

COURSE STRUCTURE FOR
M.Tech (NANO ELECTRONICS & PHOTONICS)
Choice Based Credit System (CBCS)



CENTRE FOR NANOSCIENCE AND TECHNOLOGY
INSTITUTE OF SCIENCE AND TECHNOLOGY
JAWAHARLAL NEHRU TECHNOLOGICAL
UNIVERSITY HYDERABAD-500 085

2016-2017

COURSE STRUCTURE FOR P.G. PROGRAMMES M.TECH NANO ELECTRONICS AND PHOTONICS

I Year

I Semester	Codes	New Title	Int. marks	Ext. marks	L	P	C
Core Course I	NEP101	Optical, electronic & photonic Properties Of Nanostructures	25	75	4	--	4
Core Course II	NEP102	Magnetic, Mechanical & thermal properties of Nanostructures	25	75	4	--	4
Core Course III	NEP103	Synthesis of Nanomaterials and Quantum Dots	25	75	4	--	4
Core Elective-I	NEP104	1.Fundamentals Of Nanoelectronics 2. Nano Electronics & Nano Photonics	25	75	4	--	4
Core Elective-II	NEP105	1.Elements Of Solid State Physics and Quantum Mechanics Of Electronics 2. Introduction to Nano Science and Nanotechnology	25	75	4	--	4
Open Elective-I	NEP106	1.Fabrication Techniques of Thin Films 2. Applied mathematics and numerical methods	25	75	4	--	4
Laboratory I	NEP107	Synthesis, Characterization and Simulation Lab-I	25	75	--	6	2
Seminar I			50	50	--	4	2
	Total		225	575	24	10	28

II Semester	Code	New Title	Int. marks	Ext. marks	L	P	C
Core Course IV	NEP201	Nano Sensors and Devices	25	75	4	--	4
Core Course V	NEP202	Advanced Nanomaterial Characterization-I	25	75	4	--	4
Core Course VI	NEP203	Advanced Nanomaterial Characterization-II	25	75	4	--	4
Core Elective-III	NEP204	1. Advanced Nanoelectronics 2.Nano Photonics and Plasmonics	25	75	4	--	4
Core Elective-IV	NEP205	1. MEMS and NEMS Design and Applications 2. Lithography Techniques	25	75	4	--	4
Open Elective-II	NEP206	1.Carbon Nano Materials And Its Applications 2. Nanotechnology For Energy System	25	75	4	--	4
Laboratory II	NEP207	Fabrication, characterization and Simulation Lab-II	25	75	--	6	2
Seminar II			50	50	--	4	2
	Total		225	575	24	10	28

II Year

I Semester		Int. marks	Ext. marks	L	P	C
1.	Comprehensive Viva	0	100	--	--	4
2.	Seminar-I on Project Work	50	--	--	24	12
	Total	50	100	--	24	16

II Semester		Int. marks	Ext. marks	L	P	C
1	Project Work Review II	50	--	--	8	4
2	Project Evaluation (Viva-voce)	--	150	--	16	12
	Total	50	150	--	24	16

NEP101 OPTICAL, ELECTRONIC & PHOTONIC PROPERTIES OF NANOSTRUCTURES

Objective: To bring out the distinct properties like electronic, optical, and photonic properties of nanostructures.

Outcome of the study:

1. To familiarize about the various properties of nanostructures.
2. To bring out the differences between nano and macro structures.
3. To discuss applications and specific properties of nanomaterials.

Pre visit Request:

1. Familiarization on energy band gap
2. Basics physics & mechanics of solids

Unit-I: Optical properties , Photonic crystals, optical properties of semiconductors, band edge energy, band gap, dependence on nanocrystallins size, Quantum dots, optical transitions, absorptions, interband transitions, quantum confinements.

Unit-II: Fluorescence/luminescence, photoluminescence/fluorescence, optically excited emission, electroluminescence, Laser emission of quantum dot, Photo fragmentation and columbic explosion, phonons in nanostructures, luminescent quantum dots for biological labeling.

Unit-III: Electronic properties, Energy bands and gaps in semiconductors, Fermi surfaces ,localized particle, donors, acceptors, deep traps, excitons, mobility, size dependent effects, conduction electrons and dimensionality Fermi gas and density of states, semiconducting nanoparticles

Unit-IV: Electronic Properties of Copper and Silicon (NM): Direct and reciprocal lattices of the fcc structure, Brillouin zone for the fcc structure, Copper and alloy formation, Silicon. Silicon band structure.

Unit-V: Nanophotonics: Photonic crystals, Photonic Bandgap, Defects in Photonic Crystals: Localization of Light, Control of Dispersion and the Slowing and Storage of Light, High-Efficiency Optical Sources, Photonic Crystal Waveguides and Fibers.

Text books:

1. Introduction to Nano Technology by Charles. P. Poole Jr& Frank J. Owens. Wiley India Pvt. Ltd.
2. Solid State physics by Pillai, Wiley Eastern Ltd.
3. Introduction to solid state physics 7th edition by Kittel. John Wiley & sons (Asia) Pvt Ltd.

Reference books:

1. Nano Technology and Nano Electronics – Materials, devices and measurement
2. Techniques by WR Fahrner – Springer
3. Encyclopedia of Nano Technology by M.Balakrishna Rao and K.Krishna Reddy, Vol I to X Campus books.
4. Nano Technology - Science, innovation and opportunity by Lynn E. Foster. Prentice Hall Pearson education.
5. Hand book of Nano structured materials Vol I & V
6. Encyclopedia of Nano Technology by H.S.Nalwa

Journal references:

1. K K Nanda, Pramana J. Phys., Vol. 72, No. 4, April 2009

2. A.A.Shavtzburg&M.F.Gerald, Chemical Physics Letters 317 2000. 615–618
3. V P Skripov, V P Koverda and V N Skokov, Phys. Status Solid A66, 109 (1981)
4. R Goswami and K Chattopadhyay, Act Mater. 52, 5503 (2004)
5. V. Germain et al. J. Phys. Chem. B, Vol. 107, No. 34, 2003

NEP102 MAGNETIC, MECHANICAL & THERMAL PROPERTIES OF NANOSTRUCTURES

Objective: To bring out the distinct properties like magnetic, mechanical, and thermal properties of nanostructures.

Outcome of the study:

1. To bring out the differences between nano and macro structures.
2. To discuss applications and specific properties of nanomaterials.

Pre visit Request:

1. Familiarization on energy band gap
2. Basics physics & mechanics of solids

Unit-I: Peculiarities of Nanostructured Materials: introduction, Extended internal surface, Increasing of surface energy and tension, Grain boundaries, Instability of 3DNSM due to grain growth, size effects in NSM.

Unit-II: Magnetic properties, Introduction of magnetic materials, basics of ferromagnetism – ferro magnetic resonance and relaxation, magnetic properties of bulk nanostructures, magnetic clusters, dynamics of nanomagnets, nanopore containment of magnetic particles, nano carbon ferromagnets, ferrofluids, electron transport in magnetic multilayers.

Unit-III: Mechanical properties of nanocrystalline metals and alloys: Yield strength, Ductility, Inverse Hall Petch effect, Strain-rate sensitivity, ceramics and composites.

