ANNA UNIVERSITY : : CHENNAI 600 025

AFFILIATED INSTITUTIONS

REGULATIONS - 2013

CURRICULUM : I TO IV SEMESTER (FULL TIME)

M.TECH. NANOSCIENCE AND TECHNOLOGY

SEMESTER I

COURSE CODE	COURSE TITLE	L	T	P	C
THEORY					
MA7160	Mathematical Modelling and Simulation	3	0	0	3
NT7101	Quantum mechanics	3	0	0	3
NT7102	Physics and Chemistry of Nanomaterials	3	0	0	3
NT7103	Advanced Materials Technology	3	0	0	3
NT7104	Synthesis of Nanomaterials	3	0	0	3
NT7105	Nanostructures in Biological Systems	3	0	0	3
PRACTICAL					
NT7111	Material Synthesis	0	0	4	2
NT7112	Computation and Simulation	0	0	4	2
	TOTAL	**18**	**0**	**8**	**22**

SEMESTER II

COURSE CODE	COURSE TITLE	L	T	P	C
THEORY					
NT7201	Photonics for Nanotechnology	3	0	0	3
NT7202	Processing and Properties of Nano Structured Materials	3	0	0	3
NT7203	Physicochemical Methods for Characterization of Nanomaterials	3	0	0	3
NT7204	Imaging techniques for nanotechnology	3	0	0	3
NT7205	Nanotechnology in Health Care	3	0	0	3
NT7206	Nanoelectronics and Sensors	3	0	0	3
PRACTICAL					
NT7211	Nanometrology & Microscopy	0	0	4	2
	TOTAL CREDIT	**18**	**0**	**4**	**20**

SEMESTER III

COURSE CODE	COURSE TITLE	L	T	P	C
THEORY					
NT7301	Lithography and Nanofabrication	3	0	0	3
E1	Elective-I	3	0	0	3
E2	Elective-II	3	0	0	3
E3	Elective-III	3	0	0	3
PROJECT					
NT7311	Project Work (Phase – I)	0	0	12	6
	TOTAL CREDIT	**12**	**0**	**12**	**18**

SEMESTER IV

COURSE CODE	COURSE TITLE	L	T	P	C
PROJECT					
NT7411	Project Work (Phase – II)	0	0	24	12
	TOTAL CREDIT	**0**	**0**	**24**	**12**

LIST OF ELECTIVES

COURSE CODE	COURSE TITLE	L	T	P	C
NT7001	Top Down Manufacturing Methods	3	0	0	3
NT7002	Bottom up Synthesis of Nanostructures	3	0	0	3
NT7003	Semiconductor Nanostructures & Nano-particles	3	0	0	3
NT7004	Nanotechnology for Energy Systems	3	0	0	3
NT7005	Molecular Electronics	3	0	0	3
NT7006	Product Design, Management Techniques and Entrepreneurship	3	0	0	3
NT7007	Nanocomposites	3	0	0	3
NT7008	MEMS and Bio MEMS	3	0	0	3
NT7009	Chemical Nanotechnology	3	0	0	3
NT7010	Nanoparticles and Microorganisms, Bionano Composites	3	0	0	3
NT7011	Optical Properties of Nanomaterials, Nanophotonics and Plasmonics	3	0	0	3
NT7012	Advanced Nano Drug Delivery Systems	3	0	0	3
NT7013	Biomolecular Machines	3	0	0	3
NT7014	Biosensors	3	0	0	3
NT7015	Biophotonics	3	0	0	3
NT7016	Nanotoxicology	3	0	0	3
BY7022	Nanobiotechnology	3	0	0	3

MA7160 MAMATHEMATICAL MODELING AND SIMULATION L T P C
3 0 0 3

UNIT I FUNDAMENTAL PRINCIPLES OF NUMERICAL METHODS 9

Numerical data and Numerical operations - Numerical Algorithms - Numerical Programs - Numerical Software - Numerical analysis and Numerical methods - assumptions and limitations in numerical solutions - Numerical differentiation: Using Newton's Forward, backward and divided differences – Numerical integration: Using Trapezoidal, Simpson's and Gaussian quadrature rules in one and two dimensions.

UNIT II MATRICES AND LINEAR SYSTEMS OF EQUATIONS 8

Solution of Linear Systems: Cramer's rule, Matrix Inversion Method, Gauss - Jordan Method, Gauss-Seidel iteration Methods - Eigen value Problems: Power method with deflation for both symmetric and unsymmetric matrices and Jacobi Method for symmetric matrices.

UNIT III MATHEMATICAL MODELING 8

Scientific Modeling - Mathematical modeling - stages of mathematical modeling and life cycle - Advantages of modeling and limitations - Developing model equations - Approximations in Mathematical Model building - first order ODE modeling equations and examples – concept of physical domain and computational domain - process control - Transport phenomena - Variational methods: Rayleigh's method, Ritz method.

UNIT IV DIFFERENTIAL EQUATIONS & APPLICATIONS 10

Solution of differential equations – Initial Value Problems - single step methods Euler method, Runge-Kutta method - Multi step method: Milne's method - boundary value problems – Finite difference approximations to derivatives - Finite difference method of solving second order ODEs - partial differential equations - Classification of second order PDEs - Finite difference approximations to partial derivatives - Elliptic equations: Solution of Laplace and Poisson equations - one dimensional parabolic equation - Bender Schmidt method - hyperbolic equation: one dimensional wave equation.

UNIT V SIMULATION & MONTE CARLO METHODS 10

Basic concepts of simulation - data manipulation, data exchange of the structure, physical simulation - advantages and limitations - properties and processing of materials - Basics of the Monte Carlo method – Algorithms for Monte Carlo simulation - Molecular dynamics simulation - applications to systems of classical particles - modified Monte Carlo techniques - percolation system – variation Monte Carlo method.

TOTAL : 45 PERIODS

REFERENCES

1 S.C. Chapra and R.P.Canale, "Numerical methods for Engineers", Tata McGraw Hill, New Delhi, 2002.
2 Erwin Kreyzig, "Advanced Engineering Mathematics", John Wiley & Sons, 2004.
3 R.J. Schilling and S.L. Harris, "Applied Numerical Methods for Engineers using MATLAB and C", Thomson publishers, New Delhi, 2004.
4 F R Giordano, W P Fox, S B Horton and M D Weir, "Mathematical Modeling Principles and Applications", CENGAGE Learning, New Delhi, 2009.
5 D. Frenkel and B. Smith, "Understanding molecular simulation from algorithm to applications", Kluwar Academic Press, 1999.
6 K. Ohno, K. Esfarjani and Y. Kawazoe, "Introduction to Computational Materials Science from ab initio to Monte Carlo Methods", Springer-Verlag, 1999.

NT7101 QUANTUM MECHANICS L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Inadequate of classical mechanics–Blackbody radiation - Compton Effect - Photoelectric effect – Planck's quantum concepts – Correspondence principle - Wave-particle duality - Schrödinger equation and expectation values - Uncertainty principle.

UNIT II BASICS OF QUANTUM MECHANICS 9

Solutions of the one-dimensional Schrödinger equation for free particle - particle in a box - particle in a cubical potential – Density of states – quantum free electron theory of metals – Electronic states in a quantum confined system – particle in a infinitely deep well potential, linear harmonic oscillator - Reflection and transmission by a potential step – particle tunneling – reflection and transmission coefficient – single particle tunneling – through multiple barrier – Kronig penny model – tunneling in planar barrier – Resonant tunnel diodes – Landauer formula – coulomb blockade.

UNIT III OPERATORS AND COMPUTATIONAL LAWS 9

Linear operator - Hermitian operator - Postulates of Quantum mechanics - Simultaneous measurability of observable - Equations in motion - Linear harmonic oscillator - Operator method - particle moving in a spherically symmetric potential - hydrogen atom - Hydrogen orbitals - Matrix representations of wave functions.

The angular momentum problem - The spin half problem and properties of Pauli spin matrices - Eigen values and Eigen functions of L and L - Eigen values J and J-spin angular momentum – Addition of angular momenta – Clebsh - Gordan coefficients – Computations – Spherically symmetric potential in 3D–3D square well potential.

UNIT IV APPROXIMATE METHODS 9

Time independent and time dependent perturbation theory for non-degenerate and degenerate energy levels - the variational method - WKB approximation - adiabatic approximation - sudden approximation - Klein-Gordon equation - particle in a coulomb field - Dirac's equation for a free particle - plane wave solution - Negative energy states - Magnetic moment of the electron - Radial equation for an electron in general potential - many electrons atoms - Hatree equations - Hatree- Fock equation.

UNIT V QUANTUM COMPUTATION 9

Physical proprieties and logic – Physical processes and algorithms – Qubits and quantum circuits – examples of a quantum algorithm – Shor–Grover – Simple programs using quantum concepts – Factorial applications.

TOTAL : 45 PERIODS

REFERENCES

1. Modern Physics – Beiser 6th edition 2009.
2. "Quantum Mechanics", I.L. Schiff McGraw Hill book company 1968.
3. Quantum Mechanics - Bransden and Joachen 2nd edition 2000.
4. Modern Physics – Beiser 6th edition 2009.
5. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, 2nd Edition by Eisberg, Robert; Resnick, Robert, 1985
6. Quantum Physics – Theory and application, Ajoy Ghatak, Springer 2004.
7. Principles of Quantum Mechanics 2nd ed. - R. Shankar 2000.
8. Quantum Mechanics – Vol. 1&2 - Cohen-Tannoudji,1997
9. S. Abramsky and B. Coecke, Categorical quantum mechanics, Handbook of Quantum Logic and Quantum Structures—Quantum logic, Elsevier (2009).

