M.Sc. (Nanotechnology) SCHOOL OF NANO SCIENCES
Programme structure and Syllabus
From 2018-19 onwards

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 406	Principles of Biology and Nano Biotechnology	4
NSC 407	Synthesis and Characterisation of Nanomaterials	4
NSC 405	Nano Science Practicals – I	4
	M.Sc Semester II (Total Credits -20)	
NSC 454	Nanostructured Materials and their Application	4
NSC 452	Nanotoxicology and Biosafety	4
NSC 453	Advanced Characterisation of nanomaterials - II	
	OPTIONALS (total 12 credits from any of the courses given below)	
NSC 471	Mathematics and Computational Science	4
NSC 477	Thin film and Vacuum Technology	4
NSC 491	Nano Science Practicals – II	4
NSC 474	Nanotechnology in agriculture and food processing	4
NSC 478	Basics of Pharmaceutical Sciences	4
NSC 492	Nano Science Practicals – III	4
	M.Sc Semester III (Total Credits -16)	
NSC 562	Nano fabrication and nanotechnologies	4
	OPTIONALS (total 12 credits from any of the courses given below)	
NSC 521	Nanomaterials in energy technology	4
NSC 524	Nano devices and sensors	4
NSC 523	Semiconductor materials and applications	4
NSC 527	Nanocarriers for drug and gene delivery	4
NSC 525	Environmental Nanotechnology	4
NSC 526	Basics of Nanomedicines	4
	M.Sc Semester IV (Total Credits -16)	
NSC 591	Dissertation and defence	8
NSC 551	Term paper, Project proposal and defence I	4
	OPTIONALS (total 4 credits from any of the courses given below)	
NSC 572	Carbon Nanoscience and its applications	4
NSC 574	Basics of Nanotechnology in Tissue Engineering	4
TOTAL		**72**

M.Sc Semester I

NSC 401 Physics of Nanomaterials (4C)

Module I: Scales In Nanophysics,Quantum Structure: 3D-Pontential Wells (Spherical & Rectangular Parallelepiped), 2D (Circular & Square, Quantum Corrals), 1D (Quantum Wires), 0D (Quantum Dots).

Module II: Barrier Penetration: Step Potential; Rectangular Barrier Penetration; Tunneling; WKB. Applications of Barrier Penetration: TEM, AFM, STM.

Module III: 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.

Module IV: Molecular Physics: H2+ 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)

Module I: Classification and Nomenclature of Nanomaterials: Nanosized metals and alloys, semiconductors, ceramics – a comparison with respective bulk materials; Organic semiconductors, carbon materials; Zero-, one, two and three dimensional nanostructures – quantum dots, quantum wells, quantum rods, quantum wires, quantum rings; bulk nanostructured, nanocomposites, Nanomachines and Devices.

Module II: Synthesis of Nanomaterials: Nucleation and growth of nanosystems; self-assembly, mechanical milling, laser ablation, sputtering and microwave plasma, chemical reduction and oxidation, hydrothermal, micelles, sol-gel processes, photolysis, radiolysis, and metallo-organic chemical vapor deposition; designing of advanced integrated nanocomposites, functional nanomaterials and nanostructured thin films.

Module III: Structure and Morphology of Nanoparticles: Fundamental Properties - size effects on structure and morphology of free or supported nanoparticles, size and confinement effects. Fraction of surface atoms - specific surface energy and surface stress, effect on the lattice parameter. Nanoparticle morphology - Equilibrium shape of a macroscopic crystal and nanometric crystals, morphology of supported particles.

Module IV: Novel Properties of Nanomaterials: Size and shape dependent optical, emission, electronic, transport, photonic, refractive index, dielectric, mechanical, magnetic, non-linear optical properties; Transition metal sols, origin of plasmon band, Mie theory, influence of various factors on the plasmon absorption. quantum confinement in semiconductors – particle in a box like model for quantum dots; origin of charge on colloidal sols, zeta potential, catalytic and photocatalytic properties, Mechanical properties.

