M.Tech. (Nanoscience and Nanotechnology)

Course Structure and Syllabus

Semester I

Sl. No	Course Code	Title of the Course (Offering Dept)	L/T/P:C
1	TNT 1001	Introduction to Nano Science and Nano Technology (Appl Phy)	3/1/0:4
2	SAC 1109	Synthesis of Nanomaterials (Appl Chem)	**3 /0/ 0**: 3
3	TNT 1103	Nano Structures and Applications (Appl Phy)	3/ 0/ 0:3
4	SAC 3006	Nanochemistry Lab	0/0/3:2
5	TNT 1002	Nanomaterials Lab-I	0/0/3:2
6,7		**Elective-I (Any Two)**	
	TNM 1007	i. Numerical Methods and Computer Programming (Appl Phy)	3/0/0:3
	TBT 1023	ii. Nanobiotechnology (Bio Tech)	3/0/0:3
	TNT 1005	iii. Semiconductor Nanostructures & Nano-particles (Appl Phy)	3/0/0:3
	TPL 1017	iv. Polymer Nanocomposites (Poly Engg)	3/0/0:3
		Total	**22H/20C**

Semester-II

Sl. No	Course Code	Title of the Course	L/T/P:C
1	TNT 2101	Characterization of Nanostructures (Appl Phy)	**3/1/0**:4
2	TNT 2003	Nanophotonics (Appl Phy)	3/0/0:3
3	MEC 2073	Nanodevices & Nanosensors (ECE)	3/0/0:3
4	TNT 2002	Laboratory-III - Nanomaterials Lab	0/0/3:2
5	TNT 2004	Laboratory-IV - Advanced characterization of Nanostructures Lab	0/0/3:2
6		**Elective (Any One)**	
	TNT 2005	i. Nanotechnology in energy conversion and storage (Appl Phy)	3/0/0:3
	TNT 2107	ii. Carbon Nanostructure & Its Functionalisation (Appl Phy)	3/0/0:3
	TPL 2021	iii. Colloid and Interface Science (Poly Engg)	3/0/0:3
	SAC3011	iv. Molecular modeling and Computational chemistry (Appl Chem)	3/0/0:3
	MEC 2019	v. MEMS (ECE)	3/0/0:3
7	**Breadth paper**	**Of M.E. / M. Tech level of other Departments***	3/0/0:3
		Total	**22H/20C**

*Should not have been taken earlier by the student in any other programme

Semester- III &IV

Sl.No	Course Code	Title of the Course	Credit
1	**TNT 3002**	Project work	**15 C**
2	**TNT 4002**	Project work	**20 C**
		Total of all semesters:	**75 C**

Semester-I

TNT 1001: Introduction to Nano Science and Nano Technology L/T/P: 3/1/0 4Cr

Unit-I: Introduction to Quantum Mechanics; Schrodinger equation and expectation values, Solutions of the Schrodinger equation for free particle, particle in a box, particle in a finite well, Reflection and transmission by a potential step and by a rectangular barrier.

Unit II: Angular momentum and its operators, Eigen values and Eigen functions of the angular momentum operators, spin, Pauli spin operators and their properties, hydrogen atom, density of states, free electron theory of metals.

Unit III**:** Confinement and Transport in nanostructure, Current, Reservoirs and Electron channels, Conductance formula for nanostructures, Quantized conductance. Local density of states. Ballistic transport, Coulomb blockade, Diffusive transport, Fock space.

Unit IV: Statistical Mechanics, Microstates and entropy and its statistical definition, Entropy of mixing, Gibb's free energy, Gibb's paradox, phase space density, ergodic hypothesis, Liouville's theorem, The microcanonical-, canonical- and grand canonical- ensemble and their connections, Fluctuations, Classical Statistical systems, Boltzman statistics, and quantum statistical systems, Fermi-Dirac and Bose-Einstein Statistics and their applications.

Unit-V**:** Electronic Properties: Free electron theory of metals, Band theory of solids, Bloch theorem, Kroning-Penne model, Metals and Insulators, Semiconductors: Classification, Transport properties, Size and Dimensionality effects, Band structures, Brillouin zones, Mobility, Resistivity, Relaxation time, Recombination centers, Hall effects.

Unit-VI**:** Optical Properties, Photoconductivity, Optical absorption & transmission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence.

Unit-VII**:** Magnetic Materials: Basic Magnetic Phenomena; Diamagnetism, Paramagnetism, Ferromagnetism, Ferrimagnetism, Anti-ferromagnetism, Some examples of these materials and their applications, RKKY Interactions, Ferrofluids, Introduction to superconductivity; London Equation and Josephson effect.