Unit-IV: Mechanical Properties of nanomaterials, Types of indentation: Oliver & Pharr, Vickers indentation process, Nano Indentation by AFM, Young's modulus, Contact angle, Scratch implant measurements.

Unit-V: Thermal properties of nanostructures-thermal conductivity measurements for nanowires, nanotubes, thin films.

Text books:

1. Introduction to Nano Technology by Charles. P. Poole Jr& Frank J. Owens. Wiley India Pvt. Ltd.
2. Solid State physics by Pillai, Wiley Eastern Ltd.
3. Introduction to solid state physics 7th edition by Kittel. John Wiley & sons (Asia) Pvt Ltd.

Reference books:

1. Nano Technology and Nano Electronics – Materials, devices and measurement
2. Techniques by WR Fahrner – Springer
3. Encyclopedia of Nano Technology by M.Balakrishna Rao and K.Krishna Reddy, Vol I to X Campus books.
4. Nano Technology - Science, innovation and opportunity by Lynn E. Foster. Prentice Hall Pearson education.
5. Hand book of Nano structured materials Vol I & V
6. Encyclopedia of Nano Technology by H.S.Nalwa

Journal references:

1. K K Nanda, Pramana J. Phys., Vol. 72, No. 4, April 2009
2. A.A.Shavtzburg&M.F.Gerald, Chemical Physics Letters 317 2000. 615–618
3. V P Skripov, V P Koverda and V N Skokov, Phys. Status Solid A66, 109 (1981)
4. R Goswami and K Chattopadhyay, Act Mater. 52, 5503 (2004)
5. V. Germain et al. J. Phys. Chem. B, Vol. 107, No. 34, 2003

NEP103 SYNTHESIS OF NANOMATERIALS AND QUANTUM DOTS**Objective:**

This course is intended to cover the two groups of synthesis of nanostructures namely top-down and bottom-up approach various synthesis methods, including biological methods, advantages and disadvantages etc and also about quantum dots.

Outcome of the study:

- 1.The students will be exposed to various structure specific synthesis methods, their advantages etc.
- 2.To know about Top-down to Bottom up approach techniques.
- 3.To optimize the methods for specific material applications.
- 4.To familiarize about the importance of quantum dots and their applications.

Pre visit Request:

1. Basic chemistry fundamentals
2. Basics physics fundamentals

Unit -I: Introduction

Introduction to synthesis of nanostructure materials, Bottom-up approach and Top-down approach with examples-Trapped particles-Quantum dots and artificial atoms-Quantum wires and Quantum wells.

Unit -II: Physical Methods

Inert gas condensation, Arc discharge, RF-plasma, plasma arc technique, electric explosion of wires, laser ablation, laser pyrolysis, ball milling, molecular beam epitaxy, electro-deposition, Laser emission of quantum dot.

Unit-III: Chemical Methods

Nanocrystals by chemical reduction, photochemical synthesis, electrochemical synthesis, Nanocrystals of semiconductors and other materials by arrested precipitation, emulsion synthesis, sonochemical routes

Unit-IV: Thermolysis Route

Thermolysis route – Flame spray pyrolysis, Flame spray Hydrolysis, solvated metal atom dispersion, sol-gel method, solvothermal and hydrothermal routes, solution combustion synthesis, Chemical vapor deposition techniques: Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, boundaries and flow, Different kinds of CVD techniques: Metallorganic CVD (MOCVD), Thermally activated CVD, plasma enhanced (RF-Wave) CVD, Low Pressure (LP) CVD, Atmospheric pressure (AP) CVD

Unit-V: Biological Methods

Biological methods – use of bacteria, fungi, actinomycetes for nano-particle synthesis-magnetotactic bacteria for natural synthesis of magnetic nano-particles, luminescent quantum dots for biological labeling.

Text Books:

1. Inorganic Materials Synthesis and Fabrication by J.N. Lalena, D.A. Cleary, E.E. Carpenter, N.F. Dean, John Wiley & Sons Inc.
2. Introduction to Nano Technology by Charles P. Poole Jr and Frank J. Owens. Wiley India Pvt Ltd.
3. The Chemistry of nanomaterials: Synthesis, Properties and Applications, Vol-I by C.N.R. Rao, A. Muller and A.K. Cheetham

Reference Books:

1. Encyclopedia of Nanotechnology by M.Balakrishna Rao and K.Krishna Reddy, Vol I to X, Campus books.
2. Encyclopedia of Nanotechnology by H.S. Nalwa
3. Nano: The Essentials – Understanding Nano Science and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill
4. Handbook of chemical Vapor deposition (cvd), Principles, technology, and applications, By Hugh o. Pierson, Second edition, Noyes publications, William Andrew Publishing, LLC

NEP104 FUNDAMENTALS OF NANO ELECTRONICS**Objective:**

This course is intended to cover basics of electronics, transistor, band structure models, nanocapacitors, coulomb blockade, single electron transistor and nanophotonics.

Outcome of the study:

1. To know nanoelectronics holds the capacity for mass production of high-quality nanodevices with an enormous variety of applications from computers to biosensors, from cell phone to space shuttles and from large display screens to small electronic toys.
2. To know the scaling of transistors and other devices to smaller and smaller sizes, which has provided the basis for this exponential growth, has limits, physical (size of the atoms), technological (lithography) and economic, which will be reached by nanoelectronics in the next coming decade.
3. In the near future from photonics, molecular electronics or revolutionary engineering solutions, such as departure from two-dimensional ICs on the surface of silicon wafers to three-dimensional structures. All these gigantic challenges and potential nanotechnology solutions are actively debated.

Pre visit Request:

1. Basics of nano linear optics and electronics.

UNIT-I: Free Electron Theory & The New Ohm's Law: Why Electrons flow, Classical free electron theory, Sommerfeld's theory, The quantum of conductance, Coulomb blockade, Towards Ohm's law. The Elastic Resistor: Conductance of an Elastic Resistor, Elastic Resistor- Heat dissipation.

Unit-II: Materials for nanoelectronics:

Semiconductors, Crystal lattices: bonding in crystals, Electron energy bands, Semiconductor heterostructures , Lattice-matched and pseudomorphic heterostructures ,Inorganic nanowires, Organic semiconductors , Carbon nanomaterials: nanotubes and fullerenes

UNIT-III: Ballistic and Diffusive Transport: Ballistic and Diffusive Transfer Times, Channels for Conduction Conductivity, **Conductivity:** $E(p)$ or $E(k)$ Relations, Counting States, Drude Formula, Quantized Conductance, Electron Density -Conductivity

Unit-IV: Electron transport in semiconductors and nanostructures

Time and length scales of the electrons in solids, Statistics of the electrons in solids and nanostructures, Fermi statistics for electrons, the density of states of electrons in nanostructures, Electron transport in nanostructures.

Unit - V: Electrons in traditional low-dimensional structures

Electrons in quantum wells: Single modulation-doped heterojunctions, Numerical analysis of a single heterojunction, Control of charge transfer, Electrons in quantum wires, Electron transport in quantum wires, Electrons in quantum dots .

TEXT BOOK:

1. Introduction to Nano Science and Technology by S.M. Lindsay.
2. Supriyo Dutta -Lessons from Nanoscience: A Lecture Note Series, World Scientific (2012).
3. Supriyo Dutta --Quantum Transport- Atom to Transistor, Cambridge University Press (2005).
4. Introduction to Nanoelectronics : Science, Nanotechnology, Engineering & Applications by Vladimir.V.Mitin.

