Ref. No.: Ex/PG/Nano/T/113A/2024

M. TECH. IN NANO SCIENCE AND TECHNOLOGY EXAMINATION, 2024

(1ST Year, 1st Semester)

PROPERTIES OF NANOMATERIALS

Full Marks: 100

Answer any Five questions:

1. (a) Discuss the classical theory of nucleation.
In a solution growth process why does nucleation takes place when solute concentration above some critical value?

Obtain the expression for total energy for a growing nuclei and plot graphically the variation of different contribution along with the total energy with radius. Hence determine the diameter of critical nucleus.

(b) Describe with a diagram crystal growth by Choralski method. What are the advantages and limitations of this method.

(12+8)

2. (a) Define density of state function.
What is periodic boundary condition? Applying periodic boundary condition obtain an expression for the density of state function for a three –dimensional solid.

(b) Show that the density of state function depends on dimension 'd' of a solid by the following general relation

$$D(E) \ \alpha \ E^{\frac{d}{2}-1}$$

(c) Discuss and show graphically how the above function varies with energy for a

(i) Two dimensional solid, like extremely thin films;
(ii) One dimensional solid like Nanorods;
(iii) Zero dimensional solid like quantum dots

(10+6+4)

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3. (a) Explain how the free electrons originate in a metal. Hence discuss qualitatively the origin of energy bands in solids. Draw a schematic diagram to indicate the conduction and valence band of a semiconductor.

(b) Write the expression for Fermi-Dirac distribution function. Plot graphically the variation of Fermi-Dirac distribution function with energy, taking temperature as a parameter. Show the Fermi-energy in such a plot.

(c) Suppose a one dimensional potential is defined as follows

$V(x) = 0$ for $0 < x < L$
$V(x) = \infty$ otherwise

Write down the Schrodinger equation for the above and solve it for energy eigen values and also for wave function. Plot the wave functions in first three energy levels and also show probability density.

(d) Calculate the Fermi level if there are N number of electrons in the potential well. What will happen to the energy levels if L becomes in the nanometer range.

(8+4+8)

4. (a) What do you understand by symmetry of crystal? Mention the different symmetry elements of a crystal. Suppose you have a cubic crystal- mention how many kind of symmetry elements it may have.

(b) Considering one-dimensional potential well for a metal find an expression for Fermi energy in terms of electron density of the metal.

(c) Write the expression for electrical conductivity and mention the parameters on which it depend. How can you determine band gap from the temperature variation of electrical conductivity of a semiconductor.

(8+6+6)

5. (a) Draw a block diagram to show different components of a spectrophotometer.

(b) Discuss how absorption of transmission spectra of a thin films can be obtained from such a spectrophotometer. Hence discuss how you can determine energy band gap of a nanocrystalline material.

(c) Band gap of GaP is 2.26 eV . Find the wavelength emitted by a gallium phosphide LED (light emitting diode). Comment on the portion of the electromagnetic spectrum on which it belongs.

(d) A beam of X-rays of wavelength 0.071 nm is diffracted by (110) plane of rock salt with lattice constant of 0.28 nm. Find the glancing angle for the second-order diffraction.

(4+8+4+4)

6. Write shorts notes

(i) One method of synthesizing nanocrystal
(ii) Float zone method of crystal growth
(iii) Determination of density of states of a semiconductor
(iv) Quantum size effect

(4x5)