Text Books:

1. Quantum Physics – A. Ghatak
2. Quantum Mechanics - Bransden and Joachen
3. Statistical Physics by K. Huang
4. Statistical Mechanics-Landau &Lifshitz
5. Quantum wells, Wires & Dots,: Theoretical & Computational Physics of Semiconductors Nano-stuructures, Paul Harrison
6. Principles of Quantum Mechanics 2nd ed. - R. Shankar
7. Thermodynamics and Statistical Mechanics - A N Tikhonov, Peter T Landberg, Peter Theodore Landsberg
8. Thermodynamics and Statistical Mechanics by John M. Seddon , J. D. Gale
9. Statistical Mechanics – Sonntag.
10. Statistical Mechanics – Mc Le Leland

SAC 1109: Synthesis of nano materials **L/T/P: 3/0/0** **3Cr**

Unit I: Introduction to nanomaterials, Properties of materials & nanomaterials, role of size in nanomaterials, nanoparticles, semiconducting nanoparticles, nanowires, nanoclusters, quantum wells, conductivity and enhanced catalytic activity compared to the same materials in the macroscopic state

Unit II: Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation; Metal nanocrystals by reduction, Sol-gel synthesis; Microemulsions or reverse micelles, myle formation; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; Electrochemical synthesis; , Photochemical synthesis, Synthesis in supercritical fluids

Unit III: Self Assembly and atalysis: Process of self assembly, semiconductors islands, monolayers, nature of catalysis, porous materials, pillared clays, colloids, biometrics.

Unit IV: Fabrication of Nanomaterials by Physical Methods: -Inert gas condensation, Arc discharge, Plasma arc technique, RF plasma, MW plasma, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapour deposition method and Electro deposition.

Unit V: M based nanolithography and nanomanipulation, E beam lithography and SEM basednanolithography and nanomanipulation, Ion beam lithography, oxidation and metallization. Mask and its application. Deep UV lithography, X-ray based lithography.

Unit VI: Nanocomposites: An Introduction: Types of Nanocomposite (i.e. metal oxide, ceramic, glass and polymer based); Core-Shell structured nanocomposites Superhard Nanocomposite: Synthesis, applications and milestones.

References:

1. Nanochemistry: A chemical approach to nanomaterials by G. A. Ozin, A. C. Aresnault, L. Cadematriri, RSC Publishing
2. Microfabrication and Nanomanufacturing- Mark James Jackson
3. Chemistry of nanomaterials : Synthesis, properties and applications by CNR Rao et.al.
4. Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2004.
5. 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
6. A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion Final Milling in a FIBSEM
7. Instrument E L Principe, P Gnauck and P Hoffrogge, Microscopy and Microanalysis (2005), 11: 830- 831 Cambridge University Press.
8. Processing & properties of structural naonmaterials - Leon L. Shaw (editor)
9. Nanochemistry: A Chemical Approach to Nanomaterials – Royal Society of Chemistry, Cambridge UK 2005.
1. Nanocomposite science and technology – P.M. Ajayan, L.S. Schadler, P.V. Braun, Wiley, New York.

TNT 1103: Nanostructures and Applications **L/T/P: 3/0/0** **3Cr**

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

Unit–II: Nano ceramics: Dielectrics, ferroelectrics and magnetoceramics, Magnetism; Dia-, Para-, Ferro-, Antiferro-, Ferri-magnetism, Magnetic properties; Gaint magnetoresistance, Tunneling magnetoresistance, Colossal magnetoresistance, Superparamagnetism High Tc materials: YBCO and Bi-systems (Brief idea), Superconducting nano-materials & their properties and applications.

Unit–III: Carbon Nano Structures: DLCs, Fullerenes, C_{60}, C_{80} SWNT and MWNT; Properties: Mechanical, Optical and Electrical properties.

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

Unit–V: Nano Semiconductors: Nanoscale electronic devices including CMOS, Potentiometric sensors etc., MRAM devices, Spintronic devices including spin valves.

Unit–VI: Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites, Nanoparticles polymer ensembles; Applications of Nanopolymers in Catalysis.

Unit–VII: Nanocomposites: Metal-Metal nanocomposites, Polymer-Metal nanocomposites, Ceramic nanocomposites: Dielectric and CMR based nanocomposites. (One example for each type).

References:

1. Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
2. Nanoscale materials -Liz Marzan and Kamat.
3. Physical properties of Carbon Nanotube-R Satio.
4. Polymer nanocomposites: Edited by Yiu-Wing Mai and Zhong-Zhen Yu, First published 2006, Woodhead Publishing Limited and CRC Press LLC, USA.
5. Physics of Magnetism - S. Chikazumi and S.H. Charap.
6. Magnetostriction and Magnetomechanical Effects - E.W. Lee.
7. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell.
8. CARBON NANOTECHNOLOGY- Liming Dai.
9. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing.
10. CRC Handbook of Thermoelectrics, Ed. CR Rowe

SAC 3006: Laboratory-I : Nanochemistry Lab L/T/P: 0/0/3 2Cr

1. To study kinetics of hydrolysis of an ester.
2. Effect of surfactant concentration on equivalent conductance and determination of critical micelle concentration (CMC).
3. Verification of Lambert Beer's law and determination of concentration of unknown solution by UV-Vis spectrophotometer.
4. Preparation of colloidal Silver (Ag) nanoparticles with trisodium citrate and their characterization by UV-Vis spectroscopy.
5. To study Hydrogen bonding by FT-IR spectroscopy
6. Preparation of metal oxide nanoparticles by microemulsion technique.
7. Characterization of prepared metal oxide nanoparticles by XRD and determination of their size by Scherrer's Equation.

