

**COURSE STRUCTURE AND SYLLABUS FOR M.Sc (Nanotechnology)
SCHOOL OF NANO SCIENCES**

Course Code	Course Title	Credits
	M.Sc Semester I (Total Credits -20)	
NSC 401	Physics of nanomaterials	4
NSC 402	Chemistry of nanomaterials	4
NSC 403	Synthesis of nanomaterials	4
NSC 404	Characterisation of nanomaterials - I	4
NSC 405	Nano Science Practicals – I	4
	M.Sc Semester II (Total Credits -20)	
NSC 451	Nano composites and Nano polymers	4
NSC 452	Nanotoxicology and Biosafety	4
	OPTIONALS FOR GROUP A	
NSC 471	Mathematics and Computational Science	4
NSC 472	Characterisation of nanomaterials - II	4
NSC 473	Nano Science Practicals – II	4
	OPTIONALS FOR GROUP B	
NSC 474	Nanotechnology in agriculture and food processing	4
NSC 475	Nano Biotechnology	4
NSC 476	Nano Science Practicals – III	4
	M.Sc Semester III (Total Credits -16)	
NSC 501	Nano fabrication	4
	OPTIONALS FOR GROUP A	
NSC 521	Nanomaterials in energy technology	4
NSC 522	Industrial applications of Nano Science	4
NSC 523	Semi conductor materials and applications	4
	OPTIONALS FOR GROUP B	
NSC 524	Nanoscience applications in drug delivery	4
NSC 525	Environmental nanotechnology	4
NSC 526	Basics of Nano medicine	4
	M.Sc Semester IV (Total Credits -16)	
NSC 551	Dissertation & Viva	8
	OPTIONALS FOR GROUP A	
NSC 571	Term paper, Project proposal and defense I	4
NSC 572	Carbon Nanoscience and its applications	4
	OPTIONALS FOR GROUP B	
NSC 573	Term paper, Project proposal and defense II	4
NSC 574	Basics of Nanotechnology in Tissue engineering	4
TOTAL		72

SEMESTER I

NSC 401 **Physics of Nanomaterials (4C)**

- 1) Scales In Nanophysics
Quantum Structure: 3D-Potential Wells (Spherical & Rectangular Parallelepiped), 2D (Circular & Square, Quantum Corrals), 1D (Quantum Wires), 0D (Quantum Dots).
- 2) Barrier Penetration: Step Potential; Rectangular Barrier Penetration; Tunneling; WKB.
Applications of Barrier Penetration: TEM, AFM, STM.
- 3) The Harmonic Oscillator: Schrodinger approach; Dirac's bra-ket notation & operator algebra; lattice vibrations; phonons. Hydrogenic Atoms: Spherically Symmetric Potential; Spherical Harmonics; Radial Wave Function; Orbitals.
- 4) Molecular Physics: H_2^+ Molecular Ion; Bonds (Ionic, Covalent, Hydrogen); Molecular Spectrum; Rotational & Vibration Levels; Raman Spectrum; Sigma & Pi Bonds; Carbon Nanotubes; Graphene; Fullerenes, Energy Bands: Fermi-Dirac Statistics; Kronig-Penny Model; Holes; Effective Mass; Density Of States: 3D, 2D, 1D; Conduction & Valence Bands; Semiconductor Physics.

TEXT BOOKS:

- 1) A Textbook Of Quantum Mechanics by PM Mathews and K Venkatesan, TMH Publications, 2010
- 2) Quantum Mechanics by Amit Goswami Waveland Press inc., 2003
- 3) Quantum Heterostructures: Microelectronics and Optoelectronics by Valdamir V. Mintin, V. A. Kochelap, M. A. Storscio, Cambridge University Press, 2000
- 4) Modern Physics For Scientists and Engineers by J Talyor, C Zafiratos, MA Dubson, Pearson Education, 2004
- 5) Handbook Of Nanotechnology by Bharatbhushan, Springer Publications, 2010

NSC 402 **Chemistry of Nanomaterials (4C)**

- 1) Structure, bonding & synthesis of some inorganic materials, zeolites, tetravalent metal acid salts, introduction to transition metal complexes, metal carbonyls, organo metal complexes.
- 2) Atomic structure, chemical bonding, aromatic chemistry, polynuclear aromatic hydrocarbons, methods of preparation, physical & chemical properties, molecular orbital's, LCAO method & pericyclic reactions.
- 3) Introduction to Liquid crystals, classification and synthesis of liquid crystals, heterocyclic compounds, classification, numbering, nomenclature, 5 & 6 membered heterocyclic compounds with one or more hetero atoms.
- 4) Zero, 1st, 2nd, order reaction, theories of reaction rates, statistical thermodynamics, partition functions, Colloidal state, micelles, solid state, bonding in solid state, catalysis by supported metal ion, influence of nano dimensions on catalyst function

TEXT BOOKS:

- 1) The Chemistry of Nanomaterials: Synthesis, Properties and Applications, 2 Volumes C. N. R. Rao (Editor), Achim Muller (Editor), Anthony K. Cheetham (Editor), J Wiley & Sons, 2006
- 2) Chemical Functionalization of Carbon Nanomaterials: Chemistry and Applications, Vijay Kumar Thakur, Manju Kumari Thakur, CRC Press, 2015
- 3) Organic Chemistry By Morrison And Boyd, 7th Ed
- 4) Nanochemistry: A Chemical Approach to Nanomaterials – by Geoffrey A. Ozin, Andre C. Arsenault, Ludovico Cademartiri and Chad A. Mirkin, Royal Soc Chemistry, 2008

