ACADEMIC CURRICULA

UNDERGRADUATE/ INTEGRATED POST GRADUATE DEGREE PROGRAMMES

(With exit option of Diploma)

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 19

(Syllabi for Nanotechnology Programme Courses)

Revised on July 2024

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

Engineering Science Course

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21NTS201T	**Course Name**	MATERIALS SCIENCE	**Course Category**	S	ENGINEERING SCIENCE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the structure of crystalline materials*
CLR-2:	*gain knowledge on the basics of material structures, properties and strength of materials*
CLR-3:	*gain knowledge on ceramics, polymers, copolymers and non-crystalline materials*
CLR-4:	*acquire knowledge on polymer nanocomposites, biomaterials, catalytic materials and corrosion and degradation of materials*
CLR-5:	*introduce the working principle of various characterization techniques*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*acquire the knowledge on structure of crystalline materials*	*3*	-	-	2	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*acquire the ability to identify engineering problems using plastic deformation, fatigue, fracture and creep of materials*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*understand the basic ideas about ceramics, polymers and non-crystalline solid*	*3*	-	-	2	-	-	-	-	-	-	-	-	-	2	-
CO-4:	*appreciate the concepts of reinforced matrix interface, corrosion parameters and uses of various nanocomposite*	*3*	2	-	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*apply the knowledge for structural and spectroscopic characterization of materials*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	*3*

Unit-1 - Structure of Crystalline Materials	***9 Hour***
Introduction to materials-crystalline and amorphous- Single crystalline and polycrystalline Materials- Concept of basis and lattice, Lattice translational vectors- Primitive cell and Bravais lattice- Seven types of Bravais lattices- Symmetry operations in crystals- Rotational and translational symmetry- Point and Space groups- Indexing of crystal planes- Miller indices -directions and planes- Various planes in cubic structure- Directions in cubic structure- Packing of atoms inside solids- packing fraction calculation- Ionic solids-NaCl crystal structure- Hexagonal close packed (HCP) structure- Estimation of packing fraction in HCP- Diamond structure-APF- Cubic Zinc-Sulfide structure	
Unit-2 - Defects and Material Properties	***9 Hour***
Imperfections in solids: point defects- Equilibrium concentration of vacancies- Interstitial impurities in solids- Substitutional impurities in solids- Line defects: edge dislocations- Screw dislocations- Surface and volume imperfections- Interfacial defects, stacking faults- Elastic properties-Hooke's law- Yield strength- Tensile strength- Ductile and brittle materials- Stress strain behavior of metals- Stress strain behavior of ceramics and Polymers- Tensile test, plastic deformation- Concept of necking- FatigueCreep behavior	
Unit-3 - Non-Crystalline Materials, Ceramics, Polymers and Copolymers	***9 Hour***
Semi-crystalline materials: introduction and classification- Structure and configuration of ceramics- Advanced ceramics-functional properties- Mechanical behavior of ceramics-flexural strength- Fabrication and processing of advanced ceramicsApplications of advanced ceramic materials- Glass ceramics-introduction- Glass forming and glass tempering- Polymers-classification- Thermoplastic and thermosetting polymers-Mechanical behavior of polymers- macroscopic deformati- Polymer synthesis-addition and condensation polymerization- Concept of copolymers- Applications of polymers- Types of liquid crystals- Construction and working of LCD- Non-crystalline materials-metallic glass- Glass transition-melting and glass transition temperature	

Unit-4 - Polymer Nanocomposites, Biomaterials, Catalytic Materials	***9 Hour***
Introduction to composites- Classification of composites- Polymer nanocomposites materials- Polymer-matrix composites- Fiber-reinforced composites- Metal-matrix composites- Ceramic-matrix composites- Carbon–carbon composites- Degradation of polymers- Recycling of polymers- Corrosion of metals, forms of corrosion- Corrosion prevention- Biomaterials-introduction- Classification of biomaterials- Surface properties of biomaterials- Mechanical properties of biomaterials- Catalytic biomaterials – silica, enzymatic Hydrogels- Applications of biomaterials	
Unit-5 - Materials Characterization Tools	***9 Hour***
Introduction to experimental techniques- X-Ray Diffraction (Single Crystal method- Scanning Ion Conductance Microscopy- principle- Scanning Ion Conductance Microscopy- construction and working- Molecular and spectroscopic analysisintroduction- FTIR spectroscopy- Concept of Raman spectroscopy- Raman spectroscopy- instrumentation- XPS spectroscopy-concept- XPS spectroscopy- instrumentation- Introduction to Nuclear Magnetic Resonance (NMR)- Nuclear Magnetic Resonance (NMR)- Instrumentation- Introduction to Thermal analysis- Differential Thermal Analyses (DTA)- Differential Scanning Calorimetry (DSC)- Dynamic light scattering- Particle Size Analysis	

Learning Resources	*1. V. Raghavan, Materials Science and Engineering: A First Course, 5th ed., Prentice Hall India, 2004.* *2. WilliamD.Callister,MaterialsScienceandEngineering,AnIntroduction,JohnWiley&Sons,2007*	*3. Kingery,W.D.,BowenH.K.,Uhlmann,D.R.,IntroductiontoCeramics,2nded.,JohnWiley&Sons,1976.* *4. Upadhyaya and A. Upadhyaya, Material Science and Engineering, Anshan Publications,2007*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Narayanasvamy Vijayan, National Physical Laboratory, nvijayan@nplindia.org	*1. Prof. V. Subramaniam, IITM Chennai, manianvs@iitm.ac.in*	*1. Dr. C. Preferencial Kala, SRMIST*
2. Dr. M. Krishna Surendra, Saint-Gobain Research, Chennai, krishna.muvvala@saint-gobain.com	*2. Prof. D. Arivuoli, Anna University, arivuoli@annauniv.edu*	*2. Sandeep Kumar Lakhera, SRMIST*

ACADEMIC CURRICULA

Professional Core Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu,
India

Course Code	21NTC201J	**Course Name**	NANOSCALE MATERIALS CHEMISTRY	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the role of chemistry in nanoparticle synthesis*
CLR-2:	*enhance knowledge about Symmetry and lattice parameters*
CLR-3:	*acquire knowledge about size effects, reaction kinetics and phase properties at nanoscale*
CLR-4:	*improve their ability in understanding and explore the subject to nanostructures and nanosystems*
CLR-5:	*enhance knowledge about the various nano-synthesis techniques, Utilize the knowledge of processing in nanochemistry*

		Program Outcomes (PO)												**Program Specific Outcomes**		
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*develop their ability in understanding the behavior of nanomaterials based on its chemistry Demonstrate symmetry, point groups and its application in lattice determination*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*evaluate the classifications and nomenclature of nanomaterials*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-3:	*define the existence of surface and their significance in explaining various systems and evaluate the classifications and properties of surfactants*	*3*	*1*	*2*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-4:	*demonstrate the mechanisms involved behind the different chemical routes involved in the synthesis of nanomaterials*	*3*	*1*	*2*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-5:	*develop their ability in understanding the behavior of nanomaterials based on its chemistry Demonstrate symmetry, point groups and its application in lattice determination*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Chemistry of Nanoparticles Synthesis ***15 Hour***

Chemical bonding and surface properties: Introduction to chemical bonding - Atomic bonding, types of bond: metallic, ionic bond - Covalent and Vander Waals bond - Surface energy, chemical potential as a function of curvature - Electrostatic stabilization - Surface charge density - Electric potential at the proximity at solidsurface - Vander Waals attraction potential - DLVO theory and steric stabilization - Influence of kinetic energy on the surface of nanomaterials. 1. Introduction to the basics of laboratory, 2. Synthesis of silica nanospheres using stober's method, 3. Synthesis of gold nanoparticles by chemical reduction Determination of absorption coefficient using UV-Vis spectrometer

Unit-2 - Symmetry and Lattice Parameters ***15 Hour***

Materials Structure and Features of Nanoscale Growth: Space lattice and unit cells, crystal system, symmetry operation - Structures of common metallic, semiconductor ceramic and superconductor materials - Miller indices, representation of directions - Planes packing fractions, structure determination using X-raydiffraction - Silicates and clay structures, glass transition temperature - Non-crystalline materials, imperfections in nanostructured materials - Specific features of nanoscale growth , size control, triggering the phase transition - Application to solid nanoparticles controlling nucleation , controlling growth -controlling aggregation, stability of colloidal dispersions - breaking matter into pieces. 1. Synthesis of ferro fluids using chemical precipitation, 2. Synthesis of metal oxide nanoparticles using sol-gel technique and crystallite size measurement by XRD, 3. Synthesis of zinc sulfide quantum dot using co-precipitation method

Unit-3 - Size Effects and Reaction Kinetics ***15 Hour***

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

Nanoparticles - structure, types of NP - analytical methods (Extraction and isolation, Separation, Characterization and Imaging) - general method of preparation, properties, detection, and characterization of organic nanoparticles - cyclodextrine, polysaccharides. Nanocochleates, Prospects and Future Challenges. 1. Synthesis of photocatalytic solution using co-precipitation method, 2. Repeat/Revision of experiments, 3. Synthesis of nanoparticles loaded polymer fibers using electrospinning technique and study of surface morphology using SEM	
Unit-4 - Surface and its Properties	***15 Hour***
Surface Nanoscience and Chemistry aspects: Intermolecular Forces, Van der Waals forces (Kessorn, Debye, and London Interactions) - Dynamic properties of interfaces - Contact angle - Brownian motion - Brownian Flocculation - Surface active agents - Theory and applications - Types of surfactants – Anionic, cationic, zwitterionic& non-ionic - synthesis of surfactant - CMC – Effect of chemical structure, temperature; Kraft temperature; Emulsions & gels surfactant geometry and packing - Photochemistry and Electrochemistry of nanomaterials –Ionic properties of nanomaterials- Nanocatalysis - Nanoscale heat transfer - Electron transport in transition metals and semiconducting nanostructure. 1. Low temperature synthesis of metal nanoparticles, 2. Preparation of nanoparticles using sonochemical method, 3. Fabrication of polymer membrane using phase inversion technique and characterization using scanning electron microscope (SEM) technique	
Unit-5 - Various Chemical Synthesis Routes	***15 Hour***
Chemical synthesis: Introduction to different synthesis route of nanoparticles - Overview on precipitative methods - Chemical precipitation and co-precipitation methods to synthesize nanomaterials - Chemical reduction method to synthesize metallic nanocrystals - Metathesis to prepare nanoparticles - Steps involved in Sol-gel synthesis - Reaction mechanisms: Hydrolysis and Polycondensation - Introduction to micelles, reverse micelles, and microemulsions - Synthesis of nanomaterials using microemulsion route - Preparation of inorganic nanomaterials using hydrothermal and solvothermal routes - Preparation of arrays of oxide nanocrystals using thermolysis route - Microwave heating assisted synthesis of nanomaterials - Sonochemical synthesis of nanometals - Core-shell synthesis of semiconductor nanocrystals - Electrochemical synthesis of nanoparticles - Photochemical synthesis of nanoparticles, 1. Synthesis of iron oxide nanoparticles using precipitation method, 2. Microwave assisted polymerization synthesis of ZnO nanowires, 3. Hydrothermal synthesis of ZnS Nanorods: Nanorods formation by SEM analysis	

Learning Resources	1. *Peter Atkins, Julio de Paula, Atkins' Physical Chemistry, seventh edition, Oxford University Press (2004)* 2. *C. N. Rao, A. Muller, A. K. Cheetham, "Nanomaterials chemistry", Wiley-VCH ,2007* 3. *A.W. Adamson and A.P.Gast, Physical Chemistry of surfaces, Wiley Interscience, NY 2004.*	4. *Guozhong Cao, Ying Wang, "Nanostructures and Nanomaterials: Synthesis, Properties, and Applications", World Scientific, 2011* 5. *C. Brechignac, P. Houdy, M. Lahmani, "Nanomaterials and Nanochemistry", Springer publication ,2007* 6. *Kenneth J. Klabunde, "Nanoscale materials in chemistry", Wiley Interscience Publications ,2001*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	*-*	*-*	*20%*	*20%*	*-*
Level 2	*Understand*	*20%*	*-*	*-*	*20%*	*20%*	*-*
Level 3	*Apply*	*40%*	*-*	*-*	*40%*	*40%*	*-*
Level 4	*Analyze*	*20%*	*-*	*-*	*20%*	*20%*	*-*
Level 5	*Evaluate*	*-*	*-*	*-*	*-*	*-*	*-*
Level 6	*Create*	*-*	*-*	*-*	*-*	*-*	*-*
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. C. Suresh, CSIR-Central Electro Chemical Research Institute, Karaikudi-630003, India csuresh@cecri.res.in*	1. *Dr.S. Easwaramoorthi, Senior Scientist, Inorganic & Physical Chemistry, CLRI Adayar moorthi@clri.res.in,*	1. *Dr. N.Angeline Little Flower, SRMIST*
2. *Dr. P. Sudhakar, CLRI – CSIR, Jalandhar, sudhakarp@clri.res.in*	2. *Dr.Arthanreeswaran, NIT, Trichy, arthanreeg@nitt.edu*	2. *Dr. Venkata Ravindra, SRMIST*

Course Code	21NTC202T	**Course Name**	QUANTUM MECHANICS FOR NANOTECHNOLOGISTS	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*utilize the concept of old and new Quantum Mechanics*
CLR-2:	*analyze the bound and scattering states*
CLR-3:	*utilize quantum physics behind applications - Nano dimension*
CLR-4:	*solve the many body problems using various assumptions*
CLR-5:	*identify the implications of quantum theory and approximations at Nano scale*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*explain the need for developing quantum mechanics and basics; basic non-relativistic quantum mechanics; solve time-dependent and time-independent Schrödinger equation for simple potentials*	*2*	-	-	2	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*apply principles of quantum mechanics to calculate observables on known wave functions; Solve time-dependent and time-independent Schrödinger equation for simple potentials*	2	-	-	*3*	-	-	-	-	-	-	-	-	2	-	-
CO-3:	*combine spin and angular momenta*	2	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-4:	*apply the variational method, time-independent perturbation theory and time-dependent perturbation theory to solve simple problems*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*critically evaluate and interpret cross sections, classical and quantal approaches to scattering, and the relevant aspects of atomic and nuclear structure*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-

Unit-1 - Quantum Mechanics in Nanotechnology	***9 Hour***
Importance of quantum mechanics in nanotechnology, Failures of classical mechanics, Basic ideas of quantum mechanics, wave particle Duality- Heisenberg uncertainty principle- Generalized Heisenberg uncertainty principle- Ehrenfest theorem- Linear vector space- Hilbert space- Statistical interpretation, stationary states- Orthogonal wave function- Normalization of wave function- Hermitian operator- Properties of Hermitian operator- Commutation- Energy eigen value equation- Boundary condition of wave function- Schrödinger's time dependent wave Equations- Schrödinger's time independent wave Equations- Schrödinger's representation- Heisenberg representation, interaction picture	
Unit-2 - Bound and Scattering States	***9 Hour***
Classical interpretation of scattering state- Quantum interpretation of scattering State- Reflection of particles (wavefunction)- Transmission of Particles (wavefunction)- Rectangular potential barrier (E<V0): quantitative- Rectangular potential barrier (E>V0)- Transmission probability plot as a function of energy ofparticle- Numericals in rectangular potential barrier- Tunneling effect- Relation of tunneling with nanotechnology- Alpha-particle emission- Failure of Classical Mechanics to explain Alpha-particle emission- Derivation on Alpha-particle emission- Numericals in particle emission- Resonant tunneling- Applications of resonant tunneling- Negative differential resistance- Negative differential resistance in 2D materials	
Unit-3 - Quantum Physics Applications- NanoDimenstion	***9 Hour***
Energy eigen functions and eigen values with precession coordinates- Infinite well potential in one dimension- Numericals on infinite well potential in one and three dimensions- Quantum confinement effect in nanoscale- Finite Well Potential, Delta potential- Eigen values, Schrödinger equation in spherical coordinates- Angular equation- Introduction on radial equation- Derivation of radial equation- Infinite spherical well-Numerical on infinite spherical well- Ground state properties of hydrogen atom- Angular momentum (Lx,Ly,Lz)- Angular momentum (Lx,Ly,Lz) in spherical coordinate- Generalized angular momentum (Jx,Jy,Jz), Eigen values- Eigen values of momentum operator- Spin ½, spin for two particle system- Role of spin in nanospintronics	

Unit-4 - Solving Many Body Problems	***9 Hour***
Principle of variational method- Proof of variational method and Implementation- Energy eigen value in case of time independent perturbation theory for non- degenerate energy levels- Energy eigen value in case of time independent perturbation theory for non- degenerate energy levels (quantitative approach)- Eigen function in case of time independent perturbation theory for non-degenerate energy levels- Eigen function in case of time independent perturbation theory for non-degenerate energy levels(quantitative approach)- Energy eigen value in case of Time independent perturbation theory for degenerate energy levels- Quantitative approach of energy eigen value in case of Time independent perturbation theory for degenerate energy levels- Eigen function in case of time dependent perturbation theory for two-level systems- Quantitative approach of eigen Function in case of Time dependent perturbation theory for two-level systems- Sinusoidal perturbations- Sinusoidal perturbations (quantitative approach)- Incoherent perturbation- Role of incoherent perturbation- Transition rate- Transition rate role is perturbation- Adiabatic approximations (elementary concepts)- Sudden approximations (elementary concepts)	
Unit-5 - Implications of Quantum Theory and Approximations at Nano scale	***9 Hour***
Two particle system's Schrödinger Equation- Derivation of two particle system's Schrödinger equation- Transformation to center of mass frame from laboratory frame- Exchange operator- Symmetrization of wave function- Antisymmetric wave function- Bosons and Fermions- Exchange forces- Solids, free electron gas- Band structure of solids- Quantum scattering theory- Applications in nanotechnology- Overall role and implication of quantumphenomena in nanotechnology (Low-Dimensional Quantum Systems, properties of quantum dots, Mesoscopic systems and disorder in them, Kondo effect, Graphene)	

Learning Resources	*1. G. Aruldhas, Quantum Mechanics, 2nd ed., PHI, 2013* *2. David J. Griffiths, Introduction to Quantum Mechanics, 2nd ed., Pearson, 2009*	*3. Ajoy Ghatak, S. Lokanathan, Quantum Mechanics, 6th ed., Macmillan, 2009* *4. Bransden B.H., Joachain C.J. Quantum Mechanics, 2nd ed., Pearson, 2000*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Noriaki Terakubo, Jgc Corporation, Japan, terakubo.noriaki@jgc.co.jp	*1. Dr. Uday Narayan Maiti, IITG Guwahati, udaymaiti@gmail.com*	*1. Dr. Kiran Mangalampalli, SRMIST*
2. Mr. R. Seshadri, TITAN Company Limited, seshadri@titan.co.in	*2. Dr. Noejung Park, Ulsan National Institute of Science and Technology,noejung@unist.ac.kr*	*2. Dr. Debabrata Sarkar, SRMIST*

Course Code	21NTC203T	**Course Name**	THERMODYNAMICS AND STATISTICAL MECHANICS	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
CLR-1:	*utilize the basic principles and laws of thermodynamics*	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CLR-2:	*identify the thermodynamic properties of pure substances and different kinds of equilibrium*															
CLR-3:	*utilize the concept of ensembles and classical statistics*															
CLR-4:	*analyze the concepts of quantum statistics*															
CLR-5:	*analyze the principles of Nano thermodynamics, Apply the concepts of non-equilibrium thermodynamics to Nano scale systems*															
Course Outcomes (CO):	***At the end of this course, learners will be able to:***															
CO-1:	*describe various thermodynamic processes and concepts explained by laws*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-2:	*analyze the concepts of enthalpy, entropy, chemical potential, fugacity*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*describe the postulates of statistical mechanics*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*enumerate on Bose-Einstein condensation and Fermi gas*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*describe the concept of Hill's Nano thermodynamics, Analyze the fluctuations in small systems*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Basic Principles and Laws Principles and Laws of Thermodynamics ***9 Hour***

Properties of a thermodynamic system- concept of system and boundaries - Concept of continuum - Thermodynamic equilibrium - Path and point functions - Extensive and intensive properties - Zeroth law of thermodynamics and concept of temperature - Energy transfer by heat and work - Isothermal process - Adiabatic process - Isochoric process - Isobaric process - First law of thermodynamics - Specific Heat at constant Pressure and constant volume - Second law of thermodynamics - Reversibility, irreversibility and Carnot cycle - Reversed Carnot Cycle as a refrigeration cycle- Third law of thermodynamics - Unattainability of absolute zero.

Unit-2 - Thermodynamic Properties and Equations ***9 Hour***

Thermodynamic properties of pure substances in solid, liquid, vapor phases - Phase diagrams of a pure substance - Gibb's phase rule - Different kinds of equilibrium - Entropy and energy criteria for equilibrium - Ideal gas equation of a state - Deviation from ideal gas behavior - VanderWaal's equation of state – Law of corresponding states - Determination of critical constants - Temperature and entropy (T-dS) relations - Helmholtz Function Gibbs Function - General Thermodynamic equations - Joule-Thomson coefficient - Co-efficient of volume expansion - Adiabatic and isothermal compressibility - Clapeyron equations - Clapeyron-Clausius equations.

Unit-3 - Ensembles and Classical Statistics ***9 Hour***

Fundamentals of statistical physics- microscopic approach - Concept of phase space - Concept of gamma space and μ space - Volumes in phase space - Difference between microstate and macrostate - Most probable distribution - Equal apriori probability and ergodicity - Ensemble averages - Derivation of Boltzmann equation S=KlnW - Thermodynamics of Ensembles - Canonical Ensemble and its thermodynamic parameters - Microcanonical Ensemble and its thermodynamic parameters - Stirling Approximation - Classification of statistical distributions - Maxwell-Boltzmann distribution for classical particles - Concept of degrees of freedom - Law of equipartition of energy - Specific heat capacities of gases.

