QUANTUM MECHANICS AND MATHEMATICAL MODELING
16NT 11

[As per Choice Based Credit System (CBCS) scheme]
Course: M.TechNano Technology
Semester: I

Subject Code	16INT11	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03

CREDIT - 04

Course Learning Objectives:

1. To provide knowledge of the foundations, techniques, and key result of quantum mechanics.
2. To apply the quantum mechanics theory to important physical and nanosystems
3. To appreciate the applications of quantum mechanics in physics, engineering, and related fields

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1:Introduction Milestones in nanoscience and nanotechnology, Nanostructures and quantum physics, Layered nanostructures and superlattices, Nanoparticles and nanoclusters, Carbon-based nanomaterials. Wave-particle duality: Blackbody radiation, interaction of radiation with matter, photoelectric effect, Compton effect, wave-particle duality, De-Broglie's hypothesis, uncertainty relations, wave function, Schrodinger equation, Operators.	10	L1, L2,
Module 2:Solutions of Schrodinger Equations One-dimensional potential: Free electron in vacuum, electron in a potential well with infinite barriers, finite barriers and propagation of an electron above the potential well, Tunneling: propagation of an electron in the region of a potential barrier. Three-dimensional potential: Electron in a rectangular potential well (quantum box) and spherically-symmetric potential well, Quantum harmonic oscillators, Phonons.	10	L1, L2, L3
Module 3:Approximate methods and Quantum states in atoms and molecules: Stationary perturbation theory for a system with non-degenerate states and degenerate states. Non-stationary perturbation theory, quasi-classical approximation. Quantum states in hydrogen atom, emission spectrum, spin of an electron. Many-electron atoms: wave function of a	10	L1, L2, L3

system of identical particles, hydrogen molecule.		
Module 4:Quantization in nanostructures: Number and density of quantum states, low-dimensional structures, Quantum states of an electron in low-dimensional structures, density of states for nanostructures, Double-quantum-dot structures (artificial molecules), electron in a periodic one-dimensional potential, one-dimensional superlattice of quantum dots, three-dimensional superlattice of quantum dots.	10	L1, L2, L3, L4
Module 5: Computational Modeling of Nanoparticles: Introduction, Benefits of Computer Science for nanotechnology, modeling at different scales – electronic, atomistic, meso and continuum. Concept of computational modeling of nanostructures, computational control of matter through modeling – empirical and Abinitio potentials, molecular dynamics simulation, Monte Carlo simulation, advantages and limitations of MDS and MCS. Modeling of nanoparticles - electronic transport, mechanical properties, optical properties. Bionanoparticles and polymer nanocomposites. Opportunities and challenges in computer modeling of nanoparticles.	10	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Comprehension of basic concepts will enable the students to apply quantum mechanics for solving problems in nanotechnology.
2. An ability to demonstrate a systematic knowledge of the
3. computational modeling for Nanotechnology applications.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Quantum Mechanics for Nanostructures, Vladimir V. Mitin, Dmitry I. Sementsov, Nizami Z. Vagidov. Cambridge University Press 2010.
2. Quantum Mechanics with applications to nanotechnology and information science. Yehuda B. Band, YshaiAvishai. Elsevier 2013.
3. Handbook of theoretical and computational Nanotechnology" eds. Michael Rieth and wolfram schommers, 2006.
4. Computational physics, R. C. Verma, K. C. Sharma & P. K. Ahluwalia.

NANOMATERIALS AND PROPERTIES 16NT12 [As per Choice Based Credit System (CBCS) scheme] Course: M.Tech Nano Technology Semester: I			
Subject Code	16INT12	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT - 04			

Course Learning Objective:
This course introduces various concepts of Nanoscience and nanotechnology. Understand the relation between size and properties of Nanomaterials. To learn the importance of potential Nanomaterials.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1:Introduction to nanoscience and nanotechnology: History, background scope and interdisciplinary nature of nanoscience and nanotechnology, scientific revolutions. Definition of Nanometer, Nanomaterials, and Nanotechnology. Concepts of nanotechnology - size dependent phenomena, surface to volume ratio, atomic structure, molecules and phases, energy at the nanoscale molecular and atomic size.	10	L1, L2,
Module 2:Classification of Nanostructures: Zero dimensional, one-dimensional and two dimensional nanostructure materials. Clusters of metals, semiconductors, ceramics and nanocomposites. Size effect on shapes, Quantum dots, Nanorods, nanowires, nanotubes, nanosheets, nanocones, Nanotetrapods, Nanoflowers, nanobrushes, nano and mesopores, Core-Shell nanoparticles, misnomers and misconception of nanotechnology, importance of nanoscale materials and their devices.	10	L1, L2, L3
Module 3: Properties of Nanomaterials: Mechanical properties, Nano size effect on strength, fracture toughness and fatigue behaviour. Bulk Properties of Materials, electrical conductivity, Dielectric properties, Thermal properties, thermal conductivity, heat capacity. Magnetic properties, Magnetic materials, domains in Magnetic materials.	10	L1, L2, L3

Module 4:Electronic and Optical Properties: Electronic structure of Nanomaterials, magic numbers, Fermi surface, Size effect on Electron-Phonon Coupling, Size effect on physical properties. Optical properties, Optoelectronic properties of bulk and nanostructures, relation between optical properties and electronic structure of nanomaterials – Catalytic property Catalysis by Gold Nanoparticles	10	L1, L2, L3, L4
Module 5:Types of Nanomaterial: Metal nanoparticles, Ceramics nanomaterials, Semiconductor nanoparticles, Metal oxides nanoparticles, Carbon based nanostructures, Graphene, Carbon Nanotubes, Fullerenes, Importance of these nanomaterials and their applications.	10	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Understand the structure-property relationships in nanomaterials as well as the concepts, that are different from bulk counterpart.
2. An ability to demonstrate a systematic knowledge of the range and breadth of application of nanomaterials.
3. Review critically the potential impact, in all classes of materials and nanostructure.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Edward L. Wolf, "Nanophysics and Nanotechnology - An Introduction to Modern Concepts in Nanoscience" Second Edition, John Wiley & Sons, 2006.
2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013
3. Nanostructures and Nanomaterials synthesis, properties and applications, g. Cao, Imperial College press 2004.

References:

1. Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama Nanoparticle Technology Handbook, Elsevier Science, 2007
2. Nanotechnology – Basic Science & Emerging Technologies, Chapman & Hall/CRC 2002
3. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010

SYNTHESIS AND PROCESSING TECHNIQUES 16NT13 [As per Choice Based Credit System (CBCS) scheme] Course: M.Tech Nano Technology Semester: I			
Subject Code	16INT13	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT - 04			

Course Learning Objective:
The course aims at providing overview of various nanomaterial synthesis and processing techniques. Introduce different types of synthesis methods and processing techniques. Learn to choose suitable synthesis process and condition to get desired nanostructures.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1:Physical Methods: Bottom-Up versus Top-Down; Top-down approach with examples. Ball milling synthesis, Arc discharge, RF-plasma, Plasma arch technique, Inert gas condensation, electric explosion of wires, Ion sputtering method, Laser pyrolysis, Molecular beam epitaxy and electrodeposition. Electro spinning, Physical vapor Deposition (PVD) – Chemcial vapour Deposition (CVD) - Atomic layer Deposition (ALD) – Self Assembly- LB (Langmuir-Blodgett) technique.	10	L1, L2, L3
Module 2:Chemical methods: Chemical precipitation methods- co-precipitation, arrested precipitation, sol-gel method, chemical reduction, photochemical synthesis, electrochemical synthesis, Microemulsions or reverse micelles, Sonochemical synthesis, Hydrothermal, solvothermal, supercritical fluid process.	10	L1, L2, L3
Module 3:Combustion and Solution Methods: Solution combustion process, spray pyrolysis method, flame spray pyrolysis, gas phase synthesis, gas condensation process, chemical vapor condensation. Fundamental aspects of VLS (Vapor-Liquid-Solid) and SLS (Solution-Liquid-Solid) processes – VLS growth of Nanowires – Control of the size of the nanowires – Precursors and catalysts – SLS growth – Stress induced recrystallization.	10	L1, L2, L3
Module 4:Biological methods: Use of bacteria, fungi, Actinomycetes for nanoparticle	10	L1, L2, L3, L4

synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Role of plants in nanoparticle synthesis, synthesis of nanoparticles using proteins and DNA templates.		
Module 5:Surface Modification of Nanoparticles Surface modification of inorganic nanoparticles by organic functional groups - Instantaneous nanofoaming method for fabrication of closed-porosity silica particle- Development of photocatalyst inserted into surface of porous aluminosilicate - Fabrication technique of organic nanocrystals and their optical properties and materialization - Development of new cosmetics based on nanoparticles - Development of functional skincare cosmetics using biodegradable PLGA nanospheres.	10	L1, L2, L3, L4

Course Outcomes:

Students get an idea of various synthesis and processing techniques used to design desired nanostructure and size and morphology controlled nanostructure to get desired property. Students will be able to synthesize different nanomaterial and evaluate their property for various applications.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Guozhong Cao, "Nanostructures and Nanomaterials, synthesis, properties and applications", Imperial College Press, 2004
2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013.
3. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens.

References:

1. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010
2. T. Pradeep , "NANO The Essential , understanding Nanoscience and Nanotechnology". Tata McGraw-Hill Publishing Company Limited, 2007.
3. C.A. Mirkin and C.M. Niemeyer, Nanobiotechnology- II, More Concepts and Applications, WILEY-VCH, Verlag GmbH&Co, 2007.

Additional Readings:

1. Hari Singh Nalwa - Encyclopedia of Nanotechnology.
2. Processing & properties of structural Naonmaterials by Leon L. Shaw (editor)

3. Chemistry of Nanomaterials : Synthesis, properties and applications by CNR Rao et.al.
4. Nanochemistry: A chemical approach to Nanomaterials Roayal Society of Chemistry, Ozin and Arsenault, Cambridge UK 2005,
5. Nanoparticles: From Theory to Applications, G.Schmidt, Wiley Weinheim 2004.

