



Cairo Branch

# COLLEGE OF ENGINEERING & TECHNOLOGY

Department: Electronics and Communications Engineering

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Course Title: Electronic Devices I

Course Code: EC 233

## Sheet 4

### I. Indicate whether each of the following statements is true or false (give reasons):

- 1- When an intrinsic semiconductor is doped with  $N_D$  donors, the new electron concentration is  $n = n_i + N_D$ .
- 2- The electron and hole concentration expressions,  $n = N_c \exp [(E_f - E_c)/kT]$  and  $p = N_v \exp [(E_v - E_f)/kT]$ , are valid only if  $E_f$  lies in the forbidden gap more than  $3kT$  from either band edge.
- 3- The electron and hole concentrations of a silicon wafer doped with  $10^{15} \text{ cm}^{-3}$  donor atoms at 300 K is equal to  $10^{15} \text{ cm}^{-3}$  and  $2.25 \times 10^5 \text{ cm}^{-3}$  respectively.

### II. Solve the following problems:

Boltzmann constant  $k = 8.617 \times 10^{-5} \text{ eV/K}$ , Planck's constant  $h = 6.63 \times 10^{-34} \text{ J.s}$ ,  $\hbar = h / 2\pi$ .

#### At 300 K:

Material	$m_n^*/m_o$	$m_p^*/m_o$	$E_G$ (eV)	$n_i$ ( $\text{cm}^{-3}$ )
Silicon (Si)	1.1835	0.8048	1.12	$1 \times 10^{10}$
Germanium (Ge)	0.55	0.36	0.66	$2 \times 10^{13}$
Gallium Arsenide (GaAs)	0.066	0.52	1.42	$2 \times 10^6$

- 1- A silicon wafer is uniformly doped with acceptor impurities of concentration  $10^{15} \text{ cm}^{-3}$ . What are the equilibrium electron and hole concentrations at 0 K?
- 2- The electron concentration in a piece of silicon at 300 K under equilibrium conditions is  $10^5 \text{ cm}^{-3}$ . Find the hole concentration.
- 3- Determine the location of Fermi level with respect to the top of valence band in n-type germanium at 300 K, if the impurity content is one part in  $10^6$ . There are  $4.4 \times 10^{28} \text{ atoms/m}^3$  in Ge. Let  $N_c = 4.83 \times 10^{21} \text{ T}^{3/2}$ ,  $E_g = 0.72 \text{ eV}$ .
- 4- Find the equilibrium electron and hole concentrations and the location of Fermi level (with respect to the intrinsic Fermi level  $E_i$ ) in Si at 300 K, if the Si contains  $8 \times 10^{22} \text{ m}^{-3}$  As atoms ( group 5 ) and  $2 \times 10^{22} \text{ m}^{-3}$  Br ( group 3 ) atoms.

- 5- The resistivity of pure Ge at a particular temperature is  $0.52 \Omega \cdot \text{m}$ . If it is doped with  $10^{20}$  atoms/ $\text{m}^3$  of a trivalent impurity estimate the new value of resistivity. Assume the mobility of holes and electrons are 0.2 and  $0.4 \text{ m}^2/\text{V}\cdot\text{s}$
- 6- Determine the concentration of electrons and holes in a sample of Ge at 300k, which has a concentration of donor atoms =  $2 \times 10^{20} \text{ m}^{-3}$  and concentration of acceptor atoms =  $3 \times 10^{14} \text{ cm}^{-3}$ , is this p-type? Given that  $n_i = 2.5 \times 10^{13} \text{ cm}^{-3}$ ,  $\mu_n = 3800 \text{ cm}^2/\text{V}\cdot\text{sec}$ , and  $\mu_p = 1800 \text{ cm}^2/\text{V}\cdot\text{sec}$ .

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**Good Luck ☺**