Thapar University
School of Physics & Materials Science
M. Tech. First Year, Second Semester, 2006-2007
End Semester Examination

Course Code: MS 112
Course Name: Nanomaterials & Nanotechnology
Instructor: S. D. Tiwari

Date: May 24, 2007
Time Allowed: 3 hr
Maximum Marks: 45

Note: Attempt all questions. Show all steps in your derivations/calculations.

1. (a) What is quantum well? Solve the Schrodinger equation for an infinitely deep quantum well of width L to find eigen functions and eigen values.

(b) What are the energies of first and second energy levels in a 100 Å GaAs quantum well? Assume that you can treat the problem by an infinite barrier approximation? Effective mass of an electron in GaAs is 0.067 m_0. (4.5 + 4.5)

2. (a) Consider a cube of dimensions 1 nm × 1 nm ×1 nm. Calculate the energy difference between the ground state and first excited state of an electron in this cube. Can we observe the quantum size effect in this cube at room temperature?

(b) Calculate the number of atoms in a 5 nm particle of an element. The element has a FCC structure with lattice constant 4.2 Å. Calculate the number of atoms lying on the surface of the particle assuming that surface of the particle has thickness of one lattice constant. Also calculate fraction of atoms lying on the surface of the particle. (4.5 + 4.5)

3. (a) Full width at half maximum of an x-ray diffraction peak (at $2\theta_B = 43^0$) from small particles of iron is 2.76^0.The full width at half maximum of same peak from bulk iron is 0.32^0. Calculate the average crystallite size of the sample of small particles. The wavelength of x-ray used is 1.54 Å.

(b) Magnetization M as a function of magnetic field H is performed on small particles of a magnetic material at 300 K. The magnetization increases linearly with increasing magnetic field with a slope 3.5×10^{-4} emu g^{-1} $gauss^{-1}$. Calculate the average particle magnetic moment in Bohr magnetons. Number of particles in one gram sample is given to be 3.4×10^{18}. (4.5 + 4.5)

4. (a) In a selected area electron diffraction pattern from nanoparticles of a given sample, concentric rings are observed. Derive a relation among d, r, D and λ. Where r is radius of ring in the pattern corresponding to a family of parallel atomic planes with spacing d. D and λ are normal distance between sample and screen and wavelength of electron beam respectively.

(b) In a given SAD pattern of an unknown sample radii of first, second, third, ... rings from center are 8.85 mm, 10.15 mm, 14.40 mm, 16.85 mm, 17.60 mm, ... respectively. Determine the crystal structure of the sample. Also calculate the d values corresponding to the observed rings. D and λ are given to be 60 cm and 0.035 Å respectively. (4.5 + 4.5)

5. (a) What are the advantages of chemical methods over physical methods for the preparation of nanoparticles?

(b) What is coprecipetation method? Discuss this method for the preparation of nanoparticles of $MnFe_2O_4$. Also write the required precautions for this method.

(4.5 + 4.5)

Useful information:

(i) Plank's constant $h = 6.63 \times 10^{-34}$ J s
(ii) Mass of free electron $m_0 = 9.1 \times 10^{-31}$ kg
(iii) Boltzmann constant $k = 1.38 \times 10^{-16}$ emu gauss K^{-1}
(iv) 1 Bohr magneton $= 0.9271 \times 10^{-20}$ emu