NEP105 ELEMENTS OF SOLID STATE PHYSICS AND QUANTUM MECHANICS OF ELECTRONICS

Objective:

The course is intended to cover, basics concepts of crystallography, quantum mechanics, matter and energy relations, de-Broglie hypothesis, wave function analogies, Schrodinger equation, quantum dot, wires and wells etc.

Outcome of the study:

1. To know the importance of crystal structures for property evaluation.
2. Students without quantum mechanics back ground will be able to understand the concept of quantum mechanics and nanotechnology.
3. To evaluate nanostructures in quantum mechanical approaches.

Pre visit Request:

1. Basics physics
2. Quantum mechanics
3. Basic chemistry
4. Basic material science

Unit-I: Crystal Structure

Crystalline and amorphous solids, Crystal lattice and crystal structure, Translational symmetry-space lattice, unit cell and primitive cell, symmetry elements in crystal, the seven crystal systems, some imperfections in crystals, cells-Miller indices, Miller-bravais indices, Indices of a lattice direction, The spacing of a set of crystal planes.

Unit -II: Reciprocal Lattice and Crystal Imperfections

Bragg law- Reciprocal lattice – Properties of Reciprocal lattice- Reciprocal lattice of simple cube- Reciprocal lattice of BCC- Reciprocal lattice of FCC- diffraction conditions- Brillouion zones. Importance of lattice imperfections- types of imperfection-Point defects-dislocations.

Unit-III: Bonding in Solids and Lattice Vibration

Introduction-General nature of cohesion between two atoms in a solid-ionic bond, covalent bond–metallic bond-Vander walls, London interaction and Lennard Jones potential- Phonons–experimental determination of dispersion relation, dynamics of linear chain of identical atoms, vibrations of a one–dimensional lattice with a basis-phonon process, phonon density states.

Unit-IV: Quantum Mechanics and Electronics

Introduction-Why quantum mechanics-matter waves-length scales-De-Broglie hypothesis-wave particle duality-Heisenberg’s uncertainty principle-Schrodinger wave equation–General postulates of Quantum mechanics-particle in one dimensional box, Bohr’s correspondence principle-Electron as particle and electron as wave-Time independent Schrodinger equation and boundary condition on the wave function-Analogies between quantum mechanics and classical electromagnetic theory-Probabilistic current density-multiple particle systems.

Unit -V: Free Electron Theory and Thermal Properties

Free and confined electrons: Free electrons-the free electron gas theory of metals-electrons confined to abounded region of space and quantum numbers-electrons confined to atom-the hydrogen atom and the

periodic table-quantum dots-wires-wells-Specific heat-classical theory of lattice heat capacity-The Debye model-thermal properties of solids-Einstein's theory of specific heat-Debye's theory of lattice heat capacity.

Text Books:

1. An introduction to solid states electronic devices by Ajay kumarsaxena Macmillan India Ltd
2. Solid state Physics by Kittel
3. Solid state Physics by R.K.Puri and V.K.Babbar
4. An introduction to solid states electronic devices by Ajay kumar saxena Macmillan India Ltd {Unit-I, II}
5. Solid state Physics by Kittle {Unit-I,II}
6. P.M.Mathews and K.Venkatesan, "A textbook of Quantum Mechanics", Tata McGraw Hill Publishing Company Ltd {Unit-III}
7. Quantum Mechanics – Schiff {Unit-III}
8. Quantum Mechanics by B.k.Agarwal and Hariprakash, PHI {Unit-III}
9. Fundamentals of nanoelectronics by George W.Hanson Pearson education {Unit-IV,V}

Reference Books:

1. Introduction to Nanotechnology by Charles P.Poole Jr & Frank
2. Introduction to Nanotechnology by Charles P.PooleJr& Frank J. Owens;Wiley India Pvt. Ltd
3. The Feynman lectures on Physics; Vol I to III
4. Quantum mechanics by Brandsen&Joachem
5. J.J.Sakurari, "Modern Quantum Mechanics Mc.Graw Hill, Addison Wesley Longman Inc., USA, 1999
6. Nano Technology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
7. Nano Technology – science, innovation and opportunity by Lynn E Foster;Prentice Hall - Pearson education.
8. Hand book of Nano structured materials; Vol I to V Bio Ethics Readings and cases by Branch A.Brody & H.TristramEngelhardt.Jr; Pearson Education
9. Quantum mechanics: - Pawling & Wilson
10. Quantum physics by A.Ghatak
11. Introduction to quantum chemistry by A.K.Chanda
- 12.XRD-P.S.Kulty

NEP105 INTRODUCTION TO NANOSCIENCE & NANO TECHNOLOGY

Objective:

To familiarize students with basics of nanoscience and technology, Nanobiotechnologies and Nanomaterials for environmental and toxicology

Outcome of the study:

1. To know the importance of Nanomaterials for environment and biological applications.
2. To study about the need of Nanotechnology for biology and environment.

Pre visit Request:

1. Basic physics fundamentals
2. Basic chemistry fundamentals
3. Basic material science

Unit-I: Background of Nanotechnology

Scientific Revolutions, Nanotechnology and Nanomachines, The Periodic Table, Atomic Structure, Molecules and Phases, Energy, Molecular and Atomic size, Surfaces and Dimensional Space, Top down and Bottom up approach.

Unit-II: Nanobiotechnologies: Concept-Structural principle of Bionanotechnology-Classification of Nanobiotechnologies -Micro- and Nanoelectromechanical Systems- Function of Biological Nanomolecules-DNA computers and DNA microprocessors- Biotechnology based genetic engineering - Function of Biological Nanomolecules- Bionanomachines in Action. Drug deliveries -Targeting Ligands based Drug Delivery- Cancer Treatment- Mediated Delivery - Tissue Regeneration, Growth and Repair, Tissue Bioengineering.

Unit-III: Nano Materials For Environment And Toxicology : Green nanotechnology and its principles, Nano-convergence and Environmental Engineering, different environmental systems, Potential impacts of nanomaterials on organisms and ecosystems, Environmental applications, Nanotechnology and Our Energy Challenge of nanomaterials, Nanotechnology and Renewable Energy, Introduction to toxicology, principles of toxicology, dosage-Response curve, classification of toxicity, factors affecting toxicity, LC50, LD 50, Air borne Particles,

Unit-IV: Nanoelectronics

Approaches to nanoelectronics, Fabrication of integrated circuits, MEMS, NEMS, Nano circuits, Quantum wire, Quantum well, DNA-directed assembly and application in electronics.

Unit-V: Applications

MEMS, NEMS, Coatings, Optoelectronic Devices, Environmental Applications, Nanomedicine.