NT7102 PHYSICS AND CHEMISTRY OF NANOMATERIALS L T P C
3 0 0 3

UNIT I PHYSICS OF NANOMATERIALS 9

Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials - surface area and aspect ratio - band gap energy - quantum confinement size effect.

UNIT II PHYSICAL CHEMISTRY OF SOLID SURFACES 9

Surface energy – chemical potential as a function of surface curvature - Electrostatic stabilization - surface charge density - electric potential at the proximity of solid surface - Van der Waals attraction potential - Interaction between two particles: DLVO Theory.

UNIT III CHEMISTRY ASPECTS 9

Photochemistry; Electrochemistry of Nanomaterials - Nanoscale Heat Transfer; Transport in Semiconductor Nanostructures; Transition Metal Atoms on Nano carbon Surfaces.

UNIT IV NANOSTRUCTURES 9

Classification of Nanomaterials - Zero dimensional, one-dimensional, two dimensional nanostructures and three dimensional nanostructures **-** Kinetics in nanostructured materials - multilayer thin films and super lattice- clusters of metals, semiconductors and nanocomposites.

UNIT V NANOSYSTEMS 9

Nanoparticles through homogeneous and heterogeneous nucleation - Growth controlled by surface and diffusion process - Oswald ripening process - influences of reduction reagents - solid state phase segregation.

TOTAL : 45 PERIODS

REFERENCES

1 K.W. Kolasinski, “Surface Science: Foundations of Catalysis and Nanoscience”, Wiley, 2002.
2 Joel I. Gersten, “The Physics and Chemistry of Materials”, Wiley, 2001.
3 A. S. Edelstein and R. C. Cammarata, “Nanomaterials: Synthesis, Properties and Applications”, Institute of Physics Pub., 1998.
4 S.Yang and P.Shen: “Physics and Chemistry of Nanostructured Materials”, Taylor & Francis, 2000.
5 G.A. Ozin and A.C. Arsenault, “Nanochemistry :A chemical approach to nanomaterials”, Royal Society of Chemistry, 2005.
6 H. Hahn, A. Sidorenko, I. Tiginyanu , “Nanoscale Phenomena: Fundamentals and Applications”, Springer, 2009.
7 Zikang Tang and Ping Sheng , “Nanoscience and Technology: Novel structures and Phenomena”,Taylor & Francis, 2003

NT7103 ADVANCED MATERIALS TECHNOLOGY L T P C
3 0 0 3

UNIT I INTRODUCTION TO NANO SCIENCE 9

Background to nano technology - Scientific Revolutions-Types of Nano machines and Nanotechnology - Basic principles of Nano Scale materials - Properties of Individual nanoparticles – Metal nano clusters – Magic numbers – Electronic structure – Reactivity – Fluctuations.

UNIT II PHASE TRANSFORMATIONS 9

Phase rule - Phase diagram (one component and two components only) - Fe-C phase diagram - Mechanisms of phase transformation; precipitation in solid solution; transformation with constant composition; order-disorder transformations; Martensitic transformation.

UNIT III SMART MATERIALS 9

Carbon nano tube - New forms of carbon - Types of carbon nano tube - Preparation and purification of CNT - Uses of CNT – Graphene - Shape memory alloys- Shape memory effects, Applications of shape memory alloys - Hydrophobic & Hydrophilic materials & its applications.

UNIT IV SEMI-CONDUCTING MATERIALS 9

Inorganic Semiconducting nano structures, Direct and Indirect bonding characteristics - Types of semiconductors - Doping – Principle of doping - Diffusion - Fick's Law, mechanisms of diffusion; generation of point defects; experimental methods of investigation of diffusion.

UNIT V LUMINESCENCE OF SEMICONDUCTING NANO PARTICLES 9

Importance of Quantum confinement - Fluorescence of nanoparticles – Photoluminescence of doped semiconductor nanoparticles – Shift in photoluminescence peaks – Electroluminescence – Thermo luminescence – Cathodo luminescence – Magneto luminescence.

TOTAL : 45 PERIODS

REFERENCES

1 Nano technology: Basic Science and Emerging technologies, Mick Wilson, Kamali Kannargare., Geoff Smith Overseas Press (2005).
2 Introduction to Nanotechnology, Charles P. Poole, Frank J. Owens, Wiley Interscience (2003).
3 Nanostructures & Nanomaterials-Synthesis, Properties, Applications, Guozhong Cao, Imperial College Press (2004).
4 Encyclopedia of Nanoscience and Nanotechnology, Edited by H.S.Nalwa, Volume 4, Number 1 2004.
5 Nanotechnology: A gentle introduction to the next Big idea, Mark A.Ratner, Daniel Ratner, Mark Ratne, Prentice Hall P7R:1st Edition (2002).
6 Fundamental properties of nano structureded materials Ed D. Fioran, .Sberveglier, World Scientific 1994.
7 Nano technology ed by Gregory Timp, Springer – Verlag, New York 1999.

NT7104 SYNTHESIS OF NANOMATERIALS L T P C
3 0 0 3

UNIT I VACUUM TECHNIQUE 9

Inert gas condensation technique – vacuum production - ion pumps – rotary pump – diffusion pump – molecular pump – sublimation pumps – measurement of vacuum – material selection – sealing - degassing - types of gauges - bayard alpert gauge – vacuum ranges of gauges - vacuum systems.

UNIT II BULK SYNTHESIS 9

High energy ball mill – types of balls – ball ratio – medium for grinding – limitations in getting required grain size for low melting point materials – typical systems – severe plastic deformation – melt quenching and annealing - Mechano chemical process – Arc plasma - Bulk and nano composite materials

UNIT III CHEMICAL APPROACHES 9

Sol gel processing - Solvo thermal, hydrothermal, precipitation, Spray pyrolysis - Electro spraying and spin coating routes - Self-assembly, self-assembled monolayers (SAMs). Langmuir-Blodgett (LB) films - micro emulsion polymerization - templated synthesis, pulsed electrochemical deposition.

UNIT IV PHYSICAL APPROACHES 9

Vapor deposition and different types of epitaxial growth techniques (CVD, MOCVD, MBE, ALD) - pulsed laser deposition, Magnetron sputtering - lithography: Photo/UV/EB/FIB techniques, Dip pen nanolithography - Etching process: Dry and Wet etching, micro contact printing.

UNIT V NANOPOROUS MATERIALS 9

Nanoporous Materials – Silicon - Zeolites, mesoporous materials – nano membranes and carbon nanotubes - AgX photography, smart sunglasses and transparent conducting oxides – molecular sieves – nanosponges.

TOTAL : 45 PERIODS

REFERENCES

1. A. Roth, Vacuum technology, North – Holand Pub., II Edition, 1982.
2. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
3. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of NanoScience, Engg. and Technology, CRC Press, 2002.
4. K. Barriham, D.D. Vedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
5. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2004.
6. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.

NT7105 NANOSTRUCTURES IN BIOLOGICAL SYSTEMS L T P C
3 0 0 3

UNIT I CELL BIOLOGY 10

Eukaryotic and Prokaryotic cells-Structure and functions - Principle of membrane organization - Membrane transport - Cytoskeletal proteins - Types of cell division-mitosis and meiosis - Cell cycle and its regulation.

UNIT II NUCLEIC ACIDS 10

Genome structure and organization in prokaryotes and eukaryotes, Experiments to prove nucleic acids as the genetic material - Replication, transcription and translation – mechanism - enzymology and regulation - Central Dogma of life.

UNIT III AMINO ACIDS AND PROTEINS 8

Classification and properties of amino acids - Peptide bond. Proteins - Classification and functions of proteins - Primary, secondary, super secondary, tertiary, quaternary structures and bonding interactions – Enzymes - properties, structure, assay and inhibition – Synzymes - ribozymes.

UNIT IV CARBOHYDRATES AND LIPIDS 9

Classification – Nomenclature – Structure - Function of carbohydrates and lipids.

UNIT V METABOLISM AND ENERGY PRODUCTION 8

Integrative Metabolism of biomolecules - Electron transport chain - oxidative phosphorylation- energy production.

TOTAL : 45 PERIODS

REFERENCES

1. R. Cantor, P.R.Samuel, “Biophysical Chemistry”, W.H., Freeman & Co., 1985.
2. Watson, James, T.Baker, S.Bell, A.Gann, M.Levine, and R.Losick. “Molecular Biology of the Gene”, 5th ed., San Francisco: Addison-Wesley, 2000.
3. Alberts, Bruce, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts, and Peter Walter. Molecular Biology of the Cell. 4th ed. New York: Garland Science, 2002.
4. Branden, Carl-Ivar, and John Tooze. Introduction to Protein Structure. 2nd ed. New York: Garland Pub., 1991.
5. Creighton, E, Thomas, “Proteins: Structures and Molecular Properties”, 2nd Ed. New York: W.H. Freeman, 1992.
6. B.Lewin, “Genes IX”, International Edition. Sudbury: Jones & Bartlett, 2007.

NT7111 **MATERIAL SYNTHESIS** **L T P C**
0 0 4 2

Atleast 80 % of the experiments are to be conducted.

