III Year B.Sc.-Physics Program: V Semester

PHYSICS ELECTIVE-EA-2: NANO MATERIALS AND APPLICATIONS

Work load: 60 hrs./ Semester **4 hrs./ Week**

COURSE OBJECTIVES

The syllabus introduces the basic concepts and principles to understand nanomaterials. Various nanomaterials synthesis/ growth/ preparation methods and characterization techniques are discussed to explore the field. The effect of dimensional confinement of charge carries on the electrical, optical and structural properties are also discussed. The concept of micro- and nano- electro mechanical systems (MEMS and NEMS) and important applications areas of nanomaterials are discussed.

COURSE LEARNING OUTCOME

At the end of the course the student is expected to possess the following concepts:

- In the Nano systems and its implications in modifying the properties of materials at thenanoscale.
- Concept of Quantum confinement, 3D,2D,1D and 0D nanostructure with examples.
- Different synthesis techniques including top down and bottom-up approaches.
- Characterization of nanostructured materials using X-ray diffraction (XRD), electron microscopy (SEM & TEM), Atomic Force Microscopy (AFM) and Scanning Tunneling Microscopy (STM).
- Optical properties of nanostructured materials, modification of band gap, excitonic confinement.
- Applications of nanostructured materials in making devices namely MEMS, NEMS and other heterostructures for solar cell and LEDs.
- The student will synthesize nanoparticles by different chemical routs and characterize them in the laboratory using the different techniques he has learnt in the theory.

BROAD CONTENTS OF THE COURSE

- Nanoscale Systems
- Synthesis of Nanostructure Materials
- Characterization
- Optical Properties
- Applications of Nanomaterials

SKILLS TO BE LEARNED

- Develop basic understanding of nanostructured materials.
- Learn the synthesis and characterization of nanostructured materials.
- Understanding the optical properties of nanostructured materials.
- Basics of electron transport phenomenon.
- Lean to understand the functioning of various analytical techniques:
- XRD, SEM, TEM, STM, AFM etc.
- Application of nanoparticles in various fields like:
- LED, Solar Cells
- Single Electron Transform Devices
- Magnetic Data Storage
- Micro-electrochemical Systems (MEMS)
- Nano- electrochemical Systems (NEMS)

DETAILED CONTENTS OF THE COURSE

UNIT-I **(15 Lectures)**

NANOSCALE SYSTEMS: Length scales in physics, Nanostructures: 0D, 1D, 2D and 3D nanostructures (nanodots, nanowires, nanorods, thin films), Band structure and density of states of materials at nanoscale, Size Effects in nano systems, Quantum confinement: Applications of Schrodinger equation- Infinite potential well, potential step, potential box, quantum confinement of carriers in 3D, 2D, 1D, 0D nanostructures and its consequences.

UNIT-II **(10 Lectures)**

SYNTHESIS OF NANOSTRUCTURE MATERIALS: Top down and bottom-up approach with examples. Ball milling. Physical vapor deposition (PVD): Thermal evaporation, E-beam evaporation, Pulsed Laser deposition. Chemical vapor deposition (CVD), chemical reduction, Sol-Gel., Electron deposition. Spray pyrolysis. Hydrothermal synthesis. MBE growth of quantum dots. Biological methods- Synthesis using micro organisms and bacteria, Synthesis using plant extract.

UNIT-III **(10 Lectures)**

CHARACTERIZATION TECHNIQUES: XRD, Optical Microscopy, SEM, TEM, AFM, XPS, Scanning Tunneling Microscopy and PL characterization techniques for nano materials.

UNIT-IV **(10 Lectures)**

OPTICAL PROPERTIES: Optical properties by IR and Raman Spectroscopy, Concept of dielectric constant for nanostructures, Quasi-particles and excitons. Excitons in direct and indirect band gap semiconductor nanocrystals. Quantitative treatment of quasi- particles and excitons. **Radiative processes:** General formalization-absorption, emission and luminescence. Optical properties of heterostructures and nanostructures.

UNIT-V **(15 Lectures)**

APPLICATIONS OF NANOMATERIALS: Applications of nanoparticles, quantum dots, nanowires and thin films for photonic devices (LED, solar cells). Single electron transfer devices (no derivation). CNT based transistors. Nanomaterial Devices: Quantum dots heterostructure lasers, optical switching and optical data storage. Magnetic quantum well; magnetic dots - magnetic data storage. Micro Electromechanical Systems (MEMS), Nano Electromechanical Systems (NEMS).

Text Books

1. C.P. Poole, Jr. Frank J. Owens, Introduction to Nanotechnology (Wiley India Pvt. Ltd.).
2. S.K. Kulkarni, Nanotechnology: Principles & Practices (Capital Publishing Company).
3. K.K. Chattopadhyay and A. N. Banerjee, Introduction to Nanoscience and Technology (PHI Lear. Pvt. Ltd.)

Reference Books

1. Richard Booker, Earl Boysen, Nanotechnology (John Wiley and Sons).
2. M. Hosokawa, K. Nogi, M. Naita, T. Yokoyama, Nanoparticle Technology Handbook (Elsevier, 2007).
3. Introduction to Nanoelectronics, V.V. Mitin, V.A. Kochelap and M.A. Stroscio, 2011, Cambridge Univ. Press.
4. Bharat Bhushan, Springer Handbook of Nanotechnology (Springer-Verlag, Berlin, 2004).