Text Books

1. Introduction to Nanoscience and Nanotechnology Gabor L. Hornyak, *NanoThread, Inc., Golden, Colorado, USA*; H.F. Tibbals, *University of Texas Southwestern Medical Center, Dallas, USA*; Joydeep Dutta, *Asian Institute of Technology, Pathumthani, Thailand*; John J. Moore, *Colorado School of Mines, Golden, USA* \

2. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
3. Introduction to Nanoscience and Nanotechnology, Chatopadhyaya.K.K, and Banerjee A.N,
4. Introduction to nano tech by phani kumar
5. Introduction to Nano Technology by Charles P. Poole Jr and Frank J. Owens. Wiley India Pvt Ltd.
6. Introduction to Nanoscience and Nanotechnology, Chatopadhyaya.K.K, and Banerjee A.N,
7. NANOTECHNOLOGY Basic Science and EmergingTechnologies by Michael Wilson, Kamali Kannangara Geoff Smith, Michelle Simmons, Burkhard Raguse- **CHAPMAN & HALL/CRC PRESS 2002.**
8. Nanotechnology and the Environment, Kathleen Sellers,Christopher Mackay, Lynn L. Bergeson, Stephen R. Clough, Marilyn Hoyt, Julie Chen, Kim Henry, Jane Hamblen, crc press, 2009
9. Nanotechnology,consequences for human health and the environment- issues in environmental science and technology, editors: r.e. Hester and r.m. Harrison, rsc publication - 2007
10. Essentials of Toxicology. *Klaassen CD, Watkins JB III, eds. New York: McGraw-Hill, 2003.*
11. Introduction to Toxicology, 3rd Edition. 2002. John Timbrell. Taylor and Francis Publishing. ISBN 0-415-247-632
12. Hayes, A. W. 2001. Principles and Methods of Toxicology, 4th ed. Taylor and Francis Phila. PA.

NEP106 FABRICATION TECHNIQUES OF THIN FILMS

Objective:

The course covers the importance of thin film technology and nanofabrication, vacuum technology, various physical and chemical methods of thin film fabrication and various applications of thin films including sensors.

Outcome of the study:

1. Vacuum technology and principle of vacuum pumps- various types and ranges will be covered.
2. Various fabrication methods of thin films will be dealt in detail.
3. Advantages, applications of thin films for devices also will be discussed.

Pre visit Request:

1. Vacuum pump technology
2. Basics of vacuum pump technology Perini and gauge technology

Unit-I: Conditions for the formation of thin films: Environment for thin film deposition, deposition parameters and their effects on film growth, formation of thin films (sticking coefficient, formation of thermodynamically stable cluster – theory of nucleation), capillarity theory, microstructure in thin films, adhesion. Physical Vapor Deposition techniques: Thermal evaporation, resistive evaporation, Electron beam evaporation, Laser ablation, Flash and Cathodic arc deposition, Electron beam and Ion beam lithography techniques

Unit-II: Vacuum technology: principles of vacuum pumps in range of 10^{-2} torr to 10^{-11} torr, principle of different vacuum pumps: roots pump, rotary, diffusion, turbo molecular pump, cryogenic-pump, ion pump, Ti-sublimation pump, importance of measurement of vacuum, Concept of different gauges: Bayet-Albert gauge, Pirani, Penning and pressure control.

Unit-III: Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, Ion plating, difference between thin films and coating.

Unit-IV: Electro deposition, molecular beam epitaxy and laser pyrolysis. Chemical vapor deposition techniques: Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, boundaries and flow, Different kinds of CVD techniques: Metallorganic CVD (MOCVD), Plasma Enhanced CVD (PECVD), thermally activated CVD, CVD, Spray pyrolysis, etc.

Unit-V: Properties of thin films: Defects in thin films formation and remedial measures, Mechanical, electrical, and optical properties of thin films, few applications of thin films in various fields. Application to Renewable energy technology – Thin film solar cells, Quantum well and Quantum dot solar cells, dye – sensitized solar cells.

Text Books & References:

1. Thin Film Phenomenon by K.L. Chopra, McGraw-Hill
2. Methods of Experimental Physics (Vol 14) by G.L. Weissler and R.W. Carlson “Vacuum Physics and Technology”
3. A User’s Guide to vacuum Technology by J.F. O’Hanlon, John Wiley and Sons
4. Vacuum Physics and Techniques by T.A. Delchar, Chapman and Hall
5. Evaporation: Nucleation and Growth Kinetics” by J.P. Hirth and G.M. Pound, Pergamon Press

NEP106 APPLIED MATHEMATICS AND NUMERICAL METHODS

Objective:

The course is intended to cover, basics concepts of mathematics like numerical algebra, probability, simulations specially Monte- Carlo simulations which will help in understanding theoretical concepts of Nanotechnology.

Outcome of the study:

1. To know the importance of simulations in nanotechnology.
2. Students without mathematics back ground will be able to understand the concept of mathematics.
3. To evaluate nanostructured simulations in nanotechnology.

Pre visit Request:

1. Basics differential equations
2. Basics simulation
3. Basic Gaussian eliminations
4. Basic probability functions
5. Basics engineering mathematics probability & statistics

Unit – I Numerics in general: Interpolation, Gauss elimination, Solution by iteration, least square method.

Unit - II Numeric Linear Algebra and differential equations: Matrix Eigen value problems: Introduction, Inclusion of Matrix Eigen values, Tridiagonalization and RQ factorization. Methods for first order ODEs, Multi step methods, Higher order ODES

Unit-III Introduction to probability: Probability, Sample space and events- Probability- the axioms of probability, some elementary theorems-conditional probability Baye's theorem Random Variables- Discrete and continuous – distribution- distribution function Distribution Binomial and poison distributions and normal distribution – related properties, Neural networks.

Unit- IV Systems, Models, Simulations and the Monte Carlo Methods:Systems,Models,Simulation and the Monte Carlo Methods, Random number generation, Introduction, Congruential Generators, Statistical Tests of Pseudorandom Numbers, Random variate generation, inverse Transform Method, Composition Method, Acceptance-Rejection Method,

Unit-V Monte Carlo integration and Variance reduction techniques: Introduction, Monte Carlo Integration, The Hit or Miss Monte Carlo Method, The Sample-Mean Monte Carlo Method, Efficiency of Monte Carlo Method, Integration in Presence of Noise,

Text books:

1. Advanced engineering mathematics, by Erwin Kreyszig, wiley publications
2. Probability and statistics, scham series, Arnold o. allen, academic press
3. Probability and statistics, Arnold o. allen, academic press
4. Probability and statistics for engineers, miller and john e. freund, prentice hall of india
5. A primer for the monte carlo method, Ilya M. Sobol' CRC Press
6. Simulation and monte carlo method by reuven y. rubisten
7. The monte carlo method, popular lectures in mathematics by sobol.i.m

NEP107 SYNTHESIS, CHARACTERIZATION & SIMULATION LAB-I

PART-A: SYNTHESIS & CHARACTERIZATION

1. Verification of BEER-LAMBERT's law using Colorimeter
2. Conductometry
3. Preparation of Cobalt nanoparticles by wet chemical reduction method
4. Synthesis of CuO nanoparticles using Glycine as fuel by Solution combustion method
5. Synthesis of ZnO nanoparticles using Ascorbic acid as fuel by Solution combustion Method
6. Synthesis of MgO nanoparticles using Glycine as fuel by Solution combustion method
7. Synthesis of Fe₂O₃ nanoparticles using Glycine as fuel by Solution combustion method
8. Synthesis of silica gel (SiO₂) using Sol-Gel method
9. Synthesis of PVP capped Cadmium Sulfide (CdS) nanoparticles by chemical Coprecipitation Method
10. Synthesis of oxide nanoparticles by using Multifuel solution combustion method
11. Synthesis of oxide nanoparticles by using Multioxidizer solution combustion method
12. Synthesis of colloidal copper nanoparticles by chemical reduction method
13. Synthesis of the silver nanoparticles by using green synthesis from ocium santum
14. Synthesis of the copper oxide nanoparticles by using green synthesis from Aloe vera
15. Determination of average crystalline size and microstarin by using X-Ray diffraction Analysis.
16. Determination of average particle size and zeta potential by using Dynamic light scattering.
 - (i) PH Vs size
 - (ii) PH Vs zeta potential
17. Synthesis of Graphene oxide by using hummers method
18. Reduction of the Bulk material to Nanomaterial by using Planetary Ball-Mill

