CENTRAL UNIVERSITY OF GUJARAT

NANOSCIENCES- M.Phil / Ph.D

Syllabus

Nanosciences-syllabus

Semester I	Credits	Semester II	Credits
Paper –I Fundamentals of Nanoscience and Nanotechnology	**03**	**Paper –I** Environmental Nanotechnology Practicals/Research Training	**03**
Paper –II Nanochemistry Thrust Research Areas	**03**	**Paper –II** Applied Nanochemistry Bionanotechnology	**03**
Paper –III Research methodology	**02**	**Paper –III** Instrumentation and statistics	**02**
Seminar	**01**	Assignment	**01**
Term Paper	**01**	Seminar	**01**
Total Credits	**10**	**Total Credits**	**10**
		Semester III	
		Dissertation	**20**

Syllabus-(Nanosciences)

SEMESTER I

Paper –I . Fundamentals of Nanoscience and Nanotechnology (3 credits)

UNIT I

Introduction: Introduction: Quantum chemistry, Solid state Physics, Nanomaterial & Manufacturing, Renewable energy generation, Nanotechnology in drug delivery, Nanotechnology in cosmetics, Bionanotechnology, Nanotechnology in tissue engineering, Nanotechnology applied in bioinformatics, Nanotechnology & information technology, Nanotechnology in agriculture and food industry, environmental nanotechnology, Nanotechnology Health risk , Nanotechnology- Ethics, Regulation of Nanotechnology, Nanotechnology- Future prospects

UNIT II

Nanomaterial: The Science of Nano - What is Nanobiotechnology, Introduction to Nanostructures : Carbon Nanotubes (CNT), Graphenes, Fullerenes, Nano Peapods, Quantum Dots and Semiconductor Nanoparticles Metal-based Nanostructures (Iron Oxide Nanoparticles) Nanowires Polymer-based Nanostructures including dendrimers, Introduction to metal based nanostructures, Protein-based Nanostructures: Nanomotors: Bacterial (E. coli) and Mammalian (Myosin family) Nanobiosensors: Science of Self-assembly - From Natural to Artificial Structures Nanoparticles in Biological Labeling and Cellular Imaging:

UNIT III

Bionanomaterial: Preparation and Characterization of Bionanomaterials, Microfluidics: Nano Printing of DNA, RNA, and Proteins Biochips Applications in Nano Scale Detection Lab-on-a-chip Devices (LOC) Medical Applications of Nanobiotechnology: Nanoparticles' Cytotoxicity, Nanoscience in Drug Delivery, and Controlled Release, Green nanoparticle production and characterization; Biocompatbility; Nanomedical applications of green nanotechnology; use of nanotechnologies and materials impact on biodiversity, resource conservation, ecosystems.

Text/ References:

1. Introduction to Nanoscience by Gabor L. Hornyak, Joydeep Dutta, Harry F. Tibbals, Anil K. Rao. CRC Press, 2008.
2. Nanotechnology: Importance and Application by M.H. Fulekar, IK International, 2010.
3. Environanotechnology by Mao Hong fan, Chin-pao Huang, Alan E Bland, Z Honglin Wang, Rachid Sliman, Ian Wright. Elsevier, 2010.
4. Nanotechnologies, Hazards and Resource efficiency by M. Steinfeldt, Avon Gleich, U. Petschow, R. Haum. Springer, 2007.
5. Nanotechnlogy: Health and Environmental risk by Jo Anne Shatkin. CRC press, 2008.
6. Nanotechnology in Biology and Medicine: Methods, Devices and Application by Tuan Vo-Dinh .CRC press, 2007.
7. Nanomaterials for Biosensors by Challa Kumar. Wiley-VCH, 2007.
8. Nanosystem characterization tools in the life sciences by Challa Kumar. Wiley-VCH, 2006.
9. Handbook of Nanofabrication. Edited by Gary Wiederrcht. Elsevier, 2010.

Paper-II: Nanochemistry (credit: 3)

UNIT I

Introduction: Nanoscale Science and Technology-Implications for Physics, Chemistry, Biology and Engineering; Classifications of nanostructured materials, nano particles;

quantum dots, nanowires, ultra-thinfilms-multilayered materials. Length Scales involved and effect on properties: Mechanical, Electronic, Optical, Magnetic and Thermal properties. Introduction to properties and motivation for study (qualitative only).

