KABARAK UNIVERSITY

UNIVERSITY EXAMINATIONS

2008/2009 ACADEMIC YEAR

FOR THE DEGREE OF BACHELOR OF EDUCATION SCIENCE

COURSE CODE: PHYS 422

COURSE TITLE: SEMI CONDUCTOR PHYSICS

STREAM: SESSION VIII

DAY: SATURDAY

TIME: 9.00 – 11.00 A.M.

DATE: 14/08/2010

INSTRUCTIONS:

Answer question ONE and ANY other THREE

PLEASE TURN OVER

QUESTION 1

(a) Differentiate between the following terms.

(i) Intrinsic and extrinsic carriers (2marks)

(ii) Majority and minority carriers. (2marks)

(iii) Drift and diffusion mechanisms. (2marks)

(b)

(i) Find the diffusion current density if the electron density varies linearly from $10^{23}m^{-3}$ to $10^{12}m^{-3}$ over a distance of 5µm in the +X direction and the electron diffusion coefficient is $3.5 \times 10^{-3}m^{-1}s^{-1}$. (2marks)

(ii) Find the magnitude of the electric field which produce an equal drift current to the diffusion current in b(i) above if the electron mobility is $0.14\ m^2V^{-1}s^{-1}$. Use the electron density at the mid point of the linear range (2.5µm). (4marks)

(c) What do you understand by the terms (2marks)

(i) Life time

(ii) Diffusion length

(d) Determine the built in voltage for a uniformly doped Silicon PN junction with $N_D = N_A = 10^{-17}cm^{-3}$ at room temperature. Will the built-in voltage increase or decrease with increase in temperature? (3marks)

(e) Draw the energy band diagrams when the PN junction is in equilibrium and when it is forward biased.

(3marks)

(f) State the mass action law (2marks)

(g) Describe two parameters that characterize impact ionization. (2marks)

(h)

(i) Find the resistivity of intrinsic germanium at $300^{o}K$. (1½ marks)

(ii) If a donor type impurity is added to the extent of 1 part to 10^8 of germanium atoms, find the resistivity. (2½ marks)

Use the following parameters

$\mu_n = 3800$, $\mu_p = 1800$, $n_i = 2.5 \times 10^{13}cm^{-3}$, concentrations = 4.41×10^{22} atoms/cm^{-3}

QUESTION 2

(a) Show that for uniformly doped PN junction, the junction capacitance is given by

$$C_J = A\sqrt{\frac{q\varepsilon_{si} N_D N_A}{2\left(N_D + N_A\right)\left(V_{bi} - V\right)}}$$

(6marks)

(b) When analysing current in PN junction there is always two extremes cases; ***Wide base diode*** and ***Narrow base diode***

Do the following for each case.

(i) Write down the equations for minority carrier densities. (4marks)

(ii) Draw the diagrams to show the change of carriers through the junction. (2marks)

(iii) Make conclusion. (2marks)

QUESTION 3

(a) A diode is fabricated on an n-type ($N_d = 10^{16}$ cm^{-3}) silicon substrate, on which a p-type region doped to 10^{18} cm^{-3} is created. Calculate the Fermi level positions in the p- and n-regions, determine the contact potential in the diode, and calculate the depletion widths on the p- and n-side. Use the following parameters , effective density of states relations, Nc = 2.8 x10^{19} cm^{-3}; Nv = 1 x10^{19} cm^{-3} at 300^0 K, E_g = 1.1eV, ε_{si} = 8.84 x 10^{-12}F/m, ε_r = 11.9

(9marks)

(b) Consider GaAs sample at room temperature where all impurities are completely ionized. The sample has a length of 1cm, area of 5mm^2, $N_d = 10^7$ cm^{-3} and $N_a = 0$. Find the current through the sample given that; E = 10V/m, $n_i = 2 \times 10^6$ cm^{-3}, μ_n = 8500cm^2/Vs and μ_n = 400cm^2/Vs.

(5marks)

QUESTION 4

The block diagram of a silicon p-n junction diode is shown in figure 1. Accurately sketch the variation of charge density, electric field and potential across the junction giving numerical values for these quantities.

Assume the electric field outside the depletion region is zero and the potential on the p side of the depletion region is zero. The junction occurs at x = 0 µm.

Donor concentration on n-side = 10^{21} m^{-3}

Acceptor concentration on p-side = 2×10^{21} m^{-3}

Edge position of depletion region in n-side, dn = –0.72 µm

Edge position of depletion region in p-side, dp = 0.36 µm (12marks)

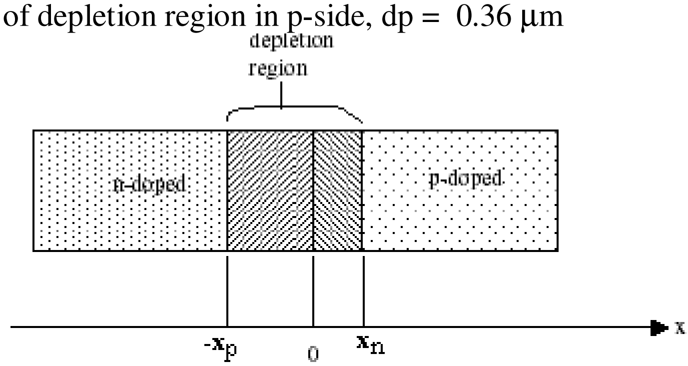

Fig. 1: PN Junction diode

QUESTION 5

(a) State the difference between recombination and generation. (2 marks)

(b) With aid of diagrams, briefly describe the following process. (8 marks)

- (i) Band-to-band recombination.
- (ii) R-G Centre recombination.
- (iii) Band-to-band generation.
- (iv) R-G Centre generation.

(c) State two common mechanisms that cause the creation of R-G centres. (2 marks)

(d) Name two major assumptions used when analyzing the junction current (2marks)

QUESTION 6

(a) A uniformly doped Silicon PN junction with very thick P and N regions has the following characteristics:

$N_D = 5 \times 10^{16}$ cm^{-3}, $D_p = 8$ cm^2/s, $\tau_p = 1\mu s$
$N_A = 10^{17}$ cm^{-3}, $D_n = 20$ cm^2/s, $\tau_n = 1\mu s$
Area = 10^{-2} cm^2, T = 300 K.

For a forward bias of 0.626 Volts, calculate, excess minority carrier concentrations and minority carrier currents at the edges of depletion region. Calculate also the net current flowing through the device.

(8marks)

(b) Describe how the reverse voltage breakdown occurs. (6marks)