PART-B: SIMULATION

I. ARGUS LAB:

1. Construction of fullerene & its energy calculations
2. Construction of Bucky balls (C20, C40, C60, C80, C100, C120)
3. Construction of Carbon nanotubes
4. Energy minimization of lysozyme and its mutant
5. Energy minimization of chymotrypsin and its mutant
6. Energy minimization of enzymes involved in Neurological science

II.MATLAB:

1. Introduction to MATLAB Programming
2. Program assembly, Execution, Data processing and graphic analysis
3. Study of Fermi – Dirac distribution function
4. Introduction to symbolic math computations
5. MATLAB program to plot the one-dimensional rectangular potential well with infinite potential barrier
6. Introduction to Simulink and Simelectronics

NEP201 NANO SENSORS AND DEVICES

Objective:

The course is intended to cover sensors and different types of sensors with their characteristics and their applications

Outcome of the study:

1. To know the importance of Nanosensors and devices for various applications.
2. To familiarize students with different types of sensors and their physical effects.

Pre visit Request:

1. Basics of nano liners optics and electronics
2. Basic of sensors, physical, chemical, mechanics phenomenon's related to sensors.

Unit I: Introduction & Sensor Characteristics: Nanotechnology, Sensors, Nanotechnology Enabled Sensors, Sensor Characteristics and Terminology, Static Characteristics, Dynamic Characteristics, Physical Effects Employed for Signal Transduction, adsorption studies.

Unit-II: Sensors & Physical Effects:

Photoelectric Effect, Photo-dielectric Effect, Photoluminescence Effect, Electroluminescence Effect, Chemiluminescence Effect, Doppler Effect, Barkhausen Effect, Hall Effect, Nernst/Ettingshausen Effect, Thermoelectric (Seebeck/Peltier and Thomson) Effect, Thermoresistive Effect, Piezoresistive Effect, Piezoelectric Effect, Pyroelectric effect, Magneto-Mechanical Effect (Magnetostriction), Magneto-resistive Effect, Faraday-Henry Law.

Unit-III: Mass-Sensitive & Conductivity Sensors:

BAW Sensors, SAW Sensors, Conductometric Sensors, Resistive and Capacitive Gas Sensors, Gas Sensors Based on Polycrystalline Semiconductors, Gas Sensors Made of Polymers and Gels, Resistive and Capacitive Sensors for Liquids.

Unit-IV: Electrochemical Sensors:

Potentiometric Sensors, Selectivity of Potentiometric Sensor, Ion-Selective Electrodes, The Ion-Selective Field Effect Transistor (ISFET), Measurement with Potentiometric Sensors, Amperometric Sensors, Selectivity of Amperometric Sensors, Electrode Design and Examples, Measurement with Amperometric Sensors, Sensors Based on Other Electrochemical Methods, Electrochemical Biosensors, Classes of Electrochemical Biosensors.

Unit-V: Thermometric & Optical Sensors:

Sensors with Thermistors and Pellistors, Pyroelectric Sensors, Sensors Based on Other Thermal Effects, Optical Fibres as a Basis for Optical Sensors, Fibre Sensors Without Chemical Receptors (Mediators), Optodes: Fibre Sensors with a Chemical Receptor, Optodes with Simple Receptor Layers, Optodes with Complex Receptor Layers.

Text Books:

1. Nanotechnology-Enabled Sensors, Kouros Kalantar-zadeh, *Springer publications (2007)*
2. Chemical Sensors-An Introduction for Scientists and Engineers, Peter Gröndler, *Springer publications (2006)*

NEP202 ADVANCED MATERIAL CHARACTERIZATION TECHNIQUES-I

Objectives:

To familiarize students with Spectroscopic, Electrical, Thermal and Magnetic characterization techniques and interpretation of results including standards etc.

Outcome of the study:

1. To bring out the importance of material characterization and various methods.
2. To familiarize about various equipment.

Pre visit Request:

1. Basic band gap, Electrical, Thermal and Magnetic characterization.
2. Mechanics of solids, metallurgy and materials science, and spectroscopic techniques.

Unit-I: Introduction to Absorption, Emission, Molecular & Atomic spectroscopy: Terms Employed in Absorption Spectroscopy, Quantitative Aspects of Absorption Measurements, Emission Spectra, Sources, Instruments, Applications of Emission Spectroscopy. Theory of Fluorescence, Instruments, Applications. Theory of Flame Spectroscopy, Characteristics, Atomizers for Atomic Spectroscopy, Electron spectroscopy.

Unit-II: UV-VIS-NIR Spectroscopy: UV/Vis spectroscopy, infrared spectroscopy (FTIR), EDS, WDS, X-ray fluorescence (XRF), luminescence spectrometer, Mossbauer spectroscopy, Circular dichroism spectroscopy, X-Ray Photoelectron Spectroscopy (XPS), Ultraviolet Photoelectron Spectroscopy (UPS), Auger Electron Spectroscopy(AES).

Unit-III: Raman, NMR & Mass spectroscopy: Theory of Raman Spectroscopy, Instrumentation, Applications of Raman Spectroscopy, micro Raman & laser Raman. Theory of Nuclear Magnetic Resonance (NMR), Experimental Methods, Applications, Electron Spin Resonance (ESR) Spectroscopy, Mass Spectrometer, Mass Spectra, Qualitative Applications of Mass Spectrometry. Secondary ion mass spectrometry (SIMS).

Unit-IV: Electrical Characterization Techniques: Measurement of resistivity by 4-prob method, Hall measurement, impedance measurements, Sebec coefficient measurements, Basics of Nano indentation techniques, electron beam induced current measurement (EBIC).

Unit-V: Thermal and Magnetic Characterization: Thermal analysis, Principle, Working and application of DTA, TGA, TMA and DSC. Vibrating Sample Magnetometer (VSM), SQUID magnetometer.

- 1.Nano: The Essentials -Understanding Nano Science and Nanotechnology by T.Pradeep, Tata Mc.Graw Hill
- 2.Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens,
3. Characterization of nanostructured materials by Z.L. Wang
4. Modern Raman Spectroscopy: A practical approach by E. Smith and G.Dent
5. Principles of Instrumental analysis by D.A. Skoog, F.J. Hollen and T.A. Nieman

Reference Books:

- 1.Nanotechnology : Principles and Practices – Sulabha K. Kulkarni – Capital Publishing Comany
2. Photoelectron spectroscopy by JHD Eland, Butterworth & Co. publishers, 2nd education.
- 3.Encyclopedia of Nanotechnology by H.S. Nalwa
4. Encyclopedia of materials Characterization C. Richard Brundle and Charles A. Evans, Jr.

