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**CS/M.Tech (ECE)/SEM-2/MVM-204A/2010**

# 2010

# QUANTUM & NANOELECTRONICS

*Time Allotted* : 3 Hours Full Marks : 70

*The figures in the margin indicate full marks.*

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

Answer Question No. 1 and any *four* from the rest.

1. Answer any *seven* questions : 7 × 2

   i) What are the nanostructured materials ?

   ii) Define Quantum dot ?

   iii) Mention a few applications of nanostructured materials ?

   iv) What are the advantages of Silicon-nanocrystal over the bulk Silicon ?

   v) Write down the time-independent Schrodinger equation with proper notation ?

   vi) What are the different modes of using Atomic force microscopy ?

   vii) What are the critical issues for nanostructure synthesis and assembly ?

   viii) What is chiral vector and chiral angle ?

   ix) What materials are used for tip fabrication of Atomic force microscopy system ?

2. a) How can you differentiate the quantum dots, quantum wire an nanotube ?

   b) Why are nanostructure materials (scientifically) interesting ?

   c) What are the properties of nanocrystalline materials ?

6 + 4 + 4

3. a) Describe a process to form Si-nanocrystals with diameter 2·5 – 5 nm, which is compatible with semiconductor processing techniques used in industry.

   b) The following figure is showing the XPS characteristics curves of Silicon implanted $SiO_2$ films annealed for 10 minutes with different temperature. From the figure, at what temperature the nanocrystalline Silicon is observed ? Explain the other curves.

Binding Energy (eV)

   c) You want to form the Germanium nanoparticles by decomposing organogermane in the presence of octanol $(C_8H_{18}O)$ as capping ligand in SC-hexane at 400-500° C. Describe the detail process.

4. a) "*A catalyst of 10 nm nanoparticles is 100 times more reactive than the same amount of material in 1 micron particles*". Justify the above statement with a simple experiment.

b) Imagine that an electron is trapped in a one-dimensional box whose length is 1·1 nm. Starting with the following equation for electron wavefunction in $H_2$ atom :

$$-\frac{\hbar}{2m}\frac{d^2\psi z}{dz^2}+V(z)\psi(z)=E\psi(z)$$

Infinite well : $V_0 \to \infty$

Calculate the energy eigenvalues and sketch the eigenfunctions for $n$ = 1 – 6.

c) What is the wavelength of an electron traveling at a velocity which is 39% of the speed of light ?

Plank's constant = $6{\cdot}626 \times 10^{-34}$ J–s, Mass of an electron = $9{\cdot}11 \times 10^{-31}$ kg. 6 + 4 + 4

5. a) You want to see the following image of Platinum surface. Which technique of surface probe microscopy, you should use ? Give in detail, the system components with proper schematics.

   b) Define piezoelectric effect with proper diagram.

   c) What is the function of photodetector in Atomic force microscopy ? 1 + 5 + 5 + 3

6. a) What are the important properties of Carbon Nanotube ?

   b) How can you classify the Arm chair and Zigzag geometry of Carbon Nanotube ? Which one is showing metallic behavior ?

   c) How can you form the Single-walled Nanotube as well as Multi-walled Nanotube using ARC discharge method ? 2 + 3 + 1+ 8

7. a) What is the difference between Single Electron Transistor (SET) and conventional MOSFET ?

   b) Explain the functionality of SET with basic operation of Single electron box.

   c) What is Coulomb Blockade ? 4 + 7 + 3