1. Chemical synthesis of Ag nanoparticles; UV-Visible absorption of the colloidal sol; Mie formalism; Estimation of size by curve fitting
2. Chemical synthesis of CdS nanoparticles; Optical absorption spectra; Band gap estimation from the band edge
3. Aqueous to organic phase transfer of Ag and CdS nanoparticles; Confirmation by UV- Visible absorption
4. Microwave assisted polymerization synthesis of ZnO nanowires.
5. Sol gel synthesis of metal oxide (ZnO, TiO, CdO) nanoparticles.
6. Mechanical ball milling technique to oxide ceramics preparation: crystallite size measurement by XRD.
7. A bio leaf extraction route to Ag/Cu/Fe nanoparticles.
8. Electro spinning of polymer nanofibers: surface morphology by SEM
9. Hydrothermal synthesis of ZnS Nanorods: Nanorods formation by SEM analysis
10. Synthesis of aqueous ferro fluid by chemical method
11. Nano crystalline copper metallic powder by polyol method
12. Metallic Ni particle by chemical reduction method
13. Multi ferrites bimetallic nanoparticles synthesis
14. Synthesis of core-shell nanoparticles

TOTAL : 60 PERIODS

NT7112 **COMPUTATION AND SIMULATION** **L T P C**
0 0 4 2

Atleast 80 % of the experiments are to be conducted.

1. MATLAB programme to plot the first four Eigen functions of a one - dimensional rectangular potential well with infinite potential barrier.
2. Numerical solution of the Schrodinger wave equation for a rectangular potential well with infinite potential barrier using MATLAB programme.
3. Toy model in molecular electronics: IV characteristics of a single level molecule.
4. To determine the lattice constant and lattice angles for atomically resolved STM image of HOPG (Highly Oriented Pyrolytic Graphite using offline Scanning Probe Imaging Processor (SPIP) Software.
5. To determine the surface roughness of raw and processed AFM images of glass, silicon and films made by different methods using offline SPIP software.
6. Simulation of I-V Characteristics for a single Junction circuit with a single quantum Dot using MOSES 1.2 Simulator.
7. Study of Single Electron Transistor using MOSES1.2 Simulator.
8. Molecular Modelling and Simulation for Benzamide, Styrene, CNT using Material studio.
9. Digital Image processing using Matlab

TOTAL : 60 PERIODS

NT7201 PHOTONICS FOR NANOTECHNOLOGY L T P C
3 0 0 3

UNIT I QUANTUM CONFINED MATERIALS 9

Quantum dots – optical transitions – absorption-inter-band transitions - quantum confinement intra band transitions - fluorescence/luminescence – photoluminescence /fluorescence optically excited emission – electroluminescence emission.

UNIT II PLASMONICS 9

Internal reflection and evanescent waves - plasmons and surface plasmon resonance (SPR) - Attenuated total reflection - Grating SPR coupling - Optical waveguide SPR coupling - SPR dependencies and materials - plasmonics and nanoparticles.

UNIT III NEW APPROACHES IN NANOPHOTONICS 9

Near-Field Optics- Aperture near-field optics - Aperture less near - field optics - Near-field scanning optical microscopy (NSOM or SNOM)- SNOM based detection of plasmonic energy transport- SNOM based visualization of waveguide structures - SNOM in nanolithography - SNOM based optical data storage and recovery.

UNIT IV BIOPHOTONICS 9

Interaction of light with cells – tissues - nonlinear optical processes with intense laser beams - photo induced effects in biological systems - generation of optical forces - optical trapping and manipulation of single molecules and cells in optical confinement - laser trapping and dissection for biological systems-single molecule biophysics - DNA protein interactions.

UNIT V PHOTONIC CRYSTALS 9

Important features of photonic crystals - Presence of photonic band gap - Anomalous Group Velocity Dispersion - Micro cavity - Effects in Photonic Crystals - Fabrication of photonic crystals - Dielectric mirrors and interference filters - Photonic Crystal Laser - PC based LEDs - Photonic crystal fibers (PCFs) - Photonic crystal sensing.

TOTAL : 45 PERIODS

REFERENCES

1. H.Masuhara, S.Kawata and F.Tokunaga, Nano Biophotonics, Elsevier Science, 2007.
2. V.M. Shalaev and S.Kawata, Nanophotonics with Surface Plasmons (Advances in Nano-Optics and Nano-Photonics), 2007.
3. B.E.A. Saleh and A.C.Teich, Fundamentals of Photonics, John-Wiley & Sons, New York, 1993.
4. M.Ohtsu, K.Kobayashi, T.Kawazoe, and T.Yatsui, Principles of Nanophotonics (Optics and Optoelectronics), University of Tokyo, Japan, 2003.
5. P.N. Prasad, Introduction to Biophotonics, John Wiley & Sons, 2003.
6. J.D.Joannopoulos, R.D.Meade and J.N.Winn, Photonic Crystals, Princeton University Press, Princeton, 1995.

NT7202	PROCESSING AND PROPERTIES OF NANO STRUCTURED MATERIALS	L T P C 3 0 0 3

UNIT I DEFORMATION PROCESSING AND METAL FORMING 10

Classification of engineering materials - Tensile testing – Stress strain curve – Flow stress - Mechanical properties – Formability - Deformation processes - Mechanics of metal working – Metal forming - forging, rolling, extrusion, wire drawing – Superplastic forming – Bulk nanostructured materials by Severe Plastic Deformation (SPD) - Comparison of processes.

UNIT II MICROSTRUCTURE AND PROPERTIES 9

Defects in solids – classifications of defects – Microstructure – grain size, grain boundary, effects of processing and defects – Processing, microstructure, properties correlations – Mechanical Properties and processing - grain size evolution and grain size control; Hall-Petch relation - strengthening mechanisms; work hardening - grain boundary strengthening - solid solution strengthening – precipitation hardening - effects of diffusion on strength and flow of materials.

UNIT III PROCESSING OF POLYMERS 7

Engineering plastics – Pellets and sheets – Glass transition temperature of polymers – Melt flow index – Polymer processing tools and process conditions - injection moulding, thermoforming, vacuum and pressure assisted forming.

UNIT IV PROCESSING OF POWDERS OF METALS AND CERAMICS 9

Metal/Ceramic Powder synthesis - Selection and characterization of powders - compacting and sintering - Production of Porous and Dense Composite Components: Advanced composite materials - Metal- polymer - and ceramic - based composites and their properties – Fabrication of composite materials.

UNIT V PROCESSING OF STRUCTURAL AND FUNCTIONAL NANOMATERIALS 10

Properties required of nanocrystalline materials used for structural, energy, environmental, textile and catalytic applications; processing techniques; techniques for retaining the nanocrystalline structure in service.

TOTAL : 45 PERIODS

REFERENCES

1. A. H. Cottrell “The Mechanical Properties of Matter”, John Wiley, New York-London, 1964.
2. R. Asthana, A. Kumar and N. Dahotre “Materials Science in Manufacturing” Butterworth-Heinemann, Elsevier 2006.
3. G. E. Dieter, adapted by D Bacon, “Mechanical Metallurgy”, SI Metric edition, McGraw-Hill, Singapore, 1988.
4. K. A. Padmanabhan, “Mechanical Properties of Nanostructured Materials”, Materials Science and Engineering, A 304-306 (2001) 200-205.
5. H. Gleiter, “Nanocrystalline Materials”, Progress in Materials Science Vol. 33, pp. 223-315, 1989
6. C. C. Koch, “Nanostructured Materials: Processing, Properties and Applications”, 2nd Edition, Ed.: 2007

NT7203 PHYSICOCHEMICAL METHODS FOR CHARACTERIZATION OF NANOMATERIALS **L T P C 3 0 0 3**

UNIT I SPECTROSCOPIC TECHNIQUES 9

Introduction to Molecular Spectroscopy and Differences with Atomic Spectroscopy - Uv-Vis. Spectroscopy and applications to nano system- Infrared (IR) Spectroscopy and Applications - Raman Spectroscopy and CARS theory - NMR Spectroscopy – Theory and Principles, Applications - Dynamic Nuclear Magnetic Resonance; Dynamic light scattering (DLS), Double Resonance Technique.

UNIT II .X-RAY DIFFRACTION 9

X-ray powder diffraction – single crystal diffraction techniques - Determination of accurate lattice parameters - structure analysis - profile analysis - particle size analysis using Scherer formula.

UNIT III THERMAL ANALYSIS METHODS 9

Principle and Instrumentation of Thermo gravimetry; Differential Thermal Analysis and Differential scanning calorimetry - Importance of thermal analysis for nanostructures.

UNIT IV QUALITATIVE AND QUANTITATIVE ANALYSIS 9

Electron Energy Loss Spectroscopy; High Resolution Imaging Techniques - HREM, Atom probe field ion microscopy - X-Ray Photoelectron Spectroscopy - EDAX and WDA analysis – EPMA – ZAF corrections.

UNIT V NANOINDENTATION 9

Nanoindentation principles - elastic and plastic deformation - mechanical properties of materials in small dimensions - models for interpretation of nanoindentation load - displacement curves - Nanoindentation data analysis methods - Hardness testing of thin films and coatings - MD simulation of nanoindentation.