TEXT BOOKS

1. Klabunde, K.J. (Ed.), "Nanoscale Materials in Chemistry", John Wiley & Sons Inc. 2001
2. Nalwa, H.S. (Ed.), "Encyclopedia of Nanoscience and Nanotechnology" 2004
3. Sergeev, G.B. Nanochemistry, Elsevier, B.V. 2010
4. Schmid, G. (Ed.), "Nanoparticles", Wiley-VCH Verlag GmbH & Co. KgaA.2004
5. Rao, C.N.R., Müller, A. and Cheentham, A.K. (Eds.),"Chemistry of Nanomaterials", Wiley – VCH. 2005

NSC 406 Principles of Biology and Nano Biotechnology (4C)

Module I: Basics of Cell biology: Basic structure of mammalian cell membrane,Cell Cycle, Different types of Cell receptors, Cell lines-Cancerous and Normal cell line, Primary and secondary cell line, Endocytosis and Exocytosis, Reticulo endothelial system (RES), Proteins structure-primary, secondary, tertiary and quaternary structure, Enzymes structure w.r.t metal part, prosthetic group (Metalloenzymes). Antigen-Antibody based assays-Elisa.

Module II: 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.

Module III: Structural & Functional Principles Of Bionanotechnology: Lipid Bilayers – liposomes – neosomes-Phytosomes, Polysacharides – Peptides –Nucleic acids – DNA scaffolds – Enzymes- Biomolecular motors: linear, rotary mortors – Immunotoxins – Membrane transporters and pumps – Antibodies – monoclonal Antibodies – immunoconjugates – limitations of natural biomolecules

Module IV: 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-based Metallic Nanowires and Networks, DNA–Gold-Nanoparticle Conjugates

Nanobio-Analytics: Luminescent Quantum Dots for Biological Labeling – Nanoparticle Molecular Labels – Surface Biology: Analysis of Biomolecular Structure by Atomic Force Microscopy 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. Molecular Cell Biology,Harvey Lodish, Published by W.H. Freeman & Company
2. Biomaterials: A Nano Approach,S Ramakrishna, M Ramalingam, T.S. Sampath Kumar, Winston O. Soboyejo,Published by CRC Press
3. Bionanotechnology: Lessons from Nature, D S. Goodsell, by John Wiley & Sons, Inc.
4. Nanobiotechnology: Concepts, Applications and Perspectives,(edited by C. M. Niemeyer and C. A. Mirkin), Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim,
5. Nanobiotechnology: Concepts, Applications and Perspectives,Edited by Christof M. Niemeyer and Chad A. Mirkin, Wiley-VCH, 2004,ISBN 3527306587, 9783527306589

NSC 407 Synthesis and Characterisation of Nanomaterials (4C)

Module I : Classifications and types of nanomaterials as nano particles and 1D 2D 3D nanomaterials. Concept of bulk versus nanomaterials and dependence of properties on size. Introduction to 'Top down' vs. 'Bottom up' approach of synthesis with suitable examples.

Module II: 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, organic block copolymers, cryochemical synthesis etc. Study of rapid solidification route, electro and electroless deposition etc. along with suitable examples.

Module III: 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. Preparation of quantum dots, nano wires and films, preparation of single-walled and multi-walled nanotubes. Brute force methods vs. soft Chemistry routes, Microwave and ultrasound assisted synthesis, CFC(controlled flow cavitations), SCF's(super critical fluids). Surfactant behavior, micelles, self assembled mono layers (SAM's),Langmuir-Blodget(LB)films,.

Module IV: Techniques of characterization of size of nano powders/ particles using BET method and laser diffraction. 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.
X-ray Fluorescence (XRF), X-ray diffraction (XRD) and Small Angle X-ray Scattering principles.

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.
5. Nanostructures and Nanomaterials, synthesis, properties and applications by Guozhong Cao, Imperial College Press, 2004.
6. Nanomaterials – Handbook by Yury Gogotsi, CRC Press, Taylor & Francis group, 2006.

