M. Tech. – I Sem.

NT101 Introduction to Nanomaterials

Unit-I: Introduction to Nanomaterials – Definitions – zero, one, two and three dimensional nanostructures; Basics of Chemistry – Chemical bonding, Hybridization, Reduction potentials.

Unit-II Crystal structure: Crystalline and amorphous solids; Crystal lattice and crystal structure; Translational symmetry; Space lattice - Unit cell and primitive cell - Symmetry elements in crystal - Seven crystal systems - Some imperfections in crystals - Wigner-Seitz cells - Miller indices - Miller-Bravais indices - Indices of a lattice direction; The inter planar spacing of a set of crystal planes.

Unit-III: 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-IV: 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.

Unit-V: Quantum mechanics of electronics: Electron as particle and electron as wave-Time independent Schrodinger equation and boundary contestation on the wave function-Analogies between quantum mechanics and classical electromagnetic-Probabilistic current density-multiple particle systems.

Textbooks:

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

Reference Books:

1. Quantum mechanics by Brandsen & Joachem
2. J.J.Sakurari, "Modern Quantum Mechanics Mc.Graw Hill, Addison Wesley Longman Inc., USA, 1999

3. Nano Technology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
4. Nano Technology – science, innovation and opportunity by Lynn E Foster;Prentice Hall - Pearson education.
5. Quantum mechanics: - Pawling & Wilson
6. Quantum physics by A. Ghatak

M. Tech. – I Sem.

NT 102 Synthesis of Nanomaterials and Properties

UNIT-I Introduction to synthesis of nanostructure materials, Bottom-up approach and Top-down approach with examples, Stabilization techniques – Electrostatic and Steric stabilizations. **Physical methods:** Inert gas condensation, Arc discharge, RF-plasma, plasma arc technique, electric explosion of wires, ball milling, **Chemical methods:** Chemical Kinetics, Gibbs Free Energy- Thermodynamics. Thermolysis route - spray pyrolysis and solvated metal atom dispersion, sol-gel method, solvothermal and hydrothermal routes, solution combustion synthesis, Chemical vapor synthesis; Introduction to Plasma technique of Synthesis of Nanomaterials in bulk.

UNIT-II: Advanced Chemical Techniques: Nanocrystals by chemical reduction, photochemical synthesis, electrochemical synthesis; Nanocrystals of semiconductors and other materials by arrested precipitation, emulsion synthesis, sonochemical routes and mild solution methods **Biological methods:** Use of bacteria, fungi, actinomycetes for nano-particle synthesis – magneto-tactic bacteria for natural synthesis of magnetic nano-particle.

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

Unit – IV Luminescence: Fluorescence, Phosphorescence, optically excited emission, electroluminescence, Laser emission of quantum dot, Photo fragmentation and columbic explosion, phonons in nanostructures, luminescent quantum dots for biological labeling.

Unit – V 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, nanocarbon ferromagnets, ferrofluids, electron transport in magnetic multilayers.

Textbooks:

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 Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill

M. Tech. – I Sem.

NT 103 Nanomaterials Characterization

UNIT-I: Compositional Analysis: X-ray Photoelectron spectroscopy (XPS), Energy Dispersive X-ray Analysis (EDX), Inductively Coupled Plasma Optical Emission Spectroscopy (ICPOES), Inert Gas Fusion for Oxygen analysis, Electron Probe Micro Analysis (EPMA).

Structural Analysis: X-ray Diffraction (XRD), Electron Diffraction, Ion Beam Techniques – SIMS and RBS.

UNIT – II: Surface characterization Techniques- High resolution microscopy; Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), scanning tunnelling microscopy (STM), Surface Area Measurements – Adsorption principle - Freundlich, Langmuir, and BET methods of measurement.

UNIT – III: Spectroscopic techniques: Fourier Transform infrared (FTIR) spectroscopy, Raman spectroscopy techniques: micro Raman and laser Raman.

UNIT – IV: Electrical characterization techniques: Measurement of resistivity by 4-probe method, Hall measurement, Seebeck coefficient measurements, Nano indentation techniques, electron beam induced current measurement (EBIC).

UNIT-V: Thermal and Magnetic characterization: VSM, Thermal analysis, impedance and ferroelectric measurements

Text Books:

1. Characterization of Nanostructured Materials by Z L Wang

2. Introduction to Nanotechnology by Charles P Poole Jr and Frank J Owns, Wiley India Pvt Ltd.
3. Nano: The Essentials -Understanding Nano Science and Nanotechnology by T.Pradeep, Tata Mc.Graw Hill
4. Principles of Instrumental Analysis by D A Skoog, F J Hollen and T A Niemann
5. A Practical Approach to X-Ray Diffraction Analysis by C Suryanarayana

Reference Books:

1. Nanotechnology: Principles and Practices – Sulabha K Kulkarni – Capital Publishing Company
2. Specimen Preparation for Transmission Electron microscopy by John & Bravmno et al, published by MRS
3. Photoelectron spectroscopy by JHD Eland, Butterworth & Co. Publishers, 2nd edition
4. Encyclopaedia of Nanoscience and Nanotechnology by H S Nalwa
5. Electron Microscopy and Analysis by P J Goodhew and F J Humpreys
6. Scanning Electron Microscopy and X- ray Microanalysis by J I Goldstein
7. Modern Raman Spectroscopy: A Practical Approach by E Smith and G Dent.