TOTAL : 45 PERIODS

REFERENCES

1. B. D.Cullity, “Elements of X-ray Diffraction”, 4th Edition, Addison Wiley, 1978.
2. M. H.Loretto, “Electron Beam Analysis of Materials”, Chapman and Hall, 1984.
3. R.M.Rose, L.A.Shepard and J.Wulff, “The Structure and Properties of Materials”, Wiley Eastern Ltd, 1996.
4. B.W.Mott, “Micro-Indentation Hardness Testing”, Butterworths, London, 1956.

NT7204 IMAGING TECHNIQUES FOR NANOTECHNOLOGY **L T P C 3 0 0 3**

UNIT I OPTICAL MICROSCOPY 9

Optical microscopy - Use of polarized light microscopy – Phase contrast microcopy – Interference Microscopy – hot stage microscopy - surface morphology – Introduction to confocal microscopy.

UNIT II SCANNING ELECTRON MICROSCOPY 12

Basic design of the scanning electron microscopy – Modes of operation – Backscattered electrons – secondary electrons- X-rays – typical forms of contrast – Resolution and contrast – enhancement – Specimen preparation - Replicas – Various applications.

UNIT III TRANSMISSION ELECTRON MICROSCOPY 9

Basic principle - Modes of operation – Specimen preparation – Diffraction in imperfect crystals – Dislocations – precipitates – Structure of grain boundaries and interfaces-HRTEM in nanostructures.

UNIT IV ATOMIC FORCE MICROSCOPY 9

Basic concepts-Interaction force - AFM and the optical lever - Scale drawing - AFM tip on nanometer scale structures - force curves, measurements and manipulations - feedback control-different modes of operation – contact, non-contact and tapping mode - Imaging and manipulation of samples in air/liquid environments - Imaging of soft samples - Scanning Force Microscopy - Shear force Microscopy - Lateral Force Microscopy - Magnetic Force microscopy.

UNIT V SCANNING TUNNELING MICROSCOPY 6

Principle- Instrumentation - importance of STM for nanostructures – surface and molecular manipulation using STM -3D map of electronic structure - Limitations.

TOTAL : 45 PERIODS

REFERENCES

1. R.Haynes, D.P.Woodruff and T.A.Talchar, “Optical Microscopy of Materials”, Cambridge University press, 1986.
2. J.Goldstein, D. E. Newbury, D.C. Joy, and C.E. Lym, “Scanning Electron Microscopy and X-ray Microanalysis”, 2003.
3. S.L. Flegler, J.W. Heckman and K.L. Klomparens, “Scanning and Transmission Electron Microscopy: A Introduction”, WH Freeman & Co, 1993.
4. P.J.Goodhew, J.Humphreys, R.Beanland, “Electron Microscopy and Analysis, 2001.

NT7205 NANOTECHNOLOGY IN HEALTH CARE L T P C
3 0 0 3

UNIT I TRENDS IN NANO BIOTECHNOLOGY 9

Nanotechnology in gene therapy - PCR, ELISA, DNA Profiling and Blotting techniques-Nanoprobes.

UNIT II NANOIMMUNO TECHNOLOGY 8

Nanoimmunoassay and nano-immuno sensors - Bio-Barcode Assay - use of magnets, gold, DNA and antibodies - Immuno diagnostics for cancer and central nervous system disorders.

UNIT III NANOTECHNOLOGY BASED MEDICAL DIAGNOSTICS 9

Improved diagnosis by i*n vivo* imaging - detection of tumors - plaque and genetic defects - Nanobot medical devices - Cantilever Sensors.

UNIT IV PROSTHETIC AND MEDICAL IMPLANTS 9

Prosthesis and implants - neural, ocular, cochlear- anatomy & physiology of nervous system & sensory physiology - dental implants. implants and prosthesis of skin, limb, bone - Artificial organ and Organ transplant - Nanofibre scaffold technology.

UNIT V BIOMEDICAL APPLICATIONS OF NANOTECHNOLOGY 10

Nano-bioconjugates and their significance - Nano scaffolds- Stem Cell technology - Magnetic Nanoparticles - Multifunctional Inorganic and organic nanoparticles and their biomedical applications.

TOTAL : 45 PERIODS

REFERENCES

1. Chemical Sensors and Biosensors; Brian, R Eggins; Wiley; New York, Chichester; 2002.
2. Biosensors and modern biospecific analytical techniques, Wilson & Wilson's Comprehensive Analytical Chemistry; Ed. L Gorton; Elsevier, Amsterdam, London; 2005.
3. The Immunoassay Handbook; Ed. David Wild; 3rd ed.; Amsterdam: Elsevier; 2005.
4. Electrochemical Methods: Fundamentals and Applications; Allen J Bard and Larry R Faulkner; Wiley, New York, Chichester : 2nd ed.; 2001.
5. Ultrathin Electrochemical Chemo- and Biosensors: Technology and Performance in Springer Series on Chemical Sensors and Biosensors; Volume Two; Ed. Vladimir M. Mirsky; Springer, Berlin; 2004.

NT7206 NANOELECTRONICS AND SENSORS L T P C
3 0 0 3

UNIT I SEMICONDUCTOR NANO DEVICES 9

Single-Electron Devices; Nano scale MOSFET – Resonant Tunneling Transistor - Single-Electron Transistors; Nanorobotics and Nanomanipulation; Mechanical Molecular Nanodevices; Nanocomputers: Optical Fibers for Nanodevices; Photochemical Molecular Devices; DNA-Based Nanodevices; Gas-Based Nanodevices.

UNIT II ELECTRONIC AND PHOTONIC MOLECULAR MATERIALS 9

Preparation – Electroluminescent Organic materials - Laser Diodes - Quantum well lasers:- Quantum cascade lasers- Cascade surface-emitting photonic crystal laser- Quantum dot lasers - Quantum wire lasers:- White LEDs - LEDs based on nanowires - LEDs based on nanotubes - LEDs based on nanorods - High Efficiency Materials for OLEDs- High Efficiency Materials for OLEDs - Quantum well infrared photo detectors.

UNIT III THERMAL SENSORS 9

Thermal energy sensors -temperature sensors, heat sensors - Electromagnetic sensors - electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetism sensors - Mechanical sensors - pressure sensors, gas and liquid flow sensors, position sensors - Chemical sensors - Optical and radiation sensors.

UNIT IV GAS SENSOR MATERIALS 9

Criteria for the choice of materials - Experimental aspects – materials, properties, measurement of gas sensing property, sensitivity; Discussion of sensors for various gases, Gas sensors based on semiconductor devices.

UNIT V BIOSENSORS 9

Principles - DNA based biosensors – Protein based biosensors – materials for biosensor applications - fabrication of biosensors - future potential.

TOTAL : 45 PERIODS

REFERENCES

1. W. Ranier, “Nano Electronics and Information Technology”, Wiley, (2003).
2. K.E. Drexler, “Nano systems”, Wiley, (1992).
3. M.C. Petty, “Introduction to Molecular Electronics”, 1995.

NT7211 NANOMETROLOGY AND MICROSCOPY L T P C
0 0 4 2

Atleast 80 % of the experiments are to be conducted.

1. Determination of size and lateral dimensions of various samples (pollen grains, strands of hair) using a high magnification optical microscope.
2. Synthesis of SiO_2 polysphere film and morphology characterization using an Optical microscope.
3. Surface topography of sputtered AlN/CuN film using AFM; thickness across a step.
4. Surface topography of SiO_2 film using AFM; step measurements.
5. Surface topography of a polymer film on glass using AFM in the non-contact (tapping) mode; Phase imaging
6. Nanoindentation on a polycarbonate substrate using AFM; F-D curves and hardness determination.
7. Dip-pen lithography using AFM with molecular inks.
8. Surface topography of a sputtered Ag film using STM; current and height imaging.
9. Surface topography of a freshly cleaved Mica.
10. Scanning Tunneling Spectroscopy (STS) on Multi walled Carbon Nanotubes deposited on HOPG.
11. Sol-gel spin coating route to SnO_2 nano thin films: surface roughness measurement by AFM.
12. Electro deposition of Cu nano structures and its morphology

TOTAL : 60 PERIODS

NT7301 LITHOGRAPHY AND NANOFABRICATION L T P C
3 0 0 3

UNIT I INTRODUCTION TO LITHOGRAPHY 10

Introduction to Lithography – Lithography Processes; Mask Making, Wafer Pre-Hear, Resist Spinning – Pre-Bake, Exposure, Development and Rinsing, Post-Bake, Resist Stripping, Positive and negative photoresists – Lift off profile - Introduction to semiconductor processing - Necessity for a clean room- different types of clean rooms-maintenance of a clean room – Micro fabrication process flow diagram – Chip cleaning, coating of photoresists, patterning, etching, inspection – Process integration - Etching techniques- Reactive Ion etching - Magnetically enhanced RIE- Ion beam etching- Other etching techniques.

UNIT II PHOTOLITHOGRAPHY AND PATTERNING OF THIN FILMS 9

Lithography - Optical lithography - different modes - Optical projection lithography - Multistage scanners – resolution and limits of photolithography – Resolution enhancement techniques - Photomask- Binary mask - Phase shift mask - Attenuated phase shift masks - Alternating phase shift masks - Off axis illumination - Optical proximity correction - Sub resolution assist feature enhancement - Optical immersion lithography

UNIT III DIRECT WRITING METHODS - MASKLESS OPTICAL LITHOGRAPHY 6

Maskless optical projection lithography – types, Advantages and Limitations – required components - Zone plate array lithography - Extreme ultraviolet lithography – Light sources - Optics and materials issues

UNIT IV ELECTRON BEAM LITHOGRAPHY (EBL), ION BEAM & X-RAY LITHOGRAPHY 10

Scanning electron-beam lithography - Electron sources and electron optics system – Maskless EBL- Electron beam projection lithography - Scattering with angular limitation projection e-beam lithography - Projection reduction exposure with variable axis immersion lenses - Ion beam lithography - Focusing ion beam lithography - Ion projection lithography – X-ray lithography – X-ray masks, resists, merits and demerits - Atom lithography.

