2023

PHYSICS — HONOURS

Paper : DSE-A-2.1

[Nanomaterials and Applications]

Full Marks : 65

The figures in the margin indicate full marks.

Candidates are required to give their answers in their own words as far as practicable.

Group - A

1. Answer ***any five*** questions : 2×5

(a) Calculate the energy in eV corresponding to room temperature (300 K).

(b) What are the differences between an amorphous material and a single crystal?

(c) Show mathematically that the surface to volume ratio of a nanoparticle is much higher than that of the identical material in bulk.

(d) Why does an electron microscope have more resolving power than an optical microscope?

(e) Why does a colloid of nano-gold appear wine-red in colour?

(f) An electron is confined in a one-dimensional box of length 5 Å. If the electron makes a transition from the first excited state to the ground state, calculate the frequency of the emitted photon. [Mass of the electron = 9.31×10^{-31} kg.]

(g) The cubic lattice of MnO has lattice constant 4.426 Å. Calculate the inter-planar spacings for the (111) and (211) planes.

Group - B

2. Answer ***any three*** questions : 3×5

(a) (i) What do you mean by density of states?

(ii) Show that the density of states for a free particle of mass m in one dimension varies inversely as the square root of its energy. Plot the variation graphically. 1+(3+1)

(b) (i) What are the intermediate steps associated with the growth of thin films by molecular beam epitaxy (MBE) method?

(ii) Write down the basic differences between the techniques of physical vapour deposition (PVD) and chemical vapour deposition (CVD). 3+2

(c) (i) Distinguish between 'direct band gap semiconductor' and 'indirect band gap semiconductor' using E-K diagram.

(ii) X-ray data is taken using a chromium anode $(\lambda_{Cr} = 2.289\,\text{Å})$. If the spectrum has a line at $2\theta = 45.4^{o}$, what would be the equivalent line position (2θ) for a copper anode $(\lambda_{Cu} = 1.5421\,\text{Å})$? 2+3

(d) (i) What are the differences between Frenkel defects and Schottky defects?

(ii) Show that the density 'n' of Schottky defects in a crystal having 'N' atoms is given by

$$n \approx N \exp\left(-\frac{E_v}{2k_B T}\right),$$

where E_v is the energy required to take an ion from a lattice site inside the crystal to a lattice site on the surface and T is the temperature. 2+3

(e) (i) What are the basic differences between optical and electrical band gap?

(ii) Explain the concept of blue shift observed in nanomaterials. 2+3

Group - C

Answer ***any four*** questions.

3. (a) For a rectangular potential barrier

$$V(x) = V_0 \text{ for } 0 \le x \le a$$
$$= 0 \text{ otherwise}$$

Show that approximate expression for transmission coefficient T is

$$T = \frac{16(V_0 - E)}{V_0^2} e^{-2Ka},$$

where E is the energy of the particle and $E < V_0$ and $K^2 = \frac{2m(V_0 - E)}{\hbar^2}$.

(b) What do you mean by quantum confinement? Calculate the exciton Bohr radius of GaAs using the following data :

Dielectric constant of GaAs = 12.4

Effective mass of electron = 0.067 m_0

Effective mass of hole = 0.45 m_0 where $m_0 = 9.1 \times 10^{-31}$ kg. 6+(2+2)

4. (a) What are the different factors affecting the synthesis of a nanomaterial?

(b) Discuss the basic features of top-down and bottom-up processes in the context of synthesis of nanomaterials. Give suitable examples.

(c) What are the advantages of electron beam evaporation? 2+(4+2)+2

5. (a) What is the full form of AFM? What are the various types of forces acting between tip and surface of the sample in AFM?

(b) What are the basic components of AFM? Discuss their functions.

(c) What are the advantages of an AFM? (1+3)+4+2

6. (a) How can the magnetic properties of a material be tailored with the reduction in size?

(b) What do you mean by magnetic quantum well?

(c) What are the basic differences between NEMS and MEMS?

(d) "Incorporation of nanostructured materials can potentially improve the efficiency of a standard solar cell." — Interpret the statement. 2+2+2+4

7. (a) What is thermoionic emission?

(b) Show that the current density 'J' of thermally escaped electron in the direction perpendicular to the heated metal surface is given by

$$J = AT^2 e^{-\frac{W}{K_B T}}$$

where W is the work function of the metal surface, A is a constant, and K_B is the Boltzmann constant.

(c) Show the variation of 'J' with 'T' graphically.

(d) What is the dimension of the constant 'A'? 2+5+2+1

8. Write short notes on : 5×2

(a) Single electron transistor

(b) Single-wall carbon nanotube.