M. Tech. – I Sem.

NT-104 Thin Film Science and Technology

UNIT – I: Vacuum technology: Clean Room – Clean room technology and its Classes.

Principles of vacuum pumps in range of 10^{-2} torr to 10^{-11} torr, principle of different vacuum pumps: roots pump, rotary, oil diffusion pump, 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 – II: 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, properties of thin films: Mechanical, electrical, and optical properties of thin films, few applications of thin films in various fields; Thermomechanical behaviour of thin film nanostructures.

UNIT-III: Physical Vapor Deposition techniques: Thermal evaporation, resistive evaporation, Electron beam evaporation, Laser ablation, Flash and Cathodic arc deposition.

UNIT –IV: Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, R.F sputtering, Triode sputtering, Ion Plating, Difference between thin films and coating.

UNIT –V: 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: Metal Organic CVD (MOCVD), Thermally activated CVD, CVD, Spray pyrolysis, etc.

Text Books

1. Thin Film Phenomenon by K.L. Chopra, McGraw-Hill

References

1. Methods of Experimental Physics (Vol 14) by G.L.Weissler and R.W.Carlson "Vacuum Physics and Technology"

2. A User's Guide to vacuum Technology by J.F.O'Hanlon, John Wiley and Sons

3. Vacuum Physics and Techniques by T.A. Delchar, Chapman and Hall

4. Evaporation: Nucleation and Growth Kinetics" by J.P. Hirth and

G.M.Pound, Pergamon Press

M. Tech. – I Sem.

NT 1051 Surface Engineering of Nanomaterials

(Elective - I)

Unit–I Adsorption phenomenon: Chemisorption & Physisorption, adsorption isotherms and methods of determination of pore size and surface area of materials using the adsorption isotherms,

Catalysis – Definition, types of catalysis with suitable examples, characteristics of a catalyst, selectivity or specificity of the catalyst, activation and deactivation of catalysts, catalytic poisoning

Unit–II Necessity for the alternate energy sources and the role of catalytic technology in the energy sector – Fuel cells, Solar cells, Biomass and Biofuels, New trends in heterogeneous catalysis – catalytic sensors, membrane and monolithic reactors

Unit–III Catalysis in environmental protection & green process- Industrial catalytic wet air oxidation processes, water purification, synthesis of specialty, commodity and fine chemicals, catalysis in automobiles : catalytic converter applications

Unit–IV Important catalytic materials – Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials (viz. mesoporous materials)

Unit–V Mesoporous materials – Introduction, synthesis & characterization, properties and applications (with suitable examples), unipore size, bimodal pore size, graphs., supramolecular chemistry, synthesis (micellar rods).

Text Book

1. Basic principles in applied catalysis – Manfredlaerns

Reference Books

1. Nanotechnology in Catalysis – Pinzhan
2. Introduction to Nanotechnology – Charles P Poole Jr & Frank J Owens
3. Nanoscale Materials –LM Liz Marzan & Prashant V. Kamat
4. Nanostructured catalysts – SL Scott, CM Crudden & CW Jones
5. Concepts of Modern Catalysis & kinetics - I. Chorkendorff, J.W. Niemantsverdriet
6. Chemistry of Nanomaterials: Synthesis, properties & applications, Volume-I – CNR Rao, A Muller & AK Cheetham

M. Tech. – I Sem.

NT 1052 **Computational Nanotechnology**

(Elective I)

UNIT I

Introduction: Computational simulation, need for discrete computation. Classical Mechanics: Mechanics of Particles, D'Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

UNIT II

Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, partition function for identical particles, Maxwell distribution of molecular speeds.

UNIT III

Atomistic Simulation Techniques: Molecular Dynamics (MD): Introduction, inter-atomic potential function, Lennard-Jones potential, MD simulation – equilibration and property evaluation, various types of potential functions, computational aspects, introduction to advanced topics.

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, Mesoscopic Simulation Techniques: Lattice Boltzmann Method (LBM): Boltzmann equation, derivation of the hydrodynamic equation from Boltzmann equation, Lattice Boltzmann equation and LBM, applications of LBM.

Text Books

1. Wolfram Hergert, Computational Materials science, Springer.

2. Multiscaling in molecular and continuum mechanics by G. C. Sih, Springer.
3. A primer for the monte carlo method, llya M. Sobol' CRC Press
4. Simulation and Monte carlo method by Reuven Y. Rubisten

Reference Books

1. Probability and statistics for engineers, miller and john e. freund, prentice hall of india
2. The monte carlo method, popular lectures in mathematics by sobol.i.m

M. Tech. – I Sem.

NT-1053 Colloid and Interface Science

(Elective I)

Unit-I: Introduction to colloids, surface properties, origin of charge on colloidal particles, preparation & characterization of colloidal particles. Applications of colloids in oil recovery, super hydrophilic surfaces, self cleaning surfaces.