UNIT V NANOIMPRINT LITHOGRAPHY AND SOFT LITHOGRAPHY 10

Nanoimprint lithography - Hot embossing - Soft Lithography- Moulding/Replica moulding: PDMS stamps - Printing with soft stamps - Edge lithography - Dip-Pen Lithography-set up and working principle – Self-assembly – LB films**.**

TOTAL : 45 PERIODS

REFERENCES

1. Chris Mack, Fundamental Principles of Optical Lithography: The Science of Microfabrication, Wiley, 2008.
2. D. S. Dhaliwal et al., PREVAIL –"Electron projection technology approach for next generation lithography", IBM Journal Res. & Dev. 45, 615 (2001).
3. M. Baker et al., "Lithographic pattern formation via meta stable state rare gas atomic beams", Nanotechnology 15, 1356 (2004).
4. H. Schift et al., "Fabrication of polymer photonic crystals using nano imprint lithography", Nanotechnology 16, 261, (2005).
5. R.D. Piner, "Dip-Pen" Nanolithography, Science 283, 661 (1999).

NT7311	PROJECT WORK (PHASE – I)	L T P C 0 0 12 6

Thin Film Deposition

Operation of Electrochemical Workstation.

Deposition of Polyaniline on ITO using Electrochemical Workstation.

Electroplating Ag film: Topography by AFM; Electrical characteristics by two and four probe measurement.

Electroless deposition of Au on Si substrate.

Physical vapor deposition of Cr and Au on glass substrates; X-ray diffraction measurement; Quartz crystal thickness monitor for thickness monitoring.

Preparation of (111) oriented films of Au by physical vapor deposition on mica substrate; X-ray diffraction measurement; characterization by AFM.

Micro & Nanolithography

Clean room: Familiarizing with essential terms, tools and practices

Cleaning procedure for Si wafer and observation of surface before and after cleaning with AFM.

Spin coating polymer resists, Thickness measurement using AFM.

Opto lithography using PMMA resist.

Nanoscale gratings by Electron beam lithography using SEM.

Nanosphere lithography using silica nanospheres.

Microcontact printing using PDMS stamp

NT7001 TOP DOWN MANUFACTURING METHODS L T P C
3 0 0 3

UNIT I INTRODUCTION 12

Introduction to micro fabrication and Moore's law – importance of lithographic techniques - different types of lithographic techniques -Optical projection lithography - Photomask- Binary mask- Phase shift mask - Optical immersion lithography - Maskless optical projection lithography - Zone plate array lithography - Extreme ultraviolet lithography.

UNIT II E-BEAM AND ION BEAM LITHOGRAPHY 15

Principle and instrumentation - Scanning electron-beam lithography - Mask less (ML2) EBL - parallel direct-write e-beam systems - E-beam projection lithography - PREVAIL X-ray lithography - Focused ion beam lithography - Ion projection lithography - Masked ion beam direct structuring - Nanoimprint lithography and soft lithography - Nanoimprint lithography - Soft lithography - Dip-Pen lithography.

UNIT III ETCHING TECHNIQUES 5

Reactive ion etching - RIE reactive ion etching - Magnetically enhanced RIE- Ion beam etching - Wet etching of silicon - Isotropic etching - Anisotropic etching - Electrochemical etching - Vapor phase etching - Dry etching - Other etching techniques.

UNIT IV BALL MILLING TECHNIQUE 5

Nanopowders produced using micro reactors; Nanocrystalline ceramics by mechanical activation; Formation of nanostructured polymers.

UNIT V MACHINING PROCESSES 8

Micromilling/microdrilling/microgrinding processes and the procedure for selecting proper machining parameters with given specifications - EDM micro machining, laser micro/nanomachining - models to simulate micro/nanomachining processes using molecular dynamics techniques -Wet chemical etching - Dry etching - Thin film and sacrificial processes .

TOTAL : 45 PERIODS

REFERENCES

1. M. J. Jackson, "Micro fabrication and Nanomanufacturing", CRC Press, 2005.
2. P.Rai-Choudhury, "Handbook of Micro lithography, Micro machining, and Micro fabrication", Vol. 2, SPIE Press, 1997.
3. M. Madou, "Fundamentals of Microfabrication," CRC Press, 1997.
4. G.Timp, "Nanotechnology", AIP press, Springer-Verlag, New York, 1999.

NT7002 BOTTOM UP SYNTHESIS OF NANOSTRUCTURES L T P C
3 0 0 3

UNIT I THIN FILM TECHNOLOGIES – I 9

CVD Chemical vapor deposition – Atmospheric pressure CVD(APCVD) – Low pressure CVD (LPCVD) - Plasma enhanced chemical vapor deposition (PECVD) - HiPCO method - Photo-enhanced chemical vapor deposition (PHCVD)- LCVD Laser – Induced CVD.

UNIT II THIN FILM TECHNOLOGIES – II 9

Physical vapor deposition - Sputter technologies - Diode sputtering - Magnetron sputtering - Ion beam (sputter) deposition, ion implantation and ion assisted deposition - Cathodic arc deposition - Pulsed laser deposition.

UNIT III EPITAXIAL FILM DEPOSITION METHODS 9

Epitaxy, Different kinds of epitaxy - Influence of substrate and substrate orientation, mismatch, MOCVD Metal Organic Chemical Vapor Deposition - CCVD Combustion Chemical Vapor Deposition - ALD Atomic Layer Deposition - LPE Liquid phase epitaxy - MBE Molecular Beam Epitaxy.

UNIT IV CHEMICAL METHODS 9

Sol-gel synthesis – different types of coatings - Spin coating- Self assembly - (Periodic) starting points for self-assembly - Directed self-assembly using conventional lithography - Template self-assembly - Vapor liquid solid growth - Langmuir-Blodgett films – DNA self assembly.

UNIT V PRINTING TECHNOLOGIES 9

Screen printing- Inkjet printing - Gravure printing and Flexographic printing - Flex graphic printing - Gravure printing – Roll to Roll techniques.

TOTAL : 45 PERIODS

REFERENCES

1. G. Cao, “Nanostructures & Nanomaterials: Synthesis, Properties &Applications” Imperial College Press, 2004.
2. W.T.S. Huck, “Nanoscale Assembly: Chemical Techniques (Nanostructure Science and Technology), 2005.
3. “Handbook of Nanoscience, Engineering and Technology”, Kluwer publishers, 2002.

NT7003 SEMICONDUCTOR NANOSTRUCTURES AND NANO-PARTICLES

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UNIT I SEMICONDUCTOR FUNDAMENTALS 9

Introduction to Semiconductor physics – Fabrication techniques – Semiconductor nanostructures – Electronic structure and physical process – Principles of semiconductor nanostructures based electronic and electro-optical devices – Semiconductor Quantum Dots – Quantum Lasers – Quantum Cascade Lasers – Quantum Dot Optical Memory.

UNIT II SEMICONDUCTOR NANOPARTICLE SYNTHESIS 9

Cluster compounds, quantum-dots from MBE and CVD, wet chemical methods, reverse micelles, electro-deposition, pyrolytic synthesis, self-assembly strategies.

UNIT III PHYSICAL PROPERTIES 9

Melting point, solid-state phase transformations, excitons, band-gap variations - quantum confinement, effect of strain on band-gap in epitaxial quantum dots, single particle conductance.

UNIT IV SEMICONDUCTOR NANOPARTICLES – APPLICATIONS 10

Optical luminescence and fluorescence from direct band gap semiconductor nanoparticles, surface-trap passivation in core-shell nanoparticles, carrier injection, polymer-nanoparticle, LED and solar cells, electroluminescence, barriers to nanoparticle lasers, doping nanoparticles, Mn-Zn-Se phosphors, light emission from indirect semiconductors, light emission form Si nanodots.

UNIT V SEMICONDUCTOR NANOWIRES 8

Fabrication strategies, quantum conductance effects in semiconductor nanowires, porous Silicon, nanobelts, nanoribbons, nanosprings.

TOTAL : 45 PERIODS

REFERENCES

1. Encyclopedia of Nanoscience and Nanotechnology- Hari Singh Nalwa, 2004.
2. Springer Handbook of Nanotechnology - Bharat Bhusan, 2004.
3. Handbook of Semiconductor Nanostructures and Nanodevices Vol 1-5- A. A. Balandin, K. L. Wang 2006.
4. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, 2011.

NT7004 NANOTECHNOLOGY FOR ENERGY SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION 9

Nanotechnology for sustainable energy - Materials for light emitting diodes – batteries - advanced turbines - catalytic reactors – capacitors - fuel cells.

UNIT II RENEWABLE ENERGY TECHNOLOGY 9

Energy challenges, development and implementation of renewable energy technologies - nanotechnology enabled renewable energy technologies - Energy transport, conversion and storage, Nano, micro and meso scale phenomena and devices.