Nanochemistry lab has been designed to introduce the students to the emerging field of nanochemistry through some carefully chosen experiments that collectively illustrate the practice of synthesizing, organizing, visualizing, measuring & utilizing a range of Nanomaterials. The goal being to emphasize the bottom up building block philosophy for making Nanomaterials using the methods of chemical synthesis. The students will also discover the impact of surface structure & composition, surface charge, hydrophilicity /hydrophobicity & functional groups & how these properties control the interaction between building blocks.

TNT 1002: Laboratory-II – Nanomaterials Lab L/T/P: 0/0/3 2Cr

1. To determine the Band-Gap of given Semiconductor Using Four Probe Method from Liquid Nitrogen Temp to Room Temperature
2. To determine the Band-Gap of given Semiconductor Using Four Probe Method From Room Temperature to 100 C
3. Synthesis of at least two different sizes of Nickel Oxide Nano Particles Using Sol-Gel Method
4. Synthesis of at least two different sizes of Copper Oxide Nano Particles Using Sol-Gel Method
5. Synthesis of at least two different sizes of Zinc Oxide Nano Particles Using Sol-Gel Method
6. Determine the Radius of Curvature of Lens using Newton's Ring Method
7. Determine the wavelength of given Laser **,** estimate the slit width using Laser
8. Calculate the diameter of given thin wire using Laser.

Elective

TNM 1007: Numerical methods and computer programming L/T/P: 3/0/0 3Cr

1. **Approximation Methods and Errors:** Accuracy and precision, Truncation and round-off errors. (5)

2. **Roots of Equations**: Bracketing Methods (false position, bisection), Iteration Methods (Newton-Raphson and secant). (5)

3. **Systems of linear algebraic equations:** Gauss elimination, matrix inversion and LU decomposition methods. (5)

4. **Curve fitting:** Least squares regression, Linear, multiple linear and nonlinear regressions, Cubic spline. (5)

5. **Interpolation Methods:** Newton's divided difference and Lagrange interpolating polynomials. (5)

6. **Fourier approximation:** Curve fitting with oscillatory functions, Frequency and time domains, Discrete Fourier and Fast Fourier transforms. (4)

7. **Numerical differentiation and integration:** Divided difference method for differentiation, Newton-Cotes formula, Trapezoidal and Simpson's rules, Romberg and Gauss quadrature methods. (4)

8. **Ordinary differential equations:** Euler's method and its modifications, Runge-Kutta methods, Boundary value and Eigen value problems. (4)

9. **Partial differential equations:** Finite difference equations, Elliptic equations, Laplace's equation and solutions, Parabolic equations, Solution of the heat conduction equation. Finite element method: General approach, Application to 1-dimensional and 2-dimensional problems. (4)

10. **Programming:** Case studies in the form of problems on the topics covered in the course to be introduced as programs in suitable computer languages for implementation on a PC. (4)

REFERENCES:

1. Numerical Mathematical Analysis, J.B. Scarborough, John Hopkins (1966).
2. Introductory Methods of Numerical Analysis, S.S. Sastry, Prentice Hall of India (1983)
3. Numerical Methods for Engineering, S.C. Chapra and R.C. Canale, McGraw-Hill (1989).
4. Numerical Methods for Scientists and Engineers, Prentice Hall of India (1988).
5. Electromagnetics and Calculation of Fields, Nathan P-Ida and J.P.A. Bastos, Springer-Verlag (1992).
6. M.K. Jain, S.R.K. Iyengar and R.K. Jain, Numerical Methods for Scientific and Engineering Computation, Wiley Eastern (1992).
7. Numerical Methods, Software and Analysis, J.H. Rice, McGraw-Hill (1983).

Elective

TBT 1023 : Nano biotechnology L/T/P: 3/0/0 3Cr

Unit I:
Functional Principles of Nanobiotechnology: From Biotechnology to Nanobiotechnology. What is Nanobiotechnology? Information-Driven Nanoassembly, Energetics, Topdown and bottom up approach for building nanomaterials, Chemical Transformation Biomaterials, Machine-Phase Nanobiotechnology

Unit II
Structural Principles of Nanobiotechnology
Construction of Nanomachines, The Raw Materials: Biomolecular Structure and Stability, Protein Folding, Self-Assembly, Self-Organization, Molecular Recognition, Atomicity limits the tolerance of combining sites, Flexibility, Flexibility poses great challenges for the design of , nanobiomachines

Unit III
Nanobiomachines in Action: The Unfamiliar World of Nanobiomachines, Modern nano biomachine using different molecular motors, Biomaterials created by nano particle, Biomaterial supplementing important human body part, Guided Tour of Natural Nanobiomachinery

Unit IV
Biosensors as Precursors of Bioelectronics, Functionalization of Sensing Substrates, Biochip, Nanosensors-Miniaturization of Biosensors, Nanomaterial Based Biosensors. Electron Transfer of Biomolecules, Nanoparticle-Biomaterial Hybrid Systems for Sensing and Electronic Devices, Effect of Biosensor in biological and physicochemical techniques

Unit V
DNA Templated Electronics, Sequence –specific molecular lithography, Single Biomolecule Manipulation for Bioelectronics, DNA as a semiconductor.