Unit-II: Surfactants type (Anionic, cationic, Zwitter ionic, Amphiphilic and non-ionic). Theory of Surfactants; CMC, Kraft temperature. Phase behavior of cone surfactant systems, surfactant geometry and packing. Emulsions, Micro emulsions & Gels. Intermolecular Forces, Van der Waals forces (Kessorn, Debye, and London Interactions).Potential energy curve, Brownian motion and Brownian Flocculation.

Unit-III: Unit Surface and interfacial Tension, Sessile drop, pendant drop, Surface free energy, Surfacetension for curved interfaces, Surface excess and Gibbs equation. Contact angle, Wetting Young-Laplace equation, Dynamic properties of interfaces .Surface viscosity, Kelvin equation.

Unit-IV: Electrical phenomena at interfaces (Electronic kinetic phenomena, Electric double layer,short range forces). DLVO theory, capillary hydrostatics, interfacial hydrodynamics, marangonic effect.

Unit-V: Measurements technique: Surface tension, Interfacial Tension, Contact angle, Zeta potential , Particle size & its distribution. Electro osmosis phenomena, Streaming potential, Electro viscous flows.

Text Books:

1) A.W. Adamson and A.P Gast, Physical Chemistry of surfaces, Wiley Interscience , NY 2004.

2) P.C Hiemen and R.Rajgopalam, Principle of colloid and surface Chemistry NY Marcel

Dekker, 1997.

3) D.J.Shaw, Colloid and surface chemistry, Butterworth Heineman, Oxford,1992.

4) M J Rosen, Surfactant and Interfacial phenomena, Wiley Inter Science Publication, NY 2004

5) Jacob Israelachvilli, Intermolecular and Surface Forces, Academic Press, NY 1992.

Reference Books:

1. Colloid and Interface Science by Pallab Ghosh, PHI Learning Pvt Ltd, 2009

M. Tech. – I Sem.

NT 1061 **Nano fluidics**

(Elective II)

UNIT I

Introduction: Fundamentals of cooling, Fundamentals of nanofluids, Making nanofluids, Mechanisms & Models for enhanced thermal transport, Future research. Synthesis of nanofluids: General issues of nanofluids, Synthesis methods-common issues, Study of nanoparticles, Variety in nanomaterials, Micro emulsion based methods for nanofluids, Solvo thermal synthesis, Synthesis using supports, Synthesis using biology, Magnetic nanofluids, Inert gas condensation, Anisotropic nanoparticles, Other nanofluids, summary.

UNIT II

Conduction heat transfer in nanofluids: conduction heat transfer, Measurement of thermal conductivity of liquids, Thermal conductivity of oxide nanofluids, Temperature dependence of thermal conductivity enhancement, Metallic nanofluids, naofluids with CNTs.

UNIT III

Theoretical modeling of thermal conductivity of nanofluids: Simple mixture rules, Maxwell approach, Particle distribution, Particle geometries, Symmetrical equivalent medium theory, Matrix particle interfacial effects, Dynamic models of thermal conductivity of nanofluids.

UNIT IV

Convection in nanofluids: Fundamentals of convective heat transfer, convection in suspensions & slurries, Convection in nanofluids, Analysis of convection in nanofluids, Numerical studies of convection in nanofluids.

UNIT V

Boiling of nano-fluids: Fundamentals of boiling, Pool boiling of nanofluids, Critical heat flux in pool boiling of nanofluids, Other investigations related to boiling of nanofluids.

TEXT BOOK:

1. Nano Fluids Science and Technology by Sarit Kumar Das, John Wiley and sons.

M. Tech. – I Sem.

NT 1062 Piezo and Pyroelectric Nanomaterials

(Elective II)

Unit I: Introduction to Dielectrics and Concept of Polarisation; Types of Polarization – Electronic, Ionic, Orientational, and Space Charge Polarisations; Frequency Dependence of Dielectric polarisation; Classification of Dielectric materials, Smart materials, Categories of Smart materials – Conducting polymers, Shape memory alloys, Liquid Crystal materials, Piezoelectric materials, Pyroelectric materials, Ferroelectric materials and Poled Polymers; Introduction to Piezoelectricity, Inverse Piezoelectricity, and Pyroelectricity, Mathematical Description of Piezoelectric effects.

Unit II: Properties of Piezoelectric Materials – Quartz, PZT, PVDF, ZnO and Other materials, Applications to Inertial Sensors, Acoustic Sensors, Tactile Sensors, Flow Sensors and Surface Elastic Waves, Piezoelectricity in wood and bone – Applications of Piezoelectricity in Nanomedicine, Piezoelectric Nanogenerators for self-powered Nanodevices.