NANOBIOTECHNOLOGY
16NT14
[As per Choice Based Credit System (CBCS) scheme]
Course: M.Tech Nano Technology
Semester: I

Subject Code	16INT14	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03

CREDIT - 04

Course Learning Objective:
This course provides fundamental aspects of biotechnology. It also provides platform to understand the interaction of nanostructures and biomolecules, application of various nanomaterials in biological application.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1:Fundamentals of Biotechnology Basic terms in biotechnology, recombinant DNA technology, genetic engineering, gene cloning. Development of nanobiotechnology, timelines and progress. Basics of cell orgenells. Biomacromolecules- carbohydrates, lipids, proteins and nucleic acids, PHA, cyanophcin inclusion, magnetosome, alginates, bacteriophages, S-layer protein, bacteriorhodpsin. Biological building blocks; Sizes of building blocks and comparison with nanostructures.	12	L1, L2, L3
Module 2:Nanostructures: DNA and protein based nanostructures, DNA origami, DNA nanotubes, polypeptide nanowire and protein nanoparticles, SAM, biological nanomotor. Nanoconjugates: DNA-gold nanoconjugates. DNA based nanoelectronics: immobilization of DNA on substrates, probing the electronic properties of single DNA molecules. Manipulation of DNA on metal surfaces.	10	L1, L2, L3
Module 3:Interaction between biomolecules and nanoparticle surface Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies, Application of nano in biology, nanoprobes for Analytical Applications - A new methodology in medical diagnostics and Biotechnology, Current status of Nanobiotechnology, Future perspectives of Nanobiology.	10	L1, L2, L3

Module 4: Applications of nanomaterials Drug delivery and gene delivery, Nanobiochips, biosensors. Nanomaterials in bone substitutes and dentistry. Polymeric nanofibres-tissue engineering, smart capsules, microemulsions, nano based cancer therapy, nanorobotics. Lotus leaf as a model self-cleansing system. Diatoms as example for silicon biomineralization. Biomechanical strength properties of Spider silk.	10	L1, L2, L3, L4
Module 5:Photoinduced Electron Transport in DNA Electronic Devices Based on DNA Architecture, DNA Nanowires, Charge Transport, DNA-Based Nanoelectronics, Electrical Manipulation of DNA on Metal Surfaces, Nanostructured Bio-compartments, DNA-Gold nanoconjugates.	08	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Demonstrate knowledge of biotechnology to understand Nanobiotechnology.
2. Analyze the interaction of various biomolecules and nanostructures.
3. Design and develop nanostructures and biomolecules for various biological applications.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Nanobiotechnology: Bioinspired devices and materials of the future by Oded Shoseyov, Ilan Levy. Humana Press 2010.
2. Bionanotechnology - Global Prospects by David E. Reisner, Taylor & Francis Group, LLC, 2009.
3. Nanotechnology in Drug Delivery by Melgardt M.deVilliers, PornanongAramwit, Glen S. Kwon, Springer-American Association of Pharmaceutical Scientists Press 2009.

References:

1. T. Pradeep , “NANO The Essential , understanding Nanoscience and Nanotechnology”. Tata McGraw-Hill Publishing Company Limited, 2007.
2. Nancy A. Monteiro-Riviere, C. Lang Tran Nanotoxicology: Characterization, Dosing and Health Effects Published:July 25, 2007 by CRC Press

ELECTIVE - I			
MICRO AND NANO FLUIDICS **16NT151** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: I**			
Subject Code	16INT151	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

A comprehensive understanding of micro and nano fluidics. Learn about Fabrication techniques of Nanofluidic channels, Lab-on-chip concept and application. Understanding the behaviour of Biomolecule's in microfluidic channels.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1:Introduction Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions-Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscale Couette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility. **Pressure Driven Liquid Microflow:** Apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro - flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis.	10	L1, L2, L3
Module 2:Laminar flow Hagen-Poiseullieeqn, basic fluid ideas, Special considerations of flow in small channels, mixing, microvalves & micropumps, Approaches toward combining living cells, microfluidics and 'the body' on a chip, Chemotaxis, cell motility. Case Studies in Microfluidic Devices. **Ionic transport:** Polymer transport – microtubule transport in nanotuble channels driven by Electric Fields and by Kinesin Biomolecular Motors - Electrophoresis of individual nanotubules in microfluidic channels.	10	L1, L2, L3
Module 3:Fabrication techniques for Nanofluidic channels – Biomolecules separation using Nanochannels -	06	L1, L2, L3, L4

Biomolecules Concentration using Nanochannels – Confinement of Biomolecules using Nanochannels. **Hydrodynamics:** Particle moving in flow fields – Potential Functions in Low Renoylds Number Flow – Arrays of Obstacles and how particles Move in them: Puzzles and Paradoxes in Low Re Flow**.**		
Module 4: Microfluidics and Lab-on-a-chip Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of Proteins-Strategies- printing types-methods and characterization- Cell nanostructure interactions-networks for neuronal cells. Applications in Automatic DNA sequencing, DNA and Protein microarrays.	07	L1, L2, L3, L4
Module 5: BioMEMS Introduction and Overview, Bio-signal Transduction Mechanisms: Electromagnetic Transducers Mechanical Transducers, Chemical Transducers, Optical Transducers – Sensing and Actuating mechanisms (for all types). Case Studies in Biomagnetic Sensors, Applications of optical and chemical transducers. Ultimate Limits of Fabrication and Measurement, Recent Developments in BioMEMS and BioNEMS - An alternative approach to traditional surgery, Specific targeting of tumors and other organs for drug delivery, Micro-visualization and manipulation, Implantation of microsensors, microactuators and other components of a larger implanted device or external system (synthetic organs).	07	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Demonstrate knowledge about Pressure driven liquid microflow, laminar flow, ionic transport, fabrication techniques for nano fluidic channels.
2. Analyze the biomolecule behavior in microfluidic channels.
3. Design the lab on chip devices and BiMEMS devices and their applications.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Joshua Edel “Nanofluidics” RCS publishing, 2009.
2. PatricTabeling “Introduction to Microfluids” Oxford U. Press, New York 2005.
3. K. Sarit “Nano Fluids; Science and Technology”, RCS Publishing, 2007.

References:

1. M. Madou, Fundamentals of Microfabrication, CRC Press, 1997
2. G. Kovacs, Micromachined Transducers, McGraw-Hill, 1998
3. Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006

ELECTIVE - I			
THIN FILM TECHNOLOGY **16NT152** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: I**			
Subject Code	16INT152	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			
Course Learning Objective: In this course, students will be taught advanced thin-film technology used in micro and Nano industries for making various electronic, bioelectronics, and optical devices.			

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module 1: Deposition Technologies Introduction to thin films, background, definition, scope of studies, coating materials, applications in various fields; classification of deposition technologies – evaporative, glow discharge, gas phase, and liquid phase; application based deposition technique selection; contamination control and defect - material purity and selection, sources of contamination, substrate preparation techniques, defect measurement techniques.	08	L1, L2, L3
Module 2: Vacuum and sputter technology: Vacuum technique kinetics of gases - speed, gas equation, collisions and interactions; Nucleation – gas/liquid/solid phases, homogenous, heterogeneous, and nucleation rate; Transport and pumping of gases; Pumping systems. Sputtering technology: Introduction, physical sputtering theory – energy dependence of sputtering, energy, and direction of sputtered atoms; Reactive sputtering; Plasma and sputtering systems; Deposition rates and efficiencies.	08	L1, L2, L3
Module 3: Plasma and thermal spraying technology surface properties of plasma and thermal spray, process parameters for thermal and plasma spray; industrial application of plasma spraying – wear: abrasive, adhesive, erosive, and corrosive, wear resistant coatings, jet engine coatings, thermal barrier coatings, and anti-reflective coatings.	08	L1, L2, L3
Module 4: Thin film deposition techniques Physical vapor deposition (PVD) – process parameters,	10	L1, L2, L3, L4

thermal and ebeam evaporation, evaporation of alloys and compounds films, reactive evaporation and safety features; Chemical vapor deposition (CVD) – conventional CVD methods: process adjustment, gas control system, leak testing, gas and dopant flow control, and safety; metal-organic CVD (MOCVD): Physical and chemical properties of materials, organometallic source packaging, growth control features in MOCVD, leak control and cleanliness, advanced safety feature used in MOCVD; Ion beam deposition – introduction, operational overview, and applications; Electrochemical methods – electroplating and electroless process; material and electrode selection, deposition rate control and safety; Atomic layer deposition (ALD) – principle ALD film formation, typical process conditions, liquid and gas precursors used in ALD, process and coating properties.		
Module 5: Metrology and polishing in thin-films Typical metrology and inspection parameters -process steps, measured attribute and metrology system; Film thickness measurement systems, resistivity measurement systems, stress measurement systems, defect inspections system in thin-films. Chemical mechanical polishing: importance of polishing, processing- oxide, STI, and Tungsten polish, and polishing equipment.	06	L1, L2, L3, L4

Course Outcomes:

By the end of the course, students should be able to:

1. Apply the vacuum and sputter technology
2. Interpret the mechanism of thin film nucleation growth
3. Explain thin film deposition techniques and related manufacturing tool
4. Demonstrate the metrology and inspection of thin film
5. Design layers of thin-film of various materials

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Handbook of Thin-film deposition processes and techniques by Krishna Seshan, ISBN 0-8115-1442-5, Noyes Publication/William Andrew Publishing Company NY USA, 2002
2. Thin-Film Deposition: Principles and Practice by Donald L. Smith, ISBN-10: 0070585024 and ISBN-13: 978-0070585027, Publisher: McGraw-Hill Education, 1995.
3. Thin film Phenomena by K. L. Chopra, McGraw-Hill, New York, 1969.
4. Thermal Spray Fundamentals by P. Fauchais, J. Heberlein, and M. Boulos, Springer, New York, (2014).