NSC 403 **Synthesis of nanomaterials (4C)**

- 1) The study of techniques such as inert gas condensation, physical vapour deposition, sputtering, plasma deposition process, chemical vapour deposition. Classifications and types of nanomaterials as nano particles and 1D 2D 3D nanomaterials. Concept of bulk versus nanomaterials and dependence of properties on size. Classifications of techniques of nano synthesis based on the nature of the starting phase as vapour, liquid or solid. Introduction to 'Top down' vs. 'Bottom up' approach of synthesis with suitable examples.

- 2) Nano synthesis techniques based on liquid and vapour phase as the starting material. The study of wet chemical method like sol-gel method, micro emulsion technique, reduction of metal salts, decomposition of organometallic precursors, cryochemical synthesis etc. Study of rapid solidification route, electro and electroless deposition etc. along with suitable examples.
- 3) Synthesis of 3D nano structured materials using high-energy mechanical attrition by devitrification of an amorphous precursor, etc. Introduction to nanolithography and self-assembly routes. Introduction to specific synthesis processes like synthesis of semiconductor nano particles in colloidal solution, preparation of quantum dots, nano wires and films, preparation of single-walled and multi-walled nanotubes.
- 4) Brute force methods vs. soft Chemistry routes, sol-gel method of synthesis, Modification, use of templates, microwave and ultrasound assisted synthesis, citrate gel method, CFC(controlled flow cavitations), SCF's(super critical fluids). Introduction to specific synthesis process, nano particles in colloidal solutions, Surfactants, physical chemistry or surfactant behavior, micelles, self assembly, self assembled mono layers (SAM's),Langmuir-Blodget(LB)films, organic block copolymers, emulsion polymerization micro emulsion.

TEXT BOOKS

- 1) Nanomaterials Chemistry by Rao C. N., A. Muller, A. K. Cheetham,, WileyVCH , 2007.
- 2) Nanomaterials and Nanochemistry by Brechignac C., P. Houdy, M. Lahmani, Springer publication, 2007.
- 3) Nanoscale materials in chemistry by Kenneth J. Klabunde, Wiley Interscience Publications,2001.
- 4) Nanochemistry by Sergeev G.B., Elseiver publication,2006.

NSC 404 **Characterisation of nanomaterials-I (4C)**

- 1) Importance of characterization of materials at nano level. Difference in behavior of materials in bulk and nano regime. Difficulties in charactizing materials of nano size.
- 2) Techniques of characterization of size of nano powders/ particles using BET method and laser diffraction. Determination of specific area and the pore volume for nano porous solids.
- 3) Principle. Scope and application of various spectroscopic techniques like optical spectroscopy. U-V visible and Infrared spectroscopy. Raman spectroscopy. X-ray photoelectron spectroscopy. Basic understanding of each technique with special emphasis on characterization at nano scale.
- 4) Characterization of nano particles in terms of their composition .Crystal structure, phase analysis and crystallite size using X-ray Fluorescence (XRF) ,X-ray diffraction (XRD) and Small Angle X-ray Scattering principles.

TEXT BOOKS

- 1) Nanostructures and Nanomaterials, synthesis, properties and applications by Guozhong Cao, Imperial College Press, 2004.
- 2) Nanomaterials – Handbook by Yury Gogotsi, CRC Press, Taylor & Francis group, 2006.
- 3) Nanomaterials: synthesis, Properties and Applictions by Edelstein A S and Cammarata R C,Taylor and Francis, 2012.
- 4) NANOTECHNOLOGY Basic Science and Emerging Technologies by Michael Wilson, Kamali Kannangara and Geoff Smith, A CRC Press Company, D.C, 2002.
- 5) Principles of Instrumental analysis by Douglas A. Skoog, F. James Holler, Saunders college publication, 1998 .
- 6) Hand book of Infrared spectroscopy of ultra thin films by Valeri P. Tolstoy, John Wiley& sons publication, 2003.

NSC 405 Nano Science Practicals – I (4C)

List of experiments:

- 1) Synthesis of various nanoparticles and analysis by UV-Vis spectrophotometer and DLS. Examples of nanoparticles such as thiolated silver nanoparticles, Gold Nanoparticles, monodispersed polymethylmethacrylate spheres, silver gallium selenide nanoparticle, Zinc selenide quantum dots, Iron Oxide Nanoparticle.
- 2) Synthesis of Nickel metal nanoparticle by hydrothermal technique and to determine particle size Using UV-Vis spectrometer.
- 3) Synthesis of Zinc Oxide semiconducting nanoparticle by co precipitation technique and to calculate the absorption coefficient & optical bandgap using UV-Vis spectrometer
- 4) Synthesis of aqueous ferrofluid by wet chemical methods and Peak analysis of IR Transmission spectrum using FTIR spectroscopy.
- 5) Chemical bath deposition – Dip coating and to calculate the absorption coefficient & optical bandgap using UV-Vis spectrometer

TEXT BOOK:

- 1) Edelstein A S and Cammarata R C, “Nanomaterials: Synthesis, Properties and Applications”, Taylor and Francis, 2012

SEMESTER II

NSC 451 Nano composites and Nano polymers (4C)

- 1) Introduction to polymers Importance of polymers: Basic concept-Classification of polymers on the basis of microstructures, macrostructures and applications- Chain Structure and configuration. Homo and heteropolymers - Copolymers-Chemistry of polymerization.
- 2) Polymeric nanostructures and nanocomposites The formation of ordered polymer structures at interfaces- Block copolymers for ordered polymeric nanostructures- Surface micelles and surface induced Nano patterns- Surface nano and microstructuring with organometallic polymers. Polymer/ clay nanocomposites- polypropylene layered silicate nanocomposites biodegradable polymer/layered silicate nanocomposites.
- 3) Metal matrix nanocomposites Metal-containing polymers: cryochemical synthesis, structure, and physicochemical properties-nanostructured polymeric nano reactors for metal nanoparticle formation- optical extinction of metal nanoparticles synthesized in polymer by ion implantation- optically anisotropic metal polymer.
- 4) Ceramic matrix nanocomposites Nanophase ceramic composites- Processing- microstructural control of metal reinforced ceramic matrix nanocomposites- Machinable nanocomposite ceramics. Silicon nitride and silicon carbide based ceramics- Functionally graded ceramics clay nanocomposites.

TEXT BOOKS:

- 1) Polymer Science by Viswanathan V.R., and NV Jayadev Sreedhar, New age International publications, 2005.
- 2) Polymernanocomposites by Yiu-Wing Mai and Zhong-Zhen yu, CRC press,2006.
- 3) The elements of polymer science and engineering by Alfred Rudin, 2nd edition, Academic press publication, 1999.
- 4) Nano and Biocomposites by Alan Kin-TakLau, Farzanahussain, Khalidlafdi, CRC press, 2010.
- 5) Advances in polymer science by Abe, A.-C. Albertsson, R.Duncan, Springer,2006.
- 6) Ceramic matrix composites:Microstructure, properties and applications by Low I. M., Woodhead Publishing Limited, 2006.

NSC 452 Nanotoxicology and Biosafety (4C)

- 1) Introduction – source of nanoparticles –epidemiological evidence –entry routes into the human body: Lungs – Inhalation – Deposition and translocation – Intestinal tract - Skin – Attributes contributing to

nanomaterial toxicology. Nanoparticles in the environment – Health threats- nanomaterials and biotoxicity –Iron oxide –Titanium dioxide-dark studies –UV irradiation- In vivo - In Vitro and cytotoxicity studies.

- 2) Classifications and source of pollutants - Air - Water - Soil - biomarkers – Environmental implication of nanomaterials – Occurrences, Fate and characterisation of Nanomaterials in the environment.
- 3) Toxicology of nanomaterials in food: Characterization of Engineered Nanomaterials: Unique Issues for Characterization of Engineered Nanomaterials for Food Applications - Safety Assessment of Oral exposure Engineered Nanomaterials for Food Application - Experimental Design Considerations for Toxicology Studies - Toxicokinetics – ADME Toxicodynamics - In Vivo Toxicity - In Vitro Toxicity - Study Reliability.
- 4) Nanocomposites for Food Packaging - Nanocomposites for Food Packaging Toxicity and Environmental Risks of Nanomaterials, Physicochemical characteristics of nanomaterials – Nanoparticle interaction with biological membrane – Neurotoxicology - Toxicity of nanoparticles in the EYE.

TEXT BOOKS:

- 1) Nanotechnology: Health and Environmental Risks by Jo Anne Shatkin, CRC Press, 2008
- 2) Nanotechnology Environmental Health and Safety: Risks, Regulation, and Management, by Matthew Hull, Diana Bowman ,William Andrew, Elsevier 2014
- 3) Nanotechnology - Toxicological Issues and Environmental Safety, by P.P. Simeonova, N. Opopol, M.I. Luster, Springer 2007
- 4) Safety of Nanoparticles: From Manufacturing to Medical Applications by Thomas J. Webster, Springer 2008

NSC 471 **Mathematics and Computational Science (4C)**

- 1) Basic Features Of MATLAB: Variables, Comments, Punctuations Matlab Workspace, Simple Math, Complex Numbers, Mathematical Function, Operation On Vectors And Matrices, Logical Arrays.2D And 3D Graphics. ODE And PDE Solvers, Optimization Tools In MATLAB
- 2) Computer Arithmetic: Floating Point Numbers And Round Off Errors, Absolute And Relative Errors, Polynomial Interpolation: Newton's And Lagrange's Interpolation Formulas, Numerical Integration by Trapezoidal Rule, Simpson's Rule, Error Analysis. Solution Of System Of Linear Equations By Direct Method (Gauss-Elimination) And Iterative Methods(Jacob's Method, Gauss-Seidel Method)
- 3) Solution of Transcendental Equation By Bisection Method And Newton's Method. System Of Non Linear Equations: Newton-Raphson's Method.
- 4) Curve-Fitting by Least Square Techniques. Numerical Solution Of ODE, Single Step Method- Runge Kutta Methods, Numerical Solution To PDE, Stability And Convergence.