Unit III: Preparation methods of Piezoelectric nanoparticles – Mixed Oxide Technology, Mechanochemical Synthesis technique, Chemical Coprecipitation, Hydrothermal synthesis, Sol-gel technique, Mechanical and Electrochemical Characterization of One dimensional Piezoelectric nanomaterials – Nanomechanical Characterization – Electromechanical Characterization

Unit IV: Fundamentals of Pyroelectric materials, Pyroelectric IR detectors, Important Pyroelectric materials – Tri-Glycine Sulphate (TGS) crystals and their isomorphs, Modified Lead Titanate, PZT, $LiTaO_3$ and $LiNbO_3$, AlN, GaN, ZnO, Organic Pyroelectrics, Processing of Pyroelectric Thin film Deposition methods – Non-solution methods: Sputtering, Laser Ablation, and CVD methods, and Solution methods: Sol gel Technique, Metal-Organic Deposition Technique.

Unit V: Applications of Pyroelectric and Pyroelectric nanomaterials - IR detectors, Energy Harvesters - Flexible Pyroelectric Nanogenerators and Particle detectors.

Text Books

1. Foundations of MEMS by Chang Liu, Pearson Education Ltd., 2011
2. Piezoelectric Nanomaterials for Biomedical applications by Gianni Ciofani, Arianna Menciassi (eds.), Springer Verlag Berlin 2012,
3. Pyroelectric Materials by A K Batra and M D Agarwal, SPIE, 2013

References

1. Ya Yang, Jong Hoon Jung etal, "Flexible Pyroelectric Nanogenerators using a Composite Structure of Lead-free$KNbO_3$ Nanowires", Advanced Materials, 2012.
2. Athanasios Batagiannis, Michael Wübbenhors, Jürg Hulliger , "Piezo and Pyroelectric Microscopy", Current Opinion in Solid State and Materials Science 14 (2010) 107–115.

M. Tech. – I Sem.

NT 1063 Carbon Nanostructures and Applications

(Elective II)

UNIT – I Allotropy of Carbon, Carbon Nano structures - Carbon clusters Fullerenes and types of Carbon Nano tubes, growth mechanisms, Mechanical reinforcements, Solid Disordered carbon Nanostructures, Nano structured crystals; Graphene, Carbon nanofibers; Electrical, Vibrational, Mechanical Properties of CNTs, Optical properties & Raman spectroscopy of CNTs

UNIT –II , Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process; Lithium & Hydrogen adsorption & storages, Fuel cell applications and energy storage, Chemical Sensors applications of CNTs, Computer applications (Nano chip), Optical and telecommunication applications, CNT Nano composites, Silicon Nanowires.

UNIT-III Graphene - Fundamentals of Graphene, Synthesis – Different routes, Exfoliation method, Industrial applications

UNIT-IV Graphene oxide – Synthesis, Properties and Applications.

UNIT-V Graphene like Structures – Borophene, Pure Metal Single layers – Properties and Applications

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

Reference Books:

1. Encyclopaedia of Nanotechnology by M.Balakrishna rao 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 education.
4. Nano:The Essentials – Understanding Nano Science and Nanotechnology by T.Pradeep; Tata Mc.GrawHill

M. Tech. – I Sem.

NT 107 Synthesis and Characterization Lab

1. Two methods for the synthesis of CNTs (CVD method and Flame Synthesis)
2. Nano – Catalyst Preparation by Chemical methods
3. Synthesis of oxide Nanostructures / nano composites by Sol-gel Process
4. Preparation of any two types of Ceramic Powders, $BaTiO_3$ (ball milling) & Al_2O_3 (flame)
    a. Composite preparation (Ball Milling)
    b. X-ray Diffraction measurements of Nano Crystallites
5. Nano Particle Size Analysis
6. Three experiments on Characterization of nanopowders using AFM, SEM, etc
7. Three experiments on Characterization of 1D, 2D and 3D structures using AFM, SEM,
8. Raman Spectroscopy of synthesized nanomaterials using BWTEK Raman Spectrophotometer

M. Tech. – II Sem.

NT 201 Green Nanotechnology

Unit-I Introduction: Introduction to Environmental Applications, Implications of Nanotechnology & Research needs; Green Chemistry - Green Chemistry Methodologies; Quantitative/Optimization-Based Frameworks for the Design of Green Chemical Synthesis Pathways; Green Chemistry Pollution Prevention in Material Selection for Unit Operations.

Unit-II: Nanoparticles for Treatment of Chlorinated Organic Contaminants: Introduction, Overview of Chlorinated Organic Solvents, Biodegradation of Chlorinated Organic Solvents, Nanoscale zero-valence iron (NZVI), Application of other Nanoscale metallic particles in chlorinated organic compound degradation. Application to treatment of Arsenic.

Nanomembranes: Nanomembranes in Drinking water treatment, Nanomembranes in Sea water Desalination. Environmental Risks of Nanomaterials: Routes of NMS into the Water environment, Hazardous effects of NMs on Human and Animal Health, Risk Management.

