NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

Mid-semester Examination-2011

Semiconductor Devices (EC204)

Max. Marks: 30

Duration: 2hrs.

Instructions:

1. *Answer all three questions.*
2. *Use the following physical constants wherever necessary:*

Boltzmann's constant, $k = 1.38 \, x \, 10^{-23} \, J/K$

Electron rest mass, $m_o = 9.1 \, x \, 10^{-31} \, Kg$

Speed of light in vacuum, $c = 3 \, x \, 10^{8} \, m/s$

Elementary charge, $q = 1.6 \, x \, 10^{-19} C$

1. (a). Explain the reasons why crystallinity and semiconductivity are important to make electronic devices. (3 marks)

(b). Calculate the atomic density of Ge having diamond structure with an inter-atomic distance of 5.64 Å. If 2×10^{16} boron atoms per cm^3 are added to this semiconductor as a substitutional impurity, determine what percentage of Ge atoms are displaced in the single crystal lattice. (3 marks)

(c). Consider growing InAs on the following crystal substrates: InP, AlAs, GaAs and GaP. For which case would the critical thickness of the InAs layer be greatest? (Use ***Figure*** *1*) Justify your answer. (4 marks)

2. (a). Explain in detail the phenomenon of impurity compensation in a semiconductor. If a semiconductor exhibits a nearly intrinsic resistivity, what can be said of its purity? (3 marks)

(b). Silicon atoms are added to a piece of GaAs. The silicon can replace either trivalent Gallium or pentavalent Arsenic atoms. Assume that silicon atoms act as fully ionized dopant atoms and that 15% of $10^{10} \, cm^{-3}$ silicon atoms added replace Gallium atoms and 85% replace Arsenic atoms. The sample temperature is 300K. Calculate:

(i). The donor and acceptor concentrations.

(ii). Find the electron and hole concentrations and the location of the Fermi level. (n_i at 300K is $1.79 \, x \, 10^{6} \, cm^{-3}$, $N_c = 4.7x10^{17} cm^{-3}$ *and* $N_v = 7x10^{18} cm^{-3}$). (4 marks)

[P.T.O]

(c). What are degenerate semiconductors? What is the consequence of such doping on the semiconductor? What is the product of electron and hole concentrations of a degenerate semiconductor at thermal equilibrium?

(3 marks)

3. (a). Show that in order to obtain maximum resistivity in a GaAs sample (E_g = 1.43 eV, n_i = 2.1x 10^6 cm^{-3}, μ_n = 8500 cm^2/V-s, μ_p = 400 cm^2/V-s), it has to be doped slightly p-type. Determine this doping concentration. Also, determine the ratio of maximum resistivity to the intrinsic resistivity.

(4 marks)

(b). Derive the expression relating the intrinsic level (E_i) to the center of the bandgap ($E_g/2$), and compute the magnitude of this displacement for Si and GaAs at 300K. Assume m_n^*/m_o = 1.1 and 0.067, and m_p^*/m_o = 0.56 and 0.48 for Si and GaAs respectively.

(3 marks)

(c). A semiconductor contains p-type region doped with boron acceptor and n-type region doped with phosphorous. The boundary between p-type and n-type regions is known as the p/n junction as can be found in many diodes and transistors. This is an electrical boundary since there is no physical or metallurgical boundary between the p-type and n-type regions the very-low concentration dopant impurity type is changed from boron to phosphorous. What is the maximum temperature when the electrical boundary disappears if N_A = 10^{17} cm^{-3} and N_D = 10^{15} cm^{-3} for different semiconductors whose n_i vs T is shown in *Figure 2*. The maximum temperature is often referred as Intrinsic temperature (It is the temperature below which the semiconductor loses its useful electrical characteristics, which may be defined mathematically as the temperature where n_i is approximately equal to ten times the doping concentration).

(3 marks)

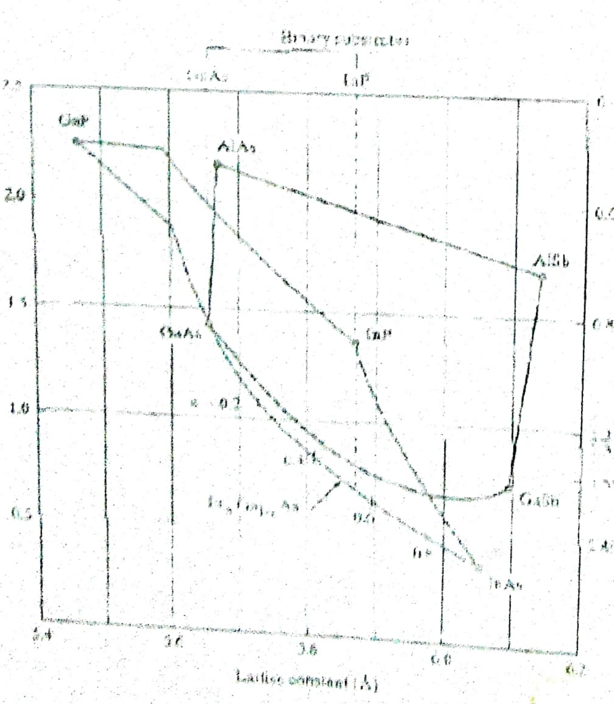

Figure 1

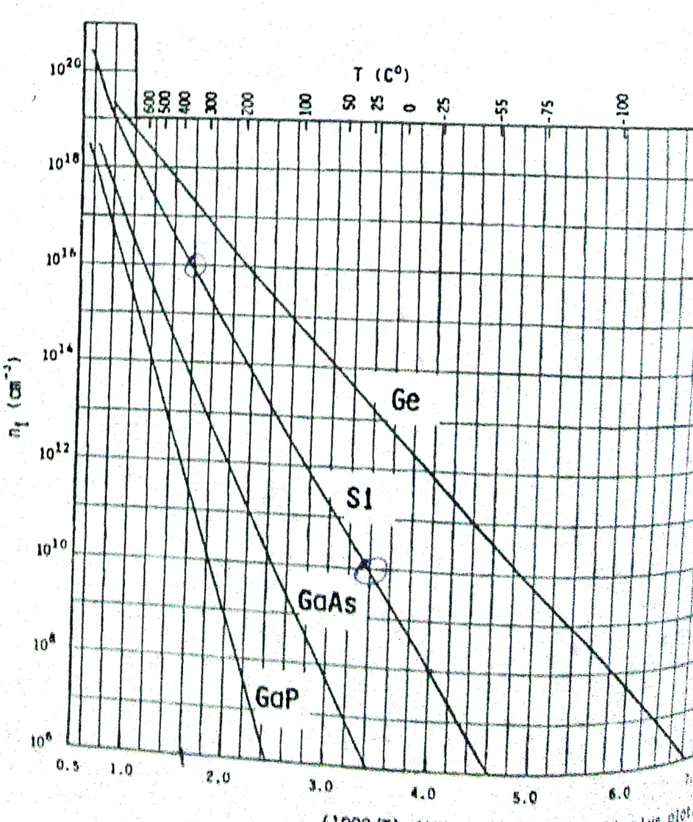

Figure 2