Unit VI
Applications of nanobiotechnology in early medical diagnostics, drug targeting, drug delivery, nanosurgery and other biomedical field.

Unit VII
The Future of Nanobiotechnology: A Timetable for Nanobiotechnology, Lessons for Molecular Nanotechnology, Case Studies: Nanotube synthesis; A general nanoscale assembler, Nanosurveillance. Ethical Considerations. Respect for life, Potential dangers.

Books:

1. Niemeyer and Mirkin ed. Nanobiotechnology: concepts, applications & perspectives,
2. Jain, KK. Nanobiotechnology in molecular diagnostics: current techniques and applications

Elective

TNT 1005: Semiconductors Nanostructure & Nano-particle L/T/P: 3/0/0 3Cr

Unit –I Semiconductor nanoparticles: size–dependant physical properties, Melting point, solid-state phase transformations, excitons, band-gap variations-quantum confinement, effect of strain on band-gap in epitaxial quantum dots. The p-n junction and the bipolar transistor; metal-semiconductor and metal-insulator, Semiconductor junctions; field-effect transistors, MOSFETs, CMOS: heterostructures, high-electron-mobility devices, HEMTs, Quantum Hall effect, Introduction to single electron transistors (SETs): quantum dots, single electron effects, Coulomb blockade.

Unit –II Semiconductor nanoparticles Synthesis, Cluster compounds, quantum-dots from MBE and CVD, wet chemical methods, reverse micelles, electro-deposition, pyrolytic synthesis, self-assembly strategies.

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

Unit-IV Semiconductor nanowires, Fabrication strategies, quantum conductance effects in semiconductor nanowires, porous Silicon, nanobelts, nanoribbons, nanosprings.

References:

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

Elective

TPL 1017: Polymer Nanocomposite L/T/P: 3/0/0 3Cr

Unit -1 Definition of nanocomposite, nanofillers, classification of nanofillers, carbon and noncarbon based nanofillers- synthesis and properties of fillers. (5)

Unit-2 Properties of various polymer nanocomposites: Nanotube/Polymer Composites, Layered Filler Polymer Composite Processing- Polyamide Matrices, Polyimide Matrices, Polypropylene and Polyethylene Matrices, Liquid-Crystal Matrices, Epoxy and Polyurethane Matrices, Rubber Matrices. (7)

Unit-3 Synthesis of Nanocomposite: Direct Mixing, Solution Mixing, In-Situ Polymerization, In-Situ Particle Processing Ceramic/Polymer Composites, In-Situ Particle Processing Metal/Polymer Nanocomposites, Modification of Interfaces, Modification of Nanotubes, Modification of Nanoparticles, (7)

Unit-4 Properties of Nanocomposite: Mechanical Properties, Modulus and the Load-Carrying Capability of Nanofillers, Failure Stress and Strain Toughness, Glass Transition and Relaxation Behavior, Abrasion and Wear Resistance, Permeability, Dimensional Stability Contents, Thermal Stability and Flammability, Electrical and Optical Properties, Resistivity, Permittivity, and Breakdown Strength, Refractive Index, Light-Emitting Devices. (7)

Unit-5: Biodegradable polymer nanocomposites, Properties, Biodegradability, Foam processing of biodegradable nanocomposites. Nanocomposites based on water soluble polymers, Crystallization behavior, Overview of nanocomposite structure and crystallization behavior, (6)

Unit-6: Nanocomposites containing functionalized nanoparticles: Organic and polymer materials for light-emitting diodes, Luminescent polymer for device applications, Photo-oxidation of emitting polymers, Nanoparticles approaches to enhance the lifetime of emitting polymers. (6)

Unit-7: Barrier properties of polymer nanocomposites, Permeation and diffusion models relevant to polymer Nanocomposites, Polymer nanocomposites diffusivity, Polymer nanocomposites sorption, Polymer nanocomposites permeability. Wear resisting polymer nanocomposites: preparation and properties, Surface treatment, Composites manufacturing, Wear performance and mechanisms. (7)

Books:

1. Polymer nanocomposites: Edited by Yiu-Wing Mai and Zhong-Zhen Yu, First published 2006, Woodhead Publishing Limited and CRC Press LLC, USA.
2. Nanocomposite Science and Technology: Edited by P.M. Ajayan, L.S. Schadler, P.V. Braun, 2003 WILEY-VCH Verlag GmbH Co. KGaA, Weinheim.

Semester-II

TNT 2101: Characterization of Nanostructures L/T/P: 3/1/0 4Cr

Unit – I: Structural Characterization
X-ray diffraction, Small angle X-ray Scattering, Optical Microscope and their description, Scanning Electron Microscopy (SEM), Scanning Probe Microscopy (SPM), TEM and EDAX analysis, Scanning Tunneling Microscopy (STM), Atomic force Microscopy (AFM).

Unit – II: Spectroscopic characterizations:
Basic concepts of spectroscopy, operational principle and application for analysis of nanomaterials, UV-VIS-IR Spectrophotometers, Principle of operation and application for band gap measurement, Raman spectroscopy

Unit – III: Surface Characterization:
X-ray Photoelectron Spectroscopy (XPS), Auger electron spectroscopy, Low Energy Ion Scattering Spectroscopy (LEISS), Secondary Ion Mass Spectroscopy (SIMS), Rutherford Backscattering Spectroscopy (RBS).