Unit-III: Clean technology and Energy: Clean Development Mechanism –Carbon Trading- examples of future Clean Technology – Biodiesel – Natural Compost – Eco- Friendly Plastic – Alternate Energy – Hydrogen – Biofuels – Solar Energy – Wind – Hydroelectric Power – Mitigation Efforts in India and Adaptation funding.

Unit–IV Introduction to Nanobiotechnology: Challenges and opportunities associated with biology on the Nanoscale; Nanobiotechnology systems; introduction to bioelectronics; Characterization techniques for biological molecular nanostructures.

Bionanomaterials: Biomolecules for designing nano-structures; nanoprinting of DNA, RNA and Proteins, use of these nano-structures in biological and medical applications; Principles of self-assembly, self-organization and its application to biology. DNA nanostructures, DNA robot, DNA microarrays, Sizes of building blocks and Nanostructures, Polypeptide nanowire and protein nanoparticles.

Unit-V Biosensors: Introduction to biosensors; the biological component; the sensor surface; Immobilization of the sensor molecule; Transduction of the sensor signal -Optical sensors; Electrochemical sensors; Suppression or subtraction of non-specific background interaction at sensor surfaces; Sensor stabilization; Data analysis

Text Books:

1.'Nanotechnologies For Water Environment Applications' American Society of Civil Engineers (ASCE) Publications by Tian C.Zhang, Zhiqiang Hu et al.

2. Mukesh Doble and Anil Kumar Kruthiventi, Green Chemistry and Engineering, Elsevier, Burlington, USA, 2007.
3. Bio Nano Technology by Good Sell, Wiley Liss
4. Introduction to Nanotechnology by Charles. P.Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
5 Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter, Pearson education
6. Nanotechnology – science, innovation and opportunity by Lynn E Foster, Prentice Hall – Pearson education.

Reference Books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nanotechnology by M.Balakrishna Rao and K.Krishna Reddy (Vol I to X), Campus books
3. Nanotechnology in Water Purification Applications Caister Academic Press by T. Eugene, Michele de Kwaadsteniet, Marelize Botes and J.Manuel Lopez-Romero.

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NT 202 Nanoelectronics

Unit - I: 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.

UNIT-II: 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,
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: Introduction, Overview, History & Background, Generation of Spin Polarization Theories of spin Injection, spin relaxation and spin dephasing, Spintronic devices and applications, spin filters, spin diodes, spin transistors.

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. Encyclopedia 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

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NT-203 Nano Technology for Energy Systems

Unit–I Battery materials and batteries: Lithium Ion based batteries. 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-II: Nanomaterials used in energy and environmental applications and their properties: Evaluation of properties and performance of practical power systems that benefit from optimization of materials processing approaches.

Unit–III 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 enthalpy formations and thermal management during hydriding reaction, multiple catalytic – degradation of sorption properties, automotive applications.

Unit–IV 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.

Unit–V Microfluidic Technology: MEMS & NEMS technology for microfluidic devices: micro and nano engines and driving mechanism, power generation, microchannel battery pump (TCP), piezoelectric membrane and their applications.

Text Book

1. Renewable Energy Resources by J. Twidell and T.Weir, E&FN Spon Ltd.

References

1. Hydrogen from Renewable Energy Source by D.Infield
2. .Fundamentals of Industrial Catalytic Process by C.H. Bartholomew and Robert J. Farraoto, John Wiley & Sons Inc.
3. Fuel storage on Board Hydrogen storage in Carbon Nanostructures by R.A. Shatwell
4. Fuel cell Technology Handbook by Hoogers, CRC Press
5. Hand book of fuel cells: Fuel cell technology and applications by Vielstich, Wiley:CRC Press

M. Tech. – II Sem.

NT204 Multifunctional Nanomaterials

Unit-I : Introduction to Multifunctional Nanomaterials - Smart materials – Examples – Properties and Applications.

Unit-II: Synthesis/Strategies for Development of multifunctional Nanomaterials – TiO_2, Fe_2O_3, ZnO, SnO_2.

Unit-III: Nanostructured Catalysts – TiO_2 Nanoparticles for Water purification - TiO_2 as a semiconductor photocatalyst, Photo catalytic mechanism, general pathways & kinetics, Intrinsic, Photocatalytic activity, Reaction variables, Photocatalytic Degradation of Specific Waterborne pollutants. Nanoparticles for treatment of Arsenic: Introduction, Environmental Chemistry of Arsenic, Treatment of Arsenic using Nanocrystalline TiO_2, Treatment of Arsenic using nanoparticles other than TiO_2.

Unit IV: TiO_2 Fabrication, Superhydrophilicity – Other applications of TiO_2.

