NANOTECHNOLOGY
(CHEN 3233)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) 2D nanomaterials have _____ dimension in the nanometer range
(a) one (b) two (c) two and half (d) zero

(ii) At sizes below 10 nm, the melting point of copper will _____ the size of the nanoparticle
(a) increase with (b) decrease with
(c) be independent of (d) fluctuate with

(iii) The process of ball milling to generate nanoparticle is
(a) a top down approach (b) a bottom up approach
(c) a typical example of self-assembly (d) none of these.

(iv) The precursors for depositing polycrystalline silicon are
(a) silane (b) trichlorosilane (c) both (a) and (b) (d) either (a) or (b).

(v) Ferritin is a naturally occurring _____ used as a _____ to create nano particles
(a) carbohydrate, substrate (b) nucleotide base, substrate
(c) fat molecules, substrate (d) protein, template

(vi) DNA denaturation is a process by which
(a) a sDNA decomposes into its nucleotide bases
(b) the hydrogen bonds in the nucleotide base pairs dissociate
(c) dDNA separates into sDNAs
(d) none of these.

(vii) In scanning electron microscope, the primary electron beam hits the sample and produces
(a) X-rays (b) Secondary electrons (c) Auger electrons (d) All of these

(viii) The component of FTIR comprising two mirrors and a beam splitter is known as
(a) Photomultiplier tube (b) Interferometer
(c) Diffraction grating (d) Prism.

(ix) The primary and secondary beams in XPS are
(a) X-rays and electrons (b) Electrons
(c) Electrons and ions (d) X-rays.

(x) Microcontact printing is a special case of _____
(a) soft lithography (b) Dip pen lithography
(c) photolithography (d) none of these

Fill in the blanks with the correct word

(xi) Reducing a 1 cm^3 cube of Platinum block to several 1 nm^3 blocks will generate a total surface area of _____ for all blocks.

(xii) The differences between PVD and CVD are i _____ and ii _____

(xiii) A detector used in EDXRF analysis is _____.

(xiv) The key element of an AFM is a_____ force sensor.

(xv) The equation used for calculating the crystallite size using information from XRD is _____.

Group - B

2. (a) For nanocrystalline ferromagnetic materials, define critical radius. What is the relationship between critical radius and saturation magnetization? *[(CO1)(Apply/IOCQ)]*

(b) What are excitons? Mathematically state the exciton Bohr radius explaining all terms contained in the equation. *[(CO1)(Understand/LOCQ)]*

(c) With a graph, explain the effects on absorption spectrum of PbSe nanocrystal as the particle size goes from 9 nm to 3 nm? *[(CO1)(Apply/IOCQ)]*

4 + 4 + 4 = 12

3. (a) What do you mean by density of states D(E)? *[(CO1,CO3)(Remember /LOCQ)]*
   (b) What do you mean by Fermi energy? *[(CO1)(Remember/LOCQ)]*
   (c) Draw graphs showing how D(E) vs E curve for bulk material and 1D quantum wire? *[(CO1)(Apply/IOCQ)]*
   (d) In a 1D nanomaterial, which are the directions of (i) confinement and (ii) delocalization respectively? State the reason behind choosing the direction. *[(CO1)(Apply/IOCQ)]*

2 + 2 + 4 + 4= 12

Group - C

4. (a) Pulsed laser deposition is a technique that is used to deposit films with desired stoichiometry. Explain the process with a labelled schematic. *[(CO2)(Remember/LOCQ)]*
   (b) How is this technique different from sputter deposition? *[(CO2)(Remember/LOCQ)]*
   (c) Why is a laser beam used in this process? *[(CO2)(Apply/IOCQ)]*

6 + 4 + 2 = 12

5. (a) What is chemical vapor deposition? *[(CO2)(Remember/LOCQ)]*
   (b) What is a micellar solution? State one specific example of micellar reaction producing nanoparticle. *[(CO2)(Remember/LOCQ)]*
   (c) Effusion cells in molecular beam epitaxy have W-Re thermocouples. Why? *[(CO2)(Analyze/IOCQ)]*
   (d) When would you say that a deposited layer is epitaxial? *[(CO2)(Remember/LOCQ)]*

