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) The total energy of an electron in a 1D nanowire extending in the x-direction is equal to the sum of Fermi energy and
(a) delocalized motion along x direction
(b) restricted motion along x direction
(c) restricted motion in y and z direction
(d) delocalized motion in y and z direction.

(ii) In moving from 3D bulk material to quantum dots, the material bandgap shifts
(a) towards longer wavelengths (b) towards higher energies
(c) towards infra-red region (d) none of above.

(iii) Coercive field of magnetization is used
(a) to enable magnetization of a ferromagnetic material
(b) to zero out the magnetization of the material
(c) in parallel to the applied magnetic field
(d) none of above.

(iv) The sol gel method requires two steps in a specific order
(a) hydrolysis and gel formation (b) hydrolysis and drying
(c) hydrolysis and condensation (d) condensation and hydrolysis.

(v) Langmuir Blodgett films are formed
(a) by chemical reaction on a substrate
(b) by ordered arrangement of long chain molecules on a substrate
(c) by coating a colloidal gel on a substrate
(d) none of these.

(vi) A commonly used field emission gun is
(a) Tungsten crystal with 100 nm tip radius (b) Tungsten filament gun
(c) Lanthanum hexaboride gun (d) Both (a) and (b)

(vii) If i_p is the probe current, C_s spherical aberration, β the beam brightness and λ the wavelength of electrons, the minimum probe size in SEM is expressed as

(a) $d_{\min} = KC_s^{1/4}\left(\frac{i_p}{\beta} + \lambda^2\right)^{3/8}$ (b) $d_{\min} = KC_s^{1/4}\left(i_p\beta + \lambda\right)^{3/8}$

(c) $d_{\min} = KC_s^{1/4}\left(i_p\beta + \lambda\right)^{2}$ (d) $d_{\min} = KC_s^{1/4}\left(\frac{i_p}{\beta} + \lambda\right)^{3/8}$

(viii) Photolithography uses _____ to draw patterns on a surface
(a) x rays (b) visible light
(c) electrons (d) gamma rays

(ix) Aerogel are widely used
(a) for creating a water resistant coating (b) as a moisture absorber
(c) as an electrical conductor (d) for thermal insulation

(x) Zeolites have a _____ structure
(a) cylindrical (b) octagonal
(c) tetrahedral (d) buckyball

Fill in the blanks with the correct word

(xi) Fermi energy in a 1D nanomaterial is express by _____.

(xii) An example of physical vapor deposition process is _____.

(xiii) The nearfield van der Waals force between the probe tip and sample in AFM is expressed as _____.

(xiv) Scherrer equation for calculating particle diameter in XRD is expressed as _____.

(xv) The resolution of patterns printed with photolithography is a function of _____.

Group - B

2. (a) Assume a rectangular solid of length, *D*, breadth *D/2* and thickness *D/4*. Calculate the surface to volume ratio of this solid in terms of *D.* *[(CO1)(Analyse/HOCQ)]*
(b) With appropriate mathematical expression, explain why 10 nm Cu nanoparticle exhibit a higher melting point than bulk copper. *[(CO1)(Remember/IOCQ)]*
(c) Why does the absorption edge shift towards blue as the confinement dimension is reduced? *[(CO1)(Remember/LOCQ)]*

4 + 4 + 4 = 12

3. (a) What are surface plasmons? What conditions are necessary for the creation of surface plamson? *[(CO1)(Analyse/HOCQ)]*
(b) What changes in <u>electrical</u> properties are observed in going from bulk to nano size and why? State with an example. *[(CO1)(Remember/LOCQ)]*
(c) Explain the phenomena of electron tunnelling. *[(CO1)(Apply/IOCQ)]*

4 + 4 + 4 = 12

Group - C

4. (a) What do you mean by chemical vapor deposition? State the chemical reactions for two different metal that are deposited through chemical vapor deposition. *[(CO2)(Understand/LOCQ)]*

   (b) How is the process of molecular beam epitaxy different from evaporation methods for depositing thin films? *[(CO2)(Remember/LOCQ)]*

   (c) What is a plasma and how is it formed? What is the mechanism by which the target material is transported to the substrate in sputter deposition? *[(CO2)(Remember/LOCQ)]*

4 + 4 + 4 = 12

5. (a) Describe the reaction and mechanism of formation of silica gel. Provide reactions where needed. *[(CO3)(Analyse/HOCQ)]*

   (b) What is supercritical drying? Why is supercritical drying necessary in aerogel formation? *[(CO4)(Remember/LOCQ)]*

   (c) What are amphiphilic molecules? Give an example of amphiphilic molecule and state the process where these molecules are used. *[(CO2)(Apply/IOCQ)]*

4 + 4 + 4 = 12

Group - D

6. (a) Distinguish between bright and dark field imaging with diagram. *[(CO3)(Analyse/IOCQ)]*

   (b) Both phase contrast and polarized light microscopes work on the principle of phase change to amplitude change. Comment on the validity of the statement by briefly discussing the working principle of both. *[(CO3)(Apply/IOCQ)]*

   (c) Discuss the function of dichroic mirror in fluorescence microscopy. *[(CO3)(Remember/LOCQ)]*

   (d) Distinguish between transmission electron microscope and transmission optical microscope. *[(CO3)(Apply/IOCQ)]*

3 + 5 + 2 + 2 = 12

7. (a) From the SEM images of nanocubes shown below, compute the Ferret diameter and average diameter of the particles. Assume a scale of 100 nm = 4.8 cm. *[(CO3)(Analyse/HOCQ)]*

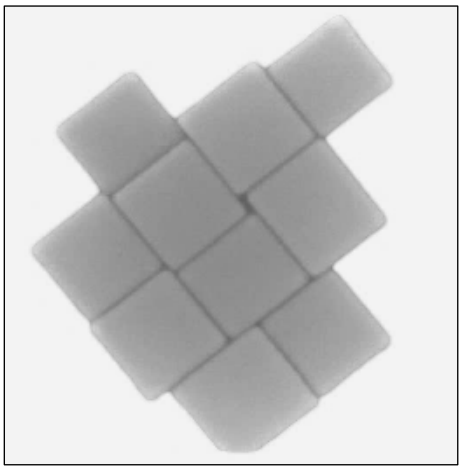

Fig. SEM images of $AuCu_3$ nanocubes

(b) "The imaging mode in HRTEM differs from the imaging modes used in TEM." Comment on the validity of the statement with appropriate diagram. *[(CO3)(Apply/HOCQ)]*

(c) Distinguish between XRD and SAD. *[(CO3)(Remember/LOCQ)]*

4 + 5 + 3 = 12

Group - E

8. (a) State the advantages and disadvantages of electron beam lithography. *[(CO4)(Understand/LOCQ)]*

(b) Describe the process of Dip-pen lithography with special mention of the components and chemicals used. *[(CO4)(Remember/LOCQ)]*

(c) With a schematic, explain the process of replica molding. *[(CO4)(Understand/LOCQ)]*

4 + 4 + 4 = 12

9. (a) What is soft lithography? State two ways it is similar to photolithography. *[(CO4)(Analyse/HOCQ)]*

(b) What is LIGA? Describe the process. *[(CO4)(Remember/LOCQ)]*

(c) Describe the process used in the synthesis of gold coated silica microspheres. *[(CO4)(Apply/IOCQ)]*

4 + 4 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	46.88	27.08	26.04