UNIT III MICRO FUEL CELL TECHNOLOGY 9

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems - thin film and micro fabrication methods - design methodologies - micro-fuel cell power sources,

UNIT IV MICROFLUIDIC SYSTEMS 9

Nano-electromechanical systems and novel microfluidic devices - nano engines - driving mechanisms - power generation – micro channel battery - micro heat engine (MHE) fabrication – thermo capillary forces – Thermo capillary pumping (TCP) - piezoelectric membrane.

UNIT V HYDROGEN STORAGE METHODS 9

hydrogen storage methods - metal hydrides - size effects - hydrogen storage capacity - hydrogen reaction kinetics - carbon-free cycle- gravimetric and volumetric storage capacities - hydriding/dehydriding kinetics - high enthalpy of formation - and thermal management during the hydriding reaction - distinctive chemical and physical properties

- multiple catalytic effects - degradation of the sorption properties - hydride storage materials for automotive applications.

TOTAL : 45 PERIODS

REFERENCES

1. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, 1986.
2. Hydrogen from Renewable Energy Sources by D. Infield 2004.
3. Fuel Storage on Board Hydrogen Storage in Carbon Nanostructures by R.A. Shatwell 1996.
4. Fuel cell technology handbook. Hoogers. CRC Press, 2003.
5. Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley, CRC Press, 2003.

NT7005 MOLECULAR ELECTRONICS L T P C
3 0 0 3

UNIT I **9**

Controlling surfaces and interfaces of semi-conductor sensing organic molecules - types of molecule-manipulation experiments - measurements in molecular electronics - soft and hard electronics - Electronic structure of absorbed organic molecule.

UNIT II **9**

Organic semiconductor for new electronic device - photo voltaic cells - Schotkey diodes FET^S digital processing and communication with molecular switches.

UNIT III **9**

Molecular Electronics overview – Rectifiers - Molecular wires – Molecular switches – Data storage-photo switches - molecular magnets.

UNIT IV **9**

Molecular Engineering of doped polymer for optoelectronics - Fabrication for Molecular Electronics organic FET^{s-} Organic thin film transistors.

UNIT V **9**

Bio Electronics – Molecular and Biocomputing – prototypes for Molecular Functional limits and Actuators – Molecular assembly – characterization of hybrid nanomaterials - Biomolecular optoelectronic device.

TOTAL : 45 PERIODS

REFERENCES

1. Introducing Molecular Electronics, G. Cumbertl & G. Fagas , Springer, 2005.
2. Nano and Molecular Electronics Handbook, S.C. Levshevski, CRC Press, 2007.
3. Nanoelectronics & Nanosystems: From Transistor to Molecular & Quantum Devices: Karl Goser, Jan Dienstuhl et al, 2004.

NT7006 PRODUCT DESIGN, MANAGEMENT TECHNIQUES AND ENTREPRENEURSHIP **L T P C 3 0 0 3**

UNIT I PRODUCT DESIGN **9**

Concept generation - Product Architecture - Industrial Design Process - Management of Industrial design Process and assessing the quality of Industrial Design - Establishing the product specification.

UNIT II PRODUCT DEVELOPMENT **9**

Criteria for selection of product- Product development process - Design for Manufacture - Estimate the manufacturing cost- Reduce the support cost- Prototyping - Economics of Product development projects - Elements of Economic analysis - financial models - Sensitive analysis and influence of the quantitative factors.

UNIT III MANAGEMENT TECHNIQUES **9**

Technology Management - Scientific Management - Development of management Thought - Principles of Management - Functions of management – planning – organization - Directing, Staffing and Controlling - Management by objective - SWOT analysis - Enterprise Resource planning and supply chain management.

UNIT IV ENTREPRENEURIAL COMPETENCE & ENVIRONMENT **9**

Concept of Entrepreneurship - Entrepreneurship as a career - Personality Characteristic a successful Entrepreneur - Knowledge and skill required for an Entrepreneur - Business environment - Entrepreneurship Development Training - Center and State government policies and Regulations - International Business.

UNIT V MANAGEMENT OF SMALL BUSINESS **9**

Pre feasibility study - Ownership - budgeting - project profile preparation - Feasibility Report preparation - Evaluation Criteria- Market and channel selection- Product launching - Monitoring and Evaluation of Business - Effective Management of Small business.

TOTAL : 45 PERIODS

REFERENCES

1. Karal, T.Ulrich Steven, D.Eppinger, “Product Design and Development”, McGraw- Hill International, editions, 2003.
2. S.Rosenthal, “Effective Product Design and Development”, Irwin, 1992.
3. H.Koontz and H.Weihrich, “Essentials of management”, McGraw Hill Publishing company, Singapore international edition, 1980.
4. J.J.Massie, “Essentials of Management” Prentice Hall of India Pvt. Ltd., 1985.
5. Hisrich, “Entrepreneurship” Tata Mc Grew Hill, New Delhi, 2001

NT7007 NANOCOMPOSITIES L T P C
3 0 0 3

UNIT I NANO CERAMICS 9

Metal-Oxide or Metal-Ceramic composites, Different aspects of their preparation techniques and their final properties and functionality.

UNIT II METAL BASED NANOCOMPOSITES 9

Metal-metal nanocomposites, some simple preparation techniques and their new electrical and magnetic properties.

UNIT III DESIGN OF SUPER HARD MATERIALS 9

Super hard nanocomposites, its designing and improvements of mechanical properties.

UNIT IV NEW KIND OF NANOCOMPOSITES 9

Fractal based glass-metal nanocomposites, its designing and fractal dimension analysis. Electrical property of fractal based nanocomposites. Core-Shell structured nanocomposites.

UNIT V POLYMER BASED NANOCOMPOSITES 9

Preparation and characterization of diblock Copolymer based nanocomposites; Polymer-carbon nanotubes based composites, their mechanical properties, and industrial possibilities.

TOTAL : 45 PERIODS

REFERENCES

1. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun 2006.
2. Physical Properties of Carbon Nanotubes- R. Saito 1998.
3. Carbon Nanotubes (Carbon , Vol 33) - M. Endo, S. Iijima, M.S. Dresselhaus 1997.
4. The search for novel, superhard materials- Stan Vepr¡ek (Review Article) JVST A, 1999
5. Electromagnetic and magnetic properties of multi component metal oxides, hetero
6. Nanometer versus micrometer-sized particles-Christian Brosseau,Jamal Ben, Youssef, Philippe Talbot, Anne-Marie Konn, (Review Article) J. Appl. Phys, Vol 93, 2003
7. Diblock Copolymer, - Aviram (Review Article), Nature, 2002

NT7008 MEMS AND BIO MEMS L T P C
3 0 0 3

UNIT I MEMS MICROFABRICATION 10

Historical Development of Microelectronics, Evolution of Microsensors, Evolution of MEMS, Emergence of Micromachines, Modeling - Finite Element Analysis, CAD for MEMS, Fabrication – ALD, Lithography Micromachining, LIGA and Micro moulding, Saw-IDT Microsensor Fabrication, Packaging – Challenges, Types, Materials and Processes.

UNIT II SCALING OF MEMS 9

Introduction to Scaling Issues, Scaling effects on a cantilever beam, Scaling of electrostatic actuators, Scaling of thermal actuator, Scaling of Thermal Sensors, mechanics and electrostatistics. Influence of scaling on material properties.

UNIT III MICROSYSTEMS 10

Microsensors, microaccelerometer, microfluidics, Mechanics for Microsystems design-Thermomechanics - fracture mechanics - thin film mechanics - Microfluid mechanics.

UNIT IV MATERIALS FOR MEMS 8

Materials for MEMS and pro MEMS - silicon-metals and polymers - Substrate Materials for MEMS - Silicon-quartz – ceramics - Bulk metallic glasses - Sharp Memory alloys, Carbon based MEMS.

UNIT V COMMERCIAL AND TECHNOLOGICAL TRENDS 8

Commercial trends in miniaturization – High density chip analysis - Micro accelerometers-micro resonators - lab-in-chip for DNA and protein analysis – Nano HPLC system-nano patches.

TOTAL : 45 PERIODS

REFERENCES

1. Marc Madou, Fundamentals of Microfabrication, CRC Press 1997.
2. MEMS and Microsystems design and manufacture, Tai-Ran Hsu,Tata Mc Graw Hill 2011.
3. Sergey Edward Lyshevski, Nano- and Microelectromechanical Systems, CRC Press 2000.
4. Vijay Varadan, Xiaoning Jiang, and Vasundara Varadan, Microstereolithography and other Fabrication Techniques for 3D MEMS, Wiley 2001.
5. Tai-Ran Hsu, MEMS and Microsystems: Design and Manufacture, McGraw-Hill 2001.
6. Ken Gilleo. MEMS/MOEMS Packaging: Concepts, Designs, Materials and Processes. McGraw-Hill, 2005.

NT7009 CHEMICAL NANOTECHNOLOGY L T P C
3 0 0 3

UNIT I CHEMISTRY OF NANOPARTICLES 9

Synthesis by Organic Molecule Templates – Molecular Self-Assembly – Spatially Constrained Synthesis – Biomimetic Synthesis – Oxide Nanoparticles – Particle size – Particle shape – Particle density – Composite structure – Pore structure – Surface modification of inorganic Nanoparticles by organic functional groups

UNIT II ADVANCED POLYMERIC MATERIALS 9

Polymer chain statistics – Static light scattering – Polymer blends – High performance thermoplastics – Polymer material for photovoltaic applications – Synthetic biomedical polymers – Assembly of polymer – Nanoparticle composite material – Fabrication of polymer – Applications of polymers in catalysis.