Preparation methods: Bottom-up Synthesis-Top-down Approach: Precipitation, Mechanical Milling, Colloidal routes, Self-assembly, Vapour phase deposition, MOCVD, Sputtering, Evaporation, Molecular Beam Epitaxy, Atomic Layer Epitaxy, MOMBE.

Organic Nanoparticles: Introduction, definition, structure, types of NP, analytical methods (Extraction and isolation, Separation, Characterization and Imaging), general method of preparation, properties, detection, and characterization of organic nanoparticles: hydrophobic drugs, protein, peptide, lipid, cyclodextrine, polysaccharides. Nanocochleates, Prospects and Future Challenges.

UNIT II

Molecular nanotechnology, bottom up and top approaches, molecular self-assemblies, surface engineering, National Nanotechnology Initiative, Nano photonics, thermodynamic applications in nanotechnology, entropic and tentropic control of nanotechnology, nanocoating materials, nanobiomaterials, liquid crystals, crystal and Nano crystals, graphene, fullerene, sol gels, nanoemulsions, nanotechnology of folding of protein, intramolecular multiple force theory, tentropy, friccohesity, molecular and ionic forces, molecular interaction engineering, Magnetorheological fluids, optical properties of nanoparticles, biosensors and their characterization, adsorbents and catalyst. Microtechnology , peizoelelctric materails, nanoemuslison, effects of gold and silver particles on proteins unfolding.

UNIT-III

Patterning and lithography for nanoscale devices: Introduction to optical/UV electron beam and X-ray Lithography systems and processes, Wet etching, dry (Plasma /reactive ion) etching, Etch resists-dip pen lithography.

Preparation environments: Clean rooms: specifications and design, air and water purity, requirements for particular processes, Vibration free environments: Services and facilities required. Working practices, sample cleaning, chemical purification, chemical and biological contamination, Safety issues, flammable and toxic hazards, biohazards.

Characterization techniques: X-ray diffraction technique, Scanning Electron Microscopy - environmental techniques, Transmission Electron Microscopy including high-resolution imaging, Surface Analysis techniques-AFM, SPM, STM, SNOM, ESCA, SIMS-Nanoindentation, Small-angle X-ray and neutron scattering, DLS, Ellipsometer, Confocal microscopy.

Paper-III: Research Methodology (2 credit)-As per existing syllabus of SESD/SCS.

SEMESTER II

Paper –I Environmental nanotechnology: (3 credit)

UNIT I

Nanomaterials for Environmental Protection: Nano technology processes – Nano Engineering materials for Pollution Prevention, Green Chemistry, Energy efficient resources and materials, Nano technology products- Nanomaterials (nanostructures) Nanodevices and nanosystems.

Synthesis of Nanomaterials: Synthesis of nanomaterials by Physico-chemical approaches.

Bionancomposites : Nano particles and Microorganisms, Microbial Synthesis of Nano materials, Biological Methods for Synthesis of nano-emulsions using bacteria, Fungi and Actinomycetes, Plants based nanoparticle synthesis, Nano composite biomaterials – Fibres, Devices and Structures, Nano Bio systems.

Advanced Characterization Methods: Optical Microscopy, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Scanning Tunneling Microscopy, Optical Absorption and Emission Spectroscopy, Thermogravimetric Analysis, Differential Scanning Calorimetry, Thermomechanical Analysis, X-Ray, neutron diffraction.

UNIT – II

Nanotechnology in Remediation

Nanoremediation: Identification and characterization of Hazardous waste, Nano Pollution, Air- Water - Soil Contaminants, Identification and Characterization of Organic and inorganics, Environmental cleanup technologies.

Nanomaterials-Remediation: Nano Membranes, Nano Meshes, Nano Fibres, Nano Clays and Adsorbents, Zeolites, Nano Catalysts, Carbon Nano Tubes, Bio Polymers, Single Enzyme Nano particles, Bio Metallic Iron Nano Particles, Nano Semi-Conductors, Photo catalysis, Nano-sensors.