2 + 5 + 3 + 2 = 12

Group - D

6. (a) Explain the difference in the working principle and construction of a scanning tunnelling microscope and an atomic force microscope. *[(CO4)(Analyse/IOCQ)]*
   (b) Discuss the sample preparation technique for SEM analysis. Explain the working principle of an Everhart-Thornley detector. *[(CO4)(Remember/LOCQ)]*
   (c) The figures below show a comparison between the Raman spectra (Fig. A) and the surface enhanced Raman scattering spectra of gold nanoparticles of different geometries dispersed in dye solution (Fig. B and C). The SPR for monodispersed (nonaggregated) spheres is 560 nm. Comment on the conclusions drawn from the figures.

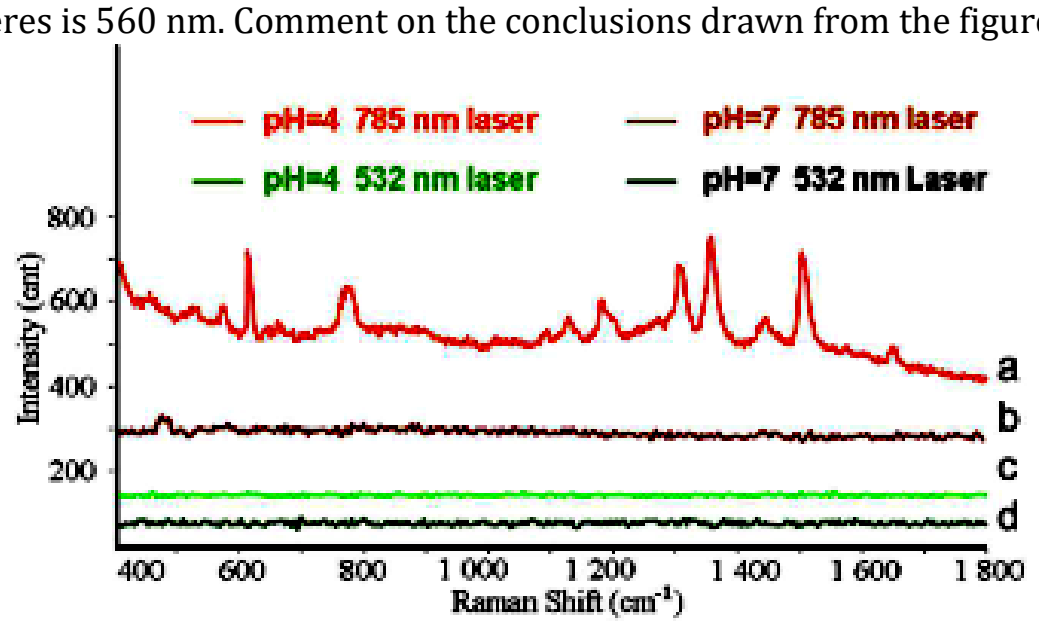

Fig. A Raman shift for **a** 785 nm pH 4 **b** 785 nm pH 7 **c** 532 nm pH 4 and **d** 532 nm pH 7

