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63/2 (SEM-3) PHY 304

2022

(Held in 2023)

PHYSICS

(Theory Paper)

Paper Code : PHY-304

(Advanced Condensed Matter Physics – I)

Full Marks – 80

Pass Marks – 32

Time – Three hours

The figures in the margin indicate full marks for the questions.

1. Answer *all* the following questions : 1×5=5

(a) The metal-n type semiconductor, where the work function of metal is greater than the semiconductor is a

(i) Rectifying contact

(ii) Ohmic contact

(iii) Near Ohmic contact

(iv) None of the above

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(b) Under reverse bias

- (i) Depletion width of a p-n junction reduces
- (ii) Depletion width of a p-n junction *increases*
- (iii) Built-in potential decreases
- (iv) None of the above

(c) Electroplating technique is suitable for

- (i) Coating with considerable thickness
- (ii) Coating without use of electric current
- (iii) Making conduction films of gold or copper
- (iv) Making dielectric films

(d) Advantage of sputtering is

- (i) Good coating and step coverage
- (ii) Less adhesion
- (iii) Targets wear out uniformly
- (iv) Preserves stoichiometry of multi-component compounds

(e) Which are the main parameters governing film nucleation?

- (i) Substrate temperature and deposition rate
- (ii) Particle density and source temperature
- (iii) Particle mass and energy
- (iv) Particle mass and deposition rate.

2. Answer the following questions : $2 \times 5 = 10$

- (a) Why DC sputtering does not work for an *insulating film*? Explain how do you overcome this?
- (b) What do you mean by size effect? Mention the two fundamental scattering mechanisms of electrons in thin films.
- (c) What are the types of capacitance associated with a p-n junction? Explain.
- (d) Discuss the operating principle of photodiode and LEDs.
- (e) What are the important characteristics of Quantum confinement?

3. Answer any *five* of the following questions :

$$5 \times 5 = 25$$

- (a) Discuss the sol-gel process for the preparation of nanomaterial with the help of block diagram. Write its drawbacks. $4 + 1 = 5$
- (b) Explain the term Nucleation. What are Homogenous and Heterogeneous Nucleations of thin films? Discuss the various pre nucleation theories with the help of diagram. $1 + 1 + 3 = 5$
- (c) What do you mean by Quantum Hall Effect? Explain the phenomenon of integral and fractional quantum Hall Effect. $1 + 4 = 5$

- (d) Obtain the diffusion and drift current density due to electrons and holes in a semiconductor. 5

- (e) Deduce the effective band gap of a quantum dot. How the band gap of a quantum dot is different from its parent bulk material? 4+1=5

- (f) Obtain the density of states of two-dimensional systems. 5

- (g) An abrupt Si p-n junction with cross-section area $A = 0.001 \text{ cm}^2$ has $N_a = 10^{15} \text{ cm}^{-3}$ on one side and $N_d = 10^{17} \text{ cm}^{-3}$ on the other. Calculate the following:

- (i) Contact potential V_0 at room temperature

- (ii) Space-charge width at zero bias voltage

(Consider for silicon, $\epsilon_r = 12$, $n_i = 1.5 \times 10^{10} \text{ cm}^{-3}$ and $\epsilon_0 = 8.85 \times 10^{-12} \text{ F/m}$).

4. Answer any *four* of the following questions: 10×4=40

- (a) (i) Explain the working principle of resistive thermal evaporation with the help of schematic diagram. Discuss the advantages and disadvantages of this technique. 3+2=5

- (ii) Explain the three different growth modes of thin films. Which one of the mode is favorable for smooth, continuous growth of thin film? Explain. 3+2=5

- (b) (i) Write the statement of Beer's law. Discuss the Beer's law for a material having absorption coefficient α and thickness l and hence deduce the relation 1+4=5

$$T = (1 - R)^2 \exp(-\alpha l)$$

(The symbols have their usual meanings.)

- (ii) Explain the term interband luminescence. Discuss the luminescence for direct band gap and indirect band gap semiconductors with the help of schematic band diagram. 1+4=5

- (c) (i) Explain the term Phonon. Discuss the Normal and Umklapp process of phonon scattering using relevant momentum vector diagram. 1+4=5

- (ii) Discuss the inelastic scattering of photons by phonons and hence obtain the relation: 5

$$\Omega = \frac{2\nu\omega\mu \sin \phi}{C}$$

where the symbols have usual meanings.

- (d) Obtain the built-in potential of a p-n junction and deduce the expression for space charge region.

4+6=10

- (e) Discuss the types of semiconductor-semiconductor heterojunctions with energy band diagrams. Draw the energy band diagrams before and after junction of the following given specifications of the semiconductors S_1 (p-type), and S_2 (n-type) and discuss under forward and reverse bias condition.

$$\phi_{m1} > \phi_{m2}$$

$$E_{g1} < E_{g2}$$

$$\chi_1 > \chi_2$$

$$\gamma_1 < \gamma_2$$

6+4=10