Unit V: Other Examples of Multifunctional Nanomaterials – Fe_2O_3, ZnO, SnO_2, Ag and Au nanomaterials – Properties and Applications

Text Book:

1. Nanoscale Multifunctional materials by S Mukhopadhyay – Wiley 2011

References:

1. 'Silver Nanoparticles – Universal Multifunctional Nanoparticles for Bio Sensing, Imaging for Diagnostics and Targeted Drug Delivery for Therapeutic Applications' by Anitha Sironmani and Kiruba Daniel

2.Silver–Polymer Composite Stars: Synthesis and Applications by Tae-Jong Yoon et al Angew. Chem. Int. Ed. 2005, 44, 1068 –1071

3.Encyclopedia of Nanoscience and Nanotechnology by H S Nalwa Vol I to Vol 10

4.Bulk Nanostructured Materials with Multifunctional properties by I Sabirov, NA Enikeev, MYu Murashkin, and RZ Valiev – Springer

5.Multifunctional Transparent Epoxy Nanocomposites As Encapsulating Materials For Led Devices by Shao-Yun Fu - iccm-central.org/Proceedings

6.Multifunctional composite core–shell nanoparticles by Suying Wei,et al - Nanoscale, 2011, 3, 4474

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NT – 2051 Biomedical Nanotechnology

(Elective 1)

Unit-I Imaging of Bionanostructures: Practical and theoretical aspects of imaging biological systems, from the cellular level through to whole-body medical imaging, basic physical concepts in imaging; Major techniques using ionizing and non-ionizing radiation including fluorescence and multi-photon microscopy, spectroscopy, OCT, MRI, X-ray CT, PET, Confocal and SPECT imaging.

Unit-II Nano Bioactive Glasses: Nanobiosensors, Nano Bioactive glasses, Biomaterials – Preparation – Methods - Nanobioactive glass powders – Properties –Mechanical-measurement of bioactivity – In vitro studies - coating on metallic implant – Characterization - Implant applications.

Unit-III Cancer Treatment: Gold and Silver nanoparticles in cancer targeting and treatment - Nanoparticles in treatment of breast cancer –Chemotherapy: Active and Passive cancer tissue targeting – micro fluidics – Chemotherapeutic agents –Immunotherapy – Vaccine immunotherapy – Radiotherapy – Thermotherapy – Photo dynamic therapy – Nano particulate targeting.

Unit-IV Delivery Mechanism: Introduction, Antibody conjugated nanoparticles, Conjugated nanoparticles interaction with biological surfaces, Biomedical nanoparticles, Liposomes, Dendrimers, Different types of drug loading, drug release and Biodegradable polymers, Applications.

Unit-V Targeted Drug Delivery: Basic and special pharmacology – strategies for targeted delivery – in nature – Bacteria – virus – prion -strategies for targeted delivery – by human – oral delivery – transdermal – transmucosal – invasive – Targeted delivery to brain – macrophage targeting.

Text Books:

1. 'Biomedical Applications of Nanotechnology' by Vinod Labhasetwar, Diandra L. Leslie-Pelecky John Wiley & Sons

2. 'Nanomedicine and Drug delivery' by Mathew Sebastian Neethu Ninan A. K. Haghi, Apple Academic Press
3. 'Nanotechnology for Cancer Therapy' by Mansoor M. Amji, CRC press

References:

1 Challa Kumar, Nanomaterials for medical diagnosis and therapy , Wiley VCH 2005

2 James A. Schwarz, Cristian I. Contescu, Karol Putyera, "Dekker encyclopedia of nanoscience and nanotechnology" CRC Press, 2004.

3 Natalie P. Praetorius and Tarun K. Mandal, Recent Patents on Drug Delivery & Formulation

4. Y. Lu, S.C. Chen, "Micro and nano-fabrication of biodegradable polymers for drug delivery" Advanced Drug Delivery Reviews, 56 (1621-1633) 2004.

M. Tech. – II Sem.

NT – 2052 Nanocomposites and Applications

(Elective I)

Unit – I Introduction to Nanocomposites, Composite material, Mechanical properties of Nano composite material: stress - strain relationship, toughness, strength, plasticity.

Unit – II Ceramic-Metal Nanocomposites, Ceramic based nanoporous composite, Metal matrix nanocomposites, Polymer-based nanocomposites Carbon nanotube based nanocomposites and Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites; Applications to Strategic Sector (Aerospace, Defense - CNT based structures - CNT based Nose cones for reentry vehicles), Armour protection (Polymer-Tungsten, Polymer-CNT Nanocomposites)

Unit – III Synthesis methods for various nanocomposite materials: mechanical alloying, thermal spray synthesis etc. Nano composites for hard coatings; DLC coatings; Thin film nanocomposites; Modeling of nanocomposites.

Unit – IV Nano Indentation, Types of indentation: Oliver & Pharr, Joslin-Oliver, Vickers Indentation process.

Unit – V Processing of polymer nanocomposites, properties of nanocomposites, Salt infiltration, Powder mixing, Intrusion method, Exfoliation & interaction, Gel-casting impregnation techniques: Hot melt impregnation, solution impregnation.

Text Books:

1. Nanocomposite Science & Technology by P.M. Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co.
2. Thomas E. Twardowski, Introduction to Nanocomposite Materials, Properties, Processing, Characterization, DesTech Publications, April 2007

Reference Books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopedia of Nano Technology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X
3. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens; Wiley India Pvt Ltd.
4. Nanotechnology, A gentle introduction to the next big idea by Mark Ratner, Daniel Ratner Pearson education.