ELECTIVE - I			
NANOCOMPOSITES AND APPLICATIONS **16NT153** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: I**			
Subject Code	16INT153	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

Learn different types of Nanocomposites and Develop the knowledge of various nanostructures used in designing Nanocomposites. Applications Nanocomposites in industrial applications, the present course gives an overview of Nanocomposites and its application.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Introduction to nanocomposites Definition of composite material, Classification based on matrix and topology, Constituents of composites, Interfaces and Interphases, Distribution of constituents, Nano-composites. Advantage of composite materials, mechanical properties, Thermal, electrical and electronic and optical properties. Super hard nanocomposites-designing and mechanical properties - stress-strain relationship, toughness, strength, and plasticity.	06	L1, L2, L3
Module 2: Ceramic metal nanocompsites Ceramic based nanoporous composites, metal matrix nanocomposites, natural nano-bioccomposites, bio-mimetic nanocompostes and biologically inspired nanocomposites, nanocompsites for hard coatings, DLC coatings, thin film naocomposites, modelling of nanocomposites, synthesis of various nanocomposites materials, sputtering, mechanical alloying.	08	L1, L2, L3
Module 3: Polymer nanocomposites Introduction to polymer composites, Processing of nanoparticles, binding mechanisms in nanoparticles, dispersion of nanoparticles, and stabilization of nanoparticles. Processing and fabrication of polymer nanocomposites, Melt blending, solvent casting, In-situ polymerization, solution polymerization, template synthesis, high shear mixing. Homogeneous/heterogenous nucleation, plasma promoted nucleation. Polymer nanocomposites with	10	L1, L2, L3

structural, gas barrier and flame retardant properties, carbon fiber reinforced polymer composites, elastomer and thermoplastic elastomer nanocomposites for propulsion systems, water borne fire-retardant nanocomposites, hybrid composites for cosmetics, protective and decorative coatings.		
Module 4: Natural nanocomposite systems Spider silk, bones, shells; organic–inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; use of synthetic nanocomposites for bone teeth replacement. Bioactive nanocomoposites in bone grafting and tissue engineering, inorganic/polymer nanocomposites for dental restoration and bone replacement applications.	08	L1, L2, L3, L4
Module 5: Bio ceramics for implant coating Calcium phosphates-hydroxy epatites Ti6Al4V and other biomedical alloys, implant tissue interfacing-metal organic CVD-use of tricalcium phosphate-biomimetic and solution based processing- osteoporosis- osteo plastic, regeneration of bones by using bio compatible ceramics, bioninteractive hydro gels- PEG coating and surface modifications, PEG hydrogels patterned on surfaces- PEG based hydrogels.	08	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Design different types nanostructures that are suitable to specific application.
2. Demonstrate a knowledge of polymer based nanocomposites and its applications.
3. Analyze the properties of polymer Nanocomposites and their behaviour depending on the type of nanomaterials.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Nanocomposite science and technology by P.M.Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co. 2003.
2. Encyclopedia of Nanotechnology by H.S.Nalwa, American Scientific Publishers, 2003.
3. Metalopolymer nanocomposites, Ed A.D. Pomogailo and V.N.Kestelman, Springer-Verlag, 2005.
4. Composite materials, K.K. Chawala, 2nd ed., (1987) Springer-Verlag, New York.

References:

1. Biomedical nanostructures by Kenneth E.Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair. John-Wiley & Sons, 2008.
2. Nanobiotechnology II: Edited by Chad A. Mirkin and Christof M. Niemeyer, Wiley-VCH, 2006.

3. Handbook of Biomineralization: Biomimetic and Bioinspired, Chemistry edited by Peter Behrens, Edmund Bäuerlein John-Wiley Sons, 2006.3. Steven S Saliterman, Fundamentals of BioMEMS and Medical Microdevices, 2006

ELECTIVE - I			
INDUSTRIAL APPLICATIONS OF NANOTECHNOLOGY **16NT154** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: I**			
Subject Code	16INT154	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

- To elucidate on advantages of nanotechnology based applications in each industry.
- To provide instances of contemporary industrial applications of nanotechnology.
- To provide an overview of future technological advancements and increasing role of nanotechnology in each industry

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Nanotechnology in Electrical and Electronics Industry Advantages of nano electrical and electronic devices – Electronic circuit chips – Lasers - Micro and Nano-Electromechanical systems – Sensors, Actuators, Optical switches, Bio-MEMS –Diodes and Nano-wire Transistors - Data memory –Lighting and Displays – Filters (IR blocking) – Quantum optical devices – Batteries - Fuel cells and Photo-voltaic cells – Electric double layer capacitors – Lead-free solder – Nanoparticle coatings for electrical products	10	L1, L2, L3
Module 2: Nanotechnology in Biomedical and Pharmaceutical Industry Nanoparticles in bone substitutes and dentistry – Implants and Prosthesis - Reconstructive Intervention and Surgery – Nanorobotics in Surgery – Photodynamic Therapy - Nanosensors in Diagnosis– Neuro-electronic Interfaces – Protein Engineering – Drug delivery – Therapeutic applications.	10	L1, L2, L3
Module 3: Nanotechnology in Chemical Industry Nanocatalyts – Smart materials – Heterogenous nanostructures and composites – Nanostructures for Molecular recognition (Quantum dots, Nanorods, Nanotubes) – Molecular Encapsulation and its applications – Nanoporous zeolites – Self-assembled Nanoreactors - Organic electroluminescent displays	08	L1, L2, L3

Module 4: Nanotechnology in Agriculture and Food Technology Nanotechnology in Agriculture -Precision farming, Smart delivery system – Insecticides using nanotechnology – Potential of nano-fertilizers - Nanotechnology in Food industry - Packaging, Food processing - Food safety and bio-security – Contaminant detection – Smart packaging	10	L1, L2, L3, L4
Module 5: **Nanotechnology In Textiles And Cosmetics** **Nanofibre production** - Electrospinning – Controlling morphologies of nanofibers – Tissue engineering application – **Polymer nanofibers** - Nylon-6 nanocomposites from polymerization - Nano-filled polypropylene fibers - **Bionics**– Swim-suits with shark-skin-effect,Soil repellence, Lotus effect - Nano finishing in textiles (UV resistant, antibacterial, hydrophilic, self-cleaning, flame retardant finishes) – **Modern textiles** (Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof, Cleaner kids clothes, Wired and Ready to Wear) **Cosmetics** – Formulation of Gels, Shampoos, Hair-conditioners (Micellar self-assembly and its manipulation) – Sun-screen dispersions for UV protection using Titanium oxide – Color cosmetics.	12	L1, L2, L3, L4

Course Outcomes:

The Student will be able to

1. Demonstrate the knowledge of various industrial applications of nanotechnology.
2. Will be able predict future technological advancements and increasing role of nanotechnology in each industry

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Mark A. Ratner and Daniel Ratner,Nanotechnology: A Gentle Introduction to the Next Big Idea, Pearson (2003). 10 NT – 12–13 – SRM – E&T
2. Bharat Bhushan,Springer Handbook of Nanotechnology, Barnes & Noble (2004).
3. Neelina H. Malsch (Ed.),Biomedical Nanotechnology, CRC Press (2005)

References:

1. Udo H. Brinker, Jean-Luc Mieusset (Eds.), Molecular Encapsulation: Organic Reactions in Constrained Systems,Wiley Publishers (2010).
2. Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, (2006).

3. Lynn J. Frewer, WillehmNorde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, (2011).
4. P. J. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead Publishing Limited, Cambridge, (2007).
5. Y-W. Mai,Polymer Nano composites, Woodhead publishing, (2006).
6. W.N. Chang, Nanofibres fabrication, performance and applications, Nova Science Publishers Inc, (2009).

Synthesis and Characterization Lab
16NTL16
[As per Choice Based Credit System (CBCS) scheme]
Course: M.Tech Nano Technology
Semester: I

Subject Code	16INTL16	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	36	Exam Hours	03
CREDIT - 02			

Course Learning Objective:
- To learn the basic principles involved in nanoparticle synthesis.
- To get hands on experience in synthesis of various nanoparticles. To design desired size and morphology controlled nanostructures.

Experiments

1. Verification of Beer Lombard's Law
2. Synthesis of Au/Ag metal nanoparticles by Chemical reduction method, UV-Visible absorption studies of the Au/Ag metal nanoparticles
3. Synthesis of ZnO nanoparticles by hydrothermal method and Optical absorption spectra of the ZnO; Band gap estimation from the band edge
4. Synthesis of TiO2 nanoparticles by Solvothermal method and Photocatalytic degradation property analysis
5. Synthesis of ceramic BaTiO3 nanomaterial by combustion process and their crystal structure identification by X-ray diffraction studies
6. Synthesis of ceramic SrTiO3 nanomaterial by Sol-Gel method and their Size Calculation Scherer's law by X-ray diffraction pattern
7. Surface functionalization or modification of Al2O3 metal oxide nanoparticles with organic reagents. Surface modification confirmation by dispersion in binary solvent (Organic-Aqueous) system.
8. Synthesis of Fe2O3/Mn3O4 nanoparticles by Co-precipitation method
9. Surface functionalization or modification of Fe2O3 metal oxide nanoparticles with organic reagents. Surface functional group identification by FTIR measurement
10. Synthesis of ZnS/MoS nanoparticles by microwave Solvothermal method followed by size and morphology analysis

Course Outcomes:

The Student will be able to Design the experiments and synthesize various

nanoparticles. Prepare size and morphology controlled nanostructures.
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.