Unit-IV: Resonance Methods
Electron Spin Resonance (ESR), Ferromagnetic Resonance (FMR), Nuclear Magnetic Resonance (NMR), Mossbauer Spectroscopy

Unit-V: Thermal Characterization of Materials:
DTA, TGA, DSC (Principle and Applications), Determination of thermo physical parameters.

Books

1. Elements of X –ray Diffraction, B. D. Cullity
2. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton
3. Thermal Analysis of Materials, Robert F Speyer, New York.

TNT 2003: Nano Photonics L/T/P: 3/0/0 3Cr

Unit I: Foundations for Nanophotonics: Photons and electrons: similarities and differences, freespace propagation. Confinement of photons and electrons. Propagation through a classically forbidden zone: tunneling. Localization under a periodic potential: Band gap. Cooperative effects for photons and electrons. Nanoscale optical interactions, axial and lateral nanoscopic localization. Nanoscale confinement of electronic interactions: Quantun confinement effects, nanoscale interaction dynamics, nanoscale electronic energy transfer. Cooperative emissions.

Unit II: Quantum Confined Materials: Inorganic semiconductors, quantum wells, quantum wired, quantum dots, quantum rings. Manifestation of quantum confinement: Optical properties nonlinear optical properties. Quantum confined stark effect. Dielectric confinement effect, superlattices. Core-shell quantum dots and quantum-dot-quantum wells. Quantum confined structures as Lasing media. Organic Quantum-confined structures.

Unit III: Photonic Crystals: Basics Concepts, Features of Photonic Crystals, wave propagation, photonic bansgaps, light guiding. Theoretical Modeling of Photonic Crystals. Methods of Fabrication. Photonic Crystal Optical Circuitry. Nonlinear Photonic Crystals. Photonic Crystals and Optical Communications. **A**pplication to high efficiency emitters, miniaturized photonic circuits and dispersion engineering. Photonic Crystal Sensors.

Unit IV: Microstructure Fibers: Photonic crystal fiber, photonic band gap fibers (PBG), band gap guiding, single mode and multi mode, dispersion engineering, nonlinearity engineering, devices using crystal fibers.

Unit V: Plasmonics: Metallic nanoparticles, nanorods and nanoshells, local field enhancement. Collective modes in nanoparticle arrays, particle chains and arrays. suface plasmons, plasmon waveguides. Applications of Metallic Nanostructures.

Unit VI: Nanophotonic Devices : Resonant cavity quantum well lasers and light-emitting diodes, , Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavity LED. Microcavity-based single photon sources.

References:

1. Nanophotonics, Paras N Ptrasad, John Wiley & Sons (2004)
2. Photonic Crystals: Towards Nanoscale Photonic Devices; Jean Michel Lourtioz, Springer ; ISBN 354024431X
3. Fundamentals of Photonic Crystal Fibers; Fredric Zolla- Imperial College Press. ISBN 1860945074
4. Photonic Crystals; John D Joannopoulos, Princeton University Press; ISBN 0691037442
5. Photonic Crystals: Modelling Flow of Light; John D Joannopoulos , R.D. Meade and J.N.Winn, Prenceton University Press (1995)
6. The Handbook of Photonics By Mool Chand Gupta, John Ballato

MEC 2073: Nanodevices & Nanosensors L/T/P: 3/0/0 3Cr

Unit-I QUANTUM DEVICES

Quantum Electronic devices – Electrons in mesocopic structures – Short channel, MOS Transistor – split Gate Transistor – Electron wave transistor – Electron spin transistor – Quantum Dot array – Quantum computer- Bit and Qubit. Carbon Nanotube based logic gates, optical devices. . Connection with quantum dots, quantum wires, and quantum wells

Unit-II TUNNELING DEVICES

Tunneling element – Tunnel Effect and Tunneling Elements-Tunneling Diode – Resonant Tunneling Diode – Three -Terminal Resonate Tunneling Devices-Technology of RTD-Digital circuits design based on RTDs - Basics Logic Circuits – Single Electron Transistor(SET) – Principle – Coulomb Blockade- Performance – Technology- Circuit Design- Logic and Memory Circuits – SET adder as an Example of a Distributed Circuit.

Unit-III SUPERCONDUCTING DEVICES AND PHOTONICS

Basics - Macroscopic model- Super conducting switching Devices – Cryotron- Josephson Tunneling Devices- Elementary circuits – Associative or Content – Addressable Memory - SQUID – Flux Quantum device –LC –Gate – Magnetic Flux Quantum – Quantum cellular Automata- Quantum computer with Single Flux devices – SFQD- RSFQD – Application of superconducting devices

Unit-IV NANOSENSORS I

Micro and nano-sensors, Fundamentals of sensors, biosensor, micro fluids, Packaging and characterization of sensors, Method of packaging at zero level, dye level and first level. Sensors for aerospace and defense: Accelerometer, Pressure Sensor, Night Vision System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry,

Unit-V NANOSENSORS II

Sensor for bio-medical applications: Cardiology, Neurology and as diagnostic tool, For other civil applications: metrology, bridges etc. Biosensors. Clinical Diagnostics, generation of biosensors, immobilization, characteristics, applications, conducting Polymer based sensor, DNA Biosensors, optical sensors. Biochips. Metal Insulator Semiconductor devices, molecular electronics, information storage, molecular switching, Schottky devices,

Unit-VI NEMS

Inertial sensors – accelerometer – gyroscope - micromechanical pressure sensors – pizoresistive –capacitive - microrobotics – micro channel heat sinks – optical MEMS – visual display – precision optical platform – optical data switching – RF MEMS – MEMS variable capacitors – MEMS switches – Resonators.