Nano Remediation Technologies: Environmental Nano Remediation Technology - Thermal, Physico-Chemical and Biological Methods, Nano Filtration for treatment of waste – removal of organics & inorganics and pathogens, Nanotechnology for water

remediation and purification. Treatment of hi-tech industrial waste waters using nano particles/ modified structures/devices. Environmental Benefits of nanomaterials.

UNIT – III

Sustainable Nanotechnology: Application of industrial ecology to nanotechnology, Fate of nanomaterials in environment, environmental life cycle of nano materials, environmental and health impacts of nano materials, toxicological threats, eco-toxicology, exposure to nano particles – biological damage, threat posed by nano materials to humans, environmental reconnaissance and surveillance. Corporate social responsibility for nanotechnology, Nano materials in future - implications.

Text/ References:

1. Environanotechnology by Mao Hong fan, Chin-pao Huang, Alan E Bland, Z Honglin Wang, Rachid Sliman, Ian Wright. Elsevier, 2010.
2. Nanotechnology: Importance and Application by M.H. Fulekar, IK International, 2010.
3. Nanotechnologies, Hazards and Resource efficiency by M. Steinfeldt, Avon Gleich, U. Petschow, R. Haum. Springer, 2007.
4. Nanotechnlogy: Health and Environmental risk by Jo Anne Shatkin. CRC press, 2008.
5. Handbook of Nanofabrication. Edited by Gary Wiederrcht. Elsevier, 2010.
6. Nanoporous materials: Advance techniques for characterization, Modeling and Processing. Edited by Nick Kanello Poulos. CRC press, 2011.
7. Inorganic Nanoparticles: Synthesis, Application and Perspectives. Edited by Claudia Altavilla and Enrico Ciliberto. CRC Press, 2011.
8. Nanostructured conductive polymers. Edited by Ali Eftekhari. Wiley, 2010.
9. Adsorption and diffusion in nanoporous material by Rolando M.A. Raque Malherbe. CRC press, 2007.
10. Introduction to Nanoscience by Gabor L. Hornyak, Joydeep Dutta, Harry F. Tibbals, Anil K. Rao. CRC Press, 2008.

Paper II.

A) Applied Nanochemistry (credit: 2)

UNIT-I

Application of Organic Nanoparticles: Application of Lipids, CNTs, Proteins, peptides, Dendrimer, cyclodextrin, Polysaccharide based organic nanoparticles in nanomedicine and drug delivery through nanoscopic structure and nanoformulation; Applications of zero-dimensional Nanoparticles: Quantum dots for solar cells, Quantum dots for light-emitting diode, Molecular electronics, Nanoparticles as catalysts; Applications of one dimensional nanotubes and nanowires: Nanotube/nanowire-based field effect transistors for biosensing, gas sensing, Piezoelectric nanowires as nanogenerator, Thermoelectric Nanowires, Quantum dots for bio-sensing; Application of Nanoporous materials: A Single Nanopore for DNA sequencing, Nanoporous anodized aluminum oxide, Nanoporous metal-organic framework for gas absorption, Nanoporous materials for Li/Cd-ion battery applications;

UNIT-II

Application of Nano ceramics: Dielectrics, ferroelectrics, magnetoceramics, and multiferroics Magnetism; Dia-, Para-, Ferro-, Antiferro-, Ferri-magnetism, Magnetic properties; Gaint magnetoresistance, Tunneling magnetoresistance, Colossal magnetoresistance, Superparamagnetism *High-temperature* superconducting (High-Tc) materials: *Yttrium barium copper oxide* (YBCO) and Bi-systems, Superconducting nano-materials & their properties and applications; Application of Thermo Electric Materials (TEM): Concept of phonon, Thermal conductivity, Specific heat; Application of Carbon Nano Structures: DLCs, C60, C80 SWNT and MWNT; Properties: Mechanical, Optical and Electrical properties; Application of Nano Semiconductors: Nanoscale electronic devices including CMOS, Potentiometric sensors etc., *Magnetoresistive random-access memory* (MRAM) devices, Spintronic devices including spin valves; Application of Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Applications of Nanopolymers in Catalysis, Nanofibers, nanophotonics; Application of Nanocomposites: Metal-Metal nanocomposites, Polymer-Metal nanocomposites, Ceramic nanocomposites: Dielectric and CMR based nanocomposites.