DESIGN AND FABRICATION TECHNIQUES
16NT21

[As per Choice Based Credit System (CBCS) scheme]

Course: M.Tech Nano Technology

Semester: II

Subject Code	16INT21	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03

CREDIT - 04

Course Learning Objective:

The learning objectives of the course are to provide students with the knowledge of miniaturization concept and Quantum mechanical aspects. Understand the principles of Nanofabrication process; determine the suitability of nanostructures for fabrication of devices. The course provides a strong theoretical and analytical understanding of nanostructures and devices fabrication process for its applications.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: The Science of Miniaturization Miniaturization of Electrical and Electronic Devices, Moore's law and technology road map, Quantum Mechanical Aspects, Simulation of the Properties of Molecular Clusters, Formation of the Energy Gap, Confinement Effects, Discreteness of Energy Levels, Tunneling Currents.	10	L1, L2, L3
Module 2:Nanofabrication by Photons Principles of Optical Projection Lithography, Process of Optical Lithography. Photoresists Characteristics. Optical Lithography at Shorter Wavelengths-Deep UV, Extreme UV and X-ray Lithography. Optical Lithography at High Numerical aperture, Near-Field Optical Lithography.	10	L1, L2, L3
Module 3: **Nanofabrication by Ion Beam** Introduction, Liquid Metal Ion Sources, Focused Ion Beam Systems, Ion Scattering in Solid Materials , FIB Direct Nanofabrication , Ion Sputtering, Ion Beam Assisted Deposition, Applications, Focused Ion Beam Lithography, Ion Projection Lithography.	10	L1, L2, L3
Module 4:Nanofabrication by Scanning Probes Introduction, Principles of Scanning Probe Microscopes, Exposure of Resists- Exposure of Resist by STM, Exposure of Resist by NSOM, Additive Nanofabrication, Field Induced Deposition, Dip-Pen Nanolithography, Subtractive Nanofabrication-Electrochemical Etching, Field Induced	10	L1, L2, L3, L4

Decomposition, Thermomechanical Indentation, Mechanical Scratching, High Throughput Scanning Probe Lithography.		
Module 5:Fabrication of micro/nano devices Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Lithium Ion Battery and Super capacitors device fabrication, Operating and structure of Solar cells-CIGS solar cells, Dye-Sensitized solar cells, and Perovskite solar cell. MEMS and NEMS based devices	10	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Understand and appreciate the importance of nanostructure and its impact device fabrication
2. Differentiate between nanofabrication process and understand the advantages and limitations of process for device fabrication
3. Understand the miniaturization of devices to Nano devices, process challenges and analyze theory for emerging Nano scale devices
4. Evaluate the advances in Nano scale technology and device fabrication their application in electronics, sensors, biomedical and energy generation and storage.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Guozhong Cao, Nanostructures & Nanomaterials Synthesis, Properties G; Z: Applications, World Scientific Publishing Private, Ltd., Singapore (2004).
2. W.R.Fahrner, Nanotechnology and Nanoelectronics – Materials, Devices, Measurement Techniques, SpringerVerlag Berlin, Germany (2006).
3. R. H. J. Hannink and A. J. Hill, Nanostructure control of materials, Woodhead Publishing Limited and CRC Press LLC, Cambridge, England (2006).
4. Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, Springer Science + business media, New York (2008).

References:

1. Hari Singh Nalwa, Handbook of Nanostructured Materials and Nanotechnology (Vol. 3)- Electrical Properties, Academic Press, San Diego, USA (2000).
2. Huff, Howard, Into The Nano Era: Moore's Law Beyond Planar Silicon CMOS (Vol. 106), Springer Series in Materials Science, Springer-Verlag Berlin (2009).
3. Marc J. Madou, Fundamentals of Microfabrication: The Science of Miniaturization, 2nd Edition, CRC Press, California, USA (2002).
4. Kostya (Ken) Ostrikov and Shuyan Xu, Plasma-Aided Nanofabrication: From Plasma Sources to Nanoassembly, WILEY-VCH Verlag GmbH & Co. KGaA (Weinheim) (2007).

NANOELECTRONICS 16NT22 [As per Choice Based Credit System (CBCS) scheme] Course: M.Tech Nano Technology Semester: II			
Subject Code	16INT22	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT - 04			

Course Learning Objective:

The learning objectives of the course in nanoelectronics are to understand the importance of nanoelectronics, technology roadmap in nanoelectronics and limitations of existing CMOS technologies for design of electronic circuits. The course provides an insight on the advances in nanoelectronics devices such as High-K devices, FINFETs, CNTFETs, Molecular Electronics and Spintronics. The course provides a strong theoretical and analytical understanding of nanoelectronic devices and its applications in design of electronic circuits.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Introduction to nanoelectronics Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of semiconductor devices, Quantum statistical mechanics, Energy bands in silicon,**Metal Oxide Semiconductor Field Effect Transistors (MOSFET),** MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage characteristics, Finite Element Modeling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect.	10	L1, L2, L3
Module 2:Nanoscale MOSFETs MOSFET as digital switch, Propagation delay, Dynamic and static power dissipation Moore's law, Transistor scaling, Constant field scaling theory, Constant Voltage Scaling, Generalized scaling, Short channel effects, Reverse short channel effect, Narrow width effect, Subthreshold conduction leakage, Subthreshold slope, Drain Induced Barrier Lowering, Gate Induced Drain Leakage, Design of NanoMOSFET, Halo implants, Retrograde channel profile, Shallow source/drain extensions, Twin well CMOS process flow, Gate Tunneling : Fowler Nordheim and Direct Tunneling, High k gate dielectrics, Metal gate transistor,	12	L1, L2, L3

Transport in Nanoscale MOSFET, Ballistic transport, Channel quantization.		
Module 3: Designing with FINFETs Evolution of FinFET, Principle of FinFET, Finfet Technology, FinFET Schematic, Compact Drain-Current equation, Small Signal Model of Si- Based FinFET, FinFET Fabrication Flow, Power dissipation in FinFETs, Leakage power reduction techniques, Power gating, Dual sleep, Dual stack, Sleepy stack, Basic gate design using FinFET's, combinational logic, sequential logic, Adders, Multiplier, SRAM cell design	10	L1, L2, L3
Module 4: Designing with CNTFETs Introduction to CNTs, CNT structure, metallic and semiconductor CNTs, energy bands in CNTs, types of CNTs: Single walled and multiwalled, physical, electrical and thermal properties of CNTs, fabrication of CNTs. CNTFETs, structure and model, small signal model, predictive technology models, N-Channel and P-Channel CNTFETs, model files of CNTFETs, basic gates using CNTFET, VI characteristics of CNTFET based inverter, designing of sub systems using CNTFETs, combinational and sequential circuits using CNTFETs, adders, multipliers and SRAM cell using CNTFETs.	10	L1, L2, L3, L4
Module 5: Advances in Nanoelectronics MOLECULAR NANOELECTRONICS: Electronic and optoelectronic properties of molecular materials, TFTs- OLEDs- OTFTs – logic switches, SPINTRONICS: Spin tunneling devices - Magnetic tunnel junctions- Tunneling spin polarization, -spin diodes - Magnetic tunnel transistor - Memory devices and sensors - ferroelectric random access memory- MRAMS	08	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Understand and appreciate the importance of nanoelectronics and its impact in next generation electronics and electronic products
2. Differentiate between MOS and emerging nanodevices technology, understand the advantages and limitations of MOS based circuits
3. Understand the technology migration from MOS to nano devices, process challenges and analyse the mathematical models for emerging Nanoscale devices
4. Design logic circuits, sub systems and complex digital circuits using FINFETs and CNTFETs
5. Evaluate the advances in Nanoscale technology development and understand the importance of emerging devices and technologies of molecular electronics and spintronics

Graduate Attributes (as per NBA):

- Engineering Knowledge.

- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Yuan Taur and Tak H. Ning, Fundamentals of Modern VLSI Devices, Cambridge
2. Karl Goser, Peter Glosekotter, Jan Dienstuhl, ―Nanoelectronics and Nanosystems‖, Springer (2004)
3. Cyril Prasanna Raj P., Designing with FINFETs and CNTFETs, MSEC E-Publication (2016)
4. Sadamichi Maekawa, ―Concepts in Spin Electronics‖, Oxford University Press (2006)

References:

1. V. Mitin, V. Kochelap, M. Stroscio, Introduction to Nanoelectronics, Cambridge University Press (2008)
2. Edward L. Wolf, ―Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience‖, Wiley-VCH (2006)
3. Streetman and Banerjee, Solid State Electronic Devices, Prentice-Hall
4. Rainer Waser, ―Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices, Wiley-VCH

ADVANCED MATERIALS
16NT23
[As per Choice Based Credit System (CBCS) scheme]
Course: M.Tech Nano Technology
Semester: II

Subject Code	16INT23	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT - 04			

Course Learning Objective:
Provide foundation about crystal structure, arrangement of atoms in different structure. Course gives an over view of various advance materials and their application. Enrich students with advanced material science techniques.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Crystal structure Crystal systems, Crystal classes, Bravais lattice. Unit cell: Wigner-Seitz cell, equivalent positions in a unit cell. Notations of planes and directions. Atomic packing: packing fraction, Co-ordination number. Examples of simple crystal structures: NaCl, ZnS and diamond. Symmetry operations, point groups and space groups.	10	L1, L2, L3
Module 2: Crystal bonding Types of bonding. Van der Waals-London interaction, Repulsive interaction. Modelung constant. Born's theory for lattice energy in ionic crystals and comparison with experimental results. Ideas of metallic binding, Hydrogen bonded crystals. Vibrations of monoatomic lattices. First Brillouin zone. Quantization of lattice vibrations - Concept of Phonon, Phonon momentum. Specific heat of lattice (qualitative).	10	L1, L2, L3
Module 3: **Photonic Materials:**Need for New Photonic Materials, composite materials for nonlinear optics, nanostructured waveguides for nonlinear optics quantum and nonlinear optics for advanced imaging applications. **Spintronics Materials:**Modeling the growth of Mn on semiconductor substrates, Dilute magnetic semiconductor nanocrystals, Advances in wide bandgap materials for semiconductor spintronics	10	L1, L2, L3