Unit-VII NANOLITHOGRAPHY

Basics of lithography, optical, micro, ion beam lithography, lithographic tools, nanoimprint lithography – polymeric nanofiber templates – focused ion beam doping wet chemical etching – stencil lithography and sacrificial etching – large scale integration – future challenges - applications

Reference:

1. K. Goser, P. Glosekotter and J. Dienstuhl, “Nanoelectronics and Nanosystems-From Transistors to Molecular Quantum Devices” , Springer, 2004.
2. Herve Rigneault, Jean-Michel Lourtioz, Claude Delalande, Ariel Levenson, “Nanophotonics”, ISTE.
3. W.R.Fahrner, “Nanotechnology and Nanoelectronics – Materials, Devices and Measurement Techniques” Springer, 2006

4. Sensors: Micro & Nanosensors, Sensor Market trends (Part 1&2) by H. Meixner.
5. Nanoscience & Technology: Novel structure and phenomea by Ping Sheng (Editor)
6. Nano Engineering in Science & Technology : An introduction to the world of nano design by Michael Rieth.
7. Tai –Ran Hsu, "MEMS & Microsystems Design and Manufacture", Tata McGraw-Hill publication, 2001.
8. P. Rai-Choudhury, "MEMS and MOEMS technology and applications", PHI learning private Ltd, 2009.
9. Mohamed Gad-el-Hak, "The MEMS Handbook", CRC Press, 2002.

TNT 2002: Laboratory-III – Nanomaterials Lab II L/T/P: 0/0/3 2Cr

1. To investigate adsorption of oxalic acid from aqueous solution by activated charcoal and examine the validity of Freundlich and Langmuir adsorption isotherm.
2. Determination of critical micelle concentration of ionic and non-ionic surfactant by surface tension method.
3. Determination of mutual solubility curve of phenol & water, and hence the consulate point. Study the effect of presence of salt to the above system.
4. Preparation of water-in-oil microemulstion and measurement of droplet sizes by Dynamic Light Scattering (DLS).
5. To study the effect of salt & valency of adsorbing ions on particle dispersion stability.
6. Preparation of quantum dot (ZnS) nanoparticles and estimation of band gap from band edge.
7. Preparation of liquid crystals

TNT 2004: Laboratory-IV – Advanced characterization of Nanostructures Lab

L/T/P: 0/0/3 2Cr

1. Synthesize copper oxide nanoparticles by sol-gel method and determine the average size of nanoparticles using Zetasizer.
2. Synthesize nickel oxide nanoparticles by sol-gel method and determine the average size of nanoparticles.
3. Fabricate silver nanoparticles embedded in silica glass by ion exchange method and study surface Plasmon resonance using UV-visible spectroscopy.
4. Fabricate copper nanoparticles embedded in silica glass by ion exchange method and determine the size of nanoparticles using optical absorption spectroscopy.
5. Synthesize silver nanocrystals in solution by citrate reduction method and study the effect of capping using optical absorption spectroscopy.
6. Study the growth kinetics of silver nanoparticles embedded in ion exchanged glass at different temperatures using optical absorption spectroscopy.

Elective

TNT 2005: Nano technology in energy conversion and storage L/T/P: 3/0/0 3Cr

Unit 1. Energy conversion process, indirect and direct energy conversion.

Unit 2. Introduction to physics of semiconductor devices and basis of solar cells, Material aspect of solar cells, High efficiency solar cells, III-IV and II-VI and thin film cells, Tandem, multi junction and stacked solar cells, Solar PV concentrator cells and systems, Advanced solar cell concepts, Solar cell characteristics and characterization.

Unit 3. Nano- , micro-, and poly crystalline and amorphous Si for solar cells, Nano-micro Si composite structure, various techniques of Si deposition.

Unit 4. Conjugated polymers, organic/plastic/flexible solar cells, Polymer composites for solar cells, device fabrication and characterization.

Unit 5. Photovoltaic conversion: Optical effects of p-n junction, design and analysis of PV cells, PV cell fabrication, system design, Aplication of nano semiconductors for PV devices, Dye sensitized solar cells.

Unit 6. Fuel Cells, Polymer membranes for fuel cells, PEM fuel cell. Acid/ alkaline fuel cells, design of fuel cells, Carbon Nanotubes for energy storage, Hydrogen Storage in Carbon Nanotubes, Use of nanoscale catalysts to save energy and increase the productivity in industry, Rechargeable batteries based on nanomaterials, Nanocomposites for electrodes and electrolyte applications.

