this temperature the intrinsic carrier concentration must contribute no more than 5 percent of the total electron concentration. Determine the minimum donor concentration required to meet this specification. — 8 — CO1 PO2

d Draw the k-space diagram of Si and GaAs. Derive an expression for thermal equilibrium concentration of holes in the valence band using the Fermi-Dirac probability function, density of states and other terms. — 7 — CO1 PO1

Q.4

a Derive an expression for drift current density and diffusion current density and write the expression for total current density explaining each term associated with it. To calculate the diffusion current density given gradient. Assuming that in an n-type gallium arsenide semiconductor at T=300K, the electron concentration varies linearly from 1×10^{18} to 7×10^{17} cm^{-3} over a distance of 10 cm. Calculate diffusion current density if the electron diffusion coefficient is $D_n = 225$ cm^2/s. — 8 — CO2 PO2

b Derive the Einstein relation? — 7 — CO2 PO1

OR

c What is junction breakdown? Discuss different breakdown that is associated with a PN junction. Calculate the built in potential in a silicon PN junction at 300 K with doping concentration of $N_d = 10^{16}$/cm^3 and $N_a = 5\times10^{17}$/cm^{3}respectively. Assume $n_i = 1.5\times10^{10}$/cm^3 and kT/e=0.026 V. — 7 — CO2 PO2

d Derive the ideal current-voltage relation for pn junction and plot the I-V characteristics curve. Calculate the quasi-Fermi energy levels. Consider an n-type semiconductor at T= 300K with carrier concentration of $n_0 = 10^{15}$cm^{-3}, $n_i = 10^{10}$cm^{-3} and $p_0 = 10^5$cm^{-3}. In the non- equilibrium, assume that the excess carrier concentration is $\delta n = \delta p = 10^{13}$ cm^{-3} — 8 — CO2 PO2

Q.5

a What do you mean by Ebers-Moll model? In what type of application of BJT Eber's moll model is used? Derive expression for excess minority carrier electron concentration in the base region for an NPN transistor operating in the forward active mode. — 7 — CO3 PO1

b What is meant by base width modulation? What is another term used for this effect? A particular transistor has an output resistance of 200 KΩ and an Early voltage of $V_A = 125$V. Determine the change in collector current when V_{CE} increase from 2 V to 8 V. — 8 — CO3 PO2

OR

c Compare the forward-biased current-voltage characteristics of a schottky barrier diode to that of PN junction diode. Consider an ideal chromium-to-n-type silicon Schottky diode at T=300K. Assume the semiconductor is doped at a concentration of $N_d = 3\times10^{16}$ cm^{-3}. Determine the (a) Ideal Schottky barrier height (b) Built-in potential barrier (c) Peak electric field with an applied reverse-bias voltage of $V_A = 5$V, (d) Junction capacitance per unit area for $V_R = 5$V. — 10 — CO3 PO2

d What is heterojunction? Sketch the ideal energy band diagram of a metal-semiconductor in which $\varphi_m < \varphi_s$. Explain why this is an ohmic contact. — 5 — CO3 PO1

Q.6

a What is the value of surface potential under flat band condition? Draw the energy band diagram of MOS capacitor. Discuss C-V characteristics of the MOS capacitor for different operating conditions. — 7 — CO4 PO1

b Write short notes on flat band condition including supporting expression and diagram.Calculate the flat-band voltage for an MOS capacitor with p-type semiconductor substrate. Consider an MOS structure with a p-type semiconductor substrate doped to $N_d = 10^{16}$cm^{-3}, a silicon dioxide insulator with a thickness of $t_{ox} = 500$ Å and an n^+ polysilicon gate. Assume that $Q'_{ss} = 10^{11}$ electronic charge per cm. — 8 — CO4 PO2

OR

c Discuss why the threshold voltage changes when a reverse-biased source-to-substrate voltage is applied to a MOSFET. An MOS transistor with an aluminium gate is fabricated on a p-type silicon substrate. The oxide thickness is $t_{ox} = 750$ A, and the equivalent fixed oxide charge is $Q'_{ss} = 10^{11}$cm^{-2}. The measured threshold voltage is $V_T = +0.80$V. Determine the p-type doping concentration — 7 — CO4 PO2

d Write short note on — 8 — CO4 PO1

(a) High mobility FETs

(b) pinch-off voltage of MOSFET