UNIT III SUPRAMOLECULAR CHEMISTRY 9

Catenanes and rotaxanes – Synthesis and uses as molecular switches – Dendrimers – Preparations – Classifications – Applications

UNIT IV NANOCATALYSIS 9

Types of catalysis – Homogeneous, heterogeneous and biocatalysis – Catalysis by nanoparticles – Physical properties of free and supported nanoparticles – Reactivity of supported metal nanoparticles – Gold nanoparticles – Preparative methods and properties – Reactions – Water gas shift – vinyl acetate synthesis – hydrogenation – CO oxidation – Heck reaction – Commercial application**.**

UNIT V ELECTROCHEMISTRY OF NANOMATERIALS 9

Electrochemistry of Semiconductor Nanostructures, Nanostructured Metal Oxide Films – Electrochemistry with Nanoparticles – Preparation of Nanostructures, Electrochemistry with Metallic Nanoparticles – Monolayer protected nanoclusters, Nanoelectrode Ensembles, Single Electron Events, Probing Nanoparticles using Electrochemistry Coupled with Spectroscopy

TOTAL : 45 PERIODS

REFERENCES

1. M. Hosokawa, K. Nogi, M.Y. Naito Y,"Nanoparticle Technology Handbook" Vol. I, Elsevier, 2007
2. B. Pignataro "Tomorrow's Chemistry Today, Concepts in Nanoscience, Organic Materials and Environmental Chemistry", Wiley-Vch Verlag GmbH, 2008.
3. C.E. Carraher, R.B. Seymour, "Polymer Chemistry", CRC / Taylor and Francis, 2008
4. C.N.R. Rao, A. Muller, A.K. Cheetham, "The Chemistry of Nanomaterials: Synthesis, Properties and Applications", Wiley-Vch Verlag GmbH, 2004
5. G.A. Ozin, A.C. Aresenault, "Nanochemistry: A Chemical Approach to Nanomaterials", RSC Publishing, 2005.
6. C. Brechignac, P. Houdy, M. Lahmani "Nanomaterials and Nanochemistry", Springer-Verlag, 2007

NT7010 NANOPARTICLES AND MICROORGANISMS BIONANOCOMPOSITES

L T P C
3 0 0 3

UNIT I MICROORGANISMS FOR SYNTHESIS OF NANOMATERIALS 8

Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Testing of environmental toxic effect of nanoparticles using microorganisms;

UNIT II NANOCOMPOSITE BIOMATERIALS 9

Natural nanocomposite systems as spider silk, bones, shells; organic-inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; Use of synthetic nanocomposites for bone, teeth replacement.

UNIT III NANOBIO SYSTEMS 10

Nanoparticle-biomaterial hybrid systems for bioelectronic devices, Bioelectronic systems based on nanoparticle-enzyme hybrids; nanoparticle based bioelectronic biorecognition events. Biomaterial based metallic nanowires, networks and circuitry. DNA as functional template for nanocircuitry; Protein based nanocircuitry; Neurons for network formation.

DNA nanostructures for mechanics and computing and DNA based computation; DNA based nanomechanical devices. Biosensor and Biochips.

UNIT IV NANOPARTICLES AND NANO DEVICES 9

Targeted, non-targeted delivery; controlled drug release; exploiting novel delivery routes using nanoparticles; gene therapy using nanoparticles; Nanostructures for use as antibiotics; Diseased tissue destruction using nanoparticles;

UNIT V TISSUE ENGINEERING 9

Major physiologic systems of current interest to biomedical engineers: cardiovascular, endocrine, nervous, visual, auditory, gastrointestinal, and respiratory. Useful definitions, The status of tissue engineering of specific organs, including bone marrow, skeletal muscle, and cartilage. Cell biological fundamentals of tissue engineering.

TOTAL : 45 PERIODS

REFERENCES

1. Bionanotechnology: Lessons from Nature by David S. Goodsell, 2004.
2. Nanomedicine, Vol. IIA: Biocompatibility by Robert A. Freitas, 2003.
3. Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology - Hari Singh Nalwa 2005.
4. Nanobiotechnology; ed. C.M.Niemeyer, C.A. Mirkin 2006.
5. Nanocomposite Science & Technology Ajayan, Schadler & Braun 2003.

NT7011 OPTICAL PROPERTIES OF NANOMATERIALS, NANOPHOTONICS AND PLASMONICS

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UNIT I METAL NANOPARTICLES 8

Metal Nanoparticles, Alloy Nanoparticles, Stabilization in Sol, Glass, and other media, Change of bandgap, Blueshift, Colour change in sol, glass, and composites, Plasmon Resonance.

UNIT II SEMICONDUCTOR NANOPARTICLES – APPLICATIONS 10

Optical luminescence and fluorescence from direct, bandgap semiconductor nanoparticles, surface-trap passivation in core-shell nanoparticles, carrier injection, polymer-nanoparticle LED's and solar cells, electroluminescence; barriers to nanoparticle lasers; doping nanoparticles, Mn-ZnSe phosphors; light emission from indirect semiconductors, light emission from Si nanodots.

UNIT III PHYSICS OF LINEAR PHOTONIC CRYSTALS 8

Maxwell's Equations, Bloch's Theorem, Photonic Band Gap and Localized Defect States, Transmission Spectra, Nonlinear Optics in Linear Photonic Crystals, Guided Modes in Photonic Crystals Slab

UNIT IV PHYSICS OF NONLINEAR PHOTONIC CRYSTALS 9

1-D Quasi Phase Matching, Nonlinear Photonic Crystal Analysis, Applications of Nonlinear Photonic Crystals Devices, Materials: $LiNbO_3$, Chalcogenide Glasses, etc, Wavelength Converters, etc

UNIT V ELEMENTS OF PLASMONICS 10

Plasmonics, merging photonics and electronics at nanoscale dimensions, single photon transistor using surface plasmon, nanowire surface plasmons-interaction with matter, single emitter as saturable mirror, photon correlation, and integrated systems. All optical modulation by plasmonic excitation of quantum dots, Channel plasmon-polariton guiding

by subwavelength metal grooves, Near-field photonics: surface plasmon polaritons and localized surface plasmons, Slow guided surface plasmons at telecom frequencies.

TOTAL : 45 PERIODS

REFERENCES

1. Springer Handbook of Nanotechnology by Bharat Bhushan 2004.
2. Encyclopedia of Nanotechnology- Hari Singh Nalwa 2004.
3. The Handbook of Photonics By Mool Chand Gupta, John Ballato 2007
4. Nanotechnology for Microelectronics and Optoelectronics - J. M. Martinez-art,Raúl J. Martín-Palma, Fernando Agullo-Rueda 2006
5. Nanoplasmonics, From fundamentals to Applications vol 1 & 2- S. Kawata & H. Masuhara 2006.

NT7012 ADVANCED NANO DRUG DELIVERY SYSTEMS L T P C
3 0 0 3

UNIT I THEORY OF ADVANCED DRUG DELIVERY 10

Fundamentals of Nanocarriers - Size, Surface, Magnetic and Optical Properties, Pharmacokinetics and Pharmacodynamics of Nano drug carriers. Critical Factors in drug delivery. Transport of Nanoparticles - In Vitro and Ex Vivo Models.

UNIT II POLYMERS 8

Dendrimers- Synthesis -Nanoscale containers- Dendritic Nanoscafold systems- Biocompatibility of Dendrimers, Gene transfection. pH based targeted delivery- chitosan and alginate. Copolymers in targeted drug delivery- PCL,PLA, PLGA.

UNIT III LIPID BASED NANOCARRIERS 9

Liposomes, niosomes and solid lipid nanoparticles. Ligand based delivery by liposomes. Cubosomes.

UNIT IV MICROBES AND ANTIBODY BASED NANOCARRIERS 9

Bacterial dependent delivery of vaccines. Drug delivery and subcellular targeting by virus, Drug packaging and drug loading. Delivery of therapeutics by antibodies and antibody-bioconjugates.

UNIT V SITE SPECIFIC DRUG DELIVERY 9

Concepts and mechanism of Site specific drug delivery- Microneedles, Micropumps, microvalves. Implantable microchips.

TOTAL : 45 PERIODS

REFERENCES

1. Drug Delivery: Engineering Principles for Drug Therapy, M. Salzman, Oxford University Press, 2001.
2. Drug Delivery and Targeting, A.M. Hillery, CRC Press, 2002.
3. Drug Delivery: Principles and Applications, B. Wang, Wiley Intersceince, 2005.
4. Nanoparticle Technology for Drug Delivery, Ram B. Gupta, Uday B. Kompella Taylor & Francis, 2006

NT7013 BIOMOLECULAR MACHINES L T P C
3 0 0 3

UNIT I 9

Characterization of molecular machine - energy supply - chemical fuels- molecular shuttle-electrochemical energy - molecular machines powered by light energy: molecular switching-chemical switching and electrochemical switching.

UNIT II 9

Biomolecular machines:Transcription, translation and replication processes at single molecule level – initiation and force control of biological processes- force generation and real-time dynamics – active transport by biological motors – mechanism, dynamics and energetic of kinesin, myosin, dyneins and ATP synthesis.

