

GENERIC ELECTIVE (GE - 17) NANO PHYSICS

Course Title & Code	Credits	Credit distribution of the course			Eligibility Criteria	Pre-requisite of the course
		Lecture	Tutorial	Practical		
Nano Physics GE - 17	4	2	0	2	Class XII Pass with Science	NIL

LEARNING OBJECTIVES

The syllabus introduces the basic concepts of nanomaterials, their synthesis, properties exhibited by them and finally few applications. Various nanomaterial synthesis/growth methods and characterizations techniques are discussed to explore the field in detail. The effect of dimensional confinement of charge carries on the electrical, optical and structural properties will be discussed. Interesting experiments which shape this field like conductance quantization in 2DEG (Integer Quantum Hall Effect) and coulomb blockade are introduced. The concept of micro- and nano-electro mechanical systems (MEMS and NEMS) and important applications areas of nanomaterials are discussed.

LEARNING OUTCOMES

On successful completion of the course students should be able to,

- Explain the difference between nanomaterials and bulk materials and their property difference.
- Explain various methods for the synthesis/growth of nanomaterials.
- Explain the role of confinement on the density of state function and so on the various properties exhibited by nanomaterials compared to bulk materials.
- Explain the concept of quasi-particles such as excitons and how they influence the optical properties.
- Explain the direct and indirect band gap semiconductors, radiative and non-radiative processes and the concept of luminescence.
- Explain the structure of 2DEG system and its importance in quantum transport experiments, like integer quantum Hall effect and conductance quantization.
- Explain the conductance quantization in 1D structure and its difference from the 2DEG system.
- Explain the necessary and sufficient conditions required to observe coulomb blockade, single electron transistor and the scope of these devices.
- Explain how MEMS and NEMS devices are produced and their applications.

SYLLABUS OF GE - 17

THEORY COMPONENT

Unit – I – Introduction

(3 Hours)

Basic introduction to nano-science and technology - Implications on nanoscience on fields like Physics, Chemistry, Biology and Engineering, Classifications of nanostructured materials

as quantum dots (0D), nanowires (1D), Thin films (2D) and Multilayered materials or super lattices; introduction to properties like mechanical, electronic, optical, magnetic and thermal properties and how they change at nano scale dimensions to motivate students (qualitative only).

Unit – II - Nanoscale Systems (8 Hours)

Brief review of Schrodinger equation and its applications in- Infinite potential well, potential step and potential box problems, band structure and density of states of 3D and 2D systems in detail and qualitatively for 1D and 0D, confinement of charges in nanostructures their consequences on electronic and optical properties.

Unit – III - Properties of Nano Scale systems (10 Hours)

Time and length scales (diffusion, elastic and inelastic lengths etc.) of electrons in nanostructured materials, Carrier transport in nanostructures: diffusive and ballistic transport
2D naomaterials: Conductance quantization in 2DEG in GaAs and integer quantum hall effect (semi-classical treatment)

1D nanomaterials: Conductance quantization in 1D structures using split gate in 2DEG system (Qualitative)

0D nanomaterials: Charging effect, Coulomb Blockade effect, Single Electron Transfer (SET) device

Basic understanding of excitons in semiconductors and their consequence on optical properties of the material

Unit – IV - Synthesis of Nanomaterials (Qualitative) (5 Hours)

Top down and Bottom up approach, Ball milling, Spin Coating

Vacuum deposition: Physical vapor deposition (PVD): Thermal evaporation, Sputtering, Chemical vapor deposition (CVD).

Preparation of colloidal solutions of Metals, Metal Oxide nanoparticles

Unit – V - Applications (Qualitative) (4 Hours)

Micro Electromechanical Systems (MEMS), Nano-electromechanical Systems (NEMS), Applications of nanomaterials as probes in medical diagnostics and targeted drug delivery, sunscreen, lotions, and paints and other examples to give broader perspective of applications of nanomaterials

References:

Essential Readings:

- 1) Introduction to Nanotechnology, C. P. Poole and Jr. Frank J. Owens, 1st edition, 2003, Wiley India Pvt. Ltd.
- 2) Nanotechnology: Principles and Practices, S. K. Kulkarni, 2nd edition, 2011, Capital Publishing Company
- 3) Introduction to Nanoscience and Technology, K. K. Chattopadhyay and A. N. Banerjee, 2009, PHI Learning Private Limited
- 4) Introduction to Nanoelectronics, V. V. Mitin, V. A. Kochelap and M. A. Stroscio, 2011, Cambridge University Press
- 5) Nanotechnology for Dummies, R. Booker and E. Boysen, 2005, Wiley Publishing Inc.
- 6) Introductory Nanoscience, M. Kuno, 2012, Garland science Taylor and Francis Group
- 7) Electronic transport in mesoscopic systems, S. Datta, 1997, Cambridge University Press.
- 8) Fundamentals of molecular spectroscopy, C. N. Banwell and E. M. McCash, 4th edition, McGrawHill

Additional Readings:

- 1) Quantum Transport in semiconductor nanostructures, C. Beenakker and H. Van Houten, 1991, available at arXiv: cond-mat/0412664) Open Source
- 2) Ph.D. thesis, S. Cronewett, 2001, Available as Arxiv
- 3) Solid State Physics, J. R. Hall and H. E. Hall, 2nd edition, 2014, Wiley

PRACTICAL COMPONENT

(15 Weeks with 4 hours of laboratory session per week)

At least six experiments to be performed from the following list

- 1) Synthesis of metal (e.g. Au/Ag) nanoparticles by chemical route and study its optical absorption properties.
- 2) Synthesis of semiconductor (CdS/ZnO/TiO₂/Fe₂O₃ etc) nanoparticles and study its XRD and optical absorption properties as a function of ageing time.
- 3) Surface Plasmon study of metal nanoparticles as a function of size by UV-Visible spectrophotometer.
- 4) Analysis of XRD pattern of given nanomaterial and estimate lattice parameters and particle size.
- 5) To study the effect of the size nanoparticles on its color.
- 6) To prepare composite of CNTs with other materials and study their optical absorption/Transmission properties.
- 7) Growth of metallic thin films using thermal evaporation technique.
- 8) Prepare a ceramic disc of a given compound and study its XRD/I-V characteristics/ measure its dielectric constant or any other property.
- 9) Fabricate a thin film of nanoparticles by spin coating (or chemical route) and study its XRD and transmittance spectra in UV-Visible region.
- 10) Prepare thin film capacitor and measure capacitance as a function of temperature or frequency.
- 11) Fabricate a pn junction diode by diffusing Al over the surface of N-type Si/Ge and study its V-I characteristic.
- 12) Fabricate thin films (polymer, metal oxide) using electro-deposition
- 13) To study variation of resistivity or sheet resistance with temperature of the fabricated thin films using four probe method.

References for laboratory work:

- 1) Introduction to Nanotechnology, C. P. Poole and Jr. Frank J. Owens, 1st edition, 2003, Wiley India Pvt. Ltd.
- 2) Nanotechnology: Principles and Practices, S. K. Kulkarni, 2nd edition, 2011, Capital Publishing Company
- 3) Introduction to Nanoscience and Technology, K. K. Chattopadhyay and A. N. Banerjee, 2009, PHI Learning Private Limited
- 4) Nanotechnology for Dummies, R. Booker and E. Boysen, 2005, Wiley Publishing Inc.