M. Tech. – II Sem.

NT – 2053 Nano Photonics & Plasmonics

(Elective I)

Unit I: Foundations for Nanophotonics: Photons and electrons: similarities and differences, Free space propagation; Confinement of photons and electrons; Propagation through a classically forbidden zone: tunneling. Localization under a periodic potential: Band gap. Cooperative effects for photons and electrons; Nanoscale optical interactions, axial and lateral nanoscopic localization; Nanoscale confinement of electronic interactions: Quantum confinement effects, nanoscale interaction dynamics, nanoscale electronic energy transfer; Co-operative emissions.

Unit II: Quantum Confined Materials: Inorganic semiconductors, quantum wells, quantum wired, quantum dots, quantum rings. Manifestation of quantum confinement: Optical properties nonlinear optical properties. Quantum confined stark effect; Dielectric confinement effect, super lattices; Core-shell quantum dots and quantum-dot-quantum wells; Quantum confined structures as Lasing media.

Unit III Photonic Crystals: Basics Concepts, Features of Photonic Crystals, wave propagation, photonic band gaps, light guiding; Theoretical Modeling of Photonic Crystals; Methods of Fabrication; Photonic Crystal Optical Circuitry; Nonlinear Photonic Crystals; Photonic Crystals and Optical Communications. Application to high efficiency emitters miniaturized photonic circuits and dispersion engineering; Photonic Crystal Sensors – Microstructure Fiber applications.

Unit IV: Nanophotonic Devices: Resonant cavity quantum well lasers and light-emitting diodes,, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavity LED; Microcavity-based single photon sources.

Unit V: Plasmonics: Metallic nanoparticles, nanorods and nanoshells, local field enhancement; Collective modes in nanoparticle arrays; particle chains and arrays; surface plasmons, Plasmon Waveguides; Applications of Metallic Nanostructures - Metamaterials.

Text Books:

1. Nanophotonics, Paras N Prasad, John Wiley & Sons (2004)

References:

1. Photonic Crystals: Towards Nanoscale Photonic Devices; Jean Michel Lourtioz, Springer ; ISBN 354024431X
2.Fundamentals of Photonic Crystal Fibers; Fredric Zolla- Imperial College Press. ISBN 1860945074
3. Photonic Crystals; John D Joannopoulos, Princeton University Press; ISBN0691037442
4. Photonic Crystals: Modeling Flow of Light; John D Joannopoulos , R.D. Meade and J.N.Winn, Princeton University Press (1995)
5. The Handbook of Photonics by Mool Chand Gupta, John Ballato

M. Tech. – II Sem.

NT 2061 **Nanoscale Magnetic Materials and Devices**

(Elective II)

Unit I: Nanoscale Magnetic materials – Introduction to Magnetic materials – Dia, Para, Ferro,

Antiferro and Ferri magnetic materials, Super paramagnetic materials, Stern - Gerlach Experiment of Electron Spin, Magnetic forces and van der Waals forces in Magnetic nanoparticles (MNps), Magnetic clusters, Magnetization and Demagnetization – Experimental methods, Instruments for measuring Magnetization – VSM, AGM, SQUID magnetometers.

Unit II: Hard and Soft Magnetic materials - Magnetic Nanoparticles for Hard magnetic applications – FePt, CoPt, $SmCo_5$ nanocomposites, Magnetic Nanoparticles for Soft magnetic applications – Co, Fe, Ni Binary alloys – Synthesis, Properties and Applications.

Unit III: Biomagnetism and Biomagnetic Nanostructures – Examples – Haemoglobin, Ferritin and Magnetotactic bacteria – Biomedical Applications of Magnetic nanomaterials and nanostructures.

Unit IV: Ferrofluids – Synthesis, Properties and Applications.

Unit V: Other Magnetic Applications – Magnetoresistance – AMR, GMR, TMR, CMR – Core Shell Magnetic nanostructures – Thin Layered Films – MRAM applications, Quantum Computation and NMR.

Text Books:

1. Introduction to Magnetic materials by Cullity B D
2. Nanocrystalline materials by Glieter
3. Introduction to Nanotechnology by Poole and Owens

References:

1. Encyclopedia of Nanoscience and Nanotechnology by H S Nalwa (ed.) Vol I to X.
2. Advanced Magnetic Nanostructures by Sellmyer - Springer

M. Tech. – II Sem.

NT-2062 **MEMS and NEMS**

(Elective II)

Unit-I Introduction to MEMS and NEMS: MEMS and NEMS – multidisciplinary nature of MEMS/NEMS – working principles: as micro sensors (acoustic wave sensor, biomedical and biosensor, chemical sensor, optical sensor, capacitive sensor, pressure sensor and thermal sensor), micro actuation (thermal actuation, piezoelectric actuation and electrostatic actuation – micro gripers – micro motors – micro valves – micro pumps – accelerometers – micro fluidics and capillary electrophoresis, active and passive micro fluidic devices; Nanoelectromechanical systems – Single Electron Transistors and applications.