Text/Reference

1. Solar cells: Operating principles, technology and system applications by Martin A Green, Prentice Hall Inc, Englewood Cliffs, NJ, USA, 1981.
2. Semiconductor for solar cells, H J Moller, Artech House Inc, MA, USA, 1993.
3. Solis state electronic device, Ben G Streetman, Prentice Hall of India Pvt Ltd., New Delhi 1995.
4. Direct energy conversion, M.A. Kettani, Addision Wesley Reading, 1970.
5. Hand book of Batteries and fuel cells, Linden, Mc Graw Hill, 1984.

Elective

TNT 2107: Carbon Nano-Structures and its Functionalisations L/T/P: 3/0/0 3Cr

Unit 1
Diamond, nanodiamond particles, nanodiamond particles synthesis: high pressure high temperature technique, chemical methods, using energetic particles and beam. Applications of nanodiamond particles

Unit 2
Diamond-like Carbon films (DLC), classification of DLC, properties and applications of DLCs: internal stress and adhesion, coating morphology, porosity and diffusional property, DLC/graphite transformation, optical properties, electrical properties, mechanical properties, chemical resistance, tribological properties; deposition techniques of DLC films

Unit 3
Nanocrystalline diamond (NCD) films, pretreatment processes to enhance the nucleation of NCD films, properties and applications of NCD films: tribology, electron emission, electrochemical electrodes, conformal coatings, deposition of NCD films

Unit 4
Carbon nanotube (CNT), structure of CNT, synthesis of CNT, electronic, vibrational, mechanical and optical properties of CNT; applications of CNT. fabrication of Fullerene (C_{60}).

Unit 5
Functionalization of Carbon Nanotubes: covalent functionalization of CNTs, non covalent functionalization of CNTs; modification of CNTs via mechnochemical reactions, electrochemical deposition, electroless deposition; plasma activation of CNTs;

Text book:

1. Intoduction to Nanotechnology- Charles P Poole & Frank J. Ownes.
2. Diamond-like Amorphous Carbon – J Robertson, Materials Science and Engineering R 37 (2002) 129-281.
3. Ultrananocrystalline Diamond: Synthesis, Properties, and Applications - Olga A. Shenderova, Dieter M. Gruen William Andrew Publishing Norwich, New York, U.S.A.
4. Physical properties of Carbon Nanotube-R Satio
5. Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport Devices - S.
6. Subramony & S.V. Rotkins
7. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell
8. CARBON NANOTECHNOLOGY- Liming Dai
9. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing
10. Nanoscale materials -Liz Marzan and Kamat

Elective

TPL 2021: Colloid & Interface Science L/T/P: 3/0/0 3Cr

Unit 1: Introduction to colloidal material, surface properties, origin of chargeon colloidal particles, preparation & characterization of colloidal particles. Applications of……..….oil recovery, super hydrophilic surfaces, self cleaning surfaces. (5)

Unit 2: Surfactants type (Anionic, cationic, Zwitterinic, Gemini and non-ionic). Theory of surfactants. CMC. Kraft temperature. Phase behavior of cone surfactant systems, surfactant geometry and packing. Emulsions, Microemutsions & Gels. (7)

Unit 3: Intermolecular Forces, Van der Waals forces (Kessorn, Debye, and London Interactions). Potential energy curve, Brownian motion and Brownian Flocculation. (6)

Unit 4: Surface and interfacial Tension, Sessile drop, pendant drop, Surface free energy, Surface tension for curved interfaces, Surface excess and Gibbs equation. (5)

Unit 5: Contact angle, Wetting Young-Laplace equation, Dynamic properties of interfaces . Surface viscosity, Kelvin equation. (7)

Unit: 6: Electrical phenomena at interfaces (Electronic kinetic phenomena, Electric double layer, short range forces). DLVO theory, capillary hydrostatics, interfacial hydrodynamics, marangonic effect. (7)

Unit: 7: Measurements technique: Surface tension, Interfacial Tension, Contact angle, Zeta potential , Particle size & its distribution. Electro osmosis phenomena, Streaming potential, Electro viscous flows. (8)

Books:

1) A.W. Adamson and A.P Gast, Physical Chemistry of surfaces, Wiley Interscience , NY 2004.
2) P.C Hiemen and R.Rajgopalam, Principle of colloid and surface Chemistry NY Marcel Dekker, 1997.
3) D.J.Shaw, Colloid and surface chemistry, Butterworth Heineman, Oxford,1992.
4) M J Rosen, Surfactant and Interfacial phenomena, Wiley Inter Science Publication, NY 2004
5) Jacob Israelachvilli, Intermolecular and Surface Forces, Academic Press, NY 1992.

Elective

SAC3011: Molecular Modeling & Computational Chemistry L/T/P: 3/0/0 3Cr

Unit 1: Introduction about the computational chemistry and molecular modeling, Coordinate systems, Concept of 2D and 3D structure, molecules, Surfaces, Molecular energetic profile, Brief idea about the computational software's for drawing, visualization and simulation of small and large molecules. Basic concept of Chemoinformatics, 3D-Structure file system and Databases.