NEP203 ADVANCED MATERIAL CHARACTERIZATION TECHNIQUES-II

Objective:

The course covers the importance of characterization techniques, surface analysis and elemental analysis.

Outcome of the study:

1. To bring out the importance of material characterization on surface of Nanomaterials.
2. To familiarize about elemental characterization of nanomaterials.

Pre visit Request:

1. Basic band gap, energy systems
2. Mechanics of solids, metallurgy and materials science.

Unit-I: Diffraction Techniques: properties of x-rays, The directions of diffracted beams, Atomic scattering factor, Crystal structure factor, Debye-Scherrer method, crystal size, Electron and Neutron diffraction.

Unit-II: Microscopic Techniques: Optical Microscopes, Confocal Microscope, Light Microscopy, Electron Microscope, Scanning Electron Microscopy (SEM), Transmission Electron Microscope (TEM), Scanning Transmission Electron Microscopy (STEM)

Unit-III : Probe Microscopic Techniques: Scanning Probe Microscope (SPM), Scanning Tunneling Microscope (STM), Atomic Force Microscope (AFM), Scanning Near Field Optical Microscope (SNOM), Scanning Force Microscope (SFM).

Unit-IV: Elemental analysis Techniques: Electron probe microanalysis (EPMA). Energy Dispersive X-ray analysis (EDAX), Ion beam techniques: SIMS & RBS, ICPMS, ISPOS, Oxygen analysis-inert gas fusion analysis.

Unit-V: Advanced Surface analysis Techniques: XPS, UPS, AES, DLS, PSA and Zeta potential, BET: pore size and distribution.

Text Books:

1. Nano: The Essentials -Understanding Nano Science and Nanotechnology by T.Pradeep, Tata Mc.Graw Hill
2. Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
3. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
4. Scanning electron microscopy and x-ray microanalysis by J.I. Goldstein
5. Characterization of nanostructured materials by Z.L. Wang

Reference Books:

1. Nanotechnology : Principles and Practices – Sulabha K. Kulkarni – Capital Publishing Company.
2. Elements of X-ray diffraction by B. D. Cullity.
2. Specimen preparation for Transmission Electron microscopy by John & Bravmno et al, published by MRS

3. Encyclopedia of Nanotechnology by H.S. Nalwa
4. Encyclopedia of materials Characterization C. Richard Brundle and Charles A. Evans, Jr.

NEP204 ADVANCED NANOELECTRONICS

Objective:

This course is intended to cover basics of electronics, transistor, band structure models, Smart contacts, phonon transport and spin valves

Outcome of the study:

1. To know nanoelectronics holds the capacity for mass production of high-quality nanodevices with an enormous variety of applications from computers to biosensors, from cell phone to space shuttles and from large display screens to small electronic toys.
2. To know the scaling of transistors and other devices to smaller and smaller sizes, which has provided the basis for this exponential growth, has limits, physical (size of the atoms), technological (lithography) and economic, which will be reached by nanoelectronics in the next coming decade.

Pre visit Request:

1. Smart contacts and phonon transport
2. Spin valves and nanostructure devices

UNIT-I: Diffusion Equation for Ballistic Transport: Electrochemical Potentials Out of Equilibrium, Currents in Terms of Non-Equilibrium Potentials. **Electrostatics and it's Importance:** The Nanotransistor, Saturation current, Role of Charging, Rectifier Based on Electrostatics.

UNIT-II: Smart Contacts: Why p-n Junctions are different, Current-Voltage Characteristics, Contacts are fundamentals. **Thermoelectricity:** Seebeck Coefficient, Thermoelectric Figures of Merit, Heat Current.

UNIT-III: Phonon Transport: Phonon Heat Current, Ballistic phonon transport, Thermal Conductivity. **Hall Effect:** N- and P- Conductors, Spatial profile of Electrochemical potential, Measuring the Potential, Non-Reciprocal Circuits.

UNIT-IV: Spin Valves: Mode Mismatch and Interface Resistance, Spin Potentials, Spin-Torque, Polarizers and Analyzers, Kubo formula for an elastic resistor: One level resistor, Elastic resistor, Onsager relations.

Unit-V: Nanostructure devices

Resonant-tunneling diodes, Field-effect transistors Single-electron-transfer devices, Potential-effect transistors, Light-emitting diodes and lasers, Quantum-dot cellular automata.

Text books:

1. Supriyo Dutta -Lessons from Nanoscience: A Lecture Note Series, World Scientific (2012).
2. Supriyo Dutta --Quantum Transport- Atom to Transistor, Cambridge University Press (2005).
3. V. Mitin, V. Kochelap, M. Stroscio, —Introduction to Nanoelectronics, Cambridge University Press (2008).
4. Rainer Waser, —Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Device, Wiley-VCH (2003).
5. Karl Goser, Peter Glosekotter, Jan Dienstuhl, —Nanoelectronics and Nanosystems, Springer (2004).
6. Sadamichi Maekawa, —Concepts in Spin Electronics, Oxford University Press (2006).
7. L. Banyai and S.W.Koch, —Semiconductor Quantum Dots, World Scientific (1993).

NEP 204 NANO ELECTRONICS AND NANO PHOTONICS

Objective:

This course is intended to cover basics of electronics, transistor, band structure models, nanocapacitors, coulomb blockade, single electron transistor and nanophotonics.

Outcome of the study:

1. To know nanoelectronics holds the capacity for mass production of high-quality nanodevices with an enormous variety of applications from computers to biosensors, from cell phone to space shuttles and from large display screens to small electronic toys.
2. To know the scaling of transistors and other devices to smaller and smaller sizes, which has provided the basis for this exponential growth, has limits, physical (size of the atoms), technological (lithography) and economic, which will be reached by nanoelectronics in the next coming decade.
3. In the near future from photonics, molecular electronics or revolutionary engineering solutions, such as departure from two-dimensional ICs on the surface of silicon wafers to three-dimensional structures. All these gigantic challenges and potential nanotechnology solutions are actively debated.

Pre visit Request:

1. Basics of nano linear optics and electronics

Unit-I: Single-electron and few-electron phenomena and devices: Tunnel junction and applications of tunneling, Tunneling Through a Potential Barrier, Potential Energy Profiles for Material Interfaces, Metal—Insulator, Metal-Semiconductor, and Metal-Insulator-Metal Junctions,

Unit-II: Applications of Tunneling; Field Emission, Gate—Oxide Tunneling and Hot Electron Effects in MOSFETs, Theory of Scanning Tunneling Microscope, Double Barrier Tunneling and the Resonant Tunneling Diode.

Unit-III: Coulomb Blockade: Coulomb Blockade, Coulomb Blockade in a Nanocapacitor, Tunnel Junctions, Tunnel Junction Excited by a Current Source, Coulomb Blockade in a Quantum Dot Circuit.

Unit-IV: The Single-Electron Transistor: The Single-Electron Transistor Single-Electron Transistor Logic, Other SET and FET Structures, Carbon Nanotube Transistors (FETs and SETs), Semiconductor Nanowire FETs and SETs, Molecular SETs and Molecular Electronics.

Unit –V: Spintronics: Spintronics and Foundations of nano-photonics.