NSC 441 Nano Science Practicals – I (4C)

List of experiments:

1. Synthesis of various metal and metal oxide nanoparticles and analysis by UV-Vis spectrophotometer and DLS

2. Synthesis of transition metal oxide nanoparticle by hydrothermal technique and to determine particle size Using UV-Vis spectrometer.

3. Synthesis of semiconducting nano structured materials 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. Synthesis of nanocomposites and its characterization through FTIR and UV spectrometer
6. Synthesis of carbon based materials like fullerenes etc

TEXT BOOK:
1) Edelstein A S and Cammarata R C, "Nanomaterials: Synthesis, Properties and Applictions",Taylor and Francis, 2012

M.Sc Semester II

NSC 454 Nanostructured materials and Applications (4C)

Module I: Nanostructures: Zero-, One-, Two- and Three- dimensional structure, Size control of metal Nanoparticles and their properties: Optical, Electronic, Magnetic properties; Surface plasmon Resonance, Change of bandgap; Application: catalysis, electronic devices

Module II: Nano ceramics: Dielectrics, ferroelectrics and magnetoceramics, Magnetic properties; Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Applications of Nanopolymers in Catalysis.

Module III: Nanocomposites: Metal-Metal nanocomposites, Polymer-Metal nanocomposites, Ceramic nanocomposites: Dielectric and CMR based nanocomposites. Nano Semiconductors: Nanoscale electronic devices including CMOS, Potentiometric sensors etc., MRAM devices, Spintronic devices including spin valves.

Module IV: Thermo Electric Materials (TEM): Concept of phonon, Thermal conductivity, Specific heat, Exothermic & Endothermic processes. Bulk TEM Properties, Different types of TEM; One dimensional TEM; Composite TEM; Applications.

TEXT BOOKS
1. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
2. Nanoscale materials -Liz Marzan and Kamat.
3. Physical properties of Carbon Nanotube-R Satio.
4. Polymer nanocomposites: Edited by Yiu-Wing Mai and Zhong-Zhen Yu, First published 2006, Woodhead Publishing Limited and CRC Press LLC, USA.
5. Physics of Magnetism - S. Chikazumi and S.H. Charap.
6. Magnetostriction and Magnetomechanical Effects - E.W. Lee.
7. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.

8. CARBON NANOTECHNOLOGY- Liming Dai.
9. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing.
10. CRC Handbook of Thermoelectrics, Ed. CR Rowe

NSC 452: Nanotoxicology and Biosafety (4C)

Module I: Introduction, source of nanoparticles, epidemiological evidences, entry routes for nanoparticles in human body: lungs, intestinal tract and skin, Deposition and translocation in the body, Attributes contribute to nanomaterials toxicity.

Module II: Classification of nanoparticles for biological applications, nanoparticles interaction with the biological membrane, uptake and toxicological effects of different nanoparticles.

Module III: Mechanisms of nanomaterial toxicity: oxidative stress, ecotoxicity, genotoxicity, hemolytic toxicity, mutagenicity and immunotoxicity.

Module IV: Assessment of nanomaterial toxicity: In vitro toxicity assessment-cell viability, lactate dehydrogenase release, reactive oxygen species generation, change in mitochondrial membrane potential and nuclear fragmentation. In vivo toxicity assessment: inflammatory response, acute toxicity studies, LD50 determination, histopathological studies.

TEXT BOOKS

1.Handbook of Nanotoxicology, Nanomedicine and Stem Cell Use in Toxicology. Saura C Sahu, Daniel A Casciano.
2.Nanotoxicology - Interactions of Nanomaterials with Biological Systems. Yuliang Zhao and Hari Singh Nalwa.
3.Biointeractions of Nanomaterials. Vijaykumar B. Sutariya, Yashwant Pathak
4.New Technologies for Toxicity Testing. Michael Balls DPhil, Robert D. Combes PhD, Nirmala Bhogal.

NSC 453 Advanced Characterisation of nanomaterials - II (4C)

Module I: Understanding of micro structural developments in nanomaterials using optical microscopy. Scanning Electron Microscopy (STM) and Transmission Electron Microscopy (TEM) approach. High resolution Transmission Electron Microscopy (HRTEM).