Module 4: Smart Materials and Systems Thermoresponsive materials, piezoelectric materials, electrostrictive and magnetostrictive materials, Magnetic materials, superparamagntism in metallic nanoparticles, Giant and colossal magnetic materials, ferrofluids, ER and MR fluids, biomimetic materials, smart gel, shape memory alloys and polymers.	10	L1, L2, L3, L4
Module 5: **Advanced Materials in Catalysis:** Bimetallic Catalysts, Supported Bimetallic Catalysts, Graphite Intercalation Compounds as catalysts, Carbides, Nitrides, and Borides for Catalysis, Synthetic Layered Silicates and Aluminosilicates; Complex Catalysts on Inorganic Supports. **Advanced materials in Biomedical Application:** Zeolite Structures as Drug Delivery Systems, Mesoporous Silica Nanoparticles and Multifunctional Magnetic Nanoparticles in Biomedical Applications, Metal-Organic Frameworks for Biological and Medical Applications	10	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Understand the crystal structure and characterization of various nanomaterials
2. Evaluate the characteristic crystal structure and their influence on properties of the materials.
3. Demonstrate their knowledge in advanced material science which helps in applications of various materials in engineering applications.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Introduction to Solid State Physics, C. Kittel, Wiley Eastern
2. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
3. Semiconductor Physics, P. S. Kireev, MIR Publishers.

References:

1. Solid State Physics, A. J. Dekkar, Prentice Hall Inc.
2. Introduction to Superconductivity, M. Tinkham, McGraw-Hill, International Editions
3. Elementary Solid State Physics: Principles and applications, M. A. Omar, Addison-Wesley.
4. Advanced Materials in Catalysis, Frank Bolz, Academic Press, 1977
5. Advanced Healthcare Materials Tiwari, A. (ed) (2014), John Wiley & Sons, Inc.,

Hoboken, NJ, USA.

CHARACTERIZATION TECHNIQUES
16NT24
[As per Choice Based Credit System (CBCS) scheme]
Course: M.Tech Nano Technology
Semester: II

Subject Code	16INT24	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03

CREDIT - 04

Course Learning Objective:
The course aims at providing overview of various characterization techniques. Analyze the data obtained from different techniques and evaluate size, structure, morphology and properties of nanomaterials.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: X-Ray based characterization Principles and applications of X-ray diffraction, powder (polycrystalline) and single crystalline XRD techniques; Debye-Scherrer equation to treat line broadening and strain induced in nanoparticles and ultra-thin films. Basics of structure refinement (Reitveld). Rotating anode and synchrotron based X-ray diffraction for probing structure.X-ray photoelectron spectroscopy – basic principle, instrumentation, X-ray absorption techniques: XANES, EXAFS.	12	L1, L2, L3
Module 2: Electron microscopy techniques Introduction, Principles and applications of Electron beam, Electron beam interaction with matter. Scanning electron microscopy (SEM/FESEM), transmission electron microscopy (TEM/HRTEM), Electron-diffraction, SAED. Scanning Probe Microscopy: Principles and applications, Atomic Force Microscope, Scanning Tunneling Microscope.	12	L1, L2, L3
Module 3: Spectroscopic techniques UV-VIS Spectrophotometers, IR/FTIR Spectrophotometers, Principles, operation and application for band gap measurements. Raman spectroscopy principles and applications. Optical microscope: Nanoparticle size measurement by Dynamic light scattering methods zeta potential.	10	L1, L2, L3

Module 4: Magnetic characterization Types of magnetic materials, Magnetic susceptibility, Curie-Weis plot for paramagnetic materials, Neel temperature, Curie temperature VSM and SQUID magnetometers – M vs H, M vs T, MH-loops.	10	L1, L2, L3, L4
Module 5: Electrical measurements Cyclic Voltameter, Impedence Measurement, IV, AC and DC electric measurements, impedance spectral information.	06	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Identify the characterization technique suitable for their studies
2. Analyze the data from various characterization techniques used to evaluate nanomaterial structure, size, morphology and properties.
3. Understand the size and structure relationship and their suitability for an given engineering application.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Characterization of Nanostructure materials by XZ.L.Wang
2. Instrumental Methods of Analysis, 7th edition- Willard, Merritt, Dean, Settle
3. *Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)- Roland Wiesendanger*

References:

1. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition
2. - Harold P. Klug, Leroy E. Alexander
3. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter
4. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton.

ELECTIVES – II			
SENSORS AND ACTUATORS **16NT251** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: II**			
Subject Code	16INT251	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

The learning objectives of the course are to Understand the basic concept and features of sensors. Learn the relation between physical effects on the main sensing/transduction mechanisms. Determine the suitability of nanostructures for sensors application. Knowing how to gather, interpret and use scientific and technical information on sensors and biosensors. The course provides a strong theoretical and analytical understanding of Nano sensor and their application

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Fundamentals of sensors Micro and nano-sensors, biosensor, packaging and characterization of sensors, method of packaging at zero level, and first level. Thermal energy sensors: temperature sensors, heat sensors, electromagnetic sensors, electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetic sensors, Mechanical sensors, pressure sensors, gas and liquid flow sensors, position sensors, chemical sensors, optical and radiation sensors- gas sensor.	08	L1, L2, L3
Module 2: Sensor Characteristics and Physical Effects Active and Passive sensors – Static characteristic: Accuracy, offset and linearity – Dynamic characteristic: First and second order sensors, Physical effects involved in Signal Transduction: Photoelectric effect – Photodielectric effect, Photoluminescence Effect – electroluminescence effect – chemiluminescence effect, Doppler effect, Barkhausen effect, Hal effect – nernst / Ettinshausen effect, Thermoelectric effect – Peizoresistive effect – piezoelectric effect, pyroelectric effect, magneto-mechanical effect (magnetostriction) – Magnetoresistive effect, Faraday-Henry Law, magneto optice Kerr effect, KerrandPockels Effect.	08	L1, L2, L3

Module 3: Sensor Architecture and Classification: Sensor characteristics:linearity, repeatability, hysteresis and drift. Sensor models in the time & frequency domains. Sensors for physical measurands: strain, force, pressure, acceleration, flow, volume, temperature and biopotentials. Nano based Inorganic Sensors: One dimensional gas sensors: - gas sensing with nanostructured thin films, absorption on surfaces, metal oxide modifications by additives, surface modifications, Nano optical sensors, nanomechanical sensors, plasmon resonance sensors with nanoparticles, AMR, Giant and colossal magnetoresistors, magnetic tunnelling junctions.	08	L1, L2, L3
Module 4:Actuators What is an actuator, Transducing materials as a basis for actuator design, Energy domains and transduction phenomena, Transducer basics, The role of the actuator in a control system: sensing, processing and Actuation-Impedance matching. Emerging versus traditional actuator, Other actuator technologies - Electrostatic actuators, Thermal, Magnetic shape memory actuators, Piezoelectric actuators.	08	L1, L2, L3, L4
Module 5: Biological Sensors-2 Noninvasive Biosensors in Clinical Analysis. Applications of Biosensor-based instruments for the bioprocess industry. Application of Biosensors for environmental samples. Introduction to Biochips and their application to genomics. BIAcore, an optical Biosensor. Photoinduced Electron Transport in DNA: Electronic Devices Based on DNA Architecture, DNA Nanowires, Charge Transport, DNA-Based Nanoelectronics, Electrical Manipulatio of DNA on Metal Surfaces, Nanostructured Biocompartments, DNA-Gold nanoconjugates.	08	L1, L2, L3, L4
Course Outcomes: At the end of the course, students will be able to: 1. Demonstrate the basics knowledge of sensors and actuators 2. Interpretat and analyze the signal data from sensors measurement 3. Applications of nanostructures in sensors and actuators		
Graduate Attributes (as per NBA): • Engineering Knowledge. • Problem Analysis. • Design / development of solutions (partly). • Interpretation of data.		
Question paper pattern:		
TEXT BOOKS: 1. Nanotechnology enabled sensors by KouroushKalantar – Zadeh, Benjamin Fry,		

Springer Verlag New York, (2007)
2. Biosensing: International Research and Development, Jerome Schultz, MilarMrksich, Sangeeta N. Bhatia, David J. Brady, Antionio J. Ricco, David R. Walt, Charles L. Wilkins, Springer 2006
3. Sensors and signal conditioning, 2nd edition Ramon Pallas-Areny, John G. Webster John Wiley & Sons (2001).

References:

1. Handbook of Biosensors and Electronic Noses: Medicine, Food and the Environment: CRC-Press; 1 edition;1996.
2. D. L. Wise, Biosensors: Theory and Applications, CRC Press,1993.
3. Rao & Guha, Principles of Medical Electronics & Biomedical Instrumentation, Orient Longman.2001.