Text books:

1. Fundamentals of nano electronics by George W Hanson Pearson publications ,India 2008{Unit-I-IV)
2. Introduction to photoelectron Spectroscopy (Chemical Analysis Vol. 67) by P.K. Ghosh; Wiley Interscience
3. Nanophotonics by P.N.Prasad – Springer Education series.
4. Nanotechnology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
5. Nanomaterials: Synthesis, properties and applications\edited by A S Edelstein and R C Cammarata (Institute of Physics, UK Series in Micro and Nanoscience and Technology)

Reference books:

1. Encyclopaedia of Nano Technology by M.Balakrishna Rao and K.Krishna Reddy (Vol I to X)
Campus books.
2. Nano: The Essentials – Understanding Nano Science and Nanotechnology by T.Pradeep; Tata
Mc.Graw Hill
3. Spin Electronics by M. Ziese and M.J. Thornton
4. Nanoelectronics and Nanosystems – From Transistor to Molecular and Quantum Devices by Karl
Goser, Peter Glosekotter, Jan Dienstuhl
- 5.Silicon Nanoelectronics by Shunri Odo and David Feny, CRC Press, Taylor & Franicd Group
- 6.Nanotubes and nanowires by C.N.R. Rao and A. Govindaraj, RSC Publishing
- 7.Encyclopedia of Nanotechnology by H.S. Nalwa, American Scientific Publishers
- 8.Handbook of Nanoscience, Engineering and Technology by W. Goddard, D. Brenner, S.
Lyshevski, G.J.Iafrate, CRC Press (2000)
- 9.Quantum-Based Electronic Devices and Systems by M. Dutta and M.A. Stroschio,
WorldScientific

NEP205 MEMS/NEMS DESIGN AND APPLICATIONS

Objective: The course is intended to cover deep understanding of micro and nano electromechanical systems their design and various applications as well as micro and nano fabrication techniques.

Outcome of the study:

1. To provide understanding of MEMS/NEMS applications specially sensors, Micro machining tools etc.,
2. To provide silicon micro fabrication techniques etc.,
3. To bring out scaling and packaging issues of physical system

Pre visit Request:

1. Machano- electronic properties , fabrication techniques.

Unit-I: Introduction to MEMS : MEMS and NEMS – working principles- MEMS processes & features, various components of MEMS, applications and standards, micromachining, basic process tools- epitaxy, sputtering, chemical vapor deposition and spin on methods, oxidation, evaporation, lithography and etching, advanced process tools, sol gel process, EFAB.

Unit-II: Materials for MEMS and Engineering aspects: Silicon, Silicon oxide and nitride, Thin metal films, Polymers, Other materials and substrates, polycrystalline materials, mechanics of Microsystems, static bending, mechanical vibrations, thermo mechanics, fracture mechanism, fatigue, stress and strain, young's modulus and modulus of rigidity, scaling laws in miniaturization.

Unit-III: MEMS Sensors, Design and processing: Micro sensors (acoustic wave sensors, biomedical sensors, chemical sensors, optical sensors, capacitive sensors, pressure sensors, thermal sensors), microactuators (thermal, piezoelectric, electrostatic actuators, micrometers, microvalves& pumps, accelerometer, microfluidics and devices), design consideration, process design and mechanical design.

Unit-IV: MEMS/NEMS Scaling issues and Packaging: Introduction – Scaling of physical systems – Mechanical system scaling, Thermal system scaling, Fluidic system scaling, Electrical system scaling, Packaging- mechanical and microsystem package, design considerations, Process steps, Diepreparation- interconnects, surface and Wafer bonding, wire bonding and scaling, 3D packaging and assembly signal Thermal management, Hermetic packaging, Electrical/Micro fluidic/and optical interconnects, Signal mapping transduction, Microfluidic technology - MEMS and NEMS technology for microfluidic devices.

Unit-V: MEMS/NEMS applications: Applications in automotive industry – health care – aerospace – industrial product consumer products – lab on chip – molecular machines – data storage devices – micro reactor – telecommunications, Servo systems.

Text Books:

1. “An introduction to Micro electro mechanical systems Engineering” by NadimMalut and Kirt Williams – Second edition – Artech House, Inc, Boston
2. “Micro electro mechanical systems Design”. by James J Allen- CRC Press – Taylor and Francis Group
3. “Mechanics of micro electro mechanical systems “by Nicolae Lobontiu and Ephrahim Garcia Kluwer. Academic Publishers – Boston
4. The Physics of Micro/Nano- Fabrication by Ivor Brodie and Julius J.Murray

5. Nano- and Micromaterials by Kaoru Ohno, Masatoshi Tanaka, Jun Takeda and Yoshijuki Kawazoe

References Books:

1. “Springer Hand Book of Nano Technology “ by BharathBhushan – Springer
2. “Nano and Micro electro Mechanical systems” by Sergey Edward Lysherski – CRC Press.

NEP205 LITHOGRAPHIC TECHNIQUES

Objective: The course is intended to cover deep understanding of basics and different types of lithographic techniques useful for Nanofabrication.

Outcome of the study:

1. To provide understanding of importance of lithography.
2. To bring out different types of lithographic techniques.

Pre visit Request:

1. Clean room technology, thin films coating techniques

Unit-I: Introduction to lithography and Optical lithography: Introduction to lithography- Contact, proximity printing and Projection Printing, Resolution Enhancement techniques, overlay-accuracies, Mask-Error enhancement factor (MEEF), Positive and negative photoresists.

Unit-II: Electron Lithography: Electron optics, Raster scan and Vector scan, Electron proximity / Projection Printing, Direct writing, Electron resists, Electron Beam Applications.

Unit-III: X-ray Lithography: X-ray Proximity and projection printing X-ray masks, X-ray sources, X-ray resists.

Unit-IV: Ion Lithography: Focussed ion beam – Point sources of Ion, Ion Column, Beam writing, Focused Ion Beam Lithography, Masked Ion Beam Lithography, Ion Projection Lithography.

Unit-V: Lithography based on Surface Instabilities: Wetting, De-wetting, Adhesion, Limitations, Resolution and Achievable / line widths of each of the above techniques.

Reference books:

1. K.L. Chopra, “Thin Film Phenomenon”, McGraw-Hill, 1968
2. John N. Helbert, “Handbook of VLSI Microlithography”, Noyes Publication, USA, 2001.
3. James R Sheats and Bruce W. Smith, “Microlithography Science and Technology”, Marcel Dekker Inc., New York, 1998.
4. S. Wolf “Silicon processing for the VLSI era”, Vol-1 to 4, Lattice Press.
5. J.P. Hirth and G.M. Pound “Evaporation: Nucleation and Growth Kinetics” (Pergamon Press, Oxford, 1963

Journals references:

1. R.F. Bunshah and C.V. Deshpandey “Evaporation Processes” MRS Bulletin p.33, Dec.1988.
2. W.D. Westwood “Sputter Deposition Processes” MRS Bulletin p.46, Dec.1988.
3. P. Harris “Taking the Lead in Electron-beam Deposition” Vacuum & Thin Film, Feb.1999, p.26.
4. B. Heinz Sputter Target and Thin Film Defects” Vacuum & Thin Film, October 1999, p.22.
5. G.S. Bales et al., “Growth and Erosion of Thin Splid Films”, Science, 249, 264 (1990).
6. C.R.M. Grovenor, H.T.G. Hentzell and D.A. Smith, “The Development of Grain Structure during Growth of Metallic Films” Acta Metallurgica 32, 773 (1984).
7. L.A. Stelmack, C.T. Thurman and G.R. Thompson “Review of Ion-assisted Deposition:

8. "Research to Production", Nuclear Instruments and Methods in Physics Research B, 37/38,787 (1989).