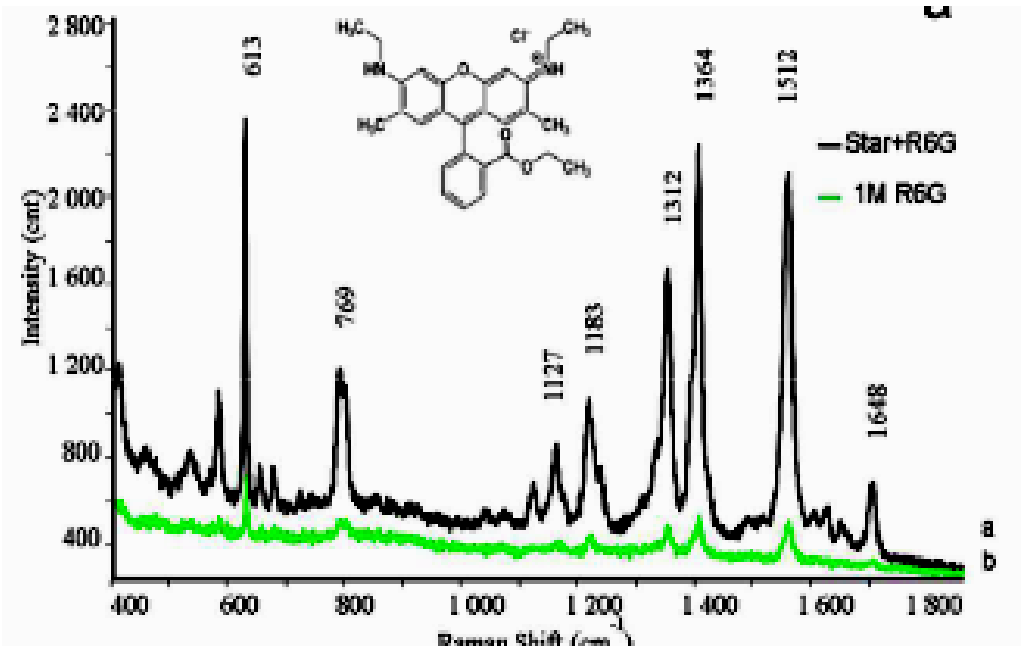

Fig. B SERS spectra for **a** nanostars + R6G dye and **b** nanostars

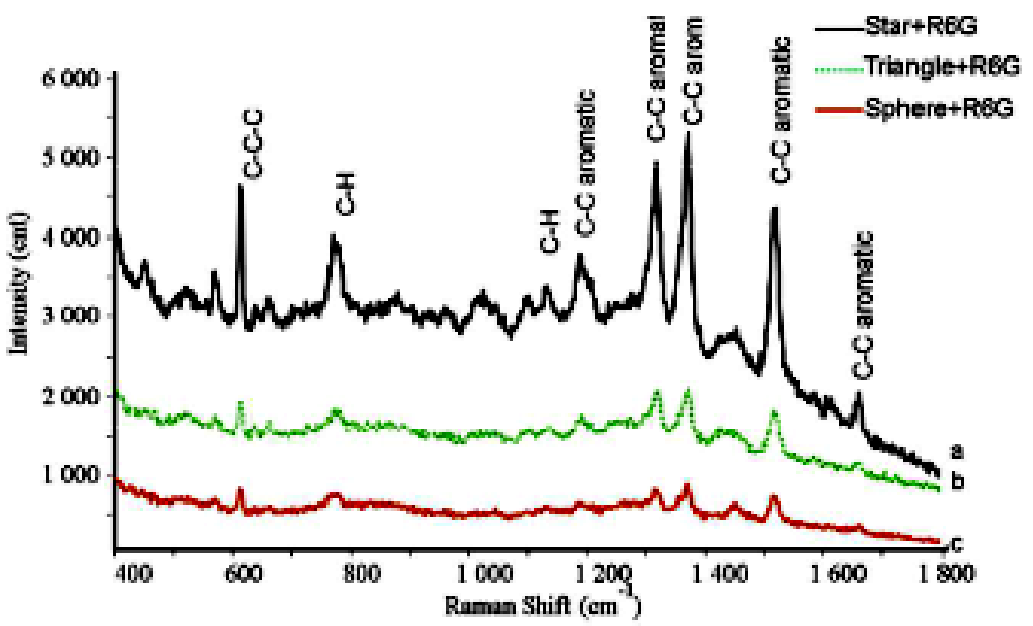

Fig. C SERS spectra for **a** stars +R6G **b** Triangle + R6G **c** Sphere + R6G

[(CO4)(Apply/IOCQ)]

4 + (3 + 2) + 3 = 12

7. (a) Calculate the particle size using Scherrer equation with the following information obtained from XRD of $CoFe_2O_4$ sample, wavelength of copper Kα line 1.5406 A, Bragg's angle of diffraction 36.23, Miller index (311) and FWHM 0.4 degree. *[(CO3)(Analyse/HOCQ)]*

(b) Discuss the working principle of a Michelson interferometer with diagram. From the Fig.D below, what information can be extracted from the FTIR patterns of pure ZnO and nickel doped ZnO? *[(CO4)(Analyze/IOCQ)]*

