Birla Institute of Technology and Science, Pilani

1st Semester 2015-2016

EEE F214/INSTR F214

Electronic Devices

Mid Semester Examination

Date: 09/10/2015 **Closed Book 90 minutes** **Max Marks:100**

Note: Use following data if not given in the problem.

ε_o=8.85x10^{-14}F/cm, ε_r(Si)=11.8, k=8.62x10^{-5}eV/K, at room temperature for Si [E_g= 1.12 eV,μ_n=1350cm^2/V·s, μ_p= 480 cm^2/V·s, n_i=1.5x10^{10}/cm^3, τ_n= τ_p= 10 ns, D_n= 49cm^2/s, D_p= 9 cm^2/s], q=1.6x10^{-19} C.

Q1: (a) An intrinsic Si sample (A) is doped with acceptor Impurity N such that $N = N_o e^{-ax}$ for $x \geq 0$, where N_o= 1.5 x 10^{16} /cm^3.

Sketch & label the energy band diagram along the x-axis of the sample showing E_C, E_F and E_V at room temperature. Also sketch the energy band diagram for the following cases:

(i) When the sample is further doped with a donor impurity having the same profile.
(ii) Sample A is now further doped with acceptor dopants having the same profile.
(iii) Sample obtained in case (ii) is heated. **(4+4+4+3=15 M)**

(b) Show that the Fermi level(E_i) of an intrinsic semiconductor with bandgap (E_g) at temperature T can be expressed as:

$$E_i = E_v + \frac{E_g}{2} - \frac{3}{4}\, kT ln(\frac{m_n^*}{m_p^*})$$

Here m_n^* and m_p^* are the effective mass of electrons and holes respectively. Also comment on the location of Fermi level for $m_n^* > m_p^*$ and $m_n^* < m_p^*$ cases. **(7+3=10 M)**

Q2: (a) Comment on the following statements with best reasoning. (Answer should not exceed more than two sentences.)

(i) Resistivity of semiconductor after doping at room temperature.
(ii) Reverse saturation current with the increase in reverse voltage.
(iii) Reverse saturation current in the short diode model.
(iv) The range of proper operation of a n-doped Silicon device as the doping concentration increases.
(v) Reverse current magnitude in terms of forward current (I_f) if the diode is switched from forward bias to reverse at t=0. **(3 x 5=15 M)**

(b) Draw the energy band diagram for a GaAs (Eg=1.43 eV) and GaAlAs (Eg =1.85 eV) junction. Assume that both are of n type and GaAs is more n type. (Electron affinity of GaAlAs is 0.3 eV less than that of GaAs.) **(10 M)**

[P.T.O]

Q3: (a) For a silicon based device there are three regions. Region 1 is p-type doped ($N_A=6.5\times10^{16}$ cm^{-3}), Region 2 is undoped, Region 3 is n-type doped. The maximum depletion widths for these three regions are 100 nm, 100 nm, 50 nm respectively.

(i) Sketch and label the electric field throughout the junctions of the device.
(ii) Calculate the built-in potential.
(iii) Calculate the junction capacitance per unit area. **(3+4+3=10 M)**

(b) Design a p-n junction diode to ensure hole diffusion current contribution as 90% of the total diffusion current. (Given: p-side doping is 10^{17} cm^{-3}, cross section is $A=10^{-4}$ cm^2)

(i) Estimate the diffusion lengths of electron an holes and hence comment on critical physical thickness for long diode model.
(ii) Estimate reverse saturation current.
(iii) Estimate current at 0.6V forward bias.
(iv) Sketch and label energy band diagram across p-n junction. **(4+4+3+4=15 M)**

Q4:(a) Hall coefficient of a silicon sample of width 1 mm is 31.25 cm^3/C. Sample provides a Hall voltage of 200 μV if flux density B_z is 10^{-4} wb/cm^2 and area of cross section is $A=10^{-4}$ cm^2. Using this sample if a p-n junction is to be formed then find the required dopant concentration on p and n side respectively if its built in potential is 0.7 V.

Also find:

(i) Current density required in the silicon sample.
(ii) Current at 0.5V forward bias in p-n junction diode.
(iii) Current at 2V reverse bias in p-n junction diode. **(5+5+3=13 M)**

(b) Sketch and label energy band diagram across a given metal semiconductor junction. The work functions of metal and semiconductor are 4.4 eV and 4 eV respectively. Also Sketch and label energy band diagram across a given metal semiconductor junction if the semiconductor is now doped with opposite type of dopants with the double of concentration of the original one.
(Assume electron affinity is 3.8 eV and band gap is 1 eV of the semiconductor at room temperature.)
(6+6=12 M)

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