M. Sc. Physics Semester-IV

Examination May-2017

Paper: PHYS 531- Physics at Nanoscale (Part-II)

Time: 3 Hours **Total Marks: 70**

Attempt all the questions as directed

Q1: Answer **all** the questions 1x10=10

i. Sketch the Gibbs' free energy versus temperature for a first order phase transition.

ii. When does the electron exhibit ballistic transfer? Calculate the minimum resistance for this system.

iii. Define two growth techniques for the formation of thin films following the self-assembly process.

iv. What is the biological process that purifies the colloidal solution in the human body?

v. Calculate the time (τ) for an electron to escape from an energy level (E) at 3.2 eV with broadening (Γ) of 100 meV to the nearest gold electrode (E_f = 5.2 eV).

vi. Name two techniques for estimating the composition of any alloy.

vii. Does spinodal decomposition provide uniform distribution of the final alloy? How?

viii. What is the function of a linker in functionalizing a molecular entity onto a nanostructure?

ix. How does the change in Gibbs' potential for solid depend on the nucleation barrier in a homogeneous nucleation process?

x. How does the thickness of the boundary layer vary as a function of gas viscosity, density and gas stream velocity parallel to the surface of the substrate?

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Q2: Answer **all** the questions 2×10=

i. What are the conditions of the total Gibbs' free energy in the temperature-composition phase diagram at the binodal and spinodal boundaries?

ii. What is the kinetic energy of photoelectrons generated in gas and solid systems?

iii. Plot the current versus voltage characteristics for a metal-nanoparticle-metal structure without and with orbital broadening due to temperature.

iv. In an artificial atom, where dN/dE is the density of states, ΔE is the difference in energy levels, Γ is the energy level broadening, find the conductance (G).

v. What are the advantages and disadvantages of the MBE technique for ultra-thin film growth?

vi. Plot the energy level spectrum for metal and semiconducting nanoparticles.

vii. In a single electron transistor, calculate the energy required to add one electronic charge into the nanostructure (NS) system having 10 pF capacitance. How does the total energy of the NS change as a function of charge?

viii. In SEM imaging, what is the depth (Δd) and width (Δw) on the sample surface upto which the electron beam can enter? What would be the values for Δd and Δw for a sample of density 10 g cm^{-3}, when excited with 20keV electron beams?

ix. Define fine and coarse dispersion. Is molecular solution a true solution?

x. Write down the steps to functionalize a biomolecule on a gold nanoparticle.

Q3: Answer any five questions 5×8=40

i. What is the origin of miscibility gap? Describe the phase transformation for spinodal decomposition. For an alloy with compositional interaction of 0.4, what would be the critical temperature at which the miscibility gap vanishes in the phase diagram? (2+3+3)

ii. What is an artificial atom? Plot and discuss the locus of points for achieving peaks in differential conductance [$\delta G = \delta I/\delta V_{sd}$] by applying minimal source-drain voltage (V_{sd}) and changing the gate voltage (V_g). Discuss the appearance of conductance diamonds in V_{sd} - V_g graph. (3+5)

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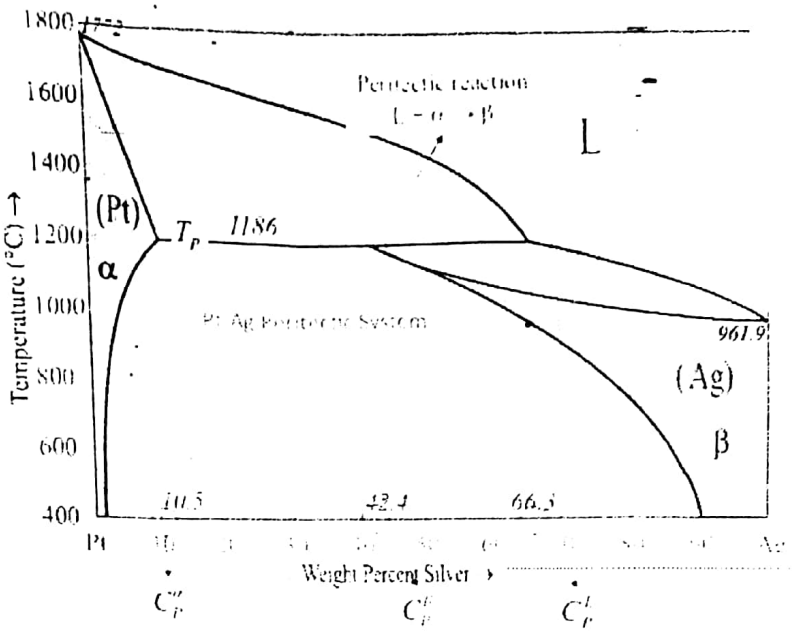
iii. Draw the Gibbs' free energy diagrams at different transition temperatures for the Pt-Ag alloy composition that represents a monotectic system with phase transition as in the diagram.



iv. Write brief notes on micelle and reverse micelle techniques for formation of nanostructures. A micelle structure is constructed with the linker having molecular chain length of 2 nm and a head group of 0.4 nm. Find the packing parameter of the micelle formed with a sphere of diameter 4.5 nm. (3+3+2)

v. Explain the working principle of the scanning electron microscope with emphasis on various parts attached to it.

vi. Derive Kelvin's equation. What would be the critical radius of a water droplet formed at the vapor-water interface at room temperature, considering the density of water as 1 g cm^{-1} and surface tension as 72.8 mN m^{-1}? Gas constant R is 8.314 J/mol K. (4+4)