TEXT BOOKS:

- 1) Higher Engineering Mathematics by B. S. Grewal, Khanna Publishers Delhi
- 2) Introductory Numerical Analysis By S. S. Sastry, Prentice Hall Publishers
- 3) Matlab, An Introduction with Applications by Amos Gilat
- 4) Getting Started with Matlab 7, Oxford Press (Indian Edition 2007)

NSC 472 **Characterisation of Nanomaterials – II (4C)**

- 1) Understanding of micro structural developments in nanomaterials using optical microscopy. Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) approach. High resolution Transmission Electron Microscopy (HRTEM).
- 2) Characterizing nano materials using techniques based on scanning probe microscopy principle namely Scanning Tunneling Microscopy (STM), Atomic Force Microscopy (AFM), Magnetic Force Microscopy (MFM) etc. Chemical Force Microscopy (CFM), Focused Ion Beam (FIB), Nanolithography.

- 3) Magnetic measurements using vibrating sample magnetometer (VSM)- magnetic force microscopy (MFM) - Electron Paramagnetic Resonance (EPR)-Nuclear Magnetic Resonance (NMR) spectroscopy – Mechanical properties-micro hardness - nano indentation- elastic and plastic deformation- fracture toughness - superplasticity.
- 4) I-V/C-V - Hall - Quantum Hall effects - Kelvin-probe measurements - Deep level transient spectroscopy (DLTS) - FET characteristics.

TEXT BOOKS:

- 1) The structure and properties of materials by R.M.Rose, L.A.Shepard and J. Wulff, Wiley Eastern Ltd., 1966.
- 2) Semiconductor Devices – Physics and Technology by S.M. Sze, Wiley, 1985.
- 3) Semiconductor Material and Device Characterization by D. K. Schroder, John Wiley & Sons, New York, 1998.
- 4) Encyclopedia of Materials Characterization by C. Richard Brundle Charles A. Evans, Jr. Shaun Wilson, Butterworth-Heinemann, 1992.

NSC 473 Nano Science Practicals – II (4C)

- 1) Handling of Atomic Force microscopy
- 2) Operation of Scanning tunneling microscopy
- 3) To determine the surface roughness of AFM images using offline SPM software
- 4) Determination of energy Bandgap of semiconductor by Photoluminescence
- 5) To synthesise quantum dot by chemical route
- 6) Colloidal suspension of nanoparticles
- 7) Preparation and analyses of LB films
- 8) To determine the density of self-assembled Au nanoparticle by AFM
- 9) To study the self-assembly of nanodots by AFM

TEXT BOOK

1. Edelstein A S and Cammarata R C, “Nanomaterials: Synthesis, Properties and Applications”, Taylor and Francis, 2012

NSC 474 Nanotechnology in agriculture and food processing (4C)

- 1) Intermolecular interactions and supramolecular structures: Water - Hydrophobic and Hydrophilic Interactions - Dispersion Interaction Electrostatic Interactions - Atoms and Small Molecules - Polymers, Particles, and Surfaces - Steric Interactions Involving Soluble Polymers - Depletion Aggregation of Particles by Non-adsorbing Polymers - Bridging Aggregation of Particles by Adsorbing Polymers - Stabilization of Dispersed Particles by Adsorbing Polymers - Polymer Brushes to Prevent Particle Aggregation and Particle Deposition at Surfaces - Plant Cells - Organized Self-Assembled Structures - Langmuir Layers Lipid Bilayers - Solid-Supported Lipid Bilayers.
- 2) Nanoparticles in agricultural and food diagnostics: Enzyme Biosensors and Diagnostics - DNA-Based Biosensors and Diagnostics Radiofrequency Identification- Integrated Nanosensor Networks: Detection and Response- Lateral Flow (Immuno)assay - Nucleic Acid Lateral Flow (Immuno)assay - Flow-Through (Immuno)assays - Antibody Microarrays Surface Plasmon Resonance Spectroscopy.
- 3) Nanotechnology in food production: Food and New Ways of Food Production - Efficient Fractionation of Crops Efficient Product Structuring -Optimizing Nutritional Values - Applications of Nanotechnology in Foods : Sensing, Packaging, Encapsulation, Engineering Food Ingredients to Improve Bioavailability - Nanocrystalline Food Ingredients - NanoEmulsions - Nano-Engineered Protein Fibrils as Ingredient Building Blocks Preparation of Food Matrices - Concerns about Using Nanotechnology in food production.
- 4) Nanotechnology in food packaging: Crop improvement - Reasons to Package Food Products - Physical Properties of Packaging Materials - Strength - Barrier Properties Light Absorption – Structuring of Interior Surfaces - Antimicrobial Functionality - Visual Indicators – Quality Assessment - Food Safety

Indication - Product Properties - Information and Communication Technology - Sensors - Radiofrequency Identification Technology- Risks - Consumer and Societal Acceptance.

TEXT BOOKS :

- 1) Nanoparticle Assemblies and Superstructures by Nicholas A. Kotov, CRC, 2006.
- 2) Nanotechnology in agriculture and food production by Jennifer Kuzma and Peter VerHage,, Woodrow Wilson International, 2006.
- 3) Bionanotechnology by David S Goodsell, John Wiley & Sons, 2004.
- 4) Nanobiomaterials Handbook by Balaji Sitharaman, Taylor & Francis Group, 2011.