Text/References:

1. Nanotechnology: Importance and Applications by M.H. Fulekar, IK International 2010.
2. Nanochemistry: A Chemical Approach to Nanomaterials by G. A. Ozin, A.C. Arsenault, and L. Cademartiri, The Royal Society of Chemistry, Cambridge, 2nd Ed., 2009.
3. Nanostructures & Nanomaterials: Synthesis, Properties, and Applications by Guozhong Cao, Imperial College Press, London, 2004.

4. Nanoscale Science and Technology, edited by R. W. Kelsall, I. W. Hamley, and M. Geoghegan, Wiley, West Sussex, 2005.
5. Introduction to Sol-Gel Processing by Alain C. Pierre, Kluwer Academic Publishers: Boston, 1998.
6. Novel Nanocrystalline Alloys and Magnetic Nanomaterials by Brian Cantor
7. Nanoscale materials by Liz Marzan and Kamat.
8. Physical properties of Carbon Nanotube by R Satio.
9. Polymer nanocomposites, edited by Yiu-Wing Mai and Zhong-Zhen Yu, First published 2006, Woodhead Publishing Limited and CRC Press LLC, USA.
10. Physics of Magnetism by S. Chikazumi and S.H. Charap.
11. Magnetostriction and Magnetomechanical Effects by E.W. Lee.
12. Carbon Nanotubes: Properties and Applications by Michael J. O'Connell.
13. Carbon Nanotechnology by Liming Dai.
14. Nanotubes and Nanowires by CNR Rao and A Govindaraj, RCS Publishing.
15. CRC Handbook of Thermoelectrics, Ed. CR Rowe
16. Microfabrication and Nanomanufacturing by Mark James Jackson
17. Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao et.al.
18. Nanoparticles: From theory to applications by G. Schmidt, Wiley Weinheim 2004.
19. Fabrication of fine pitch gratings by holography, electron beam lithography and nano-imprint lithography (Proceedings Paper) Author(s): Darren Goodchild; Alexei Bogdanov; Simon Wingar; Bill Benyon; Nak Kim; Frank Shepherd
20. A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion Final Milling in a FIB-SEM Instrument E L Principe, P Gnauck and P Hoffrogge, Microscopy and Microanalysis (2005), 11: 830- 831Cambridge University Press.
21. Processing & properties of structural naonmaterials by Leon L. Shaw (editor)
22. Nanochemistry: A Chemical Approach to Nanomaterials by Royal Society of Chemistry, Cambridge UK 2005.
23. Nanocomposite science and technology by P.M. Ajayan, L.S. Schadler, P.V. Braun, Wiley, New York.

B) Bio Nanotechnology (1 credit)

UNIT I

Bionanotechnology Concept: Biodefence application of nanotechnology, Optical meteorology for Bionanotechnology, Biological, scanning probe microscopy, Single molecule micro- spectroscopy, Structural principle of Bionanotechnology, Function of

Biological Nanomolecules, DNA computers and DNA microprocessors, Biotechnology based genetic engineering, Bionanotechnology: Examples, Structural Principle of Bionanotechnology, Function of Biological Nanomolecules, Molecular motors, force, elasticity, damping, mechano-chemical coupling, Bionanomachines in Action, Biofilm inhibition by nanoparticles, small angle scattering.

UNIT II

Nanotechnology in Drug Delivery: Introduction, Manufacturing of Nanoparticles, Nanoparticles, Drug deliveries, Drug delivery system, Nanoparticle in Drug delivery-Available applications, Nanotechnology future application understanding for treatment.Manufacture of Nanoparticles, Nanoparticles, Drug Delivery, Drug Delivery Systems, Nanopowder and Nanocrystals, Targeting Ligands Applications of Nanoparticle in Drug Delivery, Cancer Treatment, Nanoparticle, Mediated Delivery of Sirna, Nanonephrology, Nanosystems in Inflammation, Targeting Macrophages to Control Inflammation, Tissue Regeneration, Growth And Repair, Tissue Bioengineering; Nanotechnology, Future Understanding for Treatment, Drug Delivery Technology Significance, Impact of Drug Discovery and Development.