ELECTIVES – II			
MEMS AND NEMS **16NT252** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: II**			
Subject Code	16INT252	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

- Learn about basics and typical applications of microsystems
- Illustrate scaling laws & microsensors and microactuators
- Illustrate the various principles of operations of mems transducers
- Learn basic electrostatics and its applications in MEMS sensors and actuators
- Learn about ways to fabricate& a packaging needs MEMS device

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Introduction to MEMS Historical background of Micro Electro Mechanical Systems, Feynman' s vision, Nano Technology and its Applications Multi-disciplinary aspects, Basic Technologies, Applications areas, Scaling Laws in miniaturization, scaling in geometry, electrostatics, electromagnetic, electricity and heat transfer.	10	L1, L2, L3
Module 2: Micro and Smart Devices and Systems: Principles Transduction Principles in MEMS Sensors: Micro sensors-thermal radiation, mechanical and bio-sensors, Actuators: Different actuation mechanisms - silicon capacitive accelerometer, piezo-resistive pressure sensor, blood analyzer, conductometric gas sensor, silicon micro-mirror arrays, piezo-electric based inkjet print head, electrostatic comb-driver,Smart phone application, Smart buildings	10	L1, L2, L3
Module 3: Materials and Micro manufacturing Semiconducting Materials., Silicon, Silicon dioxide, Silicon Nitride, Quartz, Poly Silicon, Polymers, Materials for wafer processing, Packaging Materials Silicon wafer processing, lithography, thin-film deposition, etching (wet and dry), wafer-bonding. Silicon micromachining: surface, bulk, LIGA process, Wafer bonding process.	10	L1, L2, L3
Module 4: Electrical and Electronics aspects Electrostatics, Coupled Electro mechanics, stability and Pull-	10	L1, L2, L3, L4

in phenomenon, Practical signal conditioning Circuits for Microsystems. Characterization of pressure sensors, RF MEMS. Switches varactors, tuned filters. Micromirror array for control and switching in optical communication, Application circuits based on microcontrollersfor pressure sensor, Accelerometer, Modeling using CAD Tools (Intellisuite)		
Module 5: Integration and Packaging of Microelectromechanical Systems Integration of microelectronics and micro devices at wafer and chip levels. Microelectronic packaging: wire and ball bonding, flip-chip. Microsystem packaging examples, Testing of Micro sensors, Qualification of Mems devices	10	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Understand the basics and develop applications for microsystems
2. operations of mems transducers
3. Applications of electrostatics in MEMS sensors and actuators
4. Fabricate MEMS device

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, V. K. Aatre, “Micro and Smart Systems”, Wiley India, 2010.
2. T R Hsu, “MEMS and Microsystems Design and Manufacturing”, Tata McGraw Hill, 2nd Edition, 2008

References:

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.
2. S. D. Senturia, “Micro System Design”, Springer International Edition, 2001.

<table>
<tr><td colspan="4" align="center">ELECTIVES – II</td></tr>
<tr><td colspan="4" align="center">NANOTECHNOLOGY AND DRUG DELIVERY SYSTEMS
16NT253
[As per Choice Based Credit System (CBCS) scheme]
Course: M.Tech Nano Technology
Semester: II</td></tr>
<tr><td>Subject Code</td><td>16INT253</td><td>IA Marks</td><td>20</td></tr>
<tr><td>Number of Lecture Hours Per Week</td><td>03</td><td>Exam Marks</td><td>80</td></tr>
<tr><td>Total Number of Lecture Hours</td><td>40</td><td>Exam Hours</td><td>03</td></tr>
<tr><td colspan="4" align="center">CREDIT - 03</td></tr>
<tr><td colspan="4">Course Learning Objective:
Students will learn underlying principles of drug delivery systems. Understand the application of nanostructures as drug delivery systems. Nanoparticles based drug formulation for cancer therapy and bio imaging application.</td></tr>
</table>

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1:Principles of drug delivery systems (DDS) Design of drug delivery systems, Aims of DDS, Modes of drug delivery, ADME hypothesis – 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 targeting.	08	L1, L2, L3
Module 2:Nano sized Drug Carriers Structure and Preparation- Liposomes, Cubosomes and Hexosomes, Solid Lipid Nanoparticles (SLP). Lipid based colloidal system, Liposomal Drug Carriers, Dendrimer (PAMAM), Polymer Micelle, Ceramic and Magnetic nanoparticle, Polymer drug conjugates. Nanotubes, Nanowires, Nanocage, Nanorods, Nanofibers, and Fullerenes, Carbon nanotubes biocompatibility. Smart drug delivery systems, Multifunctional Drug carriers, organic and inorganic composites. Problems with DDS, Drug loading efficiency in nanovehicles, complexity of Nanocarriers, interface between synthetic materials and biological tissues or components, safety and ethical issues, Nanotechnology for future DDS.	08	L1, L2, L3
Module 3: Drug Discovery & Cancer therapy Drug Discovery Using Nanocrystals, Drug Discovery Using Resonance Light Scattering (RLS) Technology. Nanosensors in Drug Discovery, Drug Delivery Applications, Nanorobots, Benefits of Nano-Drug Delivery. Use of microneedles and	08	L1, L2, L3

nanoparticles for local highly controlled drug delivery. Metal nanoparticles in drugs discovery. Nanotechnology for Cancer therapy-Nanobodies, Nanoparticles, nanoshells, Nanobombs, pebbles for brain tumor therapy, Targeting through angiogenesis and Folate Receptors Liposomal formulation in cancer therapy, application of liposomes in pharmaceutical and cosmetic applications.		
Module 4: Nanomedicines Introduction, Applications of nanobiotechnology in medicine, Role of nanotechnology in methods of treatment, Nanomedicines for Nervous system, Developing Nanomedicines, Protocols for nanodrug Administration, Nanotechnology in Diagnostics applications, materials used in Diagnostics and Therapeutic applications - Molecular Nanomechanics, Molecular devices, Nanomedicines for Skin disorders, wound healing, eye diseases, infections, Nanotubes for detection and destruction of bacteria.	08	L1, L2, L3, L4
Module 5:Nanoanalytics Nanoparticles for biological labelling, Nano-Imaging Agents, Nano particles molecular labels, Immunogold-silver staining, combined fluorescent and gold probes, Protein Labeling, gold cluster labelled peptides, gold cluster conjugates of other small molecules, gold-lipids metallosomes, Larger covalent particles labels, gold targeted to His Tabs, gold cluster nanoscrystals.	08	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Demonstrate the knowledge to develop nanoparticle based new types of biomedical markers and therapeutic agents.
2. Evaluate the suitable nanostructure for drug delivery systems application.
3. Develop nanoparticles based drug formulation for cancer therap.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Nanotechnology in Drug Delivery: Melgardt M. de Villiers, PornanongAramwit, glen s. Kwon, Springer, 2009
2. NanoBiotechnology: BionInspired Devices and Materials for the Future: Oded Showeyov, Ilan Levy, Humana Press, New Jersey 2010
3. Nanobiotechnology, Concepts applications and Perspectives: C. M. Niemeyer and Chad A. Mirkin, Wiley VCH, 2009

References:

1. Bionanotechnology Global prospects II: david E Reisner, CRC Press 2012
2. Nanoparticulate Drug Delivery Systems Deepak Thassu, Michel Deleers (Editor),

Yashwant Pathak
3. Drug Delivery and Targeting, A.M.Hillery, CRC Press, 2002.
4. Bio-Applications of Nanoparticles Warren C.W. Chan
5. Lisa Brannon-Peppas, James O. Blanchette Nanoparticle and targeted systems for cancer therapy Advanced Drug Delivery Reviews 56 (2004) 1649– 1659

ELECTIVES – II			
NANOPHTONICS **16NT254** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: II**			
Subject Code	16INT254	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

The course gives an introduction to basic concepts of nanophotonics. It also provides overview of various semiconductor nanomaterials and their characteristics features along with its applications.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1:Introduction to Nanophotonics Nano photonics at a Glance, Multidisciplinary approach, Photons and Electrons: Similarities and Differences, Propagation, Nanoscale Optical Interaction, Free-Space Propagation, Confinement of Photons and Electrons, Nanoscale Confinement of Electronic Interactions.	08	L1, L2,
Module 2:Quantum-Confined Materials and characterization Inorganic Semiconductors, Quantum Wells, Wires Dots, Rings, Manifestations of Quantum Confinement Dielectric Confinement Effect, Super lattices, Core-Shell Quantum Dots and Quantum Dot-Quantum Wells Quantum-Confined Structures as Lasing Media, Organic Quantum-Confined Structures, Characterization of Nanomaterials, Different techniques- X Ray, Electron Microscopy.	08	L1, L2, L3
Module 3:Photonic Crystals Basics Concepts, Theoretical Modeling of Photonic Crystals, Features of Photonic Crystals, Methods of Fabrication, Photonic Crystal Optical Circuitry, non-linear Photonic Crystals, Photonic Crystal Fibers (PCF), Photonic Crystals and Optical Communications, Photonic Crystal Sensors.	08	L1, L2, L3
Module 4:Nanolithography Two-Photon Lithography, Near-Field Lithography, Near-Field Phase-Mask Soft Lithography, Plasmon Printing, Nanosphere Lithography, Dip-Pen Nanolithography, Nanoimprint Lithography, Photonically Aligned Nanoarrays.	08	L1, L2, L3, L4

Module 5:Silicon Photonic Applications Communications and Interconnects, Radio-over-fibre (RoF) RF Applications, Nonlinear Optical Effects in Silicon and Applications, Silicon Amplifiers and Lasers, Wavelength Conversion, Sensing - Physical Sensors, Chemical Sensors, Biochemical Sensors, Integrated Lab-on-a-chip, Power Generation and Conversion, Information Technology, Sensor Technology, Nanomedicine.	08	L1, L2, L3, L4

Course Outcomes:

At the end of the course, students will be able to:

1. Understand the basic principles involved photonics and electronics applications
2. Demonstrate knowledge about photonic, semiconductor nanostructures in developing their applications
3. Knowledge to apply nanolithography for nanphotonics based devices.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Paras N Prasad, Nanophotonics, Wiley Interscience, 2004
2. Graham T Reed, Silicon Photonics, John Wiely and Sons, 2008
3. David G. Bucknall. Nanolithography and patterning techniques in microelectronics, CRC Press,

Device Fabrication and Characterization Lab
16NTL26
[As per Choice Based Credit System (CBCS) scheme]
Course: M.Tech Nano Technology
Semester: II

Subject Code	16INTL26	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	36	Exam Hours	03

CREDIT - 02

Course Learning Objective:

The learning objectives of the course are Knowledge to design and develop the nanostructured based devices, hands on experience to fabricate the devices based on nanomaterials, Knowledge of device operation and data measurement and analyse the device performance and application.