Module II: 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.

Module III: 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.

Module IV: I-V/C-V - Hall - Quantum Hall effects - Kelvin-probe measurements - Deep level transient spectroscopy (DLTS) - FET characteristics, SQUID

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.

OPTIONALS

NSC 471 Mathematics and Computational Science (4C)

Module I :Introduction to computers and statistics. Computer Arithmetic: Floating Point Numbers And Round Off Errors, Absolute And Relative Errors, Polynomial Interpolation: Numerical Integration by Trapezoidal Rule, Simpson's Rule, Error Analysis. Solution Of System Of Linear Equations

Module II: Solution of Transcendental Equation By Bisection Method And Newton's Method. System Of Non Linear Equations: Newton-Raphson's Method. Finite difference method

Module III: Curve-Fitting by Least Square Techniques. Numerical Solution Of ODE, Single Step MethodRunge Kutta Methods, Numerical Solution To PDE, Stability And Convergence.

Module IV: Introduction to molecular dynamics, first principle solution, potential determination, Density Functional Theory (DFT)

TEXT BOOKS:

1. Higher Engineering Mathematics by B. S. Grewal, Khanna Publishers Delhi
2. Introductory Numerical Analysis By S. S. Sastry, Prentice Hall Publishers

NSC 477 Thin Film and Vacuum Technology (4C)

Module I: Vacuum Technology: Gas Laws, Kinetic Theory of Gases, Conductance and Throughput, Gas Sources in a Vacuum Chamber, Vacuum Pumps.

Module II: Thermodynamics and Thin Film growth, Film Formation and Structure: Capillarity Theory, Atomistic Nucleation processes, Cluster Coalescence, Grain Structure of Films.

Module III: Physical Vapor Deposition: Sputtering (Plasma Physics (DC Diode), rf Plasmas, Magnetic Fields in Plasmas, Sputtering Mechanisms), Evaporation. Chemical Vapor Deposition: Mechanisms, Materials, Chemistries, Systems. Etching: Wet Chemical Etching (Mechanisms, Materials and Chemistries), Dry Plasma Etching/Reactive Ion Etching (Mechanisms, Materials and Chemistries).

Module IV: Thin Film Characterization: Structural, Chemical, optical, electrical, magnetic

TEXT BOOKS

1.Thin Film Deposition and Patterning: R. K. Waits, American Vacuum Society, 1998.
2.The Materials Science of Thin Films: M. Ohring, Academic Press, Boston, 1991
3. Physics of Thin Films: Ludmila Eckertova, 2nd Plenum Press New York, 1986
4. Thin Film Phenomena: K. L. Chopra, McGraw-Hill, 1969

NSC 491 Nano Science Practical Group A (4C)

1. Absorption study of nano particles using UV-Vis spectroscopy
2. To synthesise quantum dot by chemical route
3. Determination of energy Bandgap of semiconductor by UV spectroscopy
4. Colloidal suspension of nanoparticles
5. Study of chemical kinetics using UV spectroscopy
6. Handling of Atomic Force microscopy
7. To determine the surface roughness of AFM images using offline SPM software
8. To determine the density of self-assembled Au nanoparticle by AFM
9. To study the self-assembly of nanodots by AFM
10. Visit to reputed National laboratories (BARC, IPR, FCIPT)

TEXT BOOKS

1. Edelstein A S and Cammarata R C, "Nanomaterials: Synthesis, Properties and Applictions",Taylor and Francis, 2012

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

Module I: Introduction: Rhizosphere, Emulsions, Surfactants-Biodegradable and non biodegradable, Pesticides, Insecticides, Herbicides, Weedicides, Biomagnification, Micro and Macro nutrients required by plants. Various types of nanomaterial utilized in agriculture, Soil health-Different Indicators (Assays) for determining soil health.

Module II: 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.

Module III: 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.