Unit-4 - Concepts of Quantum Statistics	***9 Hour***
Quantum statistics for identical particles - Distinguishable and indistinguishable particles - Grand canonical ensemble - Determination of Gibbs factor - Photons in an oven - Principle of detailed balance - Energy flux - Structureless Bose gas - Bose Einstein distribution law for bosons - Bose-Einstein condensation - Observation of BECs of cold atoms - Superfluid liquid helium - Fermi gases for electrons - Fermi energy - Fermi Dirac distribution law for fermions - Fermions at low temperatures – Comparison of 3 statistics	
Unit-5 - Thermodynamics for Nano systems	***9 Hour***
Thermodynamics of small systems and Gibbs equation for nanosystems - Features of Hill's nanothermodynamics - Comparison with classical equilibrium thermodynamics - Nanoensemble and its thermodynamic parameters - Gibbs energy of single-component nanoparticles - Fluctuations in small systems - Jarzyanki's inequality - Classical nucleation thermodynamics - Phase diagrams of small systems - Thermodynamics of metastable phase nucleation at the nanoscale - Nanoscale thermodynamic approach in CVD diamond - Nucleation thermodynamics of cubic boron nitride - Nonextensivity of nanosystems - Nonintensivity of nanosystems - Principles of non-equilibriumThermodynamics - Concept of Pseudo equilibrium - Self organization – Benard cells	

Learning Resources	*1. Keith Stowe, "An Introduction to Thermodynamics and Statistical Mechanics", Cambridge University, New York, 2007* *2. Richard E.Sonntag, Gordon J.VanWylen, "Introduction to Thermodynamics, Classical and Statistical", Wiley Publishing, 2010*	*3. Yunus. A.Cengel, Michael Boles, "Thermodynamics-An Engineering Approach", Tata McGraw Hill, New Delhi, 2008* *4. Pathria, R. K., Statistical Mechanics, Oxford: Pergamon Press, 1972*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	*1. Prof. V. Subramaniam, IITM, Chennai, manianvs@iitm.ac.in*	*1. Dr.R.Annie Sujatha, SRMIST*
2. Dr. C. Suresh, CSIR-Central Electro Chemical Research Institute, Karaikudi-630003, India csuresh@cecri.res.in	*2. Prof. C. Venkateswaran, Univ. of Madras, cvenkateswaran@unom.ac.in*	*2. Dr.Bhaskar Behera, SRMIST*

Course Code	21NTC204J	Course Name	ADVANCED CHARACTERIZATION OF NANOMATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*utilize the concepts of optical imaging and characterize nanomaterials*
CLR-2:	*analyze morphology and elements of nanomaterials using SEM and ED's technique*
CLR-3:	*analyze nanomaterial TEM, RHEED, LEED, XRD*
CLR-4:	*apply the broad range of application of SPM techniques in nanotechnology*
CLR-5:	*asses the advanced techniques XPS, AES and SIMS for solving problems in materials science and engineering, Demonstrate skills in the use of advanced experimental techniques*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*explain the principles of optical imaging and perform microstructural analysis*	*3*	-	*3*	*2*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*describe the construction and operation of SEM and EDS characterization techniques and analyze morphology and elements of a nanomaterial*	*3*	-	*3*	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*explain the construction and operation of TEM, XRD, RHEED, and LEED*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*explain the construction and working of SPM techniques and characterization of nanomaterials*	*3*	-	*3*	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*describe the working principles of XPS, AES and SIMS techniques, Apply the skills acquired for advanced experimental characterization*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Optical Imaging Techniques for Nanomaterials Characterization ***15 Hour***

Image formation, numerical aperture, resolution, effective magnification, Brightness and contrast, depth of field, aberrations, Instrumentation: illumination system, objective lens and eyepiece, Steps for optimum resolution, steps to improve depth of field, Imaging modes: bright-field and dark-field imaging, Kohler illumination, Phase-contrast microscopy, The behavior of waves from phase objects in brightfield microscopy, Properties of polarized light, Polarized-light microscopy, Differential interference contrast microscopy and modulation contrast microscopy: DIC optical system, Modulation contrast microscopy, Physical basis of fluorescence, Fluorescence microscopy, Confocal laser scanning microscopy: the optical principle of confocal imaging, Techniques for improving imaging of nanoscale materials, Diffraction limit, Breaking the diffraction limit

Lab 1: Introduction to the basics of laboratory, Lab 2: Optical microscope-based investigation of microfabricated structures, Lab 3: Bioimaging using fluorescence microscopy

Unit-2 - Scanning Electron Microscopy and Compositional Analysis of Nanomaterials ***15 Hour***

Scanning electron microscopy, electron optics, imaging with electrons, Magnetic and electrostatic lenses, Signal detection Detector, Probe size and current, Electron–specimen interactions, Topographic contrast, Compositional contrast, working distance and aperture size, Acceleration voltage and probe current, Astigmatism, Specimen preparation, Elemental imaging using EDS, Applications of elemental imaging, Field emission SEM, Environmental SEM, Time resolved microscopy and Applications

Lab 4: Morphological study of nanostructured material using SEM, Lab 5: SE and BSE imaging with SEM, Lab 6: EDS for chemical identification

Unit-3 - Anaysis of Nanomaterials Using Transmission Electron Microscopy and Diffraction Tools ***15 Hour***

TEM imaging system, Instrumentation of TEM, Electron sources, Specimen stage and specimen preparation, Kinematics of scattering by nucleus, Electron – electron scattering, Image modes: Mass–density contrast, Diffraction contrast, phase contrast Selected-area diffraction (SAD) and characteristics, Single-crystal diffraction, polycrystalline diffraction, Dark field images, Phase control, High resolution images, Interpretation of

high-resolution images, Ultrahigh resolution TEM, Dynamic TEM, z-contrast imaging, Coherent and incoherent imaging, Reflection High Energy Diffraction (RHEED), Low Energy Electron Diffraction (LEED), X-ray Diffraction (XRD) Lab 7: Imaging and analysis using transmission electron microscope, Lab 8: Selected area electron diffraction (SAED) using TEM, Lab 9: Grain Size determination from XRD	
Unit-4 - Scanning Probe Microscopy Techniques in Nanotechnology	***15 Hour***
Scanning probe microscopy, Scanning probe microscopy: Instrumentation, Scanning tunnelling microscopy, tunnelling current, Probe tips and working environments, Scanning tunnelling Spectroscopy (STS), Atomic force microscopy, Cantilevers and deflection measurements, Contact AFM, Non-contact AFM, Dynamic contact AFM, Taping AFM, Force modulation, Manipulation of atoms, Advanced SPM techniques, Kelvin probe force microscopy, Scanning capacitance microscopy, Scanning thermal microscopy, Magnetic force microscopy *Piezoelectric force microscopy,* *Lab 10: Tunnelling current measurements using scanning tunnelling microscope (STM), Lab 11: Nanoparticle size determination using atomic force microscopy (AFM)* *Lab 12: Surface morphology by STM and roughness determination by AFM*	
Unit-5 - Spectroscopy Tools for Nanomaterials Characterization	***15 Hour***
Basic principles: X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), Instrumentation: XPS, Instrumentation: AES, Photoelectron spectra, Auger electron spectra, Qualitative analysis, Peak identification, chemical shifts composition imaging, Quantitative analysis: peaks and sensitivity factors, Composition depth profiling, Secondary ion mass spectrometry (SIMS): Basic principles, Secondary ion generation, Dynamic and static SIMS, SIMS -instrumentation, Sample handling Spectrum interpretation, Element identification SIMS depth profiling *Lab 13: Interpretation of XPS spectra, Lab 14: Peak identification of in AES spectra, analysis of the AES depth profile, Lab 15: Analysis of SIMS profile spectra*	

Learning Resources	*1. Douglas B. Murphy, Michael W. Davidson, Fundamentals of light microscopy and electronic imaging, 2nd ed., John Wiley & Sons, 2013* *2. Yang Leng, Materials characterization, introduction to microscopic and spectroscopic methods, 2nd ed., Wiley, 2013* *3. Guy Cox, Optical imaging techniques in cell biology, CRC press, 2012*	*4. Ray, F. Egerton, Physical principles of electron microscopy, Springer, 2005* *5. Bharat Bhusan, Scanning probe microscopy in nano-science and nanotechnology, Springer, 2013* *6. Nan Yao, Zhong Lin Wang, Handbook of microscopy for nanotechnology, Kluwer Academic Publisher, 2005*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	20%	-	-	20%	20%	-
Level 2	*Understand*	20%	-	-	20%	20%	-
Level 3	*Apply*	40%	-	-	40%	40%	-
Level 4	*Analyze*	20%	-	-	20%	20%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr.N.Vijayan, CSIR-NPL, nvijayan@nplindia.org	*1. Dr. K.Ganesan, IGCAR, Kalpakkam, kganesan@igcar.gov.in*	*1. Dr.Jitendra Kumar Tripathi, SRM IST*
2. Mr. K.R.Navaneethakrishnan, GLR Laboratories Pvt Ltd	*2. Dr. Ashutosh Rath, CSIR-Institute of Minerals and Materials Technology, Bhubaneswar, ashutosh@immt.res.in*	*2. Dr.S.Chandramohan, SRM IST*

Course Code	21NTC205T	Course Name	DESIGN AND SYNTHESIS OF NANOMATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*gain insight into fundamental principles involved in the growth of nanomaterials*
CLR-2:	*familiarize with zero dimensional materials and their synthesis techniques*
CLR-3:	*know the concept of one-dimensional materials and fabrication procedures*
CLR-4:	*understand the fundamentals of thin films growth*
CLR-5:	*acquire knowledge on special nanomaterials and their fabrication methods*

		Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
Course Outcomes (CO):	***At the end of this course, learners will be able to:***															
CO-1:	*describe the fundamental concepts and theory behind nanoparticle synthesis*	-	-	*3*	*2*	-	-	-	-	-	-	-	-	*2*	-	-
CO-2:	*identify various synthesis techniques involved in solution-based synthesis of nanoparticles*	-	-	-	*3*	-	-	*2*	-	-	-	-	-	*3*	-	-
CO-3:	*distinguish nanowires, nanorods and nanotubes from bulk materials and 1D nanostructures*	-	-	*3*	-	-	-	*2*	-	-	-	-	-	-	*2*	-
CO-4:	*apply the knowledge of thin films growth using PVD and CVD techniques*	-	-	-	-	*3*	-	*2*	-	-	-	-	-	-	*2*	-
CO-5:	*describe the concept of self-assembly, biosynthesis and green synthesis of nanomaterials*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Fundamentals In the Growth of Nanomaterials ***12 Hour***

Introduction to nanomaterials-Nanomaterials classification based on dimension-Surface energy-Surface energies of different surfaces of FCC structure-Surface energy reduction-Mechanisms to reduce the surface energy-Chemical potential as a function of surface curvature-Gibbs-Thompson relation-Concept of Ostwald ripening-Role of Ostwald ripening in nanoparticle synthesis-Fundamentals of homogeneous nucleation-Critical radius and critical energy-Effect of temperature on critical size and critical free energy-Process of nucleation and subsequent growth-Growth controlled by diffusion-Growth controlled by diffusion (quantitative approach)-Growth controlled by surface process-Growth controlled by surface process-(quantitative approach)- the Relations between the nucleation and growth rates and the concentration of growth species-Fundamentals of heterogeneous nucleation-Fundamentals of heterogeneous-nucleation (Quantitative approach)

Unit-2 - Classification of Synthesis Techniques ***12 Hour***

Classification of nanoparticle synthesis techniques-Top down and bottom up approach of nanoparticles synthesis-Nanoparticle synthesis by mechanical alloying-Nanoparticle synthesis by mechanical milling-Vapor-phase synthesis of nanoparticles- Inert gas condensation of nanoparticles-Plasma-based synthesis of nanoparticles-Spark plasma method for nanoparticles synthesis-Flame-based synthesis of particles-Combustion synthesis of nanoparticles-Spray pyrolysis based synthesis of nanoparticles-Nanoparticle nucleation and growth in spray pyrolysis-Pulsed laser methods for nanoparticles-Solution processing of nanoparticles-Sol-gel processing-Kinetically confined synthesis of nanoparticles-Nanoparticle synthesis using micelles-Nanoparticle synthesis using microemulsion-Aerosol synthesis of nanoparticles-Colloidal methods-Solvothermal/hydrothermal synthesis of nanoparticles-Precipitation and Co-precipitation

Unit-3 - One Dimensional Materials and Fabrication Methods ***12 Hour***

1-Dimensional nanostructures: introduction-Various examples of 1D nanostructures-Spontaneous growth of 1D nanostructures-Evaporation (dissolution) condensation growth-Fundamentals of evaporation (dissolution) condensation growth (quantitative approach)-Various steps in crystal growth-Fundamental aspects of (vapour-liquid- solid) VLS growth-Fundamental aspects of SLS growth-Au-Si phase diagram-VLS growth of various nanowires-Control of the size of the nanowires-Catalyst size dependent nanowires growth- Various precursors and catalysts used for nanowires growth-SLS growth of various nanowires-Comparison between VLS and SLS methods-Stress induced recrystallization growth-Template based synthesis of NWs-Template filling-Nanofibres producion using Electrospinning

Unit-4 - Thin Film Growth Methods	***12 Hour***
Fundamentals of thin film growth-Basic nucleation modes-Fundamentals of thin film growth (Quantitative approach)-Growth conditions for the single crystalline, polycrystalline and amorphous films-Physical vapor deposition-Evaporation-Molecular beam epitaxy (MBE)-principle-Epitaxial growth of thin films using MBE-Sputtering and Sputtering targets-DC and RF sputtering-Magnetron sputtering-Chemical vapor deposition (CVD)-Basic chemical reactions in CVD-Reaction kinetics in CVD-Transport phenomena-Atomic layer deposition (ALD)-Self-limiting growth using ALD-Electrochemical and Electrophoretic deposition-Nernst equation and film growth-Sol-Gel Films-spin coating-Dip coating	
Unit-5 - Self Assembly Methods for Nanomaterials	***12 Hour***
Self-assembly-Self-assembled monolayers-Monolayers of organosilicon-Monolayers of alkanethiols and sulphides-Langmuir-Blodgett (LB) technique-Monolayer thin film formation using LB technique-Schaefer's method-Graphene-Introduction-Bonging in graphene-Properties of grapheme-Methods to prepare graphene-Mechanical exfoliation-Liquid phase exfoliation-Role of intercalation in graphene exfoliation-Large area synthesis of grapheme-CVD synthesis of graphene-Biological synthesis of nanoparticles-Nanoparticles synthesis using viruses-Nanoparticles synthesis using bacteria-Role of bacteria in nanoparticle synthesis-Green chemistry of nanoparticles-Nanoparticles synthesis using plant extract	

Learning Resources	1. *C. Cao, Nanostructures & Nanomaterials –Synthesis, Properties & Applications, Imperial College Press, 2004* 2. *Abdullaeva Zhypargul, Synthesis of Nanoparticles and Nanomaterials -Biological Approaches, Springer, 2017*	3. *Rai M and Poston C, Green biosynthesis of nanoparticles: mechanisms and applications, Cabi, 2013*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	*-*	*20%*	*-*	*20%*	*-*
Level 2	*Understand*	*20%*	*-*	*20%*	*-*	*20%*	*-*
Level 3	*Apply*	*30%*	*-*	*30%*	*-*	*30%*	*-*
Level 4	*Analyze*	*30%*	*-*	*30%*	*-*	*30%*	*-*
Level 5	*Evaluate*	*-*	*-*	*-*	*-*	*-*	*-*
Level 6	*Create*	*-*	*-*	*-*	*-*	*-*	*-*
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. M. Krishna Surendra, Saint-Gobain Research, Chennai, krishna.muvvala@saint-gobain.com	*1. Prof. S. Balakumar, University of Madras, balakumar@unom.ac.in*	*1. Dr. Venkata Ravindra A, SRMIST*
2. Dr. M. Sathish, CSIR-CECRI, Karaikudi, msathish@cecri.res.in	*2. Prof. S. Ramaprabhu, IIT Madras, ramp@iitm.ac.in*	*2. Dr. Bhaskar Chandra Behera, SRMIST*

Course Code	21NTC206T	**Course Name**	SOLID STATE ENGINEERING	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on various chemical bonding in solids*
CLR-2:	*understand theory of crystal diffraction, vibrations and heat capacity*
CLR-3:	*describe the concept of free electron Fermi gas and transport properties*
CLR-4:	*classify semiconductors, metals and insulators via band theory*
CLR-5:	*gain knowledge on excitons, plasmons, polarons and polaritons, Understand the principles of Raman and optical spectroscopy*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the principles of chemical bonding to understand elastic properties of solids*	-	-	*3*	*2*	-	-	-	-	-	-	-	-	*2*	-	-
CO-2:	*analyze crystalline materials and their thermal properties using the concept of phonons*	-	-	-	*3*	-	-	*2*	-	-	-	-	-	*3*	-	-
CO-3:	*utilize the Fermi-Dirac distribution function for electrical transport properties of solids*	-	-	*3*	-	-	-	*2*	-	-	-	-	-	-	*2*	-
CO-4:	*calculate carrier concentration and mobility of metals and intrinsic and extrinsic semiconductors*	-	-	-	-	*3*	-	*2*	-	-	-	-	-	-	*2*	-
CO-5:	*apply the concept of quasi-particles to understand the optical properties of solids, Utilize the spectroscopic concepts to analyze the properties of materials*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Bonding in Solids	***9 Hour***
Amorphous and crystalline materials - Introduction to crystal structure: lattice, basis and primitive cell. Crystal diffraction: Bragg's law and Reciprocal lattice vectors. Brillouin Zones (BZ) - BZ of square lattice and oblique lattice. Crystal binding - Bonding in solids: Inert gas crystals - Van der Waals interaction - Quantitative approach of London interaction. Ionic crystals: Madelung constant and Madelung energy, Evaluation of Madelung constant of NaCl. Covalent, Metallic and hydrogen bonding.)	
Unit-2 - Crystal Diffraction, Vibrations and Phonons	***9 Hour***
Hooke's law in solids – Analysis of elastic strain and stress components (Quantitative treatment). Vibration of crystals with monoatomic basis - Dispersion relation, Group velocity, Quantization of elastic waves (concept of phonon). Phonon heat capacity - Planck's distribution, Normal modes. Debye model for density of states (modes) - Debye – T3 law (Quantitative approach) Einstein model for density of states Einstein model for density of states	
Unit-3 - Fermi Gas and Transport Properties	***9 Hour***
Free electron Fermi gas: Energy levels of free electron gas in one dimension, Fermi- Dirac distribution - Effect of temperature on the Fermi – Dirac distribution function. Free electron gas in three dimensions - Fermi energy, density of states. Heat capacity of the free electron gas. Electrical conductivity and Ohm's law, Motion of electron in magnetic field - Hall effect: quantitative approach - Hall coefficient. Thermal conductivity of metals: Wiedemann-Franz law Lorentz number	
Unit-4 - Band Theory of Solids	***9 Hour***
Energy bands in solids: Nearly free electron model - Origin and magnitude of the energy gap - Bloch function. Direct and indirect band gap semiconductors. Concept of holes and effective mass. Intrinsic carrier concentration (quantitative approach) - Impurity conductivity – doping: Donor and acceptor states. Super lattices and Zener tunnelling	

Unit-5 - Quasi-Particles and Defects	***9 Hour***
Concept of excitons: Energy level diagram of excitons – Frenkel excitons - Mott-Wannier excitons. Raman effect in crystals. Concept of plasmons in metals - Concept of polarons - Concept of polaritons. Defects in solids – lattice vacancies: Schottky and Frenkel defects. Color centers: F centers - Other centers in alkali halides	

Learning Resources	*1. Charles Kittel, Introduction to Solid State Physics, 8th ed., Wiley, 2015* *2. Ashcroft and Mermin, Solid State Physics, 1st ed. Sounders College Publishing, 1976*	*3. Solid State Electronic Devices, Ben. G. Streetman amd Sanjay Banerjee, 7thEdison, Pearson, 2006*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Hemant Dixit, GlobalFoundaries,USA, aplahemant@gmail.com	*1. Dr. Ranjit Kumar Nanda, IIT Madras, nandab@iitm.ac.in*	*1. Dr. E. Senthil Kumar, SRMIST*
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research, India, Krishna.muvvala@saintgobain.com	*2. Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*2. Dr. Jaivardhan Sinha, SRMIST*

Course Code	21NTC301J	Course Name	MICRO AND NANOFABRICATION	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*overview the techniques and processes to organize nanoscale materials in device form*
CLR-2:	*understand methodology of lithography and etching to pattern materials*
CLR-3:	*acquire knowledge of different deposition techniques and ion implantation*
CLR-4:	*get acquainted with CMOS fabrication rules*
CLR-5:	*introduce next generation printed electronics technology, Make aware of VLSI technology*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*realizing the technology of Si wafer manufacturing*	*3*	-	-	*2*	*1*	-	-	-	-	-	-	-	*2*	-	-
CO-2:	*pattern diverse materials using lithography techniques to enhance the device density on chip*	-	-	*2*	*2*	*3*	-	*2*	-	-	-	-	-	*3*	-	-
CO-3:	*applying basic diffusion processes importance in semiconductor technology*	*2*	-	-	*3*	*3*	-	*2*	-	-	-	-	-	-	*3*	-
CO-4:	*fabricate small-scale devices and chip level device space management*	*3*	*3*	-	-	*2*	-	*2*	-	-	-	-	-	-	*3*	-
CO-5:	*envision low-cost production of electronic devices using printed technology, margining importance of nanoscale devices and fabrication technology*	*2*	-	*2*	-	*3*	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Production of Silicon and Wafer Technology ***15 Hour***

Importance of micro and nanofabrication techniques in IC: front and back plane, Over view of crystal and lattices, Classification of grades of silicon, Production of electronic grade, silicon, Czochralski growth technique, float zone growth technique, Silicon wafer shaping, Wafer manufacturing steps and inspection, Overview of types of epitaxy, Definition-epitaxy, Comparison of vapour phase epitaxy (VPE), liquid phase epitaxy (LPE) and molecular beam epitaxy (MBE), Working of MBE process, General epitaxy growth mechanism, Epitaxy growth kinetics and examples, Understanding silicon oxide properties, Thermal oxidation furnace, Silicon oxide growth kinetics: Deal-Groove model, Thin oxide growth and process of oxidizing polysilicon.