UNIT III **9**

Self-assembled-nanoreactors - molecular nanoreactors-covalent system-nano covalent system-macro molecular nanoreactions micelles and polymers–biomacro molecular nanoreactions-Protein cages-viruses- rod shaped and cage structured.

UNIT IV **9**

Memories Logic Gates–Multistate–Mukltifunctional Systems systems.

UNIT V **9**

Fabrication and patterning of nanoscale device.

TOTAL : 45 PERIODS

REFERENCES

1. Molecular Devices and Machines: A Journey into the Nanoworld, V. Balazani, Wiley – VCH, 2003.
2. Molecular Motors, M. Schilva, Wiley,VCH. 2005.

NT7014 **BIOSENSORS** **L T P C**
3 0 0 3

UNIT I **9**

Protein based biosensors – nano structure for enzyme stabilization – single enzyme nano particles – nano tubes microporus silica – protein based nano crystalline Diamond thin film for processing.

UNIT II **9**

DNA based biosensor- heavy metal complexing with DNA and its determination water and food samples – DNA zymo Biosensors.

UNIT III **9**

Detection in Biosensors - fluorescence - absorption – electrochemical. Integration of various techniques – fiber optic Biosensors.

UNIT IV **9**

Fabrication of biosensors- techniques used for microfabrication -microfabrication of electrodes-on chip analysis.

UNIT V **9**

Future direction in biosensor research- designed protein pores-as components of biosensors- Moleculardesign-Bionanotechnology for cellular biosensing-Biosensors for drug discovery – Nanoscale biosensors.

TOTAL : 45 PERIODS

REFERENCES

1. Biosensors: A Practical Approach, J. Cooper & C. Tass, Oxford University Press, 2004.
2. Nanomaterials for Biosensors, Cs. Kumar, Wiley – VCH, 2007.
3. Smart Biosensor Technology, G.K. Knoff, A.S. Bassi, CRC Press, 2006.

NT7015 **BIOPHOTONICS** **L T P C**
3 0 0 3

UNIT I **9**
Interaction of light with cells, tissues, non-linear optical processes with intense laser beams, photo-induced effects in biological systems.

UNIT II **9**
Imaging techniques: Light microscopy, wide-field, laser scanning, confocal, multiphoton, fluorescence lifetime imaging, FRET imaging, Frequency-Domain lifetime imaging. Cellular Imaging, Imaging of soft and hard tissues and other biological structures.

UNIT III **9**
Single molecule spectroscopy: UV-VIS spectroscopy of biological systems, single molecule spectra and characteristics – IR and Raman spectroscopy and Surface Enhanced Raman Spectroscopy for single molecule applications.

UNIT IV **9**
Optical Force Spectroscopy: Generation optical forces – Optical trapping and manipulation of single molecules and cells in optical confinement - Laser trapping and dissection for biological systems - single molecule biophysics, DNA protein interactions.

UNIT V **9**
Biosensors, fluorescence immuoassay, flow cytometry, Fluorescence correlation spectroscopy, Fluorophores as cellular and molecular tags.

TOTAL : 45 PERIODS

REFERENCES

1. Laser Tweezers in Cell Biology in Methods in Cell Biology, Vol.55, Michael P. Sheetz (Ed.), Academic Press 1997.
2. P.N. Prasad, Introduction to Biophotonics, John-Wiley, 2003.
3. G. Marriot & I. Parker, Methods in Enzymology, Vol.360,2003.
4. G. Marriot & I. Parker, Methods in Enzymology, Vol.361,2003.

NT7016 **NANOTOXICOLOGY** **L T P C**
3 0 0 3

UNIT I INTRODUCTION TO TOXICOLOGY **9**
Concept of Toxicology-Types of toxicity based on route of entry, nature of the toxin. Toxicodynamics–Dose vs Toxicity Relationships. Toxicokinetics – ADME, LADMET hypothesis. Genotoxicity and carcinogenicity – Mechanisms and Tests. Organ toxicity – Respiratory**,** dermal, hepato, neuro and nephro.

UNIT II NANOTOXICOLOGY **10**
Characteristics of Nanoparticles that determine Potential Toxicity. Bio-distribution of nanoparticles. Interation of Nanoparticles with Biomembrane and genes. Evaluation of Nanoparticle transfer using placental models. Nanomaterial toxicity – Pulmonary**,** dermal, hepato, neuro, ocular and nephro; Estimation of Nanoparticle Dose in Humans. In vitro toxicity studies of ultrafine diesel exhaust particles; Toxicity studies of carbon nanotubes

UNIT III PROTOCOLS IN TOXICOLOGY STUDIES 9

Methods for toxicity assessment – Cyto, Geno, hepato, neuro, nephrotoxicity. Assessment of toxicokinetics. Assessment of oxidative stress and antioxidant status.

UNIT IV ANIMAL MODELS 9

Types, species and strains of animals used in toxicity studies. Dosing profile for animal models. Studies on toxicology, pathology and metabolism in mouse and rat. Laws and Regulations Governing Animal Care and Use in Research.

UNIT V RISK ASSESSMENT AND EXECUTION 8

Risk assessment of Nanoparticle exposure. Prevention and control of nanopaticles exposure. Regulation and recommendations.

TOTAL : 45 PERIODS

REFERENCES

1. John H. Duffus, Howard G. J. Worth, 'Fundamental Toxicology', The Royal Society of Chemistry 2006.
2. Nancy A. Monteiro-Riviere, C. Lang Tran., 'Nanotoxicology: Characterization, Dosing and Health Effects',Informa Healthcare publishers, 2007.
3. Lucio G. Costa, Ernest Hodgson, David A. Lawrence, Donald J. Reed,William F. Greenlee, 'Current Protocols in Toxicology', John Wiley & Sons, Inc. 2005.
4. Shayne C. Gad, 'Animal models in toxicology', Taylor & Francis Group, LLC 2007.
5. P. Houdy, M. Lahmani, F. Marano, 'Nanoethics and Nanotoxicology', Springer-Verlag Berlin Heidelberg 2011.
6. A Reference handbook of nanotoxicology by M.ZafarNyamadzi 2008.
7. Andreas Luch, 'Molecular, Clinical and Environmental Toxicology Volume 2: Clinical Toxicology', BirkhauserVerlag AG 2010.

BY7022 NANOBIOTECHNOLOGY L T P C
3 0 0 3

OBJECTIVES

The 'Nanobiotechnology' course aims to provide fundamental concepts of nanotechnology and advanced knowledge on th e application of nanotechnology to biological sciences including nanomedicine.

OUTCOMES

The students would have learned the physicochemical properties of nanomaterials; the unique changes that happen at nanoscale; nanoscale view of the natural biomolecular processes; synthesis, modification, and characterization of naomaterials; and application of naomaterials to biological problems including nanomedicine.

UNIT I NANOSCALE AND NANOBIOTECHNOLOGY 6

Introduction to Nanoscience and Nanotechnology; Milestones in Nanotechnology; Overview of Nanobiotechnology and Nanoscale processes; Physicochemical properties of materials in Nanoscales.

UNIT II FABRICATION AND CHARACTERIZATION OF NANOMATERIALS 10

Types of Nanomaterials (Quantum dots, Nanoparticles, Nanocrystals, Dendrimers, Buckyballs, Nanotubes); Gas, liquid, and solid –phase synthesis of nanomaterials; Lithography techniques (Photolithography, Dip-pen and Electron beam lithography); Thin film deposition; Electrospinning. Bio-synthesis of nanomaterials.

UNIT III PROPERTIES AND MEASUREMENT OF NANOMATERIALS 9

Optical Properties: Absorption, Fluorescence, and Resonance; Methods for the measurement of nanomaterials; Microscopy measurements: SEM, TEM, AFM and STM. Confocal and TIRF imaging.

UNIT IV NANOBIOLOGY AND BIOCONJUGATION OF NANOMATERIALS 10

Properties of DNA and motor proteins; Lessons from nature on making nanodevices; Reactive groups on biomolecules (DNA & Proteins); Surface modification and conjugation to nanomaterials. Fabrication and application of DNA nanowires; Nanofluidics to solve biological problems.

UNIT V NANO DRUG DELIVERY AND NANOMEDICINE 10

Properties of nanocarriers; drug delivery systems used in nanomedicine; Enhanced Permeability and Retention effect; Blood-brain barrier; Active and passive targeting of diseased cells; Health and environmental impacts of nanotechnology.

TOTAL : 45 PERIODS

REFERENCES

1. Nanobiotechnology: Concepts, Applications and Perspectives, Christof M. Niemeyer (Editor), Chad A. Mirkin (Editor) , Wiley-VCH; 1 edition , 2004.
2. NanoBioTechnology: BioInspired Devices and Materials of the Future by Oded Shoseyov and Ilan Levy, Humana Press; 1 edition 2007.
3. NanoBiotechnology Protocols (Methods in Molecular Biology) by Sandra J Rosenthal and David W. Wright , Humana Press; 1 edition, 2005.
4. Bio-Nanotechnology_ Concepts and applications. Madhuri Sharon, Maheshwar Sharon, Sunil Pandey and Goldie Oza, Ane Books Pvt Ltd, 1 edition 2012
5. Microscopy Techniques for Material Science. A. R. Clarke and C. N. Eberhardt (Editors) CRC Press. 1st Edition, 2002.