Unit-II Materials for MEMS/NEMS: Silicon – Compatible material systems, Silicon, Silicon oxide and nitride, Thin metal films, Polymers, Other materials and substrates, Glass and fused quartz substrates, Silicon carbide and diamond, Gallium Arsenide and other group III-V compound semi conductors, Shape - memory alloys transduction atomic bonds, Material structures.

Unit-III MEMS/NEMS design, processing and Technologies: Basic process tools, Epitaxy, Oxidation, Sputter deposition, Evaporation, Chemical vapor deposition, spin on methods, Lithography, Lift off process, Bulk Micro machining, Etching processes – Wet etching, Plasma etching, Ion milling, Wafer bonding – Silicon fusion bonding, Anodic bonding, Silicon direct bonding, sol gel deposition methods, Self assembled mono layers, EFAB. LIGA electromagnetic micro drive, DRIE

Unit-IV 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.

Unit –V Introduction to lithography and Optical lithography: Introduction to lithography- Contact, proximity printing and Projection Printing, Positive and negative photoresists; Basics of Resolution Enhancement techniques, overlay-accuracies, Mask-Error enhancement factor (MEEF), Electron Lithography; X-ray Lithography; Ion Lithography (Focused Ion Beam Lithography, Masked Ion Beam Lithography, Ion Projection Lithography).

Text Books

1. “An introduction to Micro electro mechanical systems Engineering” by Nadim Malut 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.John N.Helbert, “Handbook of VLSI Microlithography”, Noyes Publication, USA, 2001.

4.James R Sheats and Bruce W.Smith, “Microlithography Science and Technology”, Marcel

Dekker Inc., New York, 1998

Reference Books

1. “Springer Hand Book of Nano Technology” by Bharath Bhushan – Springer

2 .“ Nano and Micro electro Mechanical systems” by Sergey Edward Lysherski – CRC Press.

3. MEMS & Micrsystems Design and Manufacture-Tai-Ran Hsu, Tata McGraw Hill

4.L.A.Stelmack, C.T.Thurman and G.R. Thompson “Review of Ion-assisted Deposition: Research to Production”, Nuclear Instruments and Methods in Physics Research B, 37/38,787 (1989).

8. J.M.Bennett “When is a surface clean?” p.29 in Optics and Photonics News, June, 1990.

M. Tech. – II Sem.

NT 2063 **Micro and Nanomechanics**

(Elective II)

UNIT I

Introduction: Linear Atomic Chains:

A model binary molecule (Two, three and N atoms Linear chain), Linear chain with optical modes, Quantum Mechanics and Thermodynamics of the linear chain, Effect of temperature on the Linear chain, Quantum Operators for normal modes.

UNIT II

Two And Three-Dimensional Lattices

Crystals, Two – Dimensional Crystals, Three – Dimensional Crystals, Periodic Functions, Bloch’s Theorem, Classical Theory of the Lattice, Normal Mode Hamiltonian, Connection to the Classical Continuum Theory of Solids.

UNIT III

Stress, Strain And Elasticity Relations

Relative displacement and Strain, Principal Axes of Strain, Superposition, The Stress Tensor and their properties, Inhomogeneous Stresses and Arbitrary Shapes, Body forces, Classes of Linear Elastic response, Isotropic, Orthotropic, Crystalline and Polycrystalline Materials, Stress – strain relations.

UNIT IV

Static Deformations Of Solids

System of Equations for a static deformable solids, Extensional forces, Flexure of Beams, Euler – Bernoulli Theory of Beams, Torsional Beam, Two and Three Dimensional Problems.

UNIT V

Dynamic Behavior Of Solids & Dissipation And Noise In Mechanical Systems

Simple vibrational methods, Dynamical Equations of motion in an isotropic solid, Waves in infinite isotropic solids, Waves in infinite crystalline solids, Waves in semi - infinite isotropic solids, Waves in plates and Waves in rods, Langevin equation, Zener's model of an Anelastic solid, Thermoelastic relaxation, Phonon – Phonon Interactions, Dissipation in Nanoscale Mechanical Resonators.

Text Book:

1. Andrew. N. Cleland "Foundations of Nanomechanics: From Solid – State Theory to Device Applications", Springer International Edition, 2005.

References:

1. Robert Kelsall, Ian W. Hamley, Mark Geoghegan "Nanoscale Science and Technology" John Wiley & Sons, 2006.

2. Wing Kam Liu, Eduard G. Karpov, Harold S. Park "Nano Mechanics and Materials: Theory, Multiscale Methods and Applications", John Wiley & Sons, 2006

M. Tech. – II Sem.

NT-207 Mathematical Modeling and Simulation of Nanomaterials lab

Introduction to Mathematical Modeling and ARGUS Lab:

1. Construction of fullerene & its energy calculations
2. Construction of Bucky balls (C_{20}, C_{40}, C_{60}, C_{80}, C_{100}, C_{120})
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