Experiments

1. Gas/Pressure Sensors device fabrication and device parameter measurement and analysis
2. Dye sensitized solar cell device fabrication, I-V measurement and Efficiency calculation
3. To preparation of electrodes for supercapacitor and calculate its specific capacitance using Cyclic voltammetry.
4. To fabricate metal oxide thin/thick film and analyse surface features using AFM
5. Fabrication of thin/thick films and its Crystal structure analysis using XRD
6. Design and Synthesis of 1D inorganic nanostructures and analyse their size and morphology by scanning electron micrograph
7. Preparation of 2D nanostructures and measure their thickness and morphology by AFM.
8. Modification of electrodes by nanomaterial for voltammetric applications
9. Fabrication of electrode for electrochemical oxidation of organic molecules.
10. Battery device Fabrication and its performance data analysis.

Course Outcomes:

1. Design the nanomaterial for suitable application
2. Basic hands on experience to fabricate selected nanomaterials based devices
3. Knowledge to operate the device and measure data .

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

NANOMATERIALS AND ENERGY SYSTEMS 16NT41 [As per Choice Based Credit System (CBCS) scheme] Course: M.Tech Nano Technology Semester: IV			
Subject Code	16INT41	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	50	Exam Hours	03
CREDIT - 04			

Course Learning Objective:

Learn about basic principles of different renewable energy technology. Apply nanomaterial in improving renewable energy storage and generation application. Understand the nanosize and morphology influence on improving energy generation and storage efficiency.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Renewable energy Technology Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: quantum well and quantum dot solar cells, photo-thermal cells for solar energy harvesting, thin film solar cells, CIGS solar cells, Dye sensitized solar cells. Organic PV cells, Concentrated solar power (CSP): Reflective materials, absorptive coatings, thermal storage.	10	L1, L2, L3
Module 2: Energy storage Introduction, Battery types, Li-ion Battery, Battery components materials, cathodes, anodes, effect of Nanosize on energy storage and electrode materials performance. LIB for automobiles application, EV's, HEV, PHEV and power grid. Li Air battery, Li-Sulphur battery, Next generation battery and materials such as Na ion battery, Mg ion battery.	10	L1, L2, L3
Module 3: Super capacitors Introduction, Electrochemical energy storage, Electrochemical capacitors, Electrochemical double layer capacitor, electrode materials supercapacitors, Hybrid Nanostructures for supercapacitors- metal oxides, conducting polymers, Electrolytes for super capacitors, types of electrolytes.	10	L1, L2, L3
Module 4: Hydrogen storage technology Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metal	10	L1, L2, L3, L4

organic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalpy formations and thermal management during hydriding reaction, multiple catalytic- degradation of sorption properties, automotive applications. Catalyst of hydrogen production, steam reforming & Water splitting. Nanoporous membranes for hydrogen separation.		
Module 5: Fuel cell technology Fuel cell principles, types of fuel cells (Alkaline Electrolyte, phosphoric acid, Molten carbonate, solid oxide and direct methanol and proton exchange fuel cells), Principle and operation of proton exchange membrane (PEM) fuel cell, materials and fabrication methods for fuel cell technology, micro fuel cell power sources-biofuels.	10	L1, L2, L3, L4

Course Outcomes:

Students get a clear understanding of nanotechnology beingemployed for different Renewal energy generation and storage application.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. D. Linden, Handbook of Batteries and Fuel Cells, Mcgraw-Hill, Noew York,1984
2. W. A. van Schalkwijk and B. Scrosati, Advances in Lithium- Ion Batteries, Kluwer Academic Publishers, Newyork, 2002
3. Linden , D. and Reddy , T.B. (2002) Handbook of Batteries , 3rd edn , McGraw - Hill , New York.

References:

1. Crompton, T.R. (2000) Battery Reference Book, 3rd Edn, Newnes , Oxford .
2. K. E. Aifantis and S. A. Hackney and R. Vasant Kumar, High Energy Density Lithium Batteries, Wiley-VCH Verlag, 2009.
3. University of Cambridge (2005) DoITPoMS Teaching and Learning Packages, http://www.doitpoms.ac.uk/tlplib/batteries/index.php

ELECTIVES – III			
ADVANCES IN NANODEVICES **16NT421** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: IV**			
Subject Code	16INT421	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

1. To understand CMOS technology, scaling issues and analyze the need for nano-CMOS devices
2. To study the fabrication process and applications of nano capacitors, nanoantennas, memristors, and nanomemory
3. To study fabrication process of CNTs, Nanowires and Quantum dots and understand the technologies behind use of these devices for medical and environmental applications

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Nanoelectronic Devices Nano-CMOS modelling, Nano-CMOS Predictive Technology Model, Mobility and Dopant Number Fluctuation Model, Random interface traps, Nano-CMOS Technology, Bottom-Up approach for CMOS scaling, Low power adders.	08	L1, L2, L3
Module 2: Nano Capacitors and Terahertz systems Package-compatible high density nanoscale capacitors, Carbon nanostructures for display and energy, Nano antennas for energy conversion, Ballistic transistor logic for circuit applications.	08	L1, L2, L3
Module 3: Memristors, Resistive switches and memory Nanodevices: functions and Lienard equation, Sensing and writing operations of nanocross bar memory arrays, Complementary resistive switches, Memory cell using memristor, Thermally actuated nanoelectromechanical memory.	08	L1, L2, L3
Module 4: CNT and Nanowire Fabrication of single walled CNT, CNT for TFT, Yield improvement techniques for CNTFET, GaAs nanowires on Si Substrates, Tin Oxide Nanowires for Gas sensing, Cu Silicide Nanowires for Li-Ion Batteries, Zinc Oxide Nanowires for bio sensing, ZnO thin film transistors.	08	L1, L2, L3, L4

Module 5: **Microfluidics and Lab-on-a-chip:** Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of Proteins- Strategies- printing types- methods and characterization- Cell nanostructure interactions-networks for neuronal cells. Applications in Automatic DNA sequencing, DNA and Protein microarrays.	08	L1, L2, L3, L4

Course Outcomes:

After successfully completing this course, students will be able to

1. Understand the fundamentals of nanodevices and fabrication process.
2. Evaluate the techniques for adopting nanodevices for medical and environmental applications.
3. Develop nanodevices for various applications from basic principles.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. James E. Morris, Krzysztof Iniewski, Nanoelectronic Device Applications Handbook, CRC Press, Taylog& Francis Group, ISBN 9781138072596, 2017 (Selected Chapters
2. Jun Li, Nianqiang Wu, Biosensors Based on Nanomaterials and Nanodevices, CRC Press, Taylog& Francis Group, 2014

References:

Challa S. S. R. Kumar, Nanodevices for the Life Sciences, Wiley-VCH Verlag GmbH, 2006

ELECTIVES – III			
NANOBIOELECTRONICS AND APPLICATIONS **16NT422** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: IV**			
Subject Code	16INT42	IA Marks	20
Number of Lecture Hours Per Week	04	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

Students to understand DNA and other biosystems and their structure. To introduce concept of Microfluidic devices and their application. To learn applications of different nanostructures and biomaterials in developing nanobioelectronic devices and as molecular labelling.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Bionanoelectronics Introduction,Photoinduced Electron transport in DNA: Toward Electronic Devices Based on DNA Architecture, Effective Models for charge Transport in DNA Nanowires, Optimizing Photoactive Proteins for Optoelectronic, DNA Based Nanoelectronics, Electrical Manipulation of DNA on Metal Surfaces.	08	L1, L2, L3
Module 2: Microfluidics Meets Nano: Introduction, Overview, Definition and History, Advantages of Microfluidic Devices, Concepts for Microfluidic Devices, Fluid Transport, Stacking and Sealing, Methods, Materials for the Manufacture of Microfluidic Components, Silicon, Glass, Polymers, Fluidic Structures, Fabrication Methods, Surface Modifications, Spotting, Detection Mechanisms.	08	L1, L2, L3
Module 3: Nanoparticle-Biomaterial hybrid systems for Bioelectronic Devices and Circuitry Introduction, Biomaterial- Nanoparticles Systems for Bio-electtronic and Biosensing Applications, Bioelectronic systems based on nanoparticle-Enzyme Hybrids, Bioelectronic Systems for sensing of biorecognition events on Nanoparticles, Biomaterial based Nanocircuitry, Protein based Nanocircuitry, DNA as Functional Template for Nanocircuitry.	08	L1, L2, L3

Module 4: DNA based Nanostructures Overview, Introduction, Oligonucleotide-Enzyme Conjugates, DNA Conjugates of binding proteins, Noncovalent DNA Streptavidin Conjugates, Multifunctional Protein Assemblies, DNA Protein Conjugates in Microarray Technologies, Methods, Conjugation of Nucleic Acids and Protein, Immuno PCR, Supramolecular Assembly, DNA directed Immobilization, DNA templated Electronics, Sequence Specific Molecular Lithography.	08	L1, L2, L3, L4
Module 5: Nanoparticle Molecular labels Introduction, Immunogold Silver staining, Combined Fluroscent and Gold probes, Methodology, Choice of Gold and AMG Type , Iodization, Sensitivity, Applications for the microscopical detection of Nucleic acids, guidelines and laboratary protocols, Gold derivatives of other biomolecules, protein labeling, gold Cluster of conjugates of other small molecules, gold lipids: metallasomes, Larger Covalent particle labels, Gold Targeted to His Tags, Enzymes Metallography, Gold Cluster Nanocrystals, Gold Cluster Oligonucleotide Conjugate: Nanotechnology applications, DNA Nanowires, 3-D Nanostructured Mineralized Biomaterials, Gold Quenched molecular beacons, Other Metal Cluster Labels, Platinum and Palladium, Tungstates, Iridium.	08	L1, L2, L3, L4

Course Outcomes:

After successfully completing this course, students will be able to

1. Apply DNA and its application bioelectronics devices.
2. Demonstrate knowledge about the Biomolecules and nanostructure interaction.
3. Understand Nanoparticles application in biomedical application.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

References:

1. **“Nanobiotechnology”**. Edited by **C Niemeyer, Chad Mirkin,** WILEY-VCH , ISBN 3-527-30658-7.
2. “Nanobiotechnology”. Edited by Oded Shoseyov, Ilan Levy, Humana Press Inc., ISBN 978-61737-830-0.