NEP206 CARBON NANO MATERIALS AND ITS APPLICATIONS

Objective: The course covers the structural and electronic properties of CNTs apart from various synthesis and characterization methods and applications.

Outcome of the study:

1. To understand the properties of CNTs as active component
2. To familiarize with controlled synthesis method
3. To identify applications of CNTs

Pre visit Request:

1. Structure of carbon chemistry and importance and difference types of carbon like diamonds, graphite etc.

Unit-I: Carbon Nano structures and types of Carbon Nano tubes, growth mechanisms Mechanical reinforcements, Solid Disordered carbon Nanostructures, Nano structured crystals. Carbon nano- fibers.

Unit-II: Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process, Fullerenes: Introduction to fullerenes, Formation of fullerenes, Fullerene characterizations,

Unit-III: Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs.

Unit IV: Graphene: Properties of Graphene, Graphene Nanoribbons, Potential applications of Graphene.

Unit-V: Applications of Carbon Nano Materials: Lithium ion based batteries, Hydrogen adsorption & Hydrogen storage technology, Fuel cell technology and applications. Applications on Super Capacitors, Nano fluids.

Text books:

1. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
2. Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springer publications
3. Graphene – Synthesis, Characterization, Properties And Applications Edited By Jian Ru Gong
4. Principal of Nanotechnology-Matrealas, Tools and Process at Nanoscale by phanikumar.
- 5.Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springer publications

Reference books:

1. Encyclopedia of Nanotechnology by M.Balakrishnarao and K.Krishna Reddy, Vol I to X Campus books.
2. Encyclopedia of Nanotechnology by HS Nalwa
3. Nanotechnology – science, innovation and opportunity by Lynn E.Foster. Prentice Hall Pearson

NEP206 NANO TECHNOLOGY FOR ENERGY SYSTEMS

Objective:

The course covers the various energy forms, alternate and renewable energy system using nanotechnology.

Outcome of the study:

1. To cover various renewable energy technologies.
2. To study hydrogen production and storage techniques.
3. To study solar energy generation and enhancement of conversation efficiency microfluidics and fuel cell technology will be covered.

Pre visit Request:

Different technologies like Renewable energy technology, supercapacitors and Hydrogen storage technology.

Unit–I Battery: Introduction to Battery materials and batteries: Lithium Ion based batteries.

Unit–II: Super capacitors: Super capacitor characterisation, Types of super capacitors, double layer and pseudo capacitance, hybrid super capacitors, super capacitors: Electrochemical double layer and pseudocapacitors, Hybrid supercapacitors, advantages and disadvantages of electrochemical double layer, Psudocapacitors and hybrid supercapacitors., Applications of supercapacitors.

Unit–III: Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: quantum well and quantum dot solar cells, photo- thermal cells for solar energy harvesting, Thin film solar cells, CIGS solar cells, Die sensitized solar cells.

Unit–IV Hydrogen storage Technology: Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metal-organic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalphy formations and thermal management during hydriding reaction, multiple catalytic – degradation of sorption properties, automotive applications.

Unit–V Fuel cell Technology: Fuel cell Principles, types of fuel cells (Alkaline Electrolyte, Phosphoric acid, Molten Carbonate, solid oxide and direct methanol and Proton exchange fuel cells), Principle and operation of Proton Exchange Membrane (PEM) fuel cell, Materials and fabrication methods for fuel cell technology, micro fuel cell power sources – Biofuels, Microbial biofuels.

Text Books & References

1. Renewable Energy Resources by J. Twidell and T.Weir, E&FN Spon Ltd.
2. Hydrogen from Renewable Energy Source by D.Infield
- 3.Fundamentals of Industrial Catalytic Process by C.H. Bartholomew and Robert J. Farrauto, John Wiley & Sons Inc.
4. Fuel storage on Board Hydrogen storage in Carbon Nanostructures by R.A. Shatwell

5. Fuel cell Technology Handbook by Hoogers, CRC Press
6. Hand book of fuel cells: Fuel cell technology and applications by Vielstich, Wiley: CRC Press
7. Electrochemical Supercapacitors , B E Conway, Kluwer Academic/Plenum publishers, NY 1999.
8. Metal oxide thin film based supercapacitors C.D. Lokhande, D.P. Dubal, Oh-Shim
Joo Current Applied Physics 11 (2011) 255e270
9. B.E. Conway, Electrochemical Supercapacitors: Scientific, Fundamentals, and Technological Applications. Kluwer, (New York), 1999.

NEP207 FABRICATION, CHARACTERIZATION & SIMULATION LAB-II (NANOHUB+QUANTUM WISE) LAB-II

Objective: Objective: The course is intended to cover understanding of nanomaterial fabrication technique and modeling.

The outcome of the study is:

1. To familiarize students about applying various material fabrication, characterization techniques and data analysis.
2. To help in understanding the theoretical modeling of semiconductor devices and quantum structures using online in- browser simulation tools.

Pre visit Request: Thin films, characterization techniques

PART-A: FABRICATION & CHARACTERIZATION

1. Preparation of the ZnO thin films by using spin coating technique
2. Preparation of the CuO thin films by using Dip coating technique
3. Preparation of the Carbon nanotubes by the CVD process
4. Preparation of the CdS thin films by using spray pyrolysis with different temperatures
5. Determination of average crystalline size and microstrain by using X-Ray diffraction Analysis.
6. Determination of average particle size and zeta potential by using Dynamic light scattering.
7. Investigation of the surface morphological studies by Atomic force microscope.
8. Calculation of band gap with error bar values by using U-V Visible spectroscopy.
9. Seed Germination.
10. Study of thermal properties by using TG/DTA analysis.
11. Humidity sensor applications
12. Measurement of ultrasonic velocity of the CuO nanofluid at room temperature by Nanofluid Interferometer
13. Basic overview and Study of Potentiodynamic electrochemical properties by using Cyclic voltammetry.
14. Flame synthesis process
15. In-house sensor testing unit chemical sensor for detection of poisonous and flammable gases

PART-B: SIMULATION

I. QUANTUM WISE (ATK & VNL):

1. Geometry for Transport Calculations (ATK)
2. Setting up a transport calculation with the script generator (ATK)
3. I-V Curve (ATK)
4. Building and optimizing the geometry (ATK)
5. Calculating the band structure of a SiC crystal (VNL)
6. Transmission spectrum of a graphene nanoribbon with a distortion (VNL)
7. Building a graphene nanoribbon Device (VNL)

II. NANOHUB:

1. BJT Lab(ABACUS)
2. Carrier Statistics Lab(ABACUS)
3. Crystal Viewer Tool(ABACUS)
4. Drift-Diffusion Lab(ABACUS)
5. MOSCap (ABACUS)
6. MOSFET(ABACUS)
7. Periodic Potential Lab(ABACUS)
8. Piece-Wise Constant Potential(ABACUS)
9. PN Junction Lab(ABACUS)
- 10.MOSFET
- 11.MOSFET Simulation
- 12.OMEN Nanowire
- 13.Intro to MOS-Capacitor Tool.