Module IV: 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 478: Basics of Pharmaceutical Sciences (4C)

Module I: Introduction to pharmaceutical sciences, principles and types of pharmaceutical dosage forms-solid, liquid, semi-solids, aerosols.

Module II: Basics of pharmacology: Overview, sources of drugs, routes of drug administration, Pharmacokinetics-absorption, distribution, metabolism and excretion, Pharmacodynamics, Adverse drug reactions, Drug interactions.
Module III: Pharmaceutical product development: Fundamental aspects, pharmaceutical excipients, biopharmaceutical considerations, Principles of solubilization, dissolution, partition coefficient, ionization and bioavailability.

Module IV: Kinetics and Drug stability: General concept of physical and chemical stability of pharmaceutical product, factors affecting drug stability, Degradation rate constant, Half-life determination and expiration dating, Introduction to ICH guidelines, Accelerated stability studies.

TEXT BOOKS

1. Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems. By: Loyd V. Allen,Howard C. Ansel
2. Essentials of Medical Pharmacology, by K.D. Tripathi. Published by Yaypee brothers medical publishers.
3. Rang & Dale's Pharmacology. James M. Ritter, Rod J. Flower, and Graeme Henderson,
4. Martin's Physical Pharmacy and Pharmaceutical Sciences. Lippincott Williams & Wilkins.

NSC 492 Nano Science Practical Group B (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
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
7. Visit to reputed National laboratories (BARC, IPR, FCIPT)

TEXT BOOKS

1. Nanomaterials: Synthesis, Properties and Applictions" 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

M.Sc Semester III

NSC 562: Nano fabrication and nanotechnologies (4C)

Module I: Nanofabrication processes: Concept of Top Down and Bottom Up Fabrication approach, Self-assembly, Bio-mediated assembly, template assisted synthesis, epitaxial growth.

Module II: 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.

Module III: Nanofabrication in semiconductor industry: Metal Oxide Semiconductor (MOS) transistor, NMOS and PMOS transistors, Complementary Metal Oxide Semiconductor (CMOS) transistor

Module IV: Fabrication: 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)

Module - I Introduction

Nanotechnology for sustainable energy- Energy conversion process, indirect and direct energy conversion-Materials for light emitting diodes, batteries, catalytic reactors, capacitors-fuel cells.

Module - II Nanomaterials in Energy Storage

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, Nano-electrochemical systems and novel microfluidic devices.

Module - III Electrochemical Energy Storage Systems

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.

Module - IV Hydrogen Energy
Hydrogen Production Methods: from fossil fuels, electrolysis, thermal decomposition, photochemical, photocatalytic, hybrid; Hydrogen storage methods: metal hydrides, metallic alloy hydrides, carbon nano-tubes etc.

TEXT BOOKS
1. J. Twidell and T. Weir, Renewable Energy Resources, E & F N Spon Ltd, London, (1986).
2. Martin A Green, Solar cells: Operating principles, technology and system applications, Prentice Hall Inc, Englewood Cliffs, NJ, USA, (1981).
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).
5. M.A. Kettani, Direct energy conversion, Addision Wesley Reading, (1970).
6. Linden, Hand book of Batteries and fuel cells, Mc Graw Hill, (1984).
7. Hoogers, Fuel cell technology handbook. CRC Press, (2003).
8. Vielstich, Handbook of fuel cells: Fuel cell technology and applications, Wiley, CRC Press, (2003).

NSC 524 Nanodevices and sensors (4C)

Module I: 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.

Module II: 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.

Module III: Nanomagnetism: Spintronics technology and the challenges, 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.

Module IV: Application of nanotechnology in food and Agriculture industry: fisheries and livestock sectors, 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 Semiconductor materials and applications (4C)

Module I: Energy Band Diagram: Electron Energy Bands, Semiconductor Heterostructures, Lattice-matched and Pseudomorphic Heterostructures, Inorganic-organic Heterostructures. Dopant Atoms and Energy Levels, Position of Fermi Energy Level, Nonequilibrium Excess Carriers in Semiconductors. **S**ize–dependant physical properties for semiconductor nano particles; Melting point, solidstate phase transformations, excitons, band-gap variations-quantum confinement,

Module II : 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

Module III : 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.