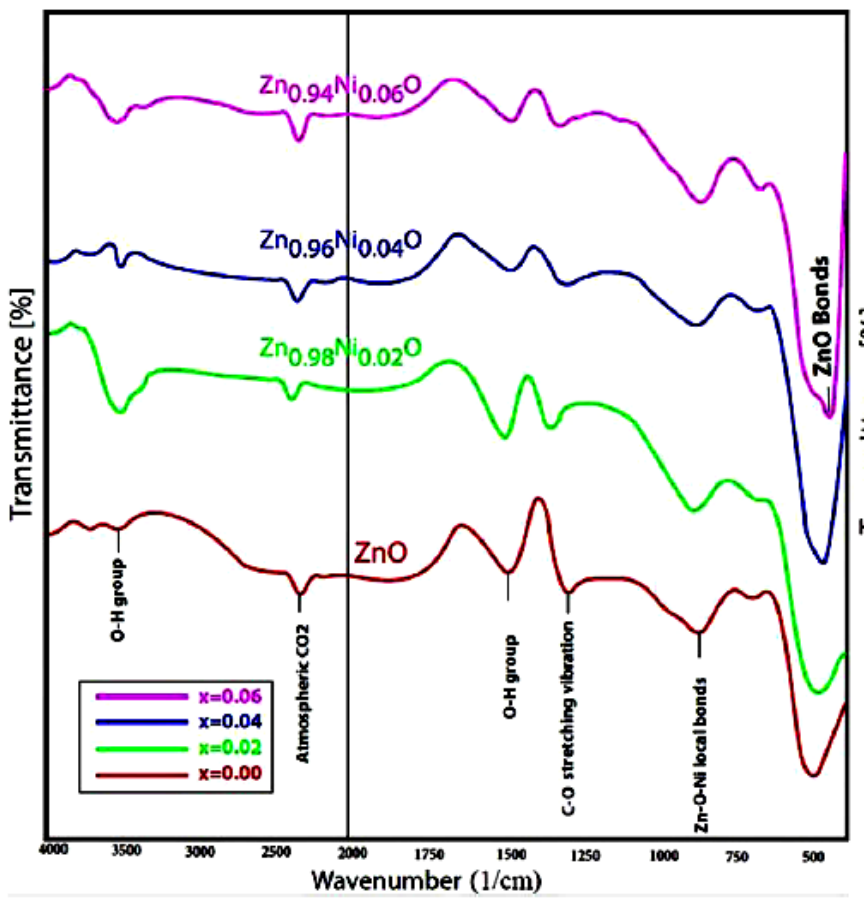

Fig. D FTIR pattern for ZnO and Ni-doped ZnO

(c) Explain the basic difference between XRF and XPS in terms of elemental analysis. Discuss the function of electron energy analyzer with the aid of schematic diagram. *[(CO4)(Remember/LOCQ)]*

3 + (3 + 2) + (2 + 2) = 12

Group - E

8. (a) State two applications of carbon nano tubes. How are they different from graphite? *[(CO3)(Remember/LOCQ)]*

(b) Describe the most widely used method of synthesis of carbon nano tubes. *[(CO2)(Remember/LOCQ)]*

(c) Dip pen lithography is widely used to print nano dots on a surface. Describe the process of attaching nano-dots to a surface with a specific example. *[(CO2)(Apply/IOCQ)]*

4 + 4 + 4 = 12

9. (a) Photoresists are material with certain characteristics rendering them suitable for photolithography. What are the characteristics? *[(CO3)(Apply/IOCQ)]*

(b) Channels in microfluidic devices are created by a process. Describe the process of channel creation with schematics. *[(CO3)(Analyze/HOCQ)]*

(c) What are aerogels? State two important properties of aerogels. *[(CO3)(Remember/LOCQ)]*

4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	50	42.70	7.30

Course Outcome (CO):

After the completion of the course students will be able to

The objective of the course is to provide an elaborated concept of different unit operations that are required in an industry. After completion of the course students will be able to:

1. Exhibit knowledge of the fundamentals of solid state physics, lattice and atomic structure, energy bands and different types of bonding in matter.
2. Classify the various types of process used in nano-manufacturing of 1D, 2D and 3D nanostructures.
3. Exhibit knowledge of the relevant physical, chemical, mechanical, electrical and optical properties of materials in nano configuration.
4. Exhibit understanding and decide on measurements and instruments used for characterizing nanomaterial.

**LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question.*