NSC 475 Nano Biotechnology (4C)

- 1) Nanobiomaterials And Biocompatibility: Surface and Bulk Properties of Bio materials – Nanobiomaterials –NanoCeramics – Nanopolymers – Nano Silica – Hydroxy apatite - Carbon Based nanomaterials Surface modification – Textured and Porous Materials – Surface immobilized biomolecules – Cell-biomaterial interactions – immune response – In Vitro and In Vivo assessment of tissue compatibility
- 2) Structural & Functional Principles Of Bionanotechnology: Lipid Bilayers – liposomes – neosomes- Polysaccharides - Peptides –Nucleic acids – DNA scaffolds – Enzymes- Biomolecular motors: linear, rotary motors – Immunotoxins – Membrane transporters and pumps – Antibodies – monoclonal Antibodies – immunoconjugates - limitations of natural biomolecules
- 3) Protein And Dna Based Nanostructures: Nanocircuitry - S-layer proteins: structure, chemistry and assembly – lipid chips – S - Layers as Templates – engineered nanopores - DNA–Protein Nanostructures DNA-templated Electronics - DNA-based Metallic Nanowires and Networks DNA–Gold-Nanoparticle Conjugates – DNA -templated Electronics – DNA Nanostructures for Mechanics and Computing
- 4) Nanobio-Analytics: Luminescent Quantum Dots for Biological Labeling - Nanoparticle Molecular Labels - Surface Biology: Analysis of Biomolecular Structure by Atomic ForceMicroscopy and Molecular Pulling - Force Spectroscopy – Biofunctionalized Nanoparticles for Surface - Enhanced Raman Scattering and Surface Plasmon Resonance - Bioconjugated Silica Nanoparticles for Bioanalytical Applications

TEXT BOOKS:

1. Nanobiotechnology: Concepts, Applications and Perspectives by Niemeyer C. M., Wiley – VCH, 2006.
2. Bionanotechnology by David S Goodsell, John Wiley & Sons, 2004.
3. Bio-Nanotechnology: A Revolution in Food, Biomedical and Health Sciences by Debasis Bagchi, Manashi Bagchi, Hiroyoshi Moriyama, Fereidoon Shahidi, Wiley-Blackwell, 2013.
4. Biomaterials Science: An Introduction to Materials in Medicine by Buddy D. Ratner, Allan S. Hoffman , Frederick J. Schoen , Jack E. Lemons, Academic Press, 2012.
5. Nanobiomaterials Handbook by Balaji Sitharaman, Taylor & Francis Group, 2011.

NSC 476 Nano Science Practicals – III (4C)

1. Synthesis of micelles and inverse micelles.
2. Isolation of DNA and Bioconjugation of DNA with Nanoparticles
3. Functionalization of nanoparticles with glycans and proteins for drug delivery
4. Toxic effect of nanoparticles on microbes, AMES test, effect of NPs on blood cell viability using MTT assay
5. UV/Vis spectrophotometric analysis of effect of NPs on DNA, protein, membrane integrity-study leakage of cytosolic enzymes
6. Effect of nanoparticles on metalloenzymes, redox status of blood cells, mitochondrial integrity

TEXT BOOK

1. Nanomaterials: Synthesis, Properties and Applications” by Edelstein A S and Cammarata R C, Taylor and Francis, 2012
2. Textbook of Nanoscience and Nanotechnology by T. Pradeep, McGraw Hill Education (India) Private Limited: , 2012

SEMESTER III

NSC 501 Nanofabrication (4C)

- 1) Nanofabrication processes: Concept of Top Down and Bottom Up Fabrication approach, Self-assembly, Directed self-assembly, Direct assembly techniques, Bio-mediated assembly, template assisted synthesis, epitaxial growth.
- 2) Precision Engineering in VLSI technology: Electron beam lithography (EBL), UV imprint lithography, Nanoimprint lithography, focused ion beam (FIB), pulsed laser ablation, Multilayers structures for device applications, ion beam nano structuring.
- 3) Nanofabrication in semiconductor industry: Metal Oxide Semiconductor (MOS) transistor, NMOS and PMOS transistors, Complementary Metal Oxide Semiconductor (CMOS) transistor, CMOS Fabrication steps: Design rules, Clean rooms, Wafer cleaning and Gettering, Oxidation, Photoresist, Photolithography, Etching, Device isolation, N and P well formation, Gate formation, Source/Drain formation, Contact and local interconnect formation (Metallization).

TEXT BOOKS:

- 1) Silicon VLSI Technology: Fundamentals, Practice, and Modeling 1st Edition by James D. Plummer, Michael Deal, Peter D. Griffin (Pearson Education).
- 2) Handbook of Nanofabrication: Editor Gary P. Wiederrecht, Elsevier publication.
- 3) Nanostructures-Fabrication and analysis: Editor: H. Nejo, Springer publication.
- 4) Principles of Lithography: Harry J. Levinson

NSC 521 Nanomaterials in Energy Technology (4C)

- 1) Nanotechnology for sustainable energy- Energy conversion process, indirect and direct energy conversion-Materials for light emitting diodes, batteries, catalytic reactors, capacitors-fuel cells. Nanomaterials for fuel cells, carbon material for energy storage, hydrogen storage in carbon nanotubes, use of nanoscale catalysts to save energy and increase the productivity in industry, Rechargeable batteries based on nanomaterials
- 2) Batteries: Primary, Secondary, Lithium, solid-state and molten solvent batteries; Lead Lead acid batteries; Nickel Cadmium Batteries; Advanced Batteries. Role of carbon nano-tubes in electrodes.
- 3) Hydrogen Production Methods: from fossil fuels, electrolysis, thermal decomposition, photochemical, photocatalytic, hybrid; Hydrogen storage: metal hydrides, metallic alloy hydrides, carbon nano-tubes etc.