Text/ References:

1. Nanotechnology: Importance and Application by M.H. Fulekar, IK International, 2010.
2. Nanotechnology in Biology and Medicine: Methods, Devices and Application by Tuan Vo-Dinh .CRC press, 2007.
3. Nanosystem characterization tools in the life sciences by Challa Kumar. Wiley-VCH, 2006.
4. Environanotechnology by Mao Hong fan, Chin-pao Huang, Alan E Bland, Z Honglin Wang, Rachid Sliman, Ian Wright. Elsevier, 2010.
5. Introduction to Nanoscience by Gabor L. Hornyak, Joydeep Dutta, Harry F. Tibbals, Anil K. Rao. CRC Press, 2008.

Paper III Instrumentation and statistics (2 credit)

UNIT-I

Basic concept of Instrumentation: UV-VIS-NIR Spectroscopy, FT-IR, NMR, Fluorescence Spectroscopy, Atomic Absorption Spectrophotometer, Gas Chromatography, High pressure Liquid Chromatography, Gas Chromatography-Mass spectrometry, HPTLC, PCR, Electrophorosis, Bioreactor, survismeter, physico-chemical properties.

UNIT-II

Advance Instrumentation Techniques: Principle, Theory, Working and Application; X-Ray Diffraction, X-Ray Reflectivity, Scanning Electron Microscopy, Transmission Electron Microscopy, High Resolution Transmission Electron Microscopy, Field Emission Scanning Electron Microscopy, Atomic Force Microscopy, Scanning Tunnelling Spectroscopy / Microscopy, Photoluminescence Spectroscopy, Electrochemical Impedance Spectroscopy, Polarized neutron Reflectivity, Differential thermal and Gravimetric Analysis, Dynamic Mechanical Analysis, Universal Testing Machine, Vibrating sample Magnetometer, Vector network Analyzer, Vibrating Sample Magnetometer, Brunauer-Emmett Teller surface areas, Zeta sizer, Environmental mode.

UNIT III:

Statistics:

Descriptive Statistics: Primary and secondary data; Basic statistics-Frequency distribution; Organization and Displaying data; spatial and non-spatial data; Measures of Central Tendency; Variability, Sampling Distribution, measures of variability; Descrete Random Variables.

Sampling theory: Random sampling, Sampling methods, Simple random samples, Stratified samples, Cluster samples, Sample planning, Relative advantages and disadvantage of different techniques.

Distributions: basics: Discrete, Continuous: Sampling distribution and significance: Parameter and statistics; Sampling distribution, standard error and its uses; Type I and Type II errors; Test of significance of large samples; Precision and Accuracy; Probability.

Hypothesis testing: Foundations of testing; Hypothesis tests; Chi-square tests: Goodness of fit, Homogeneity; Standard Deviation and Normal distribution; t-test for independent samples; t-test for dependent samples.

Applied Statistics: Linear regression; Multiple and non linear, Measurement scales, Linear correlation, Linear regression.

Semester III

Research Project (20 Credits)

Students are required to carry out a research project of 6 months duration related to Nanoscience/Nanotechnology. Each student will be assigned with a supervisor from among the panel of teachers.

Nanotechnology practicals (Any five):

1. **Synthesis of TiO_2 nano particles by sonochemical method**
2. **Synthesis of ZnO nano particles by sonochemical method**
3. **Synthesis of CdS nano particles by sonochemical method**
4. **Synthesis of $SrTiO_3$ nano particles by sonochemical method**
5. **Biogenesis of Iron nano-particles –for development of Microbial Emulsion**
6. **Characterization of nanoparticles by XRD, SEM, TEM, TG-DTA**
7. **Photocatalytic degradation of hazardous compounds by UV irradiation**
8. **Photocatalytic degradation of hazardous compounds by VIS irradiation**
9. **Photocatalytic degradation of hazardous compounds by IR irradiation**
10. **Photocatalytic degradation of hazardous compounds by solar rays**
11. **X-ray diffraction – determination of structure, composition and estimation of particle size,**
12. **Nanomicrobial degradation of various xenobiotics (e.g. pesticides, organochlorines, pyretheroids, PAH)**
13. **Immobilization bacterial cells for bioremediation of heavy metals using micronano-filtration process.**
14. **Development of Bionano-sensor**

15. **Carbon nanotubes and carbon nanoparticles: Preparation of carbon nanotubes by pyrolysis of organic gases/Pyrolytic thermal treatment of graphite followed by annealing.**