Unit 2: Brief introduction about Quantum Mechanics & Molecular Mechanics, Molecular Orbital Theory, The Hartree-Fock method, ab-initio calculation, Semi-empirical methods, Huckel theory, Valence bond theories, Force Field, Geometrical Parameters, Non-covalent Parameters: understanding of electrostatic interactions, van der Waals interaction, Hydrogen bonding, hydrophobic interactions,; application of quantum mechanics and molecular mechanics in drug design.

Unit 4: Computer simulation methods: Minimization, Molecular dynamics, Monte Carlo Simulations, Simulated Annealing, Conformational Search and Conformational Analysis, Understanding of iterations, convergence, protocols and algorithm such as steepest descents, conjugate gradient etc.,

Unit 6: Quantitative Structure Activity Relationship (QSAR): Mathematical parameters or descriptors: Lipophilicity, Electronic and Steric factor, Mathematical Models based on physicochemical relations: Hammett equations, Taft Equation and Linear Free Energy Relationship (LFER), Hansch Equations and Hansch analysis, mixed approach, Other QSAR Approaches

Unit 5: Structure-Based Drug Design: Protein Structure preparation, Ligand structure preparation, Homology modeling, Molecular docking, Induced Fit Docking, Scoring

Unit 7: Drug like properties and its *in-silico* prediction: Lipinski Rule, Drug-like properties, Understanding of the biological activity parameters such as K_i, K_d, LD_{50}, EC_{50}, IC_{50}, CC_{50}, ADMET. Brief introduction about the computational software for the prediction of drug like properties.

Text Books:

1. Computational Chemistry, Introduction to Theory and Application of Molecular and Quantum Mechanics. By Errol Lewars, Springer
2. Molecular Modelling : Principle and Application, 2nd Ed. By Andrew R. Leach, Addison-Wesley Longman Ltd, (February 2001) ISBN: 0582382106.
3. Guidebook on Molecular Modeling in Drug Design, J. G. Vinter, Mark Gardner (Editor), CRC Press (May 1994) ISBN: 084937772.

Elective

MEC 2019: Micro Electro Mechanical Systems L/T/P: 3/0/0 3Cr

Unit-1: MEMS Fabrication processes: Introduction**,** MEMS Overview, Microfabrication of MEMS: Surface Micromachining, Bulk Micromachining, LIGA, micromachining of polymeric MEMS devices, Three-dimensional micofabrications.

Unit-2: MEMS Actuators and Sensor: Electromechanical transducers: Piezoelectric transducers, Electrostrictive transducers, Magnetostrictive transducers, Electrostatic actuators, Electromagnetic transducers, Electrodynamic transducers, Electrothermal actuators, comparison of electrothermal actuation process, Microsensing for MEMS: Piezoresistive sensing, Capacitive sensing, Piezoelectric sensing, Resonant sensing, Surface Acoustic Wave sensors.

Unit- 3: MEMS Materials and Fabrication techniques: Metals, semiconductors, thin films for MEMS and their deposition techniques, materials for polymer MEMS, Bulk micromachining for silicon based MEMS, Silicon surface micromachining, Microstereolithography for polymer MEMS.

Unit-4: MEMS Switches and Micro relays: Switch parameters, basics of switching, Switches for RF and microwave applications, actuation mechanisms for MEMS devices, bistable micro relays and microactuators, dynamics of switch operation, MEMS switch design considerations, modeling and evaluation.

Unit- 5: MEMS Inductors and Capacitors: MEMS Micromachined passive elements: pros and cons, MEMS Inductors: self and mutual inductance, micromachined inductors, reduction of stray capacitance, improvement of quality factor, folded inductors, modeling and design issues of planar inductors, variable inductor and polymer based inductor. MEMS Capacitors: MEMS gap tuning capacitor, MEMS area tuning capacitor, Dielectric Tunable capacitors.

Unit- 6: MEMS packaging: MEMS packaging: Role of MEMS packaging, Types of MEMS packaging, flip-chip and multichip Unit packaging, RF MEMS packaging issues.

Unit-7: MEMS RF applications: Micromachined transmission line and components, micromachined RF Filters, Micromachined Phase shifters, and Micromachined antenna, Gyros and Bio-MEMS.

References:

1. RF MEMS: Theory, Design, and Technology, Gabriel M. Rebeiz, John Wiley & Sons, 2003.
2. RF MEMS & Their Applications by Vijay K. Varadan, K. J. Vinoy and K. A. Jose John Wiley & Sons, 2003.
3. RF MEMS: Theory, Design, and Technology, Gabriel M. Rebeiz, John Wiley & Sons, New Jersey, 2003. ISBN 0-471-20169 - 3
4. RF MEMS & Their Applications by Vijay K. Varadan, K. J. Vinoy and K. A. Jose John Wiley & Sons, Chichester, 2003. ISBN 0-470-84308 - X
5. Tai-Ran Hsu, “MEMS and Microsystems: Design and Manufacture,” McGraw- Hill, 1st edition, ISBN: 0072393912.

Breadth Paper of PG level of other Department

*** Should not have been taken earlier by the student in any other programme**

Semester- III

TNT 3002: Project **Credit: 15**

Semester- IV

TNT 4002: Project work **Credit:20**