Module IV : One dimensional semisonductors: 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 Bhusan

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.

OPTIONALS

NSC 527: : Nanocarriers for drug and gene delivery (4C)

Module I: Introduction about drug delivery systems: Basics of drug delivery, Types-polymer, lipid, metal based drug delivery system and miscellaneous. Drug targeting strategies for site specific drug delivery-passive and active targeting, time and rate controlled drug delivery.

Module II: Polymer based drug nanocarriers: Classification and types of polymeric nanocarriers, Different methods of polymeric nanocarrier preparation: Precipitation, Emulsion diffusion/Solvent evaporation, Salting out etc. Various applications of polymeric nanocarriers: Theranostic, Imaging etc.

Module III: Dendritic nanostructures for drug delivery: Introduction of different dendritic nanostructures, chemical structures, types of dendrimers, methods of preparation-convergent and divergent, physicochemical properties of dendrimers, interaction between drug molecules and dendrimers, applications of dendrimers

Module IV: Nanocarriers for gene delivery: Challenges in gene delivery, basic concept, design of nanotechnology-based systems for gene delivery, Non-viral vectors, formulation strategies, applications in delivery of genes for different diseases.

Suggested tutorials:

1. Application of Nanotechnology in Drug Delivery: Edited by Ali Demir Sezer, ISBN 978-953-51-1628-8, 552 pages, Publisher: InTech,
2. Introduction to Novel Drug Delivery Systems By N.K. Jain
3. Understanding Nanomedicine: An Introductory Textbook by Rob Burgess. 2012 CRC Press
4. Nanomedicine for Drug Delivery and Therapeutics, Editor(s): Ajay Kumar Mishra, 2013, Wiley

5. Medical Nanotechnology and Nanomedicine by Harry F. Tibbals. 2010 by CRC Press Introduction to Nanomedicine and Nanobioengineering, by Paras N. Prasad. 2012, Wiley.

NSC 525 Environmental Nanotechnology (4C)

Module I – I Introduction: 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.

Module – II Environmental applications of nanomaterials: 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.

Module - III Waste Management: 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.

Module – IV 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 NSC: Basics of Nanomedicines (4C)

Module I: Introduction: Concept of nanomedicines, Rationale for designing of nanomedicines, Materials for preparation of nanomedicines, Different structures of nanomedicines.

Module II: Cellular nanoparticle interaction and receptor-mediated endocytosis: Transport of nanoparticles across the biological barriers, parameters affecting binding and uptake of nanoparticles-size, shape, surface charge, protein corona, surface modification. Different mechanisms of receptor-mediated endocytosis.

Module III: Nanotechnology in imaging and diagnosis: Basic concept of nanotechnology in imaging, Different nanomaterials for imaging and diagnosis, Applications of nanomaterials in MRI, computed tomography and image guided disease treatment.

Module IV: Clinical translation of nanomedicines: Preclinical and clinical considerations of nanomedicines, Overview of current clinical nanomedicines, Regulations of nanomedicines for human health.

Suggested tutorials:

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

M.Sc Semester IV

NSC 591 Dissertation and defence(8 C)

NSC 551 Term paper, Project Proposal and Defence 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.

OPTIONALS

NSC 572 Carbon Nanosciene and its applications (4C)

Module I: 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

Module II: 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.

Module III: 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.

Module IV: 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 574 Basics Of Nanotechnology In Tissue Engineering - (4C)

Module I: 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

Module II: 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

Module III: Blood vessels structure - vascular grafts - Liver tissue engineering – Bioartificial liver assist device - shear forces - oxygen transport - plasma effects – Liver tissue engineering - Self-assembled organoids - decelluarized whole livers – Stem cells - basic principle - embryonic stem cells - Induced pluripotent stem cells Material Biocompatibility - Cell Mechanics - Vascularization- Stem Cell Therapies

Module IV: 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