ELECTIVES – III

NANOTECHNOLOGY AND ENVIRONMENT

16NT423

[As per Choice Based Credit System (CBCS) scheme]

Course: M.Tech Nano Technology

Semester: IV

Subject Code	16INT423	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03

CREDIT - 03

Course Learning Objective:

Students to learn applications of different nanomaterials for Environmental remedies, removal of pollutant from exhaust gases. Understand the effect of nanoparticle on health and environment and their toxicology. Also learn about controlled environment, types of cleanrooms and their importance.

Modules	Teaching Hours	Revised Bloom's Taxonomy (RBT) Level
Module 1: Environmental Application of Nanomaterials Metal oxide nanoparticles organic contamination remediation, Nanoactive materials, Advanced photocatalyst, removal organic contamination from waste water using Nanomaterials based photocatalyst. Nanostructure electrode for Electrochemical oxidation.	06	L1, L2, L3
Module 2: Nanostructure catalytic materials Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials. Nanomaterials as catalyst for exhaust gas treatment such as CO_2, H_2S, Pb, NO.	06	L1, L2, L3
Module 3: Nanomaterials as Adsorbents Meosoporous materials-synthesis and characterization, properties and application with suitable examples, unipore size, bimodal pore size. Nanoporous materials- synthesis and application. Adsorption at the Oxide Nanoparticles/Solution Interface, Nanomaterial-Based Removal of nanoparticles-Principle of particle removal - Removal of nanoparticles suspended in gas - Removal of nanoparticles in liquid. Adsorption of hazardous chemicals by metal oxide nanoparticles, Adsorption of chemical warfare agents by metal oxide nanoparticles. Nanomaterials as adsorbents for Heavy metal removal from water and Wastewater Treatment, Nanomaterials for Groundwater Remediation- Reactivity, Fate, and Lifetime Delivery and	10	L2, L3, L4

Transport Issues.		
Module 4:Nanotoxicology Health effects on nanoparticles - Inhalation of nanomaterials–overview, Nanoparticle exposure and systematic cardiovascular effects. Respiratory particulate matter exposure and cardiovascular toxicity, Toxicity of different nanomaterials, Toxicological assessment of nanoparticles: Toxicity of polymeric nanoparticles. Ecotoxicological Impacts of Nanomaterials. Nanoparticles in atmospheric environment, Ground water environments, Waste water and in exhaust gases - Industrial processes and nanoparticles. Safety of nanoparticles- Problems caused by nanoparticles - Safety assessment for the nanoparticles.	08	L1, L2, L3, L4
Module 5:Cleanroom basics, hazards, and safety Basics of cleanroom classification and ISO standards, sources of particulate contamination, clean air devices, special construction materials for cleanroom, and surface finishes. The HEPA filters and filtration process in the clean rooms. Parameters control in cleanrooms: temperature, RH, air volume and velocity, pressurization, and differential pressure. Potential hazards in cleanrooms: Fire, explosions, toxicity, and physical hazards. Cleanroom operational and behavioural requirement. Material handling issues: DI water, solvents, cleaners, ion implantation sources, diffusion sources, photoresists, developers, metals, dielectrics, toxic gases, flammable, corrosive, and packaging materials. Types of cleanroom waste: handling and disposal of chemical, biological, infectious, radioactive, and mixed waste.	10	L1, L2, L3, L4

Course Outcomes:

After successfully completing this course, students will be able to

1. Apply nanomaterials in different environmental applications.
2. Demonstrate knowledge about the nanoparticles effect on health and safety issues.
3. Understand Importance of clean rooms and their usage.
4. Nanoparticles toxicity and their effect on health.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. Glen E. Fryxell, Guozhong Cao, Environmental Applications of Nanomaterials: Synthesis, Sorbents and Sensors

2. Mark R. Wiesner, Jean-Yves Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials
3. J. B Park, "Biomaterials Science and Engineering", Plenum Press, New York, 1984.
4. P.P. Simeonova, N. Opopol and M.I. Luster, "Nanotechnology - Toxicological Issues and Environmental Safety", Springer 2006.

References:

1. J.J. Davis, Dekker, "Encyclopedia of Nanoscience and nanotechnology".
2. Dracy J. Gentleman, Nano and Environment: Boon or Bane? Environmental Science and technology, 43 (5), P1239, 2009
3. Vinod Labhasetwar and Diandra L. Leslie, "Biomedical Applications of nanotechnology", A John Willy & Son Inc, N.J, USA, 2007.
4. Cleanroom Technology: Fundamentals of Design, Testing, and Operation by William White, Print ISBN 0-471-86842-6, John Wiley & Sons Ltd, 2001
5. Hazardous Waste Management by Michael D. LaGrega, Reissue edition, ISBN-13: 978-1577666936, Waveland Press Inc., 2010

ELECTIVES – III			
MICRO-NANO PACKAGING **16NT424** **[As per Choice Based Credit System (CBCS) scheme]** **Course: M.Tech Nano Technology** **Semester: IV**			
Subject Code	16INT424	IA Marks	20
Number of Lecture Hours Per Week	03	Exam Marks	80
Total Number of Lecture Hours	40	Exam Hours	03
CREDIT - 03			

Course Learning Objective:

1. Present building block technologies to package micro and nano electronics, photonics, MEMS, and RF/wireless product.
2. Describe the role of Packaging as IC and Device Packaging.
3. Design and fabricate systems packaging to go from wafer to complete system.
4. Demonstrate the role of test, inspection and reliability of electrical, mechanical and materials in micro and nano electronics and devices packaging.

Modules	**Teaching Hours**	**Revised Bloom's Taxonomy (RBT) Level**
Module 1: Fundamentals of the Design and Packaging Process - Systems Engineering, Quality Concepts, Engineering Documentation, Design for Manufacturability, ISO9000, Bids and Specifications, Reference and Standards Organizations. Introduction to Micro and nano systems packaging, role of packaging as IC and device packaging, fundamentals of electrical package design, Single Chip, Multi-chip, IC assembly, and Wafer Level Packaging.	08	L1, L2, L3
Module 2: Surface Mount Technology - Introduction, Surface Mount Device Definitions, Substrate Design Guidelines, Thermal Design Considerations, Adhesives, Solder Joint Formation, Parts, Reflow Soldering, Cleaning and Prototype Systems. Direct Chip Attach - Overview of Die Assemblies, Known Good Die, Chip on Board, Flip Chips, and Chip-Scale Packages.	08	L1, L2, L3
Module 3: Circuit Boards- Overview, Basic Circuit Board Design, Prototypes, DFM and DFT Issues, Board Materials, Circuit Design and Board Layout, Simulation, Standards. **Hybrid Assemblies:** Introduction, Ceramic Substrates, Thick Film, Thin Film, Chip Resistors and Multilayer Ceramic Capacitors, Component and Assembly Packages, Buried Passive Circuit Elements, Bare Die Assembly,	08	L1, L2, L3

Multichip Module Technology.		
Module 4: Interconnects - General Considerations, Wires for Interconnection, Single-Point Interconnects, Connectors, Board Interconnects, Component Sockets, Fiber-Optic Interconnects and Connections, Coaxial Cable and Interconnects, Microwave Guides and Couplers. **Thermal Management:** Fundamentals of Heat, Engineering Data, Heat Transfer, Heat Removal/Cooling. **Testing:** Testing Philosophies, Test Strategies, Sources of Faults, Automatic Test Methods, Test Fixtures, Environmental Stress Screening, Test Software, and Testing Software Programs.	08	L1, L2, L3, L4
Module 5: Inspection - General Inspection Criteria, Solder Paste Deposition Volume, Solder Joint Inspection Criteria, Visual Inspection, Automated Optical Inspection, Laser Inspection, X-Ray Inspection. Package/Enclosure: Introduction, Ergonomic Considerations, User Interfaces, Environmental Issues, Maintenance, Safety. **Electronics Package Reliability and Failure Analysis:** Reliability, Micro-mechanisms of Failure in Electronic, Packaging Materials, Package Components, Failure Analyses of Electronic Packages, Thermal Management, Product Safety and Third-Party Certification.	08	L1, L2, L3, L4

Course Outcomes:

After successfully completing this course, students will be able to

1. Demonstrate packaging of micro and nano electronic based devices and system for cutting edge electronic system.
2. Test, inspect, and failure analysis of micro and nano scale packaged product.

Graduate Attributes (as per NBA):

- Engineering Knowledge.
- Problem Analysis.
- Design / development of solutions (partly).
- Interpretation of data.

Question paper pattern:

TEXT BOOKS:

1. The electronic packaging handbook edited by Glenn R. Blackwell, CRC Press LLC, 2000.
2. Fundamentals of microsystem packaging by Rao R. Tummala, McGraw-Hill, 2004.

References:

1. Micro- and Opto-Electronic Materials and Structures: Physics, Mechanics, Design, Reliability, Packaging by E. Suhir, Y.C. Lee, and C.P. Wong, Springer Science, 2007.
2. Nanopackaging: Nanotechnologies and Electronics Packaging by James E. Morris, Springer Science, 2008.