TEXT BOOKS:

- 1) Hoogers, Fuel cell technology handbook. CRC Press, (2003).
- 2) Vielstich, Handbook of fuel cells: Fuel cell technology and applications, Wiley, CRC Press, (2003).
- 3) H J Moller, Semiconductor for solar cells, Artech House Inc, MA, USA, (1993).
- 4) Ben G Streetman, Solis state electronic device, Prentice Hall of India Pvt Ltd., New Delhi (1995).

NSC 522 Industrial applications of Nano Science (4C)

- 1) Carbon Nanotechnology: Introduction to carbon nanotubes and their applications in various industries, supercapacitors, hydrogen storage, photovoltaic applications, OLED displays, handling of CNTs. Precision Engineering in VLSI technology: Electron beam lithography (EBL), focused ion beam (FIB), reactive ion etching (RIE) and femtosecond pulsed laser ablation, Multilayers structures for device applications.
- 2) Nanomaterials for solar power: Solar energy materials, Solar energy devices, silicon solar technology for clean energy. Nanomaterials and coating for nuclear power: Radiation resistance of nanomaterials, Nano-nuclear materials and coatings for generation IV fission and future fusion reactors. Applications of catalysis and supramolecular chemistry.

- 3) Nanomaterial and their catalytic potential, CHEMFET sensors. Nanomagnetism: Spintronics technology and the challenges, Modern magnetic materials: principles and applications, Magnetic nanostructures for three-dimensional memory and logic applications. Miscellaneous applications of nanotechnology: Defence, aerospace, aeronautical, construction, communication, medical (drug delivery, dental implant, adaptive structures and actuators), consumer products, biomimetic nanomaterials for tissue engineering, biopolymer tagging and light emitting semiconductor quantum dots etc.
- 4) Application of nanotechnology in food and Agriculture industry: fisheries and livestock sectors, Nano-fertilizers, toxicological effect of Nanoparticles. Nanotechnology for environmental safety: Pollution control, gas sensing, waste water treatment. Impact of nanotechnology on the environment: Health, safety and environmental risks/hazards; Social and ethical impacts.

TEXT BOOKS:

1. Nanotechnology in the Food, Beverage and Nutraceutical Industries, Ed: Qingrong Huang, 2012, Elsevier
2. Applications of Nanoscience in Photomedicine, Eds: Michael R. Hamblin and Pinar Avci, 2015, Elsevier
3. Nanotechnology in Catalysis 3, Eds: Zhou, B., Han, S., Raja, R., Somorjai, G.A., 2007 Springer
4. Nanopharmaceutics-The Potential Application of Nanomaterials, Ed: Xing-Jie Liang, 2012, World Scientific.

NSC 523 Semi conductor materials and applications (4C)

- 1) Energy Band Diagram: Electron Energy Bands, Semiconductor Heterostructures, Energy Levels shifting due to dopants, Position of Fermi Energy Level. Size-dependant physical properties for semiconductor nano particles; Melting point, solid state phase transformations, excitons, band-gap variations-quantum confinement,
- 2) Charge Carriers in Semiconductors: Intrinsic and Extrinsic Semiconductors, Equilibrium Distribution of Electrons and Holes in Intrinsic and Extrinsic Semiconductors, Carrier Transport Phenomena: Carrier Drift, Carrier Diffusion, Graded Impurity Distribution, Hall Effect. Semiconductor Electronic devices: p-n Junction, p-n Junction Diode, Metal-Semiconductor and Semiconductor Heterojunctions, Bipolar Transistor, Metal-Oxide-Semiconductor Field-Effect Transistor, Junction Field-Effect Transistor.
- 3) Growth and Fabrication Techniques for Semiconducting Nanostructures: Bulk crystal and Heterostructure growth, Nanolithography, Etching and other means for fabrication of nanostructures and nano-devices. Applications Semiconductor nanoparticles, Concept of direct and indirect band gap semiconductors, Effect of band gap on Optical luminescence and fluorescence, surface-trap passivation in core-shell nanoparticles, Semiconductor Optical Devices: Solar cells, Photodetectors, Light emitting diodes.
- 4) One dimensional semiconductors: Fabrication strategies, quantum conductance effects in semiconductor nanowires, porous Silicon, nanobelts, nanoribbons, nanosprings.

TEXT BOOKS:

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

NSC 524 Nanoscience applications in drug delivery (4C)

1. Modes of drug delivery – Absorption Distribution Metabolism Excretion characteristics of Drugs – Kinetics of Drug delivery - controlled drug delivery - site specific drugs - barriers for drug targeting - passive and active targeting Strategies for site specific - time and rate controlled delivery of drugs – antibody based and metabolism-based drug delivery systems.

2. Classification of Targetted Drug Delivery systems - Nanoparticles surface modification – bioconjugation – PEGylation – antibodies - cell-specific targeting and controlled drug release - Multi-Functional Gold Nanoparticles for Drug Delivery - Virus Based-nanoparticles for targeted Drug Delivery systems.

3. Polymers - Classification - Polymer Micelles as Drug Carriers- Polymer nanotubes- Magnetic Nanoparticles as Drug Carriers- Dendrimers - Synthesis –Tectodendrimers - Nanoscale containers – Nanoscaffold systems – Gene transfection – Carbon nanotubes in diagnosis and therapy - Liposomes for pharmaceutical and cosmetic applications - Liposomal Drug Carriers in Cancer Therapy - lipid-DNA complexes – liposomal peptide and protein drug delivery Liposomal anticancer and antifungal agents.

4. Vascular Zip Codes and Nanoparticle Targeting – Theragnostic Metal Nanoshells Photothermally-modulated Drug Delivery Using Nanoshell-Hydrogel Composites Nanoporous Microsystems for Islet Cell Replacement - Molecularly-derived Therapeutics - Transdermal Drug Delivery using Low-Frequency Sonophoresis Nanoporous Implants for Controlled Drug Delivery- Functionalized Cyclodextrin Nanoparticles.

TEXT BOOKS:

1. Nanotechnology in Modern Medical Imaging and Interventions. Xiaoming Yang. Nova Science Publisher.
2. The Clinical Nanomedicine Handbook. By Sara Brenner. CRC Press
3. Nanomedicines and Nanoproducts: Applications, Disposition, and Toxicology in the Human Body. Eiki Igarashi.
4. Novel Drug Delivery Systems. by Yie W. Chien
5. Introduction to Novel Drug Delivery Systems By N.K. Jain

NSC 525 Environmental Nanotechnology (4C)

1. Overview of physical, chemical and biological processes concerning the environment; types, transport and transformation processes of contaminants in air, water and soil; effects of contaminants on environment. Environmental impacts of nanomaterials - Exposure and risk assessment, Dose-response, mechanisms of toxicity; ecotoxicological impacts of nanomaterials.

2. Mechanism for remediation of aqueous contaminants, photocatalyst; membranes incorporating nanomaterials, transport processes in membrane technology; nanomaterial based adsorbents for water and wastewater treatment – adsorption at metal oxide surfaces, hybrid adsorbents; case studies. Hierarchical self-assembled nano-structures and nanomaterials for adsorption of heavy metals.

3. Sustainability and global conditions - Material and solid waste management, Energy management - chemical waste management and green chemistry, Climate change and air emissions management, supply water and waste water management.

4. Analytical methodologies for studying impact of nanomaterials in environment – Atomic absorption spectrometry, inductively coupled plasma spectrometry, chromatography, thermal methods, hyphenated techniques.

TEXT BOOKS:

1. Wiesner, M.R., and Bottero, J.Y. (Ed.) “Environmental Nanotechnology: Applications and Impacts of Nanomaterials” McGraw-Hill, New York. 2007
2. Diallo, M., Duncan, J., Savage, N., Street, A., and Sustich, R. (Eds). “Nanotechnology Applications for Clean Water” William Andrew. 2008
3. Lead J., and Smith, E. “Environmental and Human Health Impacts of Nanotechnology” John Wiley & Sons. 2009
4. Skoog, D.A., Holler, F.J., and Crouch S.R. “Instrumental Analysis” Clenage Learning India Private Limited, New Delhi. 2007
5. Masters, G.M. and Ela, W.P. “Introduction to Environmental Engineering and Science” Prentice Hall. 2007

NSC 526 Basics Of Nano Medicine - (4C)

1. Carbon nanotubes- gold nanorods in sensing – neural prosthetics – Isohelical DNA-Binding Oligomers- Nanospearing- Multifunctional Glyconanoparticles Nanoconstructions Based on Spatially Ordered Nucleic Acid Molecules- DNA SelfAssembling Nanostructures Induced by Trivalent Ions and Polycations - PolymerBased Capsules
2. Biocompatibility of Traditional Medical Implants- Adhesive Interactions with Implant Surfaces- Nanorobot Immunoreactivity- Nanopyrexia- Nanorobot Mutagenicity and Carcinogenicity- Thermocompatibility- Mechanocompatibilitycell membrane disruption- Systemic Nanoparticle Distribution and Phagocytosis Nanomaterial Volumetric Intrusiveness- Nanobiotechnology in Tissue Engineering - Nanobiotechnology for Organ Replacement and Assisted Function.
3. Nanoparticles as Imaging Platform in Biomedicine- Magnetic resonant imaging- principle and techniques- paramagnetic contrast agents- USPIOS, SPIOS, MPIOS for imaging- Magnetic nanosensorsradio labeled nanoparticles - Acoustically Reflective Nanoparticles: Application in Ultrasound Imaging- iodinated liposomes- quatum dots in optical imaging
4. Drug delivery to CNS - Nanowires for Monitoring Brain Activity - Drug Delivery Across BBB – Neuroregeneration – Nanoneurosurgery – Nanolipoblockers Antirestenosis Drugs - Cell Therapy for Myocardial Infarction - Regeneration of the Cardiovascular System – Nanobone Implants and Scaffolds - Nanocarriers for Ocular Drug Delivery - Nanotechnology-Based Products for Skin Disorders Nanoparticle Drug Formulations for Spray Inhalation - Wound Healing – Nanogeriatrics – Orthodontal application.

TEXT BOOKS:

1. Understanding Nanomedicine: An Introductory Textbook by Rob Burgess. 2012 CRC Press
2. Nanomedicine for Drug Delivery and Therapeutics, Editor(s): Ajay Kumar Mishra, 2013, Wiley
3. Medical Nanotechnology and Nanomedicine by Harry F. Tibbals. 2010 by CRC Press
4. Introduction to Nanomedicine and Nanobioengineering, by Paras N. Prasad. 2012, Wiley

NSC 571 Term paper, Project Proposal and Defense I (4C)

Students of non-biology background would be required to write a comprehensive review on a contemporary topic. They would be required to formulate a proposal on the basis of the background literature collected and finally defend the proposal.

NSC 572 Carbon Nanosciene and its applications (4C)

1. Introduction –Carbon molecules-nature of the carbon bond-new carbon structures-discovery of C60-structure of C60 and its crystal- From a Graphene Sheet to a Nanotube – Single wall and Multi walled Nanotubes - Zigzag and Armchair Nanotubes - Euler's Theorem in Cylindrical and Defective
2. Structure and Bonding- Nomenclature, The Structure of C60, Structure of Higher Fullerenes - Growth Mechanisms; Production and Purification- Fullerene Preparation by Pyrolysis of Hydrocarbons, Partial Combustion of Hydrocarbons, Arc Discharge Methods, Production by Resistive Heating, Rational Syntheses; Physical Properties-, Spectroscopic Properties, Thermodynamic Properties; Chemical Properties- Hydrogenation and Halogenation, Nucleophilic Addition to Fullerenes.
3. The Structure of Carbon Nanotubes- Nomenclature, Structure of Single-Walled Carbon Nanotubes and Structure of Multiwalled Carbon Nanotubes; Structure and Production of Further Tubular Carbon Materials- Spectroscopic Properties of Carbon Nanotubes- Raman and Infrared Spectroscopy of Carbon Nanotubes, Absorption and Emission Spectroscopy of Carbon Nanotubes, ESR-Spectroscopic Properties of Carbon Nanotubes.
4. Structure of graphene; Preparation of graphene – synthesis of graphene by various physical and chemical methods and Purification; Electronic Properties Band Structure of Graphene - Mobility and Density of Carriers - Quantum Hall Effect - Spectroscopic Properties of graphene - Raman, Application of Fullerene, CNT, Graphene and other carbon nanomaterials Mechanical, Thermal Applications, Electronic Applications and biological Applications.

TEXT BOOKS:

1. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.
2. Carbon Nanotechnology- Liming Dai.
3. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing.
4. Physical properties of Carbon Nanotube-R Satio.

NSC 573 Term paper, Project Proposal and Defense II (4C)

Students of biology background would be required to write a comprehensive review on a contemporary topic. They would be required to formulate a proposal on the basis of the background literature collected and finally defend the proposal.

NSC 574 Basics Of Nanotechnology In Tissue Engineering - (4C)

1. Introduction – definitions - basic principles - structure-function relationships – Biomaterials: metals, ceramics, polymers (synthetic and natural) – Biodegradable materials - native matrix - Tissue Engineering and Cell-Based Therapies -Tissue Morphogenesis and Dynamics- Stem Cells and Lineages - Cell-Cell Communication
2. Primary cells vs. cell lines - sterile techniques – plastics – enzymes - reactors and cryopreservation - Synthetic Biomaterial Scaffolds- Graft Rejection – Immune Responses-Cell Migration-Controlled Drug Delivery- Micro technology Tools, Principals of self assembly - Cell migration - 3D organization and angiogenesis - Skin tissue engineering, Organization- Cell Isolation and Culture - ECM and Natural Scaffold Materials- Scaffold Fabrication and Tailoring
3. Blood vessels structure - vascular grafts - Liver tissue engineering – Bioartificial liver assist device - shear forces - oxygen transport - plasma effects – Liver tissue engineering - Self-assembled organoids - decellularized whole livers – Stem cells - basic principle - embryonic stem cells - Induced pluripotent stem cells Material Biocompatibility - Cell Mechanics - Vascularization- Stem Cell Therapies
4. Patterning of biomimetic substrates with AFM lithography primarily focusing on DPN- Nanotemplating polymer melts - Nanotechnology-based approaches in the treatment of injuries to tendons and ligaments - Progress in the use of electrospinning processing techniques for fabricating nanofiber scaffolds for neural applications -Nanotopography techniques for tissue-engineered scaffolds

TEXT BOOKS:

1. Biomaterials and Nanotechnology for Tissue Engineering by S Sethuraman, U M Krishnan, A Subramanian, 2016, CRC Press
2. Nanotechnology Applications for Tissue Engineering, 1st Edition, Editors: Sabu Thomas, Yves Grohens, & Neethu Ninan. 2015, Elsevier
3. Nanotechnology in Tissue Engineering and Regenerative Medicine, by Ketul Popat. 2010 by CRC Press