Lab 1: Introduction to the basics of laboratory, Lab 2: To perform wafer cleaning processes followed by thermal oxidation, Lab 3: Crystallographic studies of single crystalline Silicon and Silicon Dioxide wafers by XRD

Unit-2 - Lithography and Etching Tools ***15 Hour***

Need and basics of lithography, Optical lithography, Optical lithography controls and mask making, Working concept and controls of e-beam lithography, Resolution of electron beam lithography, X-ray lithography, Stamp based lithography, Nanoimprint lithography and applications, Etching processes: Wet etching of semiconductors, metals and insulators, disadvantages; Various types of dry etching-ion beam etching, Sputter etching, Ways of plasma generation for etching processes- Classification of plasma using its density- Capacitively coupled plasma, Inductively coupled plasma, Reactive ion etching, Deep reactive ion etching and bosh process.Lab 4: To perform patterning by photolithography process, Lab 5: To perform wet chemical etching of silicon dioxide and metal films, Lab 6: Si NW array fabrication via wet lithography process

Unit-3 - Deposition Techniques and Ion Implantation Process ***15 Hour***

Classification of material deposition techniques, Overview of physical and chemical deposition technique, Physical vapour deposition, Resistive heating evaporation, Electron beam heating evaporation, Pulsed laser evaporation, Basics of sputtering, DC and magnetron sources for sputtering, Introduction to atomic layer deposition, Working principle of atomic layer deposition, Concepts of diffusion in solids, Using Fick's diffusion in semiconductor doping, Process of ion implantation, Ion implantation tool, Fundamentals of ion energy loss and stopping, Damage due to implantation, Ion distribution, junction control, Types of annealing tools-Carrier recovery using annealing process. Lab 7: To deposit Al thin film on the oxidized silicon surface by thermal evaporation, Lab 8: To deposit Al thin film on the oxidized silicon surface by e-beam evaporation
Lab 9: To estimate energy loss of ions in silicon for implantation process using SRIM software

Unit-4 - Small-Scale Devices and Chip Level Device	***15 Hour***
History of complementary metal-oxide- semiconductor (CMOS), Requirements of device isolation, Types of isolation, Local Oxidation of Silicon (LOCOS) and shallow trench isolation (STI) processes for local isolation, Concept of self-alignment-advantages and applications, MOS fabrication with self-alignment, Requirement of planarization, Local and global planarization using chemical-mechanical polishing, Importance of MOS devices, Working principle of integrated CMOS inverter, Fabrication process of CMOS inverter, Usage of isolation and biasing of inverter, 'Latch up' concept for inverter, Design rules for CMOS, MOSIS specifics for inverter, Introduction to silicon-on-insulator (SOI), On chip fabrication processes of passive components. *Lab 10: To form local anodic oxidation pattern by scanning probe microscopy, Lab 11: To fabricate MOS capacitor and study its I-V characteristics* *Lab 12: Fabrication of ZnO nanowires on ITO substrate for UV detection Applications*	
Unit-5 - Next Generation Printed Electronics Technology	***15 Hour***
History and overview of printing processes, Necessity of printed electronics technology, Requirements of printing, Printing tools, Types of fluids for ink, Properties of fluids in printing processes, Working principle of flexographic printing (FP), Advantages and disadvantages of FP, Working principle of gravure printing (GP), Advantages and disadvantages of GP, Working principle of screen printing (SP), Advantages and disadvantages of SP, Working principle of inkjet printing (IP), Advantages and disadvantages of IP, Examples of printed devices, Comparison of printed devices with lithographically fabricated devices, Concept of hybrid printed electronics, Advantages of printing, Future of printed low-cost electronics. *Lab 13: To perform contact angle measurement of solvents used in printing process on glass and plastic substrates* *Lab 14: To measure temperature dependent electrical characteristics of P-N junction diode and estimation of activation energy, Lab 15: Repeating of experiments*	

Learning Resources	*1. Hans H. Gatzen, Volker Saile, Jürg Leuthold, "Micro and Nano Fabrication", Springer 2015* *2. S. M. Sze, and S. Lee, "Semiconductor Devices Physics and Technology", Wiley, 2012*	*3. Giovanni Nisato, Donald Lupo, Simone Ganz, "Organic and Printed Electronics", CRC Press, 2016.* *4. Sorab K. Gandhi, "VLSI Fabrication and Principles", McGraw Hill, 2005*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	20%	-	-	20%	20%	-
Level 2	*Understand*	20%	-	-	20%	20%	-
Level 3	*Apply*	40%	-	-	40%	40%	-
Level 4	*Analyze*	20%	-	-	20%	20%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Pramod Rajanna, HHV Bangalore, pramod@hhv.in	*1. Dr. Aditya Sadhanala, IISc Bangalore, sadhanala@iisc.ac.in*	*1. Dr. Abhay Sagade, SRMIST*
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, , Krishna.muvvala@saintgobain.com	*2. Dr. N. N. Murthy, IIT Tirupati, nnmurty@iittp.ac.in*	*2. Dr. P. Malar, SRMIST*

							L	T	P	C
Course Code	21NTC302J	**Course Name**	NANOELECTRONICS	**Course Category**	C	PROFESSIONAL CORE	2	0	2	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on quantum confinement and low-dimensional nanostructures for use in nanoelectronics*
CLR-2:	*understand the key aspects of electron tunnelling and its application in the operation of nanodevices*
CLR-3:	*understand the functioning of tunnel junctions in single electron devices*
CLR-4:	*understand the concept of molecular electronics for realization of device miniaturization*
CLR-5:	*acquire knowledge on the fabrication, characterization and modelling of nanodevices,*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*acquaint with the fundamentals of nanoelectronics*	*3*	*3*	2	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*utilize the knowledge on the electron tunneling phenomena in semiconductor nanodevices*	*3*	*3*	-	*2*	-	-	2	-	-	-	-	-	*3*	-	-
CO-3:	*apply the knowledge on the operation and application perspectives of various tunnel devices*	*3*	*3*	-	*3*	-	-	2	-	-	-	-	-	-	*3*	-
CO-4:	*analyze the concept of molecular electronics*	*2*	-	2	*2*	-	-	2	-	-	-	-	-	-	*2*	-
CO-5:	*apply knowledge on the fabrication and modeling of nanodevices, Demonstrate skills required for using advanced experimental techniques*	*3*	-	-	*3*	*3*	-	-	-	-	-	-	-	-	-	2

Unit-1 - Quantum Confinement in Low Dimensional Systems ***12 Hour***

Introduction to nanoelectronics - Review of basic quantum physics - Moore's law and its consequences - Silicon electronics – Limitations - International technology roadmap characteristics (ITRC) - ITRC and nanoscale importance - Need for new concepts in electronics - Challenges in micro to nano conversion – Dimensionality in materials - Density of states of materials at nanoscale - Effect of band gap of material at different dimensions - Length scales of charge scattering - Special dimensionality case of carbon - Introduction to 0D, 1D, 2D and 3D carbon forms – Nanocomputing - Device simulation software at nanoscale - Future Prospects of Nanoelectronic Devices - Progress in Nanoelectronic Architectures.

1. Introduction to the experiments and basic demonstration, 2. Determination of electron concentration for various temperature

3. Determination of electron (µn) and hole (µp) mobilities for various doping concentration in semiconductor

Unit-2 - Quantum Tunneling in Semiconductor Nanostructures ***12 Hour***

Tunnel effect and tunnelling elements - Nanoelectronics in tunnelling devices - Tunnelling of electrons through a potential barrier - Electron tunnelling - Potential energy profiles for material interfaces - Metal-semiconductor and metal- insulator junctions - Metal-insulator-metal junctions - Metal work function and electron affinity - Tunnelling applications - Field electron emission - Double barrier tunnelling - Resonant tunnelling diodes - Tunnelling in MOS Transistors - Hot electron effects in MOSFETs - Gate-oxide tunnelling - Principles of scanning tunnelling microscopy (STM) - Applications of STM in nanotechnology

4. Determination of Fermi function for different temperature, 5. Determination of resistivity for various doping concentration, 6. Four probe resistivity measurement

Unit-3 - Electron Transport in Nanodevices ***12 Hour***

Classical and semi-classical transport - Ballistic transport in nanostructures - Coulomb blockade - an overview - Single electron tunnelling and Coulomb blockade - Coulomb blockade in a quantum dot circuit - Coulomb blockade in a nano-capacitor Ballistic transport and the Landauer formula - Quantized Conductance - Working principle of Single Electron Transistor (SET) - A single-electron pump and turnstile - Quantum dot - Cellular automata - Electron transport in quantum dots - Electron transport in quantum wires - Introduction to spintronics - Giant magneto resistance - Tunnel magneto resistance – Spintronic devices and applications. 7. Hall effect of semiconductors, 8. Repeat/Revision of the experiments, 9. Simulation of Zener diode and its I-V characteristics

Unit-4 - Molecular Scale Electronics	***12 Hour***
Introduction to molecular electronics - Atomic-scale junctions: an overview - Schrodinger equation - Self-consistent field - Molecular functionalities - Metal-molecule interfaces - Molecular band Structure - Level broadening - Atomistic view of electrical resistance - Conductance of atomic-scale contacts - Coherent transport through molecular junctions - Non-coherent transport in molecular electronics devices - Molecular diodes - Conducting mechanism of single- molecule junctions - Single-molecule transistors - Elastic and inelastic tunnelling - Molecular devices and logic switches - Interface engineering issues. *10. Simulation of diode and its I-V characteristics with smoke analysis, 11. Simulation of BJT and its I-V characteristics, 12. Simulation of diode in nano dimension and its characterization*	
Unit-5 - Design And Modelling of Nanoelectronic Devices	***12 Hour***
Introduction to computational methods - Necessity of computational methods - Molecular wire - Molecular wire conductance - Theoretical aspects on molecular conductance - Computational aspects on molecular conductance - Various modelling techniques - Monte Carlo method - Ab initio simulations - Ab initio simulations: examples and problems - Multi scale modelling - Modelling of nanodevices and applications. TCAD - examples and problems - NEH DFT: examples and problems *Materials studio - Future of nanoscale modelling.* *13. Designing of 2D MOSFET in nano dimension, 14. Designing of Molecular Electronic Device, 15. Simulation of I-V Characteristics for Molecular Electronic Device*	

Learning Resources	*1. G. W. Hanson, Fundamentals of Nanoelectronics, Pearson Education; 2009* *2. V. V. Mitin, V. A. Kochelap, M. A. Stroscio, Introduction to Nanoelectronics, Cambridge University Press; 2012* *3. E. Scheer and J. C. Cuevas, Molecular Electronics: An Introduction to Theory and Experiment, World Scientific Pub Co Inc; 2017* *4. K. I. Ramachandran, Computational Chemistry and Molecular Modeling, Springer, 2010* *5. Nanoelectronics simulation laboratory course manual, 2016*	*6. Sarhan. M. Musa, Computational Nanotechnology: Modeling and Applications with MATLAB, CRC Press, 2018* *7. John O. Attia, Electronics and Circuit Analysis using Matlab, CRC Press, 2018* *8. Mitchell A. Thornton, PSpice for Circuit Theory and Electronic Devices, Morgan & Claypool Publishers series, 2007* *9. Simon Li and Yue Fu, 3D TCAD Simulation for Semiconductor Processes, Devices and Optoelectronics, Springer,2012* *10. https://docs.quantumatk.com/tutorials/tutorials.html*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	*-*		*20%*	*20%*	*-*
Level 2	*Understand*	*20%*	*-*		*20%*	*20%*	*-*
Level 3	*Apply*	*40%*	*-*		*40%*	*40%*	*-*
Level 4	*Analyze*	*20%*	*-*		*20%*	*20%*	*-*
Level 5	*Evaluate*	*-*	*-*	*-*	*-*	*-*	*-*
Level 6	*Create*	*-*	*-*	*-*	*-*	*-*	*-*
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, krisha.muvvala@saintgobain.com	*1. Prof. V. Subramaniam IIT M, manianvs@iitm.ac.in*	*1. Dr. D. John Thiruvadigal, SRMIST*
2. Dr. Hemant Dixit, Global Foundaries,USA, aplahemant@gmail.com	*2. Prof. C. Venkateswaran, Univ. of Madras, cvenkateswaran@unom.ac.in*	*2. Dr. Arijith Sen, SRMIST*

Course Code	21NTC303T	**Course Name**	NANOBIOTECHNOLOGY	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the cell structure interaction of nanomaterials with biological systems*
CLR-2:	*know about various methods of membrane transport the properties of biomaterials*
CLR-3:	*know about biomaterials*
CLR-4:	*learn about different delivery systems*
CLR-5:	*understand the use of nanoparticles in sensors*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*explain the functions of cell organelles Choose appropriate biomaterial for biological application*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*describe the mode of nanoparticle transport Explain the concept of biocompatibility*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-3:	*analyse the interaction of biomaterial with biological system*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*differentiate traditional and novel drug delivery systems*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*design sensors based on nanomaterials*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Cell Structure	***9 Hour***
Cell structure, cellular organelles and functions, cell membrane, Structure of membranes, Lipid bilayer, Membrane proteins	
Unit-2 - Membrane Transport Properties of Biomaterials	***9 Hour***
Nanoparticles transport across membrane, Active transport, Passive Transport, Membrane transporters, Endocytosis, Exocytosis, receptor mediated endocytosis	
Unit-3 - ***Interactions of Biomaterials***	***9 Hour***
Biomaterials, Surface and bulk properties of bio materials, Nanoceramics, Polymers, Hydrogels, Surface modification of biomaterials, Surface immobilized in biomaterials, Interaction of biomaterials with cells, Blood-Biomaterial Interactions, Interactions with Proteins, Immune response to biomaterials, Biocompatibility, Hydroxyapatite: Structures, Chemical composition and application	
Unit-4 - Drug Delivery Systems	***9 Hour***
Drug delivery systems, Traditional drug delivery, Controlled drug delivery, Nanoparticle based drug delivery, Targeted drug delivery, Types of drug targeting, Hyperthermia treatment, Dental implants, Tissue engineering, Scaffold design and fabrication,	
Unit-5 - Nano Biosensor	***9 Hour***
Monoclonal antibodies, Biosensor, Nano biosensors design, Nanoimmuno sensors, Nano diagnosis, blotting techniques used in Nano biotechnology, Polymerase chain reaction, Detection of tumors, In vivo imaging, Nanotechnology in gene therapy	

Learning Resources	1. *Cell Biology, Gerald Karp, Janet Iwasa, Wallace Marshall, 8th Edition, John Wiley & Sons, 2018* 2. *Nanoparticulates Drug Carriers, Edited by Vladimir P Torchilin, 2006, Imperial College Press* 3. *The Chemistry of Medical and Dental Materials, John W. Nicholson, Rsc Materials Monographs, Published by The Royal Society of Chemistry,*	4. *Tissue Engineering, Clemens van Blitterswijk, Peter Thomsen, Anders Lindahl, Jeffrey Hubbell, David Williams, Ranieri Cancedda, Joost de Bruijn, Jérôme Sohier, Academic Press, Elsevier,* 5. *Nanoscale Technology in Biological Systems, edited by Ralph S. Greco, Fritz B. Prinz, R. Lane Smith, CRC PRESS* 6. *Nanoparticulate Drug Delivery Systems, Edited by Deepak Thassu, Michel Deleers, Yashwant Pathak, 2007*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. K. Chandru, HCL Health care division, Chennai	1. Dr. Mukesh Doble, IIT M	1. Dr. G. Devanand Venkatasubbu, SRMIST
2. Dr. Asifkhan Shanavas, INST Mohali	2. Dr. T. Prakash, UOM	2. Dr. N. Selvamurugan,, SRMIST

Course Code	21NTC304T	Course Name	NANOTOXICOLOGY	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the concept of toxicity*
CLR-2:	*acquire knowledge on physical properties of nanostructured materials on toxicity*
CLR-3:	*learn about nanoparticle interaction with cells*
CLR-4:	*know about various methods of toxicity assessment*
CLR-5:	*learn various in vivo toxicity methods*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*aware about toxicity caused by nanomaterials*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*relate the physical properties of nanostructured materials to its toxicit*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-3:	*analyze the various symptoms caused due to toxicity of nanoparticles*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-4:	*apply the various methods of toxicity assessment*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	*2*
CO-5:	*analyze the in vivo toxicity data*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Toxicity Concept ***9 Hour***

Size and charge specific behavior of nanomaterials, source of nanoparticles, epidemiological evidences, entry routes for nanoparticles in human body: lungs, intestinal tract and skin, Deposition and translocation in the body

Unit-2 - Nanostructured Materials Toxicity ***9 Hour***

Lung Inflammation, Nanoparticles and the Blood-Brain Barrier, Placental Barrier, Nanoparticles on the Cardiovascular System; Nanoparticles Translocation and Direct Vascular Effects; Endothelial Dysfunction and Endogenous Fibrinolysis; Coagulation and Thrombosis; Effects of Nanoparticles on the Liver and Gastrointestinal Tract; Effects of NP on the Nervous System

Unit-3 - Nanomaterial Interaction with Cells ***9 Hour***

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

Unit-4 - Toxicity Assessment ***9 Hour***

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

Unit-5 - Environmental Toxicity ***9 Hour***

Nanopollution – Nanomaterials in environment-sources of pollution-transport through environment

Learning Resources	1. *Handbook of Nanotoxicology, Nanomedicine and Stem Cell Use in Toxicology. Saura C Sahu, Daniel A Casciano, 2014.* 2. *Nanotoxicology - Interactions of Nanomaterials with Biological Systems. Yuliang Zhao and Hari Singh Nalwa, 2006.* 3. *Biointeractions of Nanomaterials. Vijaykumar B. Sutariya, Yashwant Pathak, 2014.* 4. *New Technologies for Toxicity Testing. Michael Balls DPhil, Robert D. Combes PhD, Nirmala Bhogal, 2012.*	5. *Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006.* 6. *Nanotoxicology: Characterization, Dosing and Health Effects- Nancy. A, Monteiro-Riviere, Lang Tran. C Informa healthcare, 2007*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. K. Chandru, HCL Health care division, Chennai*	1. *Dr. Vignesh Muthuvijayan, IITM*	1. *Dr. G. Devanand Venkatasubbu, SRMIST*
2. *Dr. Asifkhan Shanavas, INST Mohali*	2. *Dr. G. Hariharan, NCSCM*	2. *Dr. S. Sahabudeen,, SRMIST*

Course Code	21NTC305L	**Course Name**	NANOBIOTECHNOLOGY AND NANOTOXICOLOGY LABORATORY	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							0	0	6	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*know about microbial culture*
CLR-2:	*learn isolation of DNA*
CLR-3:	*utilize nanoparticles for drug delivery*
CLR-4:	*understand the methods of animal cell culture*
CLR-5:	*know about the interaction and toxicity of nanomaterials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*culture microorganisms*	-	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*isolate and analyse DNA*	-	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*fabricate drug delivery systems*	-	-	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*
CO-4:	*culture animal cells in laboratory*	-	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-5:	*understand different biological applications and the toxicity of nanomaterials*	-	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-

List of Experiments	***90 Hour***
Lab 1. Introduction to Nanobiotechnology laboratory *Lab 2. Inhibition of microbial growth by nanoparticles* *Lab 3. Estimation of membrane damage by nanoparticles* *Lab 4. Determination of DNA fragmentation by nanoparticles* *Lab 5. Fabrication of nanoparticles incorporated scaffolds for tissue engineering* *Lab 6. Amplification of DNA by PCR for tissue engineering* *Lab 7. Estimation of drug loading percentage* *Lab 8. Determination of controlled drug release* *Lab 9. Synthesis of polymeric nanoparticles for drug delivery* *Lab 10. Fluorescent imaging of nano-bio interaction* *Lab 11. Analysis of biocompatibility of nanoparticles by MTT assay* *Lab 12. Analysis of apoptosis induced by nanoparticle*	

Learning Resources	*1. Introduction of Practical Biochemistry by David T. Phummer. (II Edition)* *2. Cappuccino, J.G. and N. Sherman “Microbiology: A Laboratory Manual”, 4th Edition, Addison-Wesley, 1999.*	*3. Sambrook, Joseph and David W. Russell “The Condensed Protocols: From Molecular Cloning: A Laboratory Manual” Cold Spring Harbor, 2006.* *4. Masters J.R.W. Animal Cell Culture: Practical Approach. Oxford University Press.2000*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)						Final Examination (0% weightage)	
		CLA-1 Average of first cycle experiments (30%)		CLA-2 Average of second cycle experiments (30%)		Practical Examination (40% weightage)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	-	20%	-	20%	-	20%	-	-
Level 2	*Understand*	-	20%	-	20%	-	20%	-	-
Level 3	*Apply*	-	30%	-	30%	-	30%	-	-
Level 4	*Analyze*	-	30%	-	30%	-	30%	-	-
Level 5	*Evaluate*	-	-	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-	-	-
	Total	100 %		100 %		100%		-	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr.K.Chandru, HCL Health care division, Chennai	1. Dr.Mukesh Doble, IIT M	1. Dr. G. Devanand Venkatasubbu, SRMIST
2. Dr. Asifkhan Shanavas, INST Mohali	2. Dr.T.Prakash, UOM	2. Dr. N. Selvamurugan,, SRMIST

Course Code	21NTC401J	**Course Name**	POLYMER AND NANOCOMPOSITES	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							2	0	2	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge about fundamentals of polymers*
CLR-2:	*understand basics concepts about conducting polymers*
CLR-3:	*gain insight into the importance of polymers in nanotechnology*
CLR-4:	*understand the physical and mechanical properties of polymer*
CLR-5:	*gain knowledge about the preparation and properties of nanocomposites, Understand the significance of nanosize on polymer and composites*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the chemical concepts to understand the basics principles of polymer and polymerization reactions*	*3*	*2*	-	-	*1*	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*analyze the conduction mechanism, various methods of synthesis, characterization and applications in conducting polymers*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*apply the knowledge in making nanocomposites with different class of nanofillers and matrix materials*	*3*	-	*2*	-	*2*	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*incorporate nano based modification in different polymeric based composites*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*analyze the applications of polymer nanocomposites in various fields, Implement the polymerization reactions, their mechanism and analyze the characterized data*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Fundamentals of Polymers ***12 Hour***

Importance of polymers: basic concepts - Classification of polymers on the basis of microstructures & macrostructures - polymer classifications based on- occurrence, types, process and applications - Chain structure, configuration and conformation - Homo and heteropolymers – copolymers - Crystalline nature of polymers - Factors affecting crystallization phenomenon - Glass transition temperature (Tg) - Melting temperature(Tm) - Factors affecting Tg and Tm - Importance of Tg - Molecular weight distribution - Degree of polymerization - Reaction kinetics of polymerization - Molecular solution, Melt and elastomer - Dielectric constant - Polarization; Dissipation factor

1. Introduction to the basics of Polymer science, 2. Polymerization of Urea- formaldehyde resin, 3. Interfacial Polymerization of polyamide from Diamine and Diacid Chloride.

Unit-2 - Conducting Polymers ***12 Hour***

Conducting polymers – Discovery and structural characteristics - Intrinsic and extrinsic conduction in polymers - Charge carriers, polarons, bipolarons, and conducting mechanism - Chemical and electrochemical methods of synthesis of conducting polymers - Synthesis method of polyacetylene - polyaniline – Polypyrrole - advantage and disadvantage of various synthesis methods - Characterization methods – elemental analysis for dopants - Characterization using UV-Visible and FTIR spectrometer Morphological study using SEM and TEM - Applications of conducting polymers in corrosion protection – sensors - electronic and electrochemical energy devices

4. Preparation of poly vinyl alcohol nanofibers by electro spinning technique, 5. Characterization of the fibers prepared using SEM and wettability test,

6. Fabrication of polymer membrane using phase inversion techniques

Unit-3 - Nanocomposites, Nanofillers and Polymeric Matrices	***12 Hour***
Introduction to nanocomposites –reinforcements – matrix materials- - nanofillers – classification of nanofillers - Carbon and Noncarbon based nanofillers - Metal matrix, Polymeric and Inorganic composite matrix - Polyamide Matrices, Polypropylene and Polyethylene Matrices, Liquid-Crystal Matrices, Epoxy and Polyurethane Matrices, Rubber Matrices - Synthesis of Nanocomposite: Direct Mixing, Solution Mixing, In-Situ Polymerization - Super hard nanocomposites - Self-cleaning nanocomposites - Metal matrix nanocomposites: Metal with nanoceramic fillers such as SiC, CeO2, TiO2, ZrO2 PTFE, CNTs. *7. Fabrication of polymer thin film composites using phase inversion techniques, 8. Repeat/Revision of experiments, 9. Preparation of metal-polymer nanocomposites*	
Unit-4 - Nano Based Modification in Polymeric Nanocomposites	***12 Hour***
Polymer- Clay Nanocomposites - Synthesis of Nylon 6-clay hybrid (NCH) composites and characterization - Crystal structure of NCH and properties of NCH - layered silicate nanocomposites - Structure, properties and characterization - Ceramic Matrix Nanocomposites - Fibrous monolithic ceramic, fiber reinforced ceramic composites - Whisker reinforced ceramic matrix composite - Particulate reinforced, graded and layered ceramic composite - Nanophase ceramic composites - Metal reinforced ceramic matrix nanocomposites - Non-oxide ceramic composites - Functionally graded ceramics- clay nanocomposites *10. Preparation of ceramic based nanocomposites, 11. Morphological characterization of prepared composites using SEM, 12. Synthesis of Nylon-6 polymer*	
Unit-5 - Application of Polymeric Nanocomposites	***12 Hour***
Nanocomposites – Optical, Structural applications - Nanocomposites containing functionalized nanoparticles: Organic and polymer materials for light-emitting diodes, Luminescent polymer for device applications - - Polymer Nanocomposites for Bio-medical applications - antimicrobial coatings- medical implants - Nanocompoites catalysts for Fischer-Tropsch synthesis- methane oxidation and biofuels - Nanocomposites films for gas sensing - Hybrid composite materials for theraphy and food packaging *13. Synthesis of particulate reinforced composites, 14. Synthesis of hydrogel using cellulose acetate polymer, 15. Mini Project*	

Learning Resources	*1. Gowariker V.R., Viswanathan N.V., Sreedhar J., Polymer Science, New age international publications, 2005* *2. Luigi Nicolais, GianfrancoCarotenuto, Metal–polymerNanocomposites, Wiley-Interscience,2005* *3. BorZ.Jang, Advanced Polymer composites, ASM International, USA, 1994.*	*4. Alfred rudin , The elements of polymer science and engineering, 2nd edition, Academic press publication,1999* *5. Lowl.M., Ceramicmatrixcomposites: Microstructure,propertiesandapplications,WoodheadPublishing Limited,2006* *6. Anke Krueger, Carbon Materials and Nanotechnology, Wiley-VCH Verlag GmbH & Co. KGaA, 2010*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (45%)		*Life-Long Learning CLA-2 (15%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	20%	-	-	20%	20%	-
Level 2	*Understand*	20%	-	-	20%	20%	-
Level 3	*Apply*	40%	-	-	40%	40%	-
Level 4	*Analyze*	20%	-	-	20%	20%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. P. Sudhakara, CLRI – CSIR, Jalandhar, sudhakarp@clri.res.in	*1. Dr. Kothandaraman Ramanujam, IITM Chennai, rkraman@iitm.ac.in*	*1. Dr. N. Angeline Little Flower. SRMIST*
2. Dr. Sudhakar Selvakumar, CSIR-Central Electrochemical Research Institute, ssudhakar79@gmail.com	*2. Dr.Arthanreeswaran, NIT, Trichy, arthanareeg@nitt.edu*	*2. Dr. C. Siva, SRMIST*

Course Code	21NTC402T	**Course Name**	MODELLING AND COMPUTATIONAL TOOLS	**Course Category**	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*know the basics of GNU Octave and C++*
CLR-2:	*acquire detailed knowledge of Density Functional Theory*
CLR-3:	*utilize and gain knowledge of Molecular Dynamics*
CLR-4:	*solve in detail the Monte Carlo Method and problems*
CLR-5:	*understand the basics of modeling and computational tools for materials modeling*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*execute and solve problems with the basics of computational tools*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*utilize the principles of DFT*	-	*3*	*3*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*apply the knowledge of molecular dynamics to solve problems*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*solve and perform modeling with Monte Carlo method*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*execute the computational codes and predict the physical properties from modeling and simulation*	*3*	-	-	*3*	*3*	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Basics of GNU Octave ***9 Hour***

Introduction to GNU Octave -Arrays and Matrices-Matrix operation- Eigen value problem- Solution of simultaneous equation- Arithmetic operations- Logical operations- If-else clause- Loop control structure and statements- Break statement, Switch statement- Self-consistent method- Functions-data visualization in 2D and 3D- Contour Plots using GNU Octave, Plot of Fermi-Dirac Distribution Function using GNU Octave - Reciprocal (K)-space and K-space integration using GNU Octave

Unit-2 - Basics of C++ ***9 Hour***

Introduction to C++- Algorithms- Structured-programing- I/O statements- Control statement- Looping (loop statement)- Matrix: Basic matrix operations-Functions-data visualization in 2D- Examples on data visualization in 2D- Functions-data visualization in 3D- Examples on data visualization in 3D- Basic idea of parallel programming- Basic concept of Computer clusters, Master Node, Working Node - Bewolf and Shared memory clusters in introductory level-Structure Visualization tools (VESTA)

Unit-3 - Density Functional Theory ***9 Hour***

Schrodinger equation- Schrodinger equation for Many Body problem- Born-Oppenheimer approximation- Hartee-Fock-method (discussion only)- Slater Determinant- Variational Principle- Introduction to DFT-Hohenberg-Kohn Theorem 1- Discussions on Hohenberg-Kohn theorem 1- Hohenberg-Kohn Theorem 2- Discussions on Hohenberg-Kohn theorem 2- Kohn-Sham Equation- Discussion on Kohn-Sham Equation-Exchange-correlation functions LDA (Basic Concept)- LDA (explanation of the equation)- Exchange-correlation functions GGA (Basic Concept)- GGA (explanation of the equation)- LSDA+U method-Basis set- Types of basis set (basic level)- Flow chart of DFT scf procedure- Discussions on Flow chart-Discussion on DFT codes-Example of Si (determination of lattice parameter and ban gap)

Unit-4 - Molecular Dynamics and Simulations ***9 Hour***

Classical molecular dynamics- Discussions on Classical molecular dynamics- Tight binding molecular dynamics- Discussions on Tight binding molecular dynamics- The basics of molecular dynamics (MD) algorithm-Discussions with examples on MD algorithm- Verlet algorithms- Discussions Verlet algorithms- Predictor - Corrector algorithm- Discussions on - Corrector algorithm- MD in different ensembles- Discussions MD in different ensembles- Examples of MD simulation- Discussions on qualitative results- Temperature variation effects in MD- Examples on Temperature variation effects in MD- Limitations of MD- Case study examples-Scope for Quantum Molecular Dynamics Simulations.-Molecular Dynamics Simulation of water molecule

Unit-5 - Monte-Carlo Method and Modelling	***9 Hour***
Monte-Carlo method and modelling tools: Introductory examples- Brief history- Fundamental key concepts- Transformation methods- Rejection sampling- Discussions of Rejection sampling- Importance sampling-Discussions on Importance sampling- Integration by importance sampling-theory, Metropolis algorithm- Discussions on Metropolis algorithm- Introduction to Kinetic Monte Carlo (KMC)- Qualitative discussions and basic concept- Introduction to Quantum Monte Carlo (QMC)- Qualitative discussions and basic concept- Merits and demerits of KMC and QMC- Case study examples (Magnetic Spin System)	

Learning Resources	1. *Jörg-Rüdiger Hill, Lalitha Subramanian, AmiteshMaiti, Molecular modeling techniques inmaterial sciences, Taylor & Francis 2005* 2. *J.M. Thijssen, Computational Physics, Cambridge University Press, 2007* 3. *Andrew R. Leach, Molecular modelling: principles and application, Pearson Education, 2001* 4. *Rizwann Butt, Introduction to Numerical Analysis using MATLAB, Jones and Bartlett Publishers, 2008*	5. *Daan Frenkel and BerendSmit, Understanding molecular simulation: from algorithms to applications, Academic Press, 2001* 6. *Feliciano Giustino, Materials Modelling using Density Functional Theory: Properties and Predictions, Oxford University Press, 2014*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Hemant Dixit, GlobalFoundaries,USA, aplahemant@gmail.com*	1. *Dr. Ranjit Kumar Nanda, IIT Madras, nandab@iitm.ac.in*	1. *Dr. Saurabh Ghosh, SRMIST*
2. *Dr. Murali Kota, Global Foundaries,USA, kvrmmurali@gmail.com*	2. *Dr. Biswarup Pathak, IIT Indore, biswarup@iiti.ac.in*	2. *Dr. Arijit Sen, SRMIST*

ACADEMIC CURRICULA

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21NTE201T	Course Name	CARBON NANOTECHNOLOGY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge various forms of carbon*
CLR-2:	*understand the use of carbon forms in applications*
CLR-3:	*understand the physical and chemical properties of fullerenes*
CLR-4:	*understand the physical and chemical properties of graphene*
CLR-5:	*understand the physical and chemical properties of carbon nanotubes*

		Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*define different allotropes of carbon, their structure, and bonding in carbon*	*2*	*2*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*evaluate the potential of fullerene for various applications*	*2*	-	-	*2*	-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*define different carbon nanotubes and evaluate their applications*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	*3*	-	-
CO-4:	*express the key concepts of CVD, epitaxy, and exfoliation methods of graphene production and applications of graphene*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	*3*	-	-
CO-5:	*analyze the importance of diamond and amorphous carbon coatings in tribological applications*	*2*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Various Forms of Carbon ***9 Hour***

Introduction to carbon molecules –Atomic structure of carbon, Carbon hybridization; Dimensionality forms of carbon, Graphite and diamond structure, Discovery and atomic structure of fullerene (C60), Carbon nanotubes (CNTs) and their classification, From graphene sheet to a nanotube, Zigzag and armchair nanotubes, Chirality in nanotubes, Defects in carbon nanotubes, Defective nanotubes and Euler's theorem

Unit-2 - Physical and Chemical Properties of Carbon Nanotub ***9 Hour***

Fullerenes - Structure, Bonding, Nomenclature; C60 and higher fullerenes - Growth mechanisms, production and purification; Fullerene preparation by pyrolysis of hydrocarbons and partial combustion of hydrocarbons, Physical properties of fullerene, Chemical properties of fullerene, Hydrogenation of fullerene, Applications of fullerenes in – polymer solar cell, hydrogen storage21, biomedical, donor-acceptor systems

Unit-3 - Synthesis, Characterization and Applictions of Carbon Nanotubes ***9 Hour***

Carbon Nanotubes - Structure of carbon nanotubes, Nomenclature of carbon nanotubes, Electronic properties of carbon nanotubes, Synthesis and production of Single-Wall CNTs (SWCNTs), Synthesis and production of Multi-Wall CNTs (MWCNTs), Growth mechanism of CNTs, Analysis of carbon nanotubes by X-ray diffraction and Raman Spectroscopy, Carbon nanotubes as - Field Effect Transistors (FET), chemical sensors, bio-sensors, gas sensors; Electronic and sensor applications of carbon nanotubes – CNT based field-emission display, FETs, Computers; Applications in solar cells, hydrogen storage, heterogeneous catalysis; Biological applications of carbon nanotubes

Unit-4 - Synthesis, Characterization and Applictions of Carbon Graphene ***9 Hour***

Graphene – Discovery, Atomic structure of graphene, Band structure of graphene, Graphene derivatives – graphene oxide; Graphene production by - Exfoliation, Chemical Vapor Deposition, and Epitaxy; Properties of graphene, Raman spectroscopy of graphene - Phonon modes in graphene, Layer dependence of Raman spectra, Raman spectroscopy of graphene under strain; Characterization of graphene by – Fourier Transform Infrared Spectroscopy (FTIR), X-Ray Diffraction (XRD), Electron Energy Loss Spectroscopy (EELS), and X-ray Photoelectron Spectroscopy (XPS); Graphene as transparent electrode, FETs, photodetectors; Applications in solar photovoltaics, chemical sensing, and energy storage

Unit-5 - Diamond and Amorphous Carbon Coatings	***9 Hour***
Diamond thin films - Structure of diamond films, Single-, poly-, and ultranano-crystalline diamond; Preparation and growth mechanism of CVD diamond films, Structure of CVD diamond, Physical properties of CVD diamond, Chemical properties of CVD diamond, Covalent functionalization of diamond films, CVD diamond as - wear resistant coating, bio-chemical sensors. Optical applications - infrared windows, lenses, X-ray windows Amorphous carbon (a-C) thin films - Ternary phase diagram of a-C, Hydrogenated amorphous carbon films (a:C-H), Physical and chemical properties of amorphous carbon film, PECVD of a:C-H; Amorphous carbon films as anti-reflection and anti-corrosive coatings	

Learning Resources	1. *Anke Krueger, “Carbon Materials and Nanotechnology”, Wiley-VCH, 2010* 2. *Yury Gogotsi, “Carbon Nanomaterials”, Taylor and Francis, Second edition, 2014*	3. *C. N. R. Rao, Ajay K. Sood, “Graphene: Synthesis, Properties, and Phenomena”- Wiley-VCH, 2013* 4. *Wonbong Choi, Jo-won Lee, “Graphene: Synthesis and Applications” CRC Press, Taylor and Francis, 2012.*

Learning Assessment

	Bloom’s Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. R. Easwaramoorthy, ARCI, easwar@arci.res.in*	1. *Prof. M.S. Ramachandra Rao, IITM Chennai, msrrao@iitm.ac.in*	1. *Dr. S. Chandramohan, SRMIST*
2. *Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in*	2. *Prof. S. Balakumar, University of Madras, balakumar@iunom.ac.in*	2. *Dr. Abhay Sagade, SRMIST*

Course Code	21NTE202P	Course Name	VACUUM AND THIN FILM TECHNOLOGY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on vacuum systems and technology*
CLR-2:	*understand the functionalities of various vacuum pumps and gauges*
CLR-3:	*gain Knowledge on various physical and chemical vapor deposition techniques*
CLR-4:	*understand the various thin film growth mechanisms and theories explaining them*
CLR-5:	*gain knowledge on various characterization techniques tools to characterize thin films*

		Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the functionalities of vacuum systems and can operate them*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-2:	*utilize the knowledge acquired to operate vacuum pumps and create vacuum and measure at various regimes*	-	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*grow thin films using various physical and chemical vapor deposition techniques*	-	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-4:	*explore the physical and chemical properties of thin films*	-	-	-	*2*	-	-	-	-	-	-	-	-	*3*	-	-
CO-5:	*apply the concept of various characterization tools and operate them*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Introduction to Vacuum Systems — *9 Hour*

Over view, working and principles of vacuum systems and technology-Units and different regions of vacuum-Kinetic theory of gases-Gas flow and mean free path-Conductance-Different types of pumps-Mechanical Pumps-Diffusion and turbo molecular pump-Ion Pumps-Measurement of vacuum-Direct and indirect gauges-Pirani Gauge-Capacitance gauge-Penning gauge-Vacuum system-Leak detection methods-Components and operation of vacuum system-Safety practices in vacuum systems-Applications of vacuum technology

Unit-2 - Physical Vapor Deposition Methods — *9 Hour*

Over view of Physical vapor deposition techniques-Thermal evaporation, Resistive heating and RF-heating-Flash evaporation-Laser evaporation-Co-evaporation-Electron bombardment heating-Sputtering plasma, discharges and arc-Sputtering variants, yield and low pressure sputtering-RF-sputtering-Reactive sputtering-Magnetron sputtering-Magnetron configurations-Bias sputtering-Evaporation versus sputtering-Pulsed laser deposition (PLD) design and basics-PLD operating procedure and its various application-Molecular beam epitaxy (MBE) basics-MBE operating procedure – Substrate types and cleaning methods – Substrate dependence on thin film quality

Unit-3 - Chemical Vapor Deposition Methods — *9 Hour*

Introduction to chemical deposition methods-Electrodeposition-Electrolytic Deposition-Electro less deposition-Anodic Oxidation-Spray Pyrolysis-Dip coating and Spin Coating-Chemical vapor deposition (CVD)-Homogenous and heterogeneous process-CVD reactions-Hydrogen Reduction-Halide disproportionation, transfer reactions-CVD processes and systems-Low pressure CVD-Laser enhanced CVD-Metalorganic CVD (MOCVD)- Plasma Assisted Chemical Vapor Deposition (PACVD)- Safety considerations

Unit-4 - Thin Film Nucleation and Growth, Thickness Measurement Methods — *9 Hour*

Basic physics and chemistry behind thin films layer formation-Nucleation and thin thin film formation concepts-Thermodynamic aspects of nucleation-thin film growth modes-Capillary theory-Volmert-Weber growth-Frank-van der Merwe (FM) growth-Stranski-Krastanov Growth-Thickness dependent properties of thin films-Thickness Measurements-Roughness-Electrical Methods-Microbalance monitors-Quartz crystal monitor-Mechanical method (stylus)- Optical interference methods-Ellipsometry-Interference fringes

Unit-5 - Structural, Compositional and Electrical Characterization	***9 Hour***
Thin films characteristics-Topography-Structure integrity- X-ray diffraction (XRD)- Scanning electron microscopy-Transmission electron microscopy-Energy dispersive analysis of thin films-Auger electron spectroscopy-X-ray photoelectron spectroscopy-Rutherford backscattering spectroscopy-Secondary ion mass spectrometry-Resistance – 2-point probe-Resistance – 4-point probe-Optical properties-Characterization of layered structures-Atomic force microscopy (AFM)- Raman Spectrocopy- Hall effect measurements- Reflection high energy electron diffraction (RHEED)- In-situ RHEED	

Learning Resources	*1. M. Ohring, Materials Science of Thin Films: Deposition and Structure, 2nd Ed., Academic Press (An Imprint of Elsevier), 2002.* *2. K.L.Chopra, Thin Film Phenomena, Robert E.Krieger Publishing Company, 1979.*	*3. S. Campbell, the Science and Engineering of Microelectronic Fabrication, 2nd Ed., OUP, 1996.* *4. Kaufmann, Characterization of Materials, 2 nd Ed., Wiley, 2003.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*						*Final Examination (0% weightage)*	
		Formative CLA-1 Average of unit test (20%)		*Project Based Learning CLA-2 (60%)*		*Report and Viva Voce (20%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	-	*20%*	-	*20%*	-	-
Level 2	*Understand*	*20%*	-	-	*20%*	-	*20%*	-	-
Level 3	*Apply*	*30%*	-	-	*30%*	-	*30%*	-	-
Level 4	*Analyze*	*30%*	-	-	*30%*	-	*30%*	-	-
Level 5	*Evaluate*	-	-	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100%*		-	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Mohan Bhan, OAI, USA, mbhan@oainet.com	*1. Dr. Ramesh Chandra Mallik, IISc Bangalore, rcmallik@iisc.ac.in*	*1. Dr. P. Malar, SRMIST*
2. Mr, C P Sridhar, SIMCO Groups, Bangalore, sridhar.cp@simcogroup.in	*2. Dr. Bhaskar Chandra Mohanty, Thapar University, bhaskar@thapar.edu*	*2. Dr. C. Gopalakrishnan, SRM IST*

Course Code	21NTE203T	**Course Name**	NANOTRIBOLOGY	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on nanotribology*
CLR-2:	*gain insight on surfaces forces and its measurement techniques*
CLR-3:	*enhance the knowledge on lubrication, friction and wear and their importance*
CLR-4:	*know about mechanisms involved in tribology related mechanical properties*
CLR-5:	*attain knowledge on tribological applications in day-to-day life, Understand nanotribology and its importance*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*strengthen knowledge in the basic tribological concepts required for nanotechnology*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*identify, formulate, and solve engineering problem of interacting surfaces in relative motion*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*realize the significance of lubrication, friction and wear*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	-	-	*3*
CO-4:	*recognize the importance of modifying surface properties*	*2*	-	*2*	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*utilize nanotribological principles for any applications, Emphasize the knowledge of scientific disciplines in understanding tribological phenomenon*	-	-	*1*	-	*2*	-	-	-	-	-	-	-	*3*	-	-

Unit-1 - Introduction to Nanotribology	***9 Hour***
History of tribology-origin- Introduction to micro and nanotribology - Significance of micro/nanotribology- Tribology in design-Methods of solution of tribological problems- Purpose and necessity of lubrication- Modes of lubrication- hydrodynamic- Hydrostatic lubrication- Boundary lubrication- Elasto hydrodynamic lubrication- Extreme pressure lubrication- Lubricants - types and lubricating oils - working principles of liquid and solid lubricants - Lubricant properties-effect of temperature and pressure- Oxidation stability- Thermal conductivity- Type of additives- Bearings- classification based on mode of lubrication- Bearing-Classification based on relative motion between contact surfaces- Comparison of sliding and rolling contact bearing- essential properties of a lubricant	
Unit-2 - Surface Forces and Its Measurements	***9 Hour***
Surface Forces- Methods used to study surface forces- Force laws- Surface force apparatus (SFA)- Force between dry surface- Force between surfaces in liquid- Adhesion- Capillary forces- Modes of deformation-Description of AFM/FFM- Other measurement techniques- Surface roughness- Friction force- Scratching- Wear and machining- Surface potential measurements- Nanoindentation measurement- Boundary lubrication	
Unit-3 - Lubrication, Friction and Wear	***9 Hour***
Lubrication- Lubricant States- Viscosity of lubricant- Fluid film lubrication- Theories of hydrodynamics lubrication- Lubrication design of typical mechanical elements- Transformation- Parameter of surface topography-Friction- Basic laws of friction- Static and kinetic friction- Friction of materials- Solid – solid contact- Liquid mediated contact- Interfacing temperature of sliding surfaces- Wear-Laws of wear- Mild and Severe wear-Identification of wear mechanism- Typical test geometries	
Unit-4 - Tribology Related Mechanical Properties	***9 Hour***
Scale Effects in Mechanical Properties- Nomenclature- Yield strength and Hardness- Shear strength at the interface- Scale dependence on surface roughness and contact parameters- Dependence of contact parameters on load- Scale effects in friction- Adhesion Friction- Two body deformation- Three body deformation- Ratchet mechanism- Meniscus Analysis- Total value of coefficient of friction- Transformation from elastic to plastic regime- Tribological properties of SAMs- Tailoring surfaces- Modifying surface composition for application in Tribology – Lubricant re-use and disposing methods	

Unit-5 - Nanotribology Applications and Its Importance	***9 Hour***
Applications of Tribology- Introduction to various tribological phenomenon- Bio-Tribology- Tribology in the human body- Tribology in the artificial organs- Tribology in medical devices- Natural human synovial joints-Total joint replacements- Wind turbine Tribology- Biorefining- Coating applications- sliding bearings- Rolling contact- Bearings- Gears- Erosion and scratch resistant- Magnetic recording devices- Micro components-MEMS/NEMS	

Learning Resources	*1. G. Phakatkar and R.R. Ghorpade, "Tribology", Nirali publication, 2009* *2. Bharat Bhushan, "Nanotribology and Nanomechanics", Springer Publication, Second edition,2011* *3. Bharat Bhushan," Principles and Applications to Tribology", Wiley Publication, 2013*	*4. C. Mathew Mate, "Tribology on the Small Scale" Oxford University Press, 2008* *5. Nicholas D. Spencer, "Tailoring surfaces", World Scientific IISC Press, 2011*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Shinji Yamada, Kao Corporation, Tokyo, Japan, Yamada.s@kao.co.jp	*1. Dr. M. Balasubramanian, IIT Madras, mbala@iitm.ac.in*	*1. Dr. S. Yuvaraj, SRMIST*
2. Dr.Sridhar M. R, Senior Engineer, GE Global Research, Bangalore, India.	*2. Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*2. Dr. Kiran Mangalampalli, SRMIST*

Course Code	21NTE204T	**Course Name**	SURFACES AND INTERFACES	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CLR-1:	*introduces the basic concepts that are used to describe the atomic or molecular structure of surfaces and help the students to understand why/how surfaces play paramount significances in nanotechnology*															
CLR-2:	*explain various mechanisms involved in surfaces/interfaces and fundamentals of various types of bonding at surfaces/interfaces*															
CLR-3:	*describe strategies for manipulating the surfaces and how those strategies help them depending upon the application of such modified surface*															
CLR-4:	*be familiar with property equations and thermodynamic properties of gas-surface interactions along with the concepts of phase equilibrium of multi-component systems*															
CLR-5:	*acquire the knowledge in Adsorption and desorption kinetics*															
Course Outcomes (CO):	***At the end of this course, learners will be able to:***															
CO-1:	*apply the knowledge in surfaces; their structure and physical-chemical properties, and interfaces between solids*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*anticipate the stability of a given interface and the behaviour of molecules close to the interface*	3	-	2	-	-	-	-	-	-	-	-	-	-	-	2
CO-3:	*decide what are the necessary thermodynamics concept to describe an interface*	2	-	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-4:	*develop sound understanding in new phenomena such as curved surfaces, facets and fractal formations*	3	-	2	-	-	-	-	-	-	-	-	-	-	2	-
CO-5:	*validate sound understanding in collective phenomena at the surfaces/interfaces*	2	-	-	2	-	-	-	-	-	-	-	-	3	-	-

Unit-1 - Atomic or Molecular Surface	***9 Hour***
Introduction to surface quantities – Physics of Surface and interface - its importance/significance-Surface creation- Extension of a surface - Relations among surface quantities- Relations between γ and σ - Determination of surface parameters - Equilibrium at intersections of surfaces: wetting - Non-reactive versus reactive wetting - Non-reactive wetting - Work of adhesion - Capillary rise - Small droplets - Non-ideal surfaces - Reactive wetting - Selected values of interfacial energiesMolecular Interactions-General concepts of Internal Energy and Free Energy-Intramolecular Forces: Formation of a Molecule by Chemical Bonding-Interatomic forces, bonds - -Polar Interactions-van der Waals Interactions- Collective phenomena at interfaces – a) Superconductivity-Superconductivity at interfaces –-Ferromagnetism at interfaces- Magnetic layer coupling	
Unit-2 - Mechanisms in Surfaces/Interfaces	***9 Hour***
Trends in activation energies for surface reactions - Electronic effects in surface reactivity- Geometrical effects in surface reactivityThe Hierarchy of Equilibria-Thermodynamics of Flat Surfaces and Interfaces- The Interface Free Energy- Surface Excesses- Charged Surfaces at Constant Potential- Charged Surfaces at Driven potential- Maxwell Relations-Their Applications-Solid and Solid interfaces- Solid-Liquid Interfaces-Step Line Tension- Stiffness at its interfaces- Equilibrium Fluctuations of Line Defects and Surfaces- The Terrace-Step-Kink Model - Basic Assumptions and Properties- Step-Step Interactions on Vicinal Surfaces-The Ising-Model- Application to the Equilibrium Shape of Islands- Simple Solutions for the Problem of Interacting Steps	
Unit-3 - Thermodynamic Considerations In Tailoring Surfaces/Interfaces For Specific Applications	***9 Hour***
Bond formation and breaking dynamics - Adiabatic dynamics (Born-Oppenheimer approximation) - Non-adiabatic dynamics- Hot electrons from chemistry - Chemistry from hot electrons - Adsorption and Desorption Kinetics- Physisorption and Chemisorption- - Molecular adsorbates – local sites, orientations and intramolecular bondlengths- Experimental background/ techniques - Typical measurements - Rate measurements 3.2.2 Adsorption-trapping and sticking-Desorption - Symmetry of Adsorption Sites- Vibrational Frequencies of Isolated Adsorbates- Desorption - Desorption Spectroscopy- Theory of Desorption Rates-	

Photochemistry/femtochemistry- Single molecule chemistry (STM) - The Langmuir Isotherm- Lattice Gas with Mean Field Interaction- The Fowler-Frumkin Isotherm- Reduction to the Langmuir Isotherm- The Chemical Bond of Adsorbates of Hydrogen, Oxygen molecules- The Chemical Bond of Adsorbates of Water, Hydrocarbons, aliphatic and aromatic molecules

Unit-4 - Phase Equilibrium of Multicomponent Systems **9 Hour**

Structure of Surfaces- Surface Crystallography- Surface stress, Surface energy- Relaxation, Reconstruction –Surfaces of crystalline solids - Surface energy for crystalline solids- Equilibrium crystal shape - Internal boundaries - types of grain boundaries - Intersections of grain boundaries with free surfaces – Faceting - Measurement of surface and grain-boundary energies - The zero-creep technique - The multiphase-equilibrium (MPE) technique - Interphase interfaces - Interface classifications – a) Coherent interfaces - Semicoherent interfaces, c) Incoherent interfaces – d) Interface mobility - Defects at surfaces/interfaces – line & point defects- Vibrational Excitations at Surfaces - -Statistics of Random Walk- Absolute Rate Theory- Calculation of the Pre-factor- The Ehrlich-Schwoebel Barrier- The Concept of the Ehrlich-Schwoebel Barrier- Mass Transport on Stepped Surfaces- The Atomistic Picture of the EhrlichSchwoebel Barrier -The Kink Ehrlich-Schwoebel Barrier-

Unit-5 - Adsorption and Desorption Kinetics **9 Hour**

Introduction to Thin-film and its formation - Growth of thin oxide films - Formation of metal films by physical vapor deposition/evaporation – self-assembly- self-organization - Curved surfaces - Derivation of the Laplace equation - techniques that use the Laplace equation to measure surface energy - Phase equilibria in one-component and multicomponent systems – Adsorption - The Gibbs adsorption equation- Applications of the Gibbs adsorption equation- The origin of stresses in multilayer systems - Formation stresses - Thermal stresses-Applied stress - Electronic Properties at the surfaces- Beyond the Surface Selection Rule- Empty and image – potential surface states- Case studies – protective layers on superalloys in gas turbines- Formation and adhesion of protective oxide layers - Multilayer systems – thermal barrier coatings - Linear Optical Techniques at Surfaces and Interfaces- Spectroscopic Ellipsometry (SE)- Reflection Difference Techniques (Surface Differential Reflectivity (SDR)- Kelvin Probe measurements for the study of work-function changes

Learning Resources	*1. G. Bordo Vladimir and Horst-Günter Rubahn, Optics and Spectroscopy at Surfaces and Interfaces, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim 2005* *2. Harald Ibach, Physics of Surfaces and Interfaces, Springer-Verlag Berlin Heidelberg 2006* *3. H. Yıldırım Erbil, Surface Chemistry of Solid and Liquid Interfaces, First published in 2006 by Blackwell Publishing Ltd, Oxford, UK*	*4. Anders Nilsson, Lars G.M. Pettersson, Jens K. Nørskov, Chemical Bonding at Surfaces and Interfaces, Elsevier, Amsterdam, The Netherlands 2008* *5. John C. Riviere, Sverre Myhra, Handbook of Surface and Interface Analysis: Methods for Problem-Solving, 2nd Edition, CRC Press Taylor & Francis Group 2009* *6. Gerald H. Meier, Thermodynamics of Surfaces and Interfaces (Concepts in Inorganic Solids), Cambridge CB2 8BS, United Kingdom 20147. Klaus Wandelt, Surface and Interface Science, Volume Solid-Gas Interfaces II, Wiley VCH Verlag, Weinheim, Germany 2015*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	*-*	*20%*	*-*	*20%*	*-*
Level 2	*Understand*	*20%*	*-*	*20%*	*-*	*20%*	*-*
Level 3	*Apply*	*30%*	*-*	*30%*	*-*	*30%*	*-*
Level 4	*Analyze*	*30%*	*-*	*30%*	*-*	*30%*	*-*
Level 5	*Evaluate*	*-*	*-*	*-*	*-*	*-*	*-*
Level 6	*Create*	*-*	*-*	*-*	*-*	*-*	*-*
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	*1. Prof. V. Subramaniam, Physics Department, IITM, Chennai, manianvs@iitm.ac.in*	*1. Dr. AAlagiriswamy A A, SRMIST*
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	*2. Prof. Gridhar U. Kulkarni, Director at CeNS, Bangalore, guk@cens.res.in*	*2. Dr. E. Senthil Kumar, SRMIST*

Course Code	21NTE301T	**Course Name**	SPECTROSCOPY TOOLS FOR NANOSCALE ANALYSIS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire the knowledge in the basic concepts of interaction of radiation with matter and rotational spectroscopy*
CLR-2:	*comprehend the principles of vibrational spectroscopy*
CLR-3:	*understand the principles and techniques involved in of Raman scattering*
CLR-4:	*emphasize the significance of various techniques in electronic spectroscopy*
CLR-5:	*expose to concepts and applications of magnetic resonance*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*interpret the processes of absorption and radiation and analyse the rotational motion in molecules*	3	3	-	-	-	-	-	-	-	-	-	-	3	-	2
CO-2:	*analyze the vibrational spectra of diatomic and polyatomic molecules*	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-3:	*analyze the Raman spectra and various non-linear Raman techniques*	3	3	-	-	-	-	-	-	-	-	-	-	-	3	-
CO-4:	*elucidate the various optical processes involved in the electronic spectra*	3	-	-	3	-	-	-	-	-	-	-	-	-	-	2
CO-5:	*apply the concept magnetic resonance in chemical analysis and structure determination*	3	-	-	3	-	-	-	-	-	-	-	-	3	-	-

Unit-1 - Interaction of Radiation with Matter ***9 Hour***

Introduction to Electromagnetic spectrum and its applications, spectral Regions- Types of molecular energies- Interaction of light with matter- Methods of obtaining a spectrum, components and various construction types of a spectrometer- Various accessories used in a spectrometer – Various sourcer of electromagnetic spectrum used in a spectrometer - Spectral line width and broadening of spectral lines- Intensity of spectral lines- Absorption and emission of radiation- Spontaneous and stimulated processes- Einstein's co-efficients and its derivation- Laser as a spectroscopic light source- Rotational spectra of rigid diatomic molecules - Rigid rotator- Isotope effect in rotational spectra, Intensity of rotational lines - Non-rigid rotator - Vibrational excitation effect and Λ doubling - Microwave spectrometer - Applications of rotational spectroscopy.

Unit-2 - Principles of Vibrational Spectroscopy ***9 Hour***

Vibrational energy of a diatomic molecule - Classical approach - Wave mechanical approach - Morse curve and energy levels of a diatomic molecule - Selection rules for vibration - Fundamental overtones and hotbands in the vibrational spectrum - Accidental degeneracy - Diatomic vibrating rotator - Selection rules for vibration-rotation - Vibrations of polyatomic molecules - Normal vibrations of CO2 and H2O molecules - Interpretation of IR spectra - Group frequencies and various regions in IR spectrum - Perturbation of group frequencies: mass effects - Perturbation of group frequencies: inductive effects - Fourier transform infrared spectroscopy: principle and interferometer arrangement - Elucidation of molecular structure using IR Spectroscopy - Identification of molecular constituents using IR spectroscopy

Unit-3 - Vibrational Spectra of Diatomic and Polyatomic Molecules ***9 Hour***

Born oppenheimer approximation - Vibrational coarse structure - Band system and vibrational transitions - Progressions and sequences - Franck condon principle - Intensity of vibrational electronic spectra - Rotational fine structure - Assignment of bands in a fine structure - Dissociation energy and dissociation products – Predissociation - Electronic absorption spectra - Electronic angular momentum in diatomic Molecules - Singlet and doublet states - Jablonski diagram – Phosphorescene – Fluorescence - Photoelectron spectroscopy: principle - Photoelectron spectroscopy: instrumentation

Unit-4 - Fundamentals of Raman Scattering	***9 Hour***
Quantum theory of Raman scattering - Classical theory of Raman scattering - Rotational Raman spectra - Vibrational Raman spectra - Mutual exclusion principle - Polarization of Raman scattered light - Raman spectrometer - Analysis of Raman spectra - Structure determination using Raman spectroscopy - Raman investigation of phase transitions - Resonance Raman scattering - Surface enhanced Raman scattering - Non-linear Raman phenomena- preliminaries - Hyper Raman effect - Stimulated Raman scattering - Inverse Raman effect - Coherent Antistokes Raman scattering - Photo acoustic Raman scattering – Laser selection for Raman spectroscopy of materials	
Unit-5 - Magnectic Moment and Spectroscopy Tools	***9 Hour***
Magnetic moments – Quantization - Larmor precession - Resonance condition in Nuclear magnetic resonance (NMR) - Spin –spin relaxation - Spin-lattice relaxation - NMR spectrometer - Chemical shift - Factors contributing to screening- Double resonance technique - NMR imaging - Fourier transform NMR techniques – Applications of NMR spectroscopy - Electron spin resonance - Resonance condition in Electron spin resonance (ESR) - ESR spectrometer - Nuclear- electron spin coupling - Applications of ESR spectroscopy	

Learning Resources	*1. Peter Atkins, Julio de Paula Atkins, "Physical Chemistry", W. H. Freeman and Company, New York, 2010* *2. Collin Banwell, Mc Cash, "Fundamentals of Molecular Spectroscopy", McGraw Hill publishing, 2001*	*3. G. Aruldhas," Molecular structure and spectroscopy" ,Prentice Hall, 2001* *4. P.S.Sindhu, "Fundamentals of molecular spectroscopy" New age international publishers,2006*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	*1. Dr.G. Aravind, IIT Madras, garavind@iitm.ac.in*	*1. Dr. R. Annie Sujatha, SRMIST*
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	*2. Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*2. Dr. E. SenthilKumar, SRMIST*

Course Code	21NTE302P	**Course Name**	LITHOGRAPHY TECHNIQUES AND FABRICATION	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the physical significance of lithography tools in micro/nano structures creation*
CLR-2:	*acquire knowledge on masked lithography, uv and deep uv lithography, its merits and demerits*
CLR-3:	*understand the concept of direct lithography, its advantages; electron beam for lithography and their applications*
CLR-4:	*acquiring comparative knowledge of different lithography tools*
CLR-5:	*acquire knowledge on the replication tools such as nano imprint lithography, injection molding and others*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
Course Outcomes (CO):	***At the end of this course, learners will be able to:***															
CO-1:	*make use of top-down approach for micro/nano fabrication*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*analyze the limitation of masked lithography with respect to incident radiation*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*using electron beams for the creation of nano structures*	-	-	*2*	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-4:	*know the other techniques of nano fabrication using light and heavy ion beams*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-5:	*apply knowledge of mass production replication tools*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Top-Down and Bottom-Up Approaches for Micro/Nano Fabrication ***9 Hour***

Micro/nano fabrication-Top-down & bottom-up approach-Necessity for clean room, types of clean room-Construction and maintenance of clean room-Clean room standards, protocols-Lithography- process steps-Photo resists materials, types and characteristics-Spin coating methods-Exposure dose-chemical development, optimization-Etching methods, resist and other materials-Dry and wet methods-Wet etching chemicals, Si etching-Wet etching examples-Reactive ion etching-Isotropic and non-isotropic etching-Types of lithography : classification-Introduction to next generation lithography tools.

Unit-2 - Optical Lithography ***9 Hour***

Introduction to lithography - Optical(photo) lithography-Process steps-Optical lithography mask-Mask definition, and different materials-Lamp and LED UV sources-Contact and proximity exposures-Diffraction limit and resolutions enhancement methods-Projection lithography-Extreme UV (EUV) lithography-EUV: Scope and demerits-Interferometric and holographic tools -Laser writer: near UV and Deep UV masks-Synchrotron radiation for lithography processes-X-ray lithography mask-X-ray lithography, merits and demerits-Comparison of all masked lithography tools-Specific applications of different lithography tools – Defects in lithography processes(undercut/overcut)

Unit-3 - Electron Beam Lithography ***9 Hour***

Introduction-maskless/direct lithography tools-Difference between masked and maskless lithography-Advantages and disadvantages of maskless lithography-Principles of electron beam lithography (EBL) system-Electron properties for lithography-Design of electron beam lithography system-Operation of electron beam lithography system-E-beam resists-E-beam resist properties-Comparison with optical lithography resists-Dose calculation-Significance of beam blanking-Patterning resolution comparison with other methods-EBL for mask preparation-Nanofabrication with EBL – MEMS-Nanofabrication with EBL – NEMS-Nanofabrication with EBL –microfluidics applications-Nanofabrication with EBL – Nanofluidics applications – Safety precautions

Unit-4 - Ion Beam Lithography	***9 Hour***
on beam lithography (IBL) types-Heavy and light ions for lithography-Focused ion beam properties-Beam scanning-Resists for ion beam lithography-Electron lithography process flow-Focused ion beam lithography-Incident ion properties-Principle, design and operation-Masked ion beam structuring: Broad beam patterning-Atom lithography-Proton beam lithography-Comparison of electron, proton and gallium for resist patterning-Limitation and suitability of each technique in comparison with one another-IBL resists, dose calculation and process optimization-Nanofabrication with IBL – MEMS-Nanofabrication with IBL – NEMS-Nanofabrication with IBL –microfluidics applications-Nanofabrication with IBL – Nanofluidics applications	
Unit-5 - Replication tools	***9 Hour***
Micro/ Nano replication tools-Mass production tools-Application areas-MEMS/NEMS,micro/nanofluidics-Soft lithography-PDMS Casting-Mold fabrication for soft lithography-Micro injection molding-Hot embossing-Nano imprint lithography NIL principles-Mold fabrication for hot embossing and NIL-Mold fabrication for injection molding-Process flow and requirements-Polymers for imprinting-Polymer characteristics and performance-Master mold preparation for replication tools, comparison-Application-microfluidics-Application-nano fluidics-Industrial applications	

Learning Resources	*1. Chris A. Mack, Fundamental Principles of Optical Lithography: The Science of Microfabrication, John Wiley & Sons, London 2007* *2. Stefan Landis, "Lithography and nanolithography", Published by Wiley - ISTE, 2010*	*3. Theodore C HennessyLithography: Principles, Processes & Materials (Engineering Tools, Techniques and Tables), Nova Science Publishers Inc, 2011.* *4. José María De Teresa, Introduction to nanolithography techniques and their applications, IOP Publishing Ltd 2020*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*						*Final Examination (0% weightage)*	
		Formative CLA-1 Average of unit test (20%)		*Project Based Learning CLA-2 (60%)*		*Report and Viva Voce (20%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	-	*20%*	-	*20%*	-	-
Level 2	*Understand*	*20%*	-	-	*20%*	-	*20%*	-	-
Level 3	*Apply*	*30%*	-	-	*30%*	-	*30%*	-	-
Level 4	*Analyze*	*30%*	-	-	*30%*	-	*30%*	-	-
Level 5	*Evaluate*	-	-	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100%*		-	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Mohan Bhan, OAI, USA, mbhan@oainet.com	*1. Prof. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*1. Dr. P. Malar, SRMIST*
2. Mr, C P Sridhar, SIMCO Groups, Bangalore, sridhar.cp@simcogroup.in	*2. Prof. S. Balakumar, Madras University, balakumar@unom.ac.in*	*2. Dr. Abhay Sagade, SRM IST*

Course Code	21NTE303T	**Course Name**	SENSORS AND TRANSDUCERS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand basic principles and characteristics of sensors and transducers*
CLR-2:	*gain knowledge on mechanical and electromechanical sensors*
CLR-3:	*get acquainted with thermal sensors and its types*
CLR-4:	*know about magnetic sensors and radiation sensors*
CLR-5:	*gain knowledge on electrochemical sensors, and applications of other sensors in our life*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*analyze calibration techniques, characteristics and signal types of sensors*	-	-	*2*	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*explain about principle and working of physical sensors*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*understand the types of thermal sensors and its importance*	*2*	-	-	*2*	-	-	-	-	-	-	-	-	-	*3*	-
CO-4:	*be aware of magnetic and radiation sensors*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*recognize electrochemical sensors and nanosensors along with the applications of various sensors used home appliances and industries*	-	-	*3*	*2*	-	-	-	-	-	-	-	-	-	*3*	-

Unit-1 – Classification and Charaterization ***9 Hour***

Measurements-Basic method of measurement- Errors- Classification of errors- Error analysis- Statistical methods- Sensors/Transducers-Introduction- Principles of Sensors/Transducers- Classification of Sensors/Transducers- Static Characteristics of Sensors/Transducers- Accuracy-Precision-Resolution-Minimum detectable signal- Threshold-Sensitivity-Selectivity and specificity-non-linearity- Hysteresis-Output impedance-isolation and grounding- Dynamic Characteristics- Zero order and First order sensors- Second order sensors- Electrical characterization- Mechanical and thermal characterization- Optical characterization- Chemical/biological characterization

Unit-2 – Mechanical and Electromechanical Sensors ***9 Hour***

Resistive potentiometer- Strain gauge- Inductive sensors- Sensitivity and linearity of sensor- Ferromagnetic plunger type transducers- Electromagnetic transducer- Magnetostrictive transducer- Capacitive sensors-Parallel plate capacitive sensor- Serrated plate capacitive sensor- Variable thickness dielectric capacitive sensor- Stretched diaphragm variable capacitance transducer- Electrostatic transducer- Piezoelectric elements- Piezoelectric materials- Deformation modes and multimorphs- Lead zirconate titanate (PZT) family- Force/stress sensors using quartz resonators

Unit-3 – Thermal Sensors ***9 Hour***

Gas thermometric sensors- Thermal expansion type thermometric sensors- Acoustic temperature sensor- Dielectric constant and refractive index of thermosensors- Helium low temperature thermometer-Nuclear thermometer- Magnetic thermometer- Resistance change type thermometric sensors- Metal resistance thermometric sensors- Thermistors- Thermo emf sensors- Materials for thermo emf sensors- E (emf)-T(Temperature) relations- Thermosensors using semiconductor devices- Thermal radiation sensors- Detectors- Pyroelectric thermal sensors- Quartz crystal thermoelectric sensors- Heat flux sensors

Unit-4 – Magnetic Sensors and Radiation Sensors	***9 Hour***
Introduction to Magnetic sensors- Principles behind- Yoke coil sensors- Coaxial type sensors-Force and displacement sensors- Magnetoresistive sensors- Anisotropic magnetoresistive sensing- Semiconductor magnetoresistors- Active semiconductor magnetic sensors- Hall effect sensor-sensor geometry and fabrication- Variable inductance sensors- Eddy current sensors- Radiation sensors-Introduction-basic characteristics- Types of photoresistors/photodetectors- Photoemissive cell and photomultiplier- Photoconductive cell-LDR- Photocurrent- Photoresistors and photo FETs and other devices- Fibre optic sensors-Temperature sensors-microbend sensors	
Unit-5 - Electroanalytical Sensors and Sensor Technologies	***9 Hour***
Electroanalytical sensors-introduction- Electrochemical cell- Sensor electrodes-Molecular selective electrodes- ChemFET- Recent trends in sensor technologies- Film sensors- Thick and thin film sensors-Semiconductor IC technology- Micro electro mechanical system (MEMS)- Fabrication of MEMS using lithography (process steps) - micromachining- Some application examples- Nanosensors- Onboard automobile sensors-flow rate sensors-pressure sensors- Temperature sensors-oxygen sensors- Torque and position sensors- Home appliance sensors-Aerospace sensors-Fluid velocity sensors- Sensing direction of air flow-Monitoring-strain, force, thrust and acceleration- Medical diagnostic sensors- Sensors for environmental monitoring – Integration of different sensors in a MEMS device	

Learning Resources	*1. Ernest O Doebelin, "Measurement Systems – Applications and Design", 4th ed., Tata McGraw-Hill, 2009* *2. John P. Bentley, "Principles of Measurement Systems", 4th ed., Pearson Education, 2000*	*3. D. Patranabis, Sensors and Transducers, 2nd ed., Prentice Hall of India, 2010* *4. D.V.S Murthy, Transducers and Instrumentation, 2nd ed., Prentice Hall of India, 2001.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Maximilian Fleischer, Siemens, Germany, maximilian.fleischer@siemens.com	*1. Dr. A. Subrahmanyam, IIT Madras, manu@iitm.ac.in*	*1. Dr. S. Yuvaraj, SRMIST*
2. Dr. Shyam Sunder Tiwari, Sensor's technology Private Limited, India, sst@sensorstechnology.com	*2. Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*2. Dr. A. Karthigeyan, SRMIST*

Course Code	21NTE304T	**Course Name**	GREEN NANOTECHNOLOGY	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*familiarize with the field of traditional manufacturing to green manufacturing*
CLR-2:	*understand the various techniques for sustainable green manufacturing*
CLR-3:	*able to identify green nanotechnology concepts in Industrial process*
CLR-4:	*gain knowledge on industrial policies and operations in industry*
CLR-5:	*understand the list of metrics in the industry*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*incorporate the green Nanotechnology in industrial processing*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*demonstrate the various principles of green manufacturing*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	2	-	2
CO-3:	*create various metrics for Industrial manufacturing*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*produce life cycle assessments and machine tools*	-	*3*	*2*	*3*	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*apply the green manufacturing in the semiconductor industry*	-	*3*	-	*3*	2	-	-	-	-	-	-	-	-	2	-

Unit-1 - Green Manufacturing ***9 Hour***

Green manufacturing and Sustainability goals for the future - Environment impact on waste generation, Toxic chemical releases - Energy consumption and carbon emission strategies for green manufacturing – Biological sources used in Nanotechnology : Plants & Microorganisms – Mechanisms of biosynthesis of nanoparticles – Effect of parameters such as pH, temperature, concentration, exposure time, type of enzyme – Phytochemical based Nanoparticles – Plant derived nanoparticles – Mechanism of Phjytochemical synthesis

Unit-2 - Techniques for Sustainable Green Manufacturing ***9 Hour***

Social, business & policy environment, Need for change - Internal stake holders, External stake holders - Components of next transition, Linear to circular transition - Product production to service provision, Integrated information, Rich communication - Policy environment, Changing policy trends, Fostering co-operation - Principles of green manufacturing, Technology: wedgels -1st principle of green manufacturing , 2nd principle of green manufacturing - 3rd principle of green manufacturing, 4th principle of green manufacturing - Mapping of principles, Solutions

Unit-3 - Metrics for Industrial Green Manufacturing ***9 Hour***

Metrics for green manufacturing, Current metrics - Financial metrics, Metrics for ecology - Metrics for society, Multiple metrics - Impact assessment, Risk assessment - Material flow analysis, Energy flow analysis - Metric development methodologies, Ecological metric choice model - Decision tree model for equipment's Supply, Metrics development for component systems - Green energy supply, Green energy technologies - Solar photovoltaics, wind energy, Application potentials of green energy - Integration of green energy systems to conventional energy systems

Unit-4 - Life Cycle of Green Production ***9 Hour***

Closed loop production systems, Life cycle production systems - Economic and ecological benefits, Reduction of investment & increase of resources, Machine tools, Energy consumption - Life cycle assessment machine tools, Methods & results - Process parameter optimization, Constant feed per tooth - Constant spindle speed, Conventional vs high speed machining - Dry machining and minimum quantity lubrication, Health & environmental hazards – Remanufacturing: product recovery & industrial practice, Challenges & opportunities – Reuse, Approaches for sustainable factory design – Zero carbon design – available technologies towards zero carbon footprint

Unit-5 - Green Manufacturing in Semiconductor Processes	***9 Hour***
Semiconductor manufacturing, Semiconductor fabrication - Micro fabrication process, Lithography - Oxidation & annealing, Cleaning - Facility systems, resource use, Abatement - Green manufacturing in industry, Concepts & challenges - Use phase issues, Analysis phase of semiconductor manufacturing - Upstream materials, Chemicals, silicon, water - Infrastructure & equipment, Electricity - Semiconductor manufacturing, Transportation & use phase	

Learning Resources	*1. Green Manufacturing- Fundamentals and Applications, David A Dornfeld, Springer science publishing, 2013,* *2. Green Nanotechnology: Solutions for Sustainability and Energy in the Built Environment, Geoffrey B. Smith, Claes-Goran S. Granqvist, CRC Press, 2010*	*3. An Introduction to Green Nanotechnology, Mahmoud Nasrollahzadeh, Mohammad S. Sajadi, Monireh Atarod, Elsevier Science Publications, 2019.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Manoj Maurya, Jayalakhsmi Waving Mills Pvt Ltd, Salem@jailakshmi.com	*1. Dr. T. Ramesh Babu, Anna University, trb@annauniv.edu*	*1. Dr. C.Siva, SRMIST*
2. Mr.Hitesh Rathore, SHT Distributors – Salem, TN, hitheshrathore@gmail.com	*2. Dr. M. Rajmohan. Anna University, rajmohan@annauniv.edu*	*2. Dr. M. Navaneethan, SRMIST*

Course Code	21NTE305T	**Course Name**	NANOMAGNETISM AND SPINTRONICS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the basic concepts related various type of magnetism and magnetic properties of materials*
CLR-2:	*provide in-depth knowledge about low dimensional magnetic materials*
CLR-3:	*understand the magnetization behavior of magnetic nanostructures and thin films*
CLR-4:	*give an overview of different Experimental Approaches to characterize magnetic nanostructures*
CLR-5:	*acquaintance with spin transport mechanism in magnetic materials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*realize the importance of "magnetism" in contributing to past and for the advancement of new technology*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*appreciate the significance of in-depth understanding of magnetic properties in low dimension*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*obtain the knowledge about fabrication of magnetic thin films and properties of the magnetic nanostructures*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*know various sensitive characterization techniques for investigating magnetic nanostructures*	*3*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*analyze the mechanism of spin transport in magnetic nanostructures and its relevance in advancing the magnetic memory device performance*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Types of Magnetism ***9 Hour***

Basics of magnetism, Units in magnetism, Different types of magnetism: Dia, Para, Ferro, Ferri, Antiferro – Application of different materials possessing different magnetic property - Origin of various type of magnetization behaviour, Magnetization curves and hysteresis loops, Saturation magnetization, Coercive field, Magnetic susceptibility, Formation of magnetic domains, Domain walls, Domain wall width, Various type of domain walls, Bloch walls and Neel walls, Heisenberg exchange interaction, Role of Heisenberg exchange interaction in magnetism, Energy scales involved in magnetism, Zeeman energy, Magnetic anisotropy energy, exchange energy, Magnetostatic energy

Unit-2 - Magnetic ordering and Anisotropy ***9 Hour***

Concept of Magnetic ordering, Magnetic ordering in low dimensions, Physical origin of Magnetic anisotropy, Shape anisotropy and Magnetocrystalline anisotropy, Dipolar anisotropy, Interface magnetic anisotropy, Mechanisms of magnetization reversal, Coherent rotation, Fanning, curling Domain wall movement, Introduction to Gilbert damping, In-plane magnetic anisotropy, Magnetic domains in in-plane magnetized materials, Perpendicular magnetic anisotropy, Magnetic domains in out-of-plane magnetized materials, Formation of magnetic vortex, Formation of antivortex and Skyrmions

Unit-3 - Magenetic Properties in Low Dimension ***9 Hour***

Magnetism in thin films, Magnetism in multilayers, Fabrication of nanomagnets using various techniques, Top down and bottom up approach, Single domain versus multi domain behaviour, Chemical synthesis of magnetic nano-particles, Self-assembly of magnetic nanoparticles, Magnetic nanowires, Physical vapour deposition of magnetic thin films and multilayers, DC and RF Sputter deposition, E-beam evaporation technique, Magnetization reversal in magnetic thin films, Domain walls and magnetization reversal nanostructures, Magnetic properties of NiFe, CoFeB (soft) and FePt, CoPt (hard) materials

Unit-4 - Magnetometers and Characterization Tools	***9 Hour***
Introduction to various magnetometers, Working principle of magnetometers, Vibrating Sample Magnetometer, Superconducting Quantum Interference Device, Magnetic imaging techniques, Magneto-optical Kerr effect, Longitudinal, Transverse and Polar Kerr effect, Faraday effect, Magnetic force microscopy, Scanning electron microscopy with polarization analysis, Interpretation of magnetic contrast from thin films and nanostructures, Magnetic contrast from nanostructures, Spin-polarized scanning tunnelling microscope (SP-STM), Interpretation of SP-STM results, Magnetic recording and its principles, Nanomagnetic disks, Read and write head	
Unit-5 - Spin Transport in Magnetic Nanostructures and Applications	***9 Hour***
Introduction to spin transport, spin angular momentum, Spin Current, Spin valve devices, Giant magneto resistance (GMR), Spin dependent scattering, Valet-Fert model for GMR, Magnetic tunnel junction, Tunnel magneto resistance (TMR), Application of GMR and TMR, Spin transfer torque, Spin-orbit coupling induced phenomena, Spin-orbit torque, Spin Hall effect, Spin dynamics, Advanced spintronics based devices, Domain wall-based memory, Race track memory	

Learning Resources	1. *Principles of Nanomagnetism, by Alberto P. Guimaraes, XII, Springer Berlin Heidelberg New York, 2009* 2. *Advanced Magnetic Nanostructures, by David Sellmyer, Ralph Skomski, Springer Heidelberg, 2010* 3. *Spin dynamics and damping in ferromagnetic thin films and nanostructures, by Anjan Barman and Jaivardhan Sinha, Springer, Switzerland, 2018*	4. *Nanomagnetism and Spintronics Hardcover, Teruya Shinjo, Elsevier, 2013* 5. *Magnetism and Magnetic Materials – J M D Coey, Cambridge University Press 2012* 6. *B.D. Cullity, Introduction to Magnetic Materials, Addison- Wesley (1972)*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Hemant Dixit, GlobalFoundaries,USA, aplahemant@gmail.com*	1. *Dr. Arabinda Haldar, IIT Hyderabad, arabinda@iith.ac.in*	1. *Dr. Jaivardhan Sinha, SRMIST*
2. *Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com*	2. *Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	2. *Dr. Kamala Bharathi, SRMIST*

							L	T	P	C
Course Code	21NTE306T	**Course Name**	2D LAYERED NANOMATERIALS	**Course Category**	E	PROFESSIONAL ELECTIVE	3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the 2D layered Nanomaterials and its properties and importance*
CLR-2:	*familiarize the structure and properties of graphene*
CLR-3:	*acquire knowledge about different synthesis methods for producing layered materials*
CLR-4:	*reinforce and enhance the understanding of the principles of various characterization tools in studying 2D materials*
CLR-5:	*gain knowledge on various 2D layered materials and the application of layered nanomaterials*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*distinguish various 2D layered nanomaterials and their properties*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*apply the concept of atomic and electronic structure to understand the physical and chemical properties of graphene*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*utilize the different techniques for preparation of 2D layered nanomaterials*	-	-	*2*	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-4:	*analyze the 2D layered nanomaterials using various characterisation techniques*	-	-	*2*	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*apply the distinct properties of 2D layered materials in various fields*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	*3*

Unit-1 – 2D Materials and Its Examples ***9 Hour***

Introduction to 2D materials- Layered and Non-layered materials – bonds in layered materials -van der Walls force- Covalent bond-Types of Layered materials – Graphene, TMDs, Black phosphorous, h-Boron Nitride, MXenes and Layered metal oxides. Properties, Advantages and Applications of 2D Layered Nanomaterials.

Unit-2 - Graphene and its Properties ***9 Hour***

Introduction to graphene - Dimensionality forms of carbon allotropes- Graphene structure - Manipulation of quantum degree of freedom- Crystal plane of 2D graphene- Free standing model- Electronic structure of graphene- Band structure- Fermi levels in graphene- Carrier density- Role of defect and dopant- Electronic structure of graphene- Tensile strength- Physical properties of graphene- Functional properties of graphene- Chemical properties of graphene- Penta-graphene and its properties.

Unit-3 - Preparation Methods for 2d Materials ***9 Hour***

Preparation techniques for 2D layered materials - Introduction to Scotch-tape method (micromechanical cleavage)- Preparation of graphene using Scotch-tape method-Pros and cons of micromechanical cleavage method - Introduction and principle of Chemical vapor deposition- Preparation of graphene by CVD- Introduction to Solution-exfoliation- Preparation of graphene using solution- exfoliation- Introduction to Solution-exfoliation- Preparation of 2D layered material by solution exfoliation- Decomposition- Decomposition of silicon carbide

Unit-4 - Chracterization Tools for 2d Materials ***9 Hour***

Characterization techniques - Principles of Raman spectroscopy- Limitations of Raman spectroscopy- Raman spectrum of graphene- Analysis of D band Raman spectra- Analysis of G band Raman spectra- Raman shift dependence on number of layer- Raman shift dependence on defect- Raman shift dependence on doping concentration.Introduction to X-ray photoemission spectroscopy- Limitation and application of XPS-Introduction to X-ray diffraction study- Limitation and application of XRD- Introduction and limitations to BET analysis- Adsorption properties – other characterizations for analyzing 2D materials

Unit-5 - Application of 2d Materials	***9 Hour***
Introduction to h-BN structure, synthesis and properties- Application of h-BN. Introduction to SiC structure, synthesis and properties- Application of SiC structure. Introduction to layered metal oxides - structure, synthesis and properties- Applications. Introduction and types of transition metal Dichalcogenides- Introduction and application of MoS2, Introduction and application of VS2- Introduction and application of WS2- Introduction of Si2BN and its application- Introduction of BCN and its applications	

Learning Resources	1. *Houssa, Michel, Athanasios Dimoulas, and Alessandro Molle, "2D Materials for Nanoelectronics"- CRC Press, 2017.* 2. *Banks, Craig E., and Dale AC Brownson, eds. "2D Materials: Characterization, Production and Applications"- CRC Press, 2018.* 3. *Ter-Zakaryan, A., and A. D. Zhukov. "Materials Horizons: From Nature to Nanomaterials." In Materials Horizons: From Nature to Nanomaterials, pp. 349-377. 2021.(Materials Horizons: From Nature to Nanomaterials2D Nanomaterials for Energy and Environmental Sustainability)*	4. *Tiwari, Ashutosh, and Mikael Syväjärvi, eds. "Advanced 2D Materials" - John Wiley & Sons, 2016.* 5. *Dragoman, Mircea, and Daniela Dragoman,"2D Nanoelectronics: Physics and Devices of Atomically Thin Materials"- Springer,2017*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Hemant Dixit, Global Foundaries, USA, aplahemant@gmail.com*	1. *Prof. K. Sethupathi. IIT Madras, ksethu@iitm.ac.in*	1. *Dr. J. Archana, SRMIST*
2. *Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com*	2. *Dr. S. Balakumar. University of Madras, Madras, balakumar@iunom.ac.in*	2. *Dr. S. Harish, SRMIST*

Course Code	21NTE307T	Course Name	NANOCATALYSTS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire the concepts of Chemistry of Nanocatalysts*
CLR-2:	*understand the Catalytic Kinetics*
CLR-3:	*describe the reaction kinetics of Adsorption and Desorption processes*
CLR-4:	*understand the principles behind the Synthesis of Nanocatalysts*
CLR-5:	*gain knowledge about the working mechanism of Nanocatalytic materials*

		Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*express the mechanism of materials for using as catalyst*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*apply isotherms for different micro and nano porous catalytic materials*	*3*	*2*	*1*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*evaluate the photocatalyst for environmental remediation*	-	*2*	-	-	-	-	*3*	-	-	-	-	-	-	-	-
CO-4:	*analyse the working of noble metals as Nanocatalysts*	*3*	-	*1*	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*apply the nanoscale paradigm in terms of catalytic property*	*2*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-

Unit-1 - Chemistry of Nanocatalysts ***9 Hour***

Introduction to Catalysis - Classifications of Catalysis – Necessary properties of a catalyst - Heterogeneous Catalysis - Reaction on the Solid Surfaces - Active sites: Activation Energy - Adsorption Isotherms - Physisorption and Chemisorption – Brunauer Emmett Teller (BET) theory - Total Surface Area - Pore volume and Pore size distribution – Porosity characterization techniques - Hg Porosimetry Method - N2 Adsorption Desorption method - Reaction Mechanism - Kinetics of the Heterogeneous Catalytic Reactions - Activation energy (Arrhenius equation, Eyring equation) - Terminology in Catalysis: TO (Turnover),TON (Turnover number), TOF (Turnover frequency) - Sequences involved in a Catalysed Reaction – Asymmetric Synthesis using a Catalyst

Unit-2 - Catalytic Kinetics ***9 Hour***

Introduction to Adsorption and Desorption Processes - Adsorption Rate - Desorption Rate - Catalytic Activity (Bulk and Nanoscale) - Catalytic Activity Determination for Metal/Metal-Oxide Nanostructures - Langmuir Hinshelwood Mechanism for Nanocatalysts - Mass Transport - Diffusion controlled Process - Adsorption equilibrium on Uniform Surfaces: Langmuir Isotherms Single-site (non-Dissociative) Adsorption - Dual-site (Dissociative) Adsorption - Derivation of the Langmuir Isotherm - Adsorption equilibrium on non-Uniform Surfaces: Langmuir Isotherms - The Freundlich Isotherm - The Temkin Isotherm - Activated Adsorption - Catalytic Efficiency - Applications of Metal Nanoparticles in Organic Reactions - Environmental Remediation.

Unit-3 - Photocatalysis ***9 Hour***

Kinetics and Photocatalytic Activity - Introduction to Photocatalyst - Basics of Electrochemistry – Photochemistry - Electronic Structure and Photoabsorption - Jablonskii Diagram - Structure of Photocatalysts - Solar Spectrum - Fundamental Understanding of Semiconductor Interfaces - Principles and Relevance to Photoelectrochemical Mechanism - Photocatalysis Mechanism - Properties of good Photocatalysts - Advantages of Photocatalysts - Types of Photocatalysts - Homogeneous and Heterogeneous Photocatalyst - Carbonaceous Photocatalysts - Plasmonic Photocatalysts – Applications of Photocatalysts – Characterization techniques used for photocatalysts

Unit-4 - Nanocatalysts and Examples	***9 Hour***
Introduction to Nanocatalysts - Noble Metal Nanocatalysts (Ru, Rh, Pd, Pt, etc.) - Polymer Stabilized Rh and Ru Nanoparticles - Oxide supports for Nanocatalysts: Carbon supports for Nanocatalysts - Gold Nanoparticle based Catalysts Gold vs Palladium Catalysts for the Aerobic Oxidation of Alcohols - Oxide based Catalysts - Metal free Catalysts (CNT, Graphene based Catalyst) - Transition Metal Dichalcogenides based Catalysts - Microporous Materials: Zeolites-Zeotypes - Overall steps in Zeolite Crystallization - Zeolite Synthesis via Dry Gel route - Zeolite Y determination of surface Acidity - Shape Selectivity - Synthesis of Mesoporous Silica MCM 41 - Mesoporous Carbon - Sulfated Zirconia - Ag/SiO2 Composite Nanocatalyst	
Unit-5 - Applications of Nanocatalytic Materials	***9 Hour***
Applications of Nanocatalysts in Sustainable Chemistry - Toxic Gases conversion using Nanocatalysts: NOx - CO Oxidation using Nanocatalysts - Hydrogenation of Compounds with C≡C bonds, Hydrogenation of Aromatic Compounds - Green House Gases: CO2 Conversion - Dissociative Mechanism: Oxygen Reduction Reaction using Nanocatalysts - Associative Mechanism: Oxygen Reduction Reaction using Nanocatalysts - Hydrogen Production using Oxide and Dichalcogenides based Catalysts - Energy Processing: Processes involved in Crude Oil Refinery - Gasoline Production - Cracking - Fuel Cell - Biomass Gasification – Biodiesel - Photocatalysts for Self-cleaning - Purification of Water and Air - Environmental Remediation - Future Possibilities	

Learning Resources	*1. M. Albert Vannice, Kinetics of Catalytic Reactions, Springer, 2008.* *2. Nick Serpone and Ezio Pelizzetti, Photocatalysis: Fundamentals and Application, Wiley Interscience, 1st Edition, 1989. Nanocatalysis Applications and Technologies, Editor(s): Vanesa* *3. Calvino-Casilda, Antonio José López-Peinado, Rosa María Martín-Aranda, Elena Pérez Mayoral, CRC Press, 2021 Kurt W.*	*4. Kolasinaski, Surface Science: Foundations of Catalysis and Nanoscience, John Wiley & Sons, England, 2nd Edition, 2005.* *5. NanoporousMaterials: Synthesis and Applications, Edited by Qiang Xu, CRC Press, 1st Edition, 2013.* *6. Nanocatalysis Synthesis and Applications, Editor(s): Vivek Polshettiwar, Tewodros Asefa, John Wiley & Sons, Inc., 2013.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. P. Sudhakara, CLRI – CSIR, Jalandhar, sudhakarp@clri.res.in	*1. Dr. S.A. Shivashankar, Centre for Nano Science and Engineering (CeNSE), Indian Institute of Science, Bangalore, Karnataka, India. shivu@iisc.ac.in*	*1. Dr. Elangovan Elamurugu, SRMIST*
2. Dr. Sudhakar Selvakumar, CSIR-Central Electrochemical Research Institute, ssudhakar79@gmail.com	*2. Dr. Sudakar Chandran, Department of Physics, Indian Institute of Technology Madras, Chennai. csudakar@iitm.ac.in*	*2. Dr. Gopalakrishnan Chandrasekaran, SRMIST*

Course Code	21NTE308T	Course Name	MEMS AND NEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learn what are MEMS and where they are useful*
CLR-2:	*understand the basics of fabrication of electromechanical systems at micro and nanoscale and modeling*
CLR-3:	*understand the principles of sensing and actuation in electromechanical systems*
CLR-4:	*explore magnetic materials Msuitable for magnetic MEMS*
CLR-5:	*gain knowledge of thermal, micro-opto-MEMS materials*

		Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*utilize mechanics principles to analyze the mechanical performance of microsystems*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*utilize optics, electrical and mechanical principles to analyze optoelectromechanical performance of MOEMS*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-3:	*use the radio frequency and thermal principles to analyze the performance of RF and thermal MEMS*	*3*	*3*	*3*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-4:	*use magnetic and fluid principles to analyze the performance of magnetic MEMS and microfluidic devices*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*analyze the tools and processes used in micromachining of MEMS*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-

Unit-1 - Mechanical Proerties of Micro/Nano Systems ***9 Hour***

Definition of Micro and nano-electromechanical systems (MEMS and NEMS), MEMS in daily life, Scaling Laws, Conventional electromechanical systems, Mathematical Modeling, Important steps for analysis and design of engineering steps, Microsensors and microactuators, Principle of sensing and actuation, capacitive sensors, pressure sensors, Inertia sensor, Flow sensor, Thermal sensor, Thermal actuators, piezoresistive sensors, piezoelectric sensing and actuation, magnetic actuation, NEMS-Scaling Effect: Intrinsic losses: Phonon/phonon interaction, Electrical resistivity, depletion, the deactivation of dopants, Quantum confinement effect, Electron/phonon interactions, two-level, and surface effects

Unit-2 - Fabrication tools for Mems/Nems ***9 Hour***

Nano machining of NEMS based upon electron beam lithography, Nanoelectromechanical systems fabrication, Nanoimprint lithography, Polymeric nano fibre templates, Focused ion beam doping and wet chemical etching, Stencil lithography and sacrificial etching, large scale integration P and N-type doping in semiconductors, surface machining at macro and microscales. Wafer bonding and LIGA, MEMS Assembling and Packaging, Anodic bonding, fusion bonding, Lithography, electroforming, and molding. Basic Modeling elements in mechanical and electrical systems, Ampler element, mass/inertia element, capacitor, resistor, and inductor, Inertance, fluid resistance, fluid capacitor, Thermal systems modeling, Thermal capacitance, thermal resistance, Translational and rotational pure mechanical systems with spring, Damper and mass

Unit-3 - Principles of Sensing and Actuation in Mems and Nems ***9 Hour***

Principles of sensing and actuation, Role of microsensors and microactuator with examples, components of mechanical MEMS, Beam, cantilever, microplates, Diaphragm structures theory, corrugated, diaphragms, components in sensors, Capacitive effects, piezoelement, piezomechanics, Measurement methods Strain measurement, pressure measurement, Flow measurement using an integrated paddle-cantilever structure, MEMS Gyroscopes, Nano-gyroscope device: CNT vibration-based, Shear mode MEMS, principle, Compensation in gyroscope, gripping piezo actuator, design and working principle, Inchworm technology, principle, Thermal sensors and actuators, Thermal energy basics and heat transfer processes, thermistors, thermocouple, Thermal actuators, Thermodevices, micromachine thermocouple probe, thermal flow sensors - Working of radiosonde and other applications

Unit-4 - Magnetic Mems and Nems	***9 Hour***
Magnetic materials: properties, Magnetoresistive materials, magnetostrictive materials, hard magnetic materials, design considerations in magnetic materials, Magnetic sensing and design, Presence and direction detection of large object – an example, Magnetoresistive sensor, Principle of magnetoresistive sensor, hall effect, magntrotransitor, MEMS magnetic semsors and actuators, Construction of a MEMS magnetic sensor, the principle of operation, sensitivity of the sensor, Review of RF-based communication system-I, Tuners, resonators, switches, phase shifters, RF MEMS application area, advantages, Review of RF-based communication system-II, Varactors, Tuners, Filters, Resonators, phase shifter, switches	
Unit-5 - Micro Optics Mems and Applications	***9 Hour***
Principles of MOEMS technology, Applications, Hybrid systems, application, advantages, MOEMS components, Light modulators, beam splitters, Microlens, micromirror, the digital micromirror device, MOEMS devices, Optical switch, waveguide and tuning, shear stress measurement, Lab-on-a-chip, Important considerations on microscale fluid, Properties of fluids, density, viscosity, nature of the flow, surface tension, Fluid actuation methods, Dielectrophoresis, electrowetting, Electrothermal flow, Thermocapillary effect, Electroosmosis flow, Optoelectrowetting, Micropumps: design consideration, Microneedle, Construction of a micropump, modeling, working principle	

Learning Resources	1. *Mahalik N P, "MEMS", Tata McGraw-Hill Education, 2008.* 2. *Laurent Duraffourg and Julien Arcamone, "Nanoelectromechanical systems", John Wiley & Sons, Inc., 2015. Sergey Edward Lyshevski, "Micro-Electro-Mechanical and Nano-Electromechanical Systems, Fundamental of Nano-and Micro-Engineering", CRC Press, 2005*	3. *Chang Liu, 'Foundations of MEMS', Second Edition, Pearson, 2012.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Hemant Dixit, GlobalFoundaries,USA, aplahemant@gmail.com*	1. *Prof. S Balakumar, balakumar@unom.ac.in*	1. *Dr. S. Yuvaraj, SRMIST*
2. *Dr. Krishna SurendraMuvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com*	2. *Prof. M. Ghanashyam Krishna, UOHYD, mgksp@uohyd.ernet.in*	2. *Dr. Mangalampalli Kiran, SRMIST*

Course Code	21NTE309T	Course Name	SOLID STATE DEVICES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*get knowledge in the design and working principle of solid-state devices*
CLR-2:	*understand the physics of p-n junction*
CLR-3:	*familiarize with the concept of metal/semiconductor junctions and semiconductor heterojunctions*
CLR-4:	*describe the operation of basic semiconductor diodes*
CLR-5:	*understand the theory of various types of transistors*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*realize the importance of semiconducting materials and p-n junction for the development of solid-state devices*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-2:	*use knowledge of physics to understand the working of semiconductor devices*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*develop analytical approaches to understand semiconductor devices*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*develop in depth understanding on the principle of working of different solid-state devices*	-	-	-	*2*	-	-	-	-	-	-	-	-	*3*	-	-
CO-5:	*distinguish the design principles of various solid-state devices*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Design and Principles of Solid-State Devices ***9 Hour***

Concept of p-n junction-Physics of the p-n junction formation-Energy band diagram of a p-n junction-Estimation of the electric field, electric potential, and built-in potential-Depletion approximation and estimation of space charge width-Depletion layer capacitance and its estimation Qualitative description of charge flow in a p-n junction-Ideal current-voltage characteristics of a p-n junction-Derivation of Shockley equation (ideal-diode equation)-Generation-recombination process and its effect-Reverse bias breakdown mechanisms in a pn junction-Zener and Avalanche breakdown-Transient behavior of a p-n junction-Concept of Noise in semiconductor devices-Terminal functions of a p-n junction diode, The concept of tunnel diode-p-n junction as rectifier, Zener diode, Varistor, and Varactor

Unit-2 - Physics of P-N Hetero Tjunctions ***9 Hour***

Understand what a metal-semiconductor contact is.-Qualitative characteristics of energy band formation- Nonideal effects on the barrier height-Qualitative explanation of image-force-induced lowering of the potential barrier-Current transport processes in metal- semiconductor contacts-Comparison of the Schottky barrier diode and the p-n junction diode-Metal-semiconductor Ohmic contacts-Concept of ideal nonrectifying and tunneling barriers- -Photoelectric measurements-Figure of merit of ohmic contacts and its determination, the concept of specific contact resistance-Isotype and anisotype semiconductor heterojunctions - energy band diagrams-Current density equations and physical interpretation-Introduction to two-dimensional electron gas-Concept of quantum well and superlattice structures

Unit-3 - Transistors Types ***9 Hour***

Study fundamentals of BJT operation-Operation modes of a BJT-Understand the structure and working of p-n-p and n-p-n transistors-Band diagram and static characteristics-Factors involved in transistor amplification-BJT fabrication- -Evaluation of the terminal currents-Non ideal effects in BJT-Deviations from the basic theory and indicate situations in which each effect is important-The physical mechanisms of the current gain limiting factors-The voltage breakdown mechanisms in a bipolar transistor-The current-limiting factors from the current components in the transistor Heterojunction BJT-Schottky and Photo transistors

Unit-4 - Fiels Effect Transistors	***9 Hour***
Principle and types of field-effect transistors-Principle of operation of JFET -GaAs epitaxial layers for MESFET – Principle of working-Concept of high-electron mobility transistors - III-V semiconductor materials-Basic working and fabrication of MOSFET-Knowledge on modes of operation and short channel MOSFET-Short channel effects in MOSFET-Advanced MOSFET structures -Complementary MOS structure and its formation-CMOS process integration-Concept of modulation doping in HEMT-Basic device structure of AlGaAs/GaAs HEMT and I-V characteristics-Output characteristics and channel related phenomenon-Dynamic effects in MOS capacitors – The Charge-coupled device-Basic CCD structure and its applications	
Unit-5 - Applications in Optical Devices	***9 Hour***
Understand optical generation of carriers in a p-n junction- Solar radiation and ideal conversion efficiency of a solar cell-Physics of solar cell-Device configuration and technology roadmap, solar cell materials-Familiarize with the solar cell parameters and efficiency calculation-Design principle of photodetector- How light-emitting diodes work?-Basic device structure and the concept of radiative recombination-Materials of choice and technology roadmap-Specifications used in denoting the practical LED bulbs-Physics of laser action-Gain knowledge of stimulated emission and population inversion-Fabrication of p-n junction laser-Emission spectra-Familiarize with the structure and need of heterojunction lasers-Materials for semiconductor lasers and quantum cascade lasers	

Learning Resources	1. *S M Sze, Kwok k. Ng, “Physics of semiconductor devices” – John Wiley & Sons, Inc., 2007* 2. *Ben G. Streetman, Sanjay Kumar Banerjee, “Solid State Electronic Devices”, Pearson Education Ltd, 2016*	3. *Donald A. Neamen, “Semiconductor Physics and Devices: Basic Principles” – McGraw Hill, Fourth Edition, 2011.* 4. *Solid-State Electronic Devices, Christo Papadopoulos, Springer link,2014*

Learning Assessment

	Bloom’s Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org*	1. *Prof. M.S. Ramachandra Rao, IITM Chennai, msrrao@iitm.ac.in*	1. *Dr. M. Kovendhan, SRMIST*
2. *Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in*	2. *Prof. T. Som, Institute of Physics, tsom@iopb.res.in*	2. *Dr. E. Senthil Kumar, SRMIST*

Course Code	21NTE310T	**Course Name**	NANOTECHNOLOGY IN COSMETICS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*express the basis of cosmeceuticals*
CLR-2:	*demonstrate the classification and various types of cosmetics*
CLR-3:	*analyze about ingredients and effect of inclusion of nanoparticles in cosmetics*
CLR-4:	*get acquainted with current trends in the field of nano based cosmetics*
CLR-5:	*get acquainted with future aspects of cosmeceuticals*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply basic concepts of nanotechnology in cosmetics Apply knowledge in making organosilicone formulation*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*distinguish effects of using nanoparticles over conventional methods in cosmetics*	-	-	-	-	*2*	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*analyze about current trends in the field of cosmetics*	-	-	-	*2*	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*apply basic cosmetic concepts in making nanoformulation*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*apply knowledge in making organosilicone formulation*	-	-	*2*	-	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Introduction to Cosmetics ***9 Hour***

Meaning of cosmetics-Classification of cosmetics-Purpose of cosmetics-Cosmeceuticals-Pharmaceuticals in cosmetics-Quality Characteristics-Quality Assurance-Development process of cosmetics-Cosmetics for Skin-Cosmetics for hair-Cosmetics for nails-Cosmetics colour materials-Cosmetics and fragrances-Oral care cosmetics-Body Cosmetics-Physical chemistry of cosmetics-Stability of cosmetics

Unit-2 - Materials in Cosmetics ***9 Hour***

Oily materials: introduction, oils and fats, wax-Hydrocarbons-Higher fatty acids-Higher alcohols, esters, silicones-Surface active agents: introduction-Anionic Surfactant-Cationic Surfactants-Amphoteric Surfactant-Non-ionic surfactant-Other Surfactants-Humectants: introduction-Choice of humectants-unusual humectants-Special uses of humectants-Antioxidants: introduction-General oxidative theory, measurement of-oxidation-Assessment of oxidant efficiency-Choice of antioxidant

Unit-3 - Polymeric Systems in Cosmetics and its Properties ***9 Hour***

Film formers-Polymers as film formers-Thickeners-Types of thickners-Polymers in hair colouring-Types of polymers in hair colour-Conditioning Polymers-Surfactants in conditioners-cleansing agents-Ethoxylated Alcohols-Silicones-Emulsion Types of polymeric systems-Natural Polymers-Stimuli responsive polymeric systems-pH-responsive-Thermal responsive- Photo responsive

Unit-4 - Liposomes and Nano Formulations ***9 Hour***

Multiple emulsions as novel delivery systems-Nano materials in cosmetics-Nano crystals in cosmetics-Silicones and beyond-Organ modified silicones-New esters mimicking property for organ modified silicones-Silicones in shampoo-Minimalizing undesirable side effects-Substantive silicones-Effect of substantive silicones-Organo-modified delivery systems-Types of Organo-modified delivery systems-Silicones personal care delivery system-Liposomes in cosmetics-Niosomes in cosmetics-Micro emulsion in cosmetics-Nano emulsion in cosmetics-Cyclodextrin complexes in cosmetics

Unit-5 - Aspects of Cosmeceuticals	***9 Hour***
Nano delivery systems Synthesis of dual Nano delivery systems containing vitamin e for cosmetics-Synthesis of dual Nano delivery systems containing vitamin e for pharmaceuticals-Characterization of dual Nano delivery systems containing vitamin e-Various characterization techniques Preparation of keratin coatings for orthopaedic implant titanium rods-Characterization of keratin coatings-Nanotherapeutics as a treatment for inflammation-Cosmetic repair and restoration-Moisturization of skin-Fortification of the skin barrier-Contact lenses types-Beauty from contact lenses beyond vision correction	

Learning Resources	*1. New Cosmetic Science, Mitsui T., Elsevier,1998* *2. CosmeticNanotechnology: Polymers and Colloids in Cosmetics, Sarah E.M., Kathleen O.H., Robert Y.L., American Chemical Society,2006* *3. Delivery System Handbook for Personal Care and Cosmetic Products, Meyer R.R., William Andrew ASP, 2005*	*4. Nanotechnology for the Preparation of Cosmetics Using Plant-Based Extracts, Siti Hamidah Mohd Setapar, Akil Ahmad, Mohammad Jawaid, Elsevier Science, 2022*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr.Solomon Jonnes,Bengaluru,solomon@terracarb.com	*1. Dr. Amit Kumar Mishra, IIT Jodhpur, amit@iitj.ac.in*	*1. Dr. Mani Rahulan, SRMIST*
2. Dr. Nagesh Kini, Thermax, une, Maharastra, nagesh.kini@gmail.com	*2. Dr. Sampath Kumar T.S, IIT Madras, tssk@iitm.ac.in*	*2. Dr. C. Siva, SRMIST*

Course Code	21NTE311T	**Course Name**	NANOMEDICINE	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand cell labelling and imaging*
CLR-2:	*know about molecular diagnosis*
CLR-3:	*learn about drug discovery*
CLR-4:	*understand cancer diagnosis*
CLR-5:	*learn about cardiovascular diagnosis and therapy*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*explain in vivo imaging*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-2:	*apply nanomaterials for diagnosis*	*3*	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-3:	*corelate nanotechnology and drug discovery*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-4:	*apply nanotechnology for diagnosing cancer*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*relate nanoparticles to therapy*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 - Nanoparticles for in Vivo Study ***9 Hour***

Nanoparticles for In Vivo Study of Cells, Live-Cell Single Molecule Assays, Quantum Dots for Stem Cell Labeling and Apoptosis, Molecular Motors-Nanomotor Made of Nucleic Acids, Structural DNA and RNA Nanotechnology, Nanoproteomics

Unit-2 - Molecular Diagnostics ***9 Hour***

Nanoarrays for Molecular Diagnostics, Protein Nanobiochip, Quantum Dots for Molecular Diagnostics, In Vivo Imaging Using Nanoparticles, Nanobarcodes Technology, Nanobiosensors.

Unit-3 - Drug delivery applications ***9 Hour***

Nanofluidic Devices for Drug Discovery, QDs for Drug Discovery, Nanobodies, Nanotechnology based Vaccine Delivery, Nanomaterials for cell therapy, gene therapy

Unit-4 - Nanotechnology applications in Cancer diagnosis ***9 Hour***

Nanotechnology for Detection of Cancer, Nanosensors for Cancer Diagnosis, Anticancer Effect of Nanoparticles, Nanoelectrodes in Neurophysiology, Nanowires for Monitoring Brain Activity, Neurodegenerative Disorders

Unit-5 - Nanotechnology in therapy applications ***9 Hour***

Myocardial Infarction detection by nanochip, Cardiovascular Disorders, Atherosclerotic Plaques, Cardiovascular System regeneration, Hydrogels for Myocardial Tissue Engineering, Nanomaterials as Microbicidal Agents,

Learning Resources	*1. Kewal K. Jain, The Handbook of nanomedicine, Third edition, Humana Press* *2. Challa Kumar, Nanomaterials for Medical Diagnosis and Therapy, First edition, Wiley, 2006*	*3. Robert.A. Freital.Jr, "Nanomedicine"- Landes Bioscience Press2010.* *4. Francis Verpoort, Ikram Ahmad, Awais Ahmad, Anish Khan, Ching Chee, Nanomedicine Manufacturing and Applications 1st Edition, Elsevier, 2021*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. K. Chandru, HCL Health care division, Chennai*	1. *Dr. Vignesh Muthuvijayan, IIT M*	1. *Dr. G. Devanand Venkatasubbu, SRMIST*
2. *Dr. Asifkhan Shanavas, INST Mohali*	2. *Dr. T. Prakash, UOM*	2. *Dr. K. Janani Sivasankar, SRMIST*

Course Code	21NTE312T	**Course Name**	MICROELECTRONICS AND VLSI	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on importance of microelectronics*
CLR-2:	*understand the physical effects of semiconductor-semiconductor junction, its electrostatics, device and circuit level ELEoperation*
CLR-3:	*acquire knowledge on digital language of Boolean algebra, basics of logic gates for advanced memory applications*
CLR-4:	*learn process flow of CMOS IC fabrication, circuit formation and its operation*
CLR-5:	*understand intricacies of designing micro/nanoscale rules, flow of fabrication and IC testing principles*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*interpret difference between macro and micro electronics*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*apply basic semiconductor physics which is important to understand the working of semiconductor-semiconductor junctions, device and circuit level operation*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*analyze various number systems of Boolean algebra, operation of logic gates and memory circuits*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*elucidate process flow of CMOS-based logic devices, circuit formation and its operation*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*analyze power consumption and need for optimization in on-chip devices, its effect on switching speed*	-	-	-	*2*	-	-	-	-	-	-	-	-	-	*3*	-

Unit-1 - Macro and Mcroelectronics ***9 Hour***

Introduction to classification of materials- Types of semiconductors- Concept of energy band gap- Doping in semiconductors – types of doping- advantages of doping - Formation of the p-n junction- Electrostatics of junction operation- Diode as circuit element- Basics of bipolar and unipolar junction transistors- Current-voltage characteristics and operation of transistors -Ebers -Moll model for transistor design- Small-signal model- Small-signal model for bipolar junction transistor (BJT)- Small-signal model for a junction field-effect transistor (JFET)- Amplifiers- Transistor connections in various modes- Feedback concept- Ideal F/B amplifiers- Types of feedback amplifiers

Unit-2 - Electronic Operations ***9 Hour***

Number systems - Binary and octal numbering- Hexadecimal numbering- Conversions between number systems- Boolean algebra- Logic gates- Truth tables for AND, OR, NOT gates- Truth tables for NAND, NOR gates- Circuits with logic gates- combinational circuits and sequential circuits- Flip-flops- SR and JK flip-flops- Triggering of flip-flops -Edge triggered Flip Flops- Basics of counters- Asynchronous and synchronous counters-Ring and ripple counter- modulo N counter- Overview of memory devices- Logic gates for memory applications- Read-only memory- Random-access memory

Unit-3 - Integrated Circuit Technology and Fabrication ***9 Hour***

Introduction to IC Technologies – IC fabrication - Introduction to MOSFET- TYPES OF MOSFET -ENHANCEMENT AND DEPLETION MODE -Complementary Metal Oxide Semiconductor (CMOS)- VLSI for CMOS-Positive channel MOS (PMOS) and negative channel MOS (NMOS)- BiCMOS and applications- CMOS inverter- CMOS logic circuits- Combinatorial CMOS Logic- pMOS and nMOS in logic operation- D-latch-CMOS for D-latch- - Transistor logic- Pass transistor circuits

Unit-4 - VLSI Technology	***9 Hour***
Introduction to VLSI- Needs of VLSI- VLSI design styles- Layout rules- Overview of VLSI design methodologies- Needs of designing- Steps in designing- Cascading of the process- Introduction to MOSFET- VLSI for MOSFET- DC operation of MOSFET- AC operation of MOSFET- Modelling of MOSFET- Small-signal model- High-frequency MOSFET models- Testing of transistor- Need for testing- Testing principles- Design for testability- Error analysis- Safety in testing	
Unit-5 - IC Devices Testing	***9 Hour***
Usage of power in IC - Overview of power consumption, low and high power in VLSI chips- On-chip capacitors- Charging and discharging of capacitor- Currents and voltages in CMOS short circuits- Leakage current, static current- Gate-level- architecture- transistor and gate sizing- Power analysis- Data correlation analysis- Random logic signals, signal entropy- Switching activity analysis- Parallel architecture- Digital CMOS circuits- CMOS amplifiers- CMOS amplifier topologies- Common-Source topologies- Parallel architecture with voltage reduction.	

Learning Resources	1. *Behzad Razavi, Fundamentals of Microelectronics/Edition 3, Wiley, 2021* 2. *S. M. Sze, Semiconductor Devices: Physics and Technology, Wiley 2008.* 3. *Modern VLSI design: IP based design/Prentice Hall; 4th edition (December 26, 2008)*	4. *Millman and Grabel, "Microelectronics", 2nd Ed. Tata McGraw-Hill, 2003* 5. *Weste N.H., "Principles of CMOS VLSI Design", Pearson Education, India, 2002* 6. *Fundamentals of CMOS VLS I Design, Kiran Kumar and V.G Nagesh. H.R, 2011, Sanguine Technical Publishers, Bangalore:*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org*	1. *Prof. K. Sethupathi, IITM Chennai, ksethu@iitm.ac.in*	1. *Dr. A. Geetha, SRMIST*
2. *Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in*	2. *Prof. S. Balakumar, University of Madras, balakumar@iunom.acs.in*	2. *Dr. P. Malar, SRMIST*

Course Code	21NTE313T	**Course Name**	NANOTECHNOLOGY FOR ENERGY SYSTEMS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learn the importance of renewable energies for the safe survival of human kind on the earth*
CLR-2:	*understand the basics of green energy production, storage and transport*
CLR-3:	*understand how nanotechnology can improve the green energy production from various sources*
CLR-4:	*explore the methods of hydrogen production and storage*
CLR-5:	*acquire knowledge on the fabrication, characterization of nanomaterials useful for energy production, transportation and storage*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*identify the urgency of energy solutions and the expectations of Nanotechnology in providing long term solutions to these problems*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*describe the concepts of Photovoltaics*	-	-	2	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-3:	*apply Nanotechnology and nanomaterials in thermoelectrics*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*apply the principle and design of fuel cells for energy production*	-	-	2	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*knowledge on hydrogen production and storage materials*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	*3*	-

Unit-1 - Fossil and Renewable Enrgy Resources ***9 Hour***

Energy Challenge in the 21st Century-Fuel share of world total primary energy supply-Nanotechnology in energy research-The importance of nanotechnology in improving the nanoscale energy devices-Conventional fossil fuels Unconventional fossil fuels-Discussion about greenhouse gases, clean energy sources and advantages- Renewable energy sources-Nanotechnology in fuel production- fuel cells, Thermoelectric conversion

Unit-2 - Photovoltaic Principles and Devices ***9 Hour***

Terawatt challenges in photovoltaics-How can photovoltaics meet a significant fraction of energy demand?- Limits in conversion efficiency- S-Q limit - Theoretical limits of photovoltaics efficiency and possible improvements by different approaches- Different loss mechanisms in photovoltaics – Loss controlling concepts under development - Hybrid concepts-Combining organic and inorganic cells, concept of heterojunction-type photoactive layer, hole-electron pair-Semiconductors optical properties-Basics of semiconductors, bandgap-charge carrier transport in semiconductors-Optical properties of semiconducting thin films, Optical absorption-Narrow and wide band gap materials, bulk, thin film and dye sensitized solar cells - Future of photovoltaics

Unit-3 - Thermoelectric Energy Generation and Size Effects ***9 Hour***

Bulk thermoelectric materials-Basics of thermoelectricity, Seebeck effect, Peltier effect, Figure of merit, WiedemannFranz relationship-Bulk thermoelectric materials- size effects, Selection criteria for bulk thermoelectric materials-Important three guidelines-Effect of size of the quantum dots, nanowires on the conversion efficiency, classical and quantum size effects-Thermoelectric properties on nanoscale: modelling-Understanding thermoelectric properties on the nanoscale using modeling-Importance of characteristic length scale, Bi nanostructures-Importance of Bi nanowire and its diameter in thermoelectricity

Unit-4 - Fuel Cells and Nanocatalysts ***9 Hour***

Types of fuel cells, development of low-temperature fuel cells-Cathode and anode reaction-Oxygen reduction reaction, cathodic reactions, reactions at anode surface-Practical fuel cell catalysts and Electrolytes-Nanostructured materials in lowtemperature cell, Non-precious catalysts, electrolytes-High-temperature polymer electrolyte membranes, membrane-electrode assembly-High temperature fuel cells, organic fuel cells - Applications of Fuel cells – Introduction to nanotechnology in energy storage applications

Unit-5 - Nanotechnolgy for Hydrogen Production and Storage	**9 Hour**
Introduction to hydrogen fuel - Methods of hydrogen production, Importance of hydrogen energy-Nanomaterial based photoelectron chemical cell, Water splitting for producing hydrogen-Semiconductors with specific morphology such as nanotubes and discs for production of hydroge. Hydrogen storage: technological barriers-Methods of improving efficiency of cells, potential storage materials hydrogen sorption-Hydrogen storage by Physiosorption and chemisorption methods-Properties of materials: physical storage, thermodynamic and kinetics-Bond strengths for Physisorption and chemisorption - chemical hydrides nanocomposites-Hydrogen storage by chemisorption, basic structures of metal and complex hydrides, chemical hydrides – Future scope of hydrogen fuels	

Learning Resources	1. *Javier Garcia-Martinez, Nanotechnology for the Energy Challenge, WILEY-VCH Verlag GmbH & Co., 2010* 2. *Anatoli Korkin, David J, Nanoscale Applications for Information and Energy Systems, Springer, 2013*	3. *Darren P. Broom, Hydrogen Storage materials: The characterization of their properties, Springer, 2011* 4. *Dharmendra Tripathi, R. K. Sharma, Energy Systems and Nanotechnology, Springer, 2021*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Hemant Dixit, GlobalFoundaries,USA, aplahemant@gmail.com*	1. *Dr. Ramesh Chandra Mallik, IISc Bangalore, rcmallik@iisc.ac.in*	1. *Dr. P. Malar, SRMIST*
2. *Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com*	2. *Dr. Bhaskar Chandra Mohanty, Thapar University, bhaskar@thapar.edu*	2. *Dr. J. Archana, SRM IST*

Course Code	21NTE314T	**Course Name**	PHYSICS OF ELECTRONIC MATERIALS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the physics of electronic materials*
CLR-2:	*familiarize different physical properties of electronic materials*
CLR-3:	*know-how the various processes in electronic materials*
CLR-4:	*understand the physics behind the working of electronic materials-based devices*
CLR-5:	*gain a fundamental understanding of the emerging electronic materials*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply knowledge of physics in understanding the properties of semiconductors*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	-	*3*	-
CO-2:	*elucidate dielectric behavior of materials and their practical uses*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*distinguish between different magnetic materials*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-4:	*evaluate different optical processes in semiconductors and identify their applications*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*develop skills to identify materials for thermoelectric applications*	*2*	*2*	-	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Physical Properties of Electronic Materials ***9 Hour***

Introduction to Semiconductors - Defining characteristics and classification of semiconductors, Fundamentals of band theory of semiconductors, Intrinsic semiconductors, Energy band diagram and carrier movement, Conductivity of a semiconductor, Electron and hole concentrations Extrinsic semiconductors, Concepts of p-type, n-type and compensation doping, Energy band diagram and electron and hole concentrations, Estimation of the position of the Fermi energy and the resistivity, The temperature dependence of carrier concentration The temperature dependence of drift mobility, Degenerate and nondegenerate semiconductors, Direct and indirect recombination, Minority carrier life time, Carrier injection and diffusion, Optical absorption in semiconductors, Direct and indirect band gap semiconductors and the E-k diagram

Unit-2 - Dielectric Characteristics of Electronic Materials ***9 Hour***

Concept of relative permittivity, Electric dipole moment and polarizability, Polarization vector and charge density, Electric susceptibility and relative permittivity, Lorentz field in dielectrics, Clausius-Mossotti equation, Electronic polarization in covalent solids, Ionic, dipolar, interfacial and total polarization, Concept of dielectric loss, Dielectric studies and the Cole-Cole plot, Dielectric strength and insulation breakdown, Dielectric breakdown mechanisms, Capacitor dielectric materials, Typical capacitor constructions, Piezoelectricity, Piezoelectric spark generator and quartz crystal, Ferroelectricity and pyroelectricity, Practical Applications

Unit-3 - Magnetic Properties of Electronic Materials ***9 Hour***

Definition of magnetic dipole moment, Orbital and spin magnetic moment of an electron, Magnetization vector, Definition of magnetic susceptibility and magnetic permeability, Magnetic materials classification - Dia-, para-, ferro-, antiferro-, and Ferrimagnetism; Origin of ferromagnetism and exchange interaction, Saturation magnetization and curie temperature, Magnetic domains and domain walls, Magnetostriction and domain wall motion, Magnetic domains in polycrystalline materials Understanding the M versus H hysteresis curve, Demagnetization, Soft and hard magnetic materials: Examples and uses, Superconductivity, Type I and Type II superconductors, Critical current density and superconducting solenoids, Josephson effect, Introduction to anisotropic and giant magnetoresistance(GMR), applications of GMR

Unit-4 - Optoelectronic Properties and Devices	**9 Hour**
Optical properties of materials, Refractive index, Real and imaginary components of refractive index, Refractive index-wavelength behavior, Snell's law and total internal reflection, Case study: fiber optics and LEDs, Interaction of photons with materials, Absorption, transmittance and reflection, Antireflection coatings on solar cells, Fabrication methods of anti-reflective coatings based on refractive index, Dielectric mirrors, Band to band absorption, Direct and indirect transitions, Light scattering in materials, attenuation in optical fibers, Luminescence, phosphors, and white LEDs, Spontaneous and stimulated emission, Laser materials and laser action, Concept of photoluminescence and electroluminescence, Examples for devices working on the principles of PL and EL, Electro-optic effects and applications, Magneto-optic effects and applications	
Unit-5 - Thermal Properties and Prospects of Electronic Materials	**9 Hour**
Thermal properties of materials, Atomistic theory of heat capacity, Quantum mechanical considerations, Einstein and Debye model, Electronic contribution to the heat capacity, Heat capacity and specific heat, Thermal expansion and thermal conductivity, Thermal conductivity in metals, alloys, and dielectrics, Thermoelectricity in metals, Seebeck effect and the figure-of-merit, Thermoelectricity in semiconductors, Overview of thermoelectric devices, Two-dimensional electronic materials, The Era of graphene and related materials, Electronic properties at 2D limit, Optical properties- layer dependence, 2D materials-based metal, semiconductor and dielectrics, Applications and future perspectives	

Learning Resources	*1. S O Kasap, "Principles of Electronic Materials and Devices" – McGraw Hill, Fourth Edition, 2017* *2. Wei Gao, Zhengwei Li, Nigel Sammes, "An Introduction to Electronic Materials for Engineers World Scientific Publishing Co. Pte. Ltd, Second Edition, 2011* *3. David Jiles, "Introduction to the Electronic Properties of Materials: - Nelson Thornes Ltd, Second Edition, 2001*	*4. David K. Ferry, Jonathan P. Bird "Electronic Materials and Devices" – Academic Press, First Edition, 2011.* *5. Yuriy M Poplavko, "Electronic Materials: Principles and Applied Science" – Elsevier, First Edition, 2019* *6. Rolf E. Hummel, "Electronic Properties of Materials: An Introduction for Engineers" – Springer, 1993*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. K. Ashok, Vikram Sarabhai Space Centre, ashok@vssc.gov.in	*1. Prof. K. Sethupathi, IITM Chennai, ksethu@iitm.ac.in*	*1. Dr. S. Chandramohan, SRMIST*
2. Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in	*2. Prof. S. Balakumar, University of Madras, balakumar@iunom.ac.in*	*2. Dr. V. Kathirvel, SRMIST*

							L	T	P	C
Course Code	21NTE315T	**Course Name**	NANOTECHNOLOGY IN FOOD PRODUCTION	**Course Category**	E	PROFESSIONAL ELECTIVE	3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*know the various types of interactions at molecular scale*
CLR-2:	*understand the effect of nanoparticles on agricultural methodology and food technology*
CLR-3:	*gain knowledge on the types of diagnostic tools using nanotechnology*
CLR-4:	*acquire knowledge about the newer technologies in the food production*
CLR-5:	*get familiarized with the new concepts of Nano Science in the packaging industries and food production*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the concept of interactions within the supramolecular structures at molecular scale*	2	-	3	-	-	-	-	-	-	-	-	-	-	3	-
CO-2:	*utilize the assay techniques in agricultural and food diagnostics*	2	-	3	-	-	-	-	-	-	-	-	-	-	3	-
CO-3:	*apply the concepts of nanotechnology in food products*	3	-	3	-	-	-	-	-	-	-	-	-	-	3	-
CO-4:	*engineer food ingredients which are capable to improve the bioavailability*	3	-	2	-	-	-	-	-	-	-	-	-	-	3	-
CO-5:	*assess the toxic effects of the nanomaterials used in the food processing and technology*	2	-	3	-	-	-	-	-	-	-	-	-	-	3	-

Unit-1 - Interactions at Molecular Level ***9 Hour***

Intermolecular interactions and supermolecular structures – Introduction - hydrophobic and hydrophilic interactions dispersion interaction, electrostatic interactions Atoms and small molecules, Polymers, particles, and surfaces. Introduction to Steric interactions. Steric interactions involving soluble polymers Aggregation, Depletion, aggregation of particles by non- adsorbing polymers, Bridging aggregation of particles by adsorbing polymers. Stabilization of dispersed particles by adsorbing polymers. Polymer brushes to prevent particle aggregation and particle deposition at surfaces. Self-Assembly, Organized self-assembled structures, Langmuir layers, Lipid bilayers, Solid-supported lipid bilayers Micelles, Vesicles

Unit-2 - Nanoparticles on Agriculture and Diagonistics ***9 Hour***

Nanotechnology in Agriculture and Food diagnostics. Nanodiagnostic approaches in detecting microbial agents, Biosensors, Enzyme biosensors and diagnostics. DNA-based biosensors and diagnostics. Radiofrequency identification, Integrated nanosensor networks: Detection and Response. , Electrochemical biosensors – Gold Nanoparticles, Magnetic Nanoparticles in diagnostics, Fluorescent Nanoparticles in diagnostics, Silica Nanoparticles in diagnostics. Safety of nanotechnology in food and the impact in consumer health. Transduction Principles. Microfluidic Assays,Lateral flow (immuno) assay, Nucleic acid lateral flow (immuno) assay, Flow-through (immuno) assays, Antibody microarrays Surface plasmon resonance spectroscopy

Unit-3 - Nanotechnology in Food Products ***9 Hour***

Food products and its production – Introduction. Processes impacting food at nanoscale. Need for new food processing methods. Efficient fractionation of crops Efficient product structuring, Optimizing Nutritional value. Nanotechnology in Food Production. Applications of nanotechnology in foods, Sensing, packaging Encapsulation, Nano Engineering food ingredients to improve bioavailability Nanocrystalline food ingredients. Nano-engineered protein fibrils as ingredient building blocks. Preparation of food matrices. Risks of Nanotechnology. Concerns about using nanotechnology in food production. Rational argumentation versus Human feelings, Nano-emulsions. Nanotechnology for food preservatives

Unit-4 - Nantotechnology in Crop Management	***9 Hour***
Nanotechnology in Crop management - Introduction. Crop improvement - reasons to package food products. Physical properties of packaging materials, Strength, Barrier properties light absorption, structuring of interior surfaces, antimicrobial functionality. Visual indicators, Quality assessment, preservation of safety. Product properties, Information and communication technology Sensors, Radiofrequency identification technology. Health Risks, Environmental Risks, Consumer and societal acceptance, nanotechnology for pesticide and insecticides	
Unit-5 - Study of Nanotoxicology	***9 Hour***
Toxicology of Nanomaterials in food - Introduction. Characterization of engineered nanomaterials. Unique issues for characterization of engineered nanomaterials for food applications Safety assessment of oral-exposure engineered nanomaterials for food application Experimental design considerations for toxicology studies. Life cycle of nanotechnology food products Environmental behavior of nanoparticles - Toxicology of nanoparticles, Molecules in foods involved in triggering allergies. Impact of nanoscale structures on allergenic potential of foods Toxicokinetics Adme (absorption), Adme (distribution) Adme (metabolism) Adme (excretion) Toxicodynamics. In vivo toxicity, In vitro toxicity, Study Reliability	

Learning Resources	*1. Nicholas A. Kotov, “Nanoparticle Assemblies and Superstructures”, CRC, September, 2019 (ISBN 9780367392284)* *2. Lynn J. Frewer, Willem Norde, Arnout Fischer, and FransKampers,” Nanotechnology in the Agri-Food Sector”, Wiley VCH, 2011 (ISBN:9783527330607*	*3. David S Goodsell, “Bionanotechnology”, John Wiley & Sons, 2004 (ISBN 0-471-41719-X)* *4. Jennifer Kuzma and Peter VerHage, “Nanotechnology in agriculture and food production”, Woodrow Wilson International, 2006 Espresso) and Page 300-307 (VASP)*

Learning Assessment

	Bloom’s Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr.Rajendra Moorthy Rajendran, Kemin Industries, Chennai, India rajendramoorthy.r@kemin.com	*1. Dr. V Geethalakshmi, TNAU, Coimbatore, directorscms@tnau.ac.in*	*1. Dr. C. Gopalakrishnan, SRMIST*
2. Mr. Saravanan Lokasundaram, Agro Crops, Chennai, India, sara@agrocrops.com	*2. Dr. A Lakshmanan,TNAU, Coimbatore, microlaxman@yahoo.com*	*2. Dr. E. Senthilkumar, SRMIST*

Course Code	21NTE316T	**Course Name**	ADVANCED DRUG DELIVERY SYSTEMS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
CLR-1:	*understand the concept of drug delivery*															
CLR-2:	*acquire knowledge on controlled drug deliver*															
CLR-3:	*learn the concept of targeted drug delivery*															
CLR-4:	*know about the methods of drug delivery*															
CLR-5:	*learn about various nanocarriers*															
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*explain various drug delivery systems*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-2:	*analyse a controlled drug release profile*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*formulate different drug delivery systems*	*3*	-	*1*	-	-	-	-	-	-	-	-	-	-	-	*2*
CO-4:	*apply the concept of drug targeting*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*apply the concept of drug delivery systems for Cancer Imaging and Therapy*	*3*	-	*1*	-	-	-	-	-	-	-	-	-	-	*2*	

Unit-1 - Introduction to Drug Delivery Systems	***9 Hour***
Drug delivery systems- Traditional drug delivery- Advantages and disadvantages of various traditional drug delivery systems- Modes of drug delivery- Routes of administration- Novel drug delivery system-Pharmacokinetics- ADME studies- Kinetics of drug delivery- Zero order kinetics- First order kinetics- Controlled drug delivery	
Unit-2 - Targeted Drug Delivery	***9 Hour***
Targeted drug delivery system- Site specific drug release- Types of drug targeting- Active targeting- Passive targeting- Barriers for drug targeting- Strategies for site specific drug delivery- Receptors- Ligands-Antibodies based drug delivery- Metabolism based drug delivery- PEGylation of nanoparticles	
Unit-3 - Nanoparticles for Drug Delivery	***9 Hour***
Metal nanoparticles for drug delivery- Multifunctional nanoparticles- Virus based drug delivery system- Polymeric nanoparticles- Dentrimers- Magnetic nanoparticles for drug delivery- Nanoscaffolds- CNT in drug delivery- Liposomes- Gene delivery	
Unit-4 - Nanotechnology in Cancer Therapy	***9 Hour***
Cancer therapy- Drug delivery to cancer- Targeted drug delivery to cancer- Enhanced permeability and retention- Cancer markers- Folate receptor- Angiogenesis- Leaky vasculature- Targeting tumor vasculature for imaging-Pharmacodynamics- Photothermal therapy- Fluorescent Silica Nanoparticles for Tumor targeting	
Unit-5 - Nanomaterials and Devices in Drug Delivery	***9 Hour***
Photothermally-modulated drug delivery using nanoshell- Hydrogels- Nanoporous systems for drug delivery- transdermal drug delivery- low-frequency sonophoresis- implants for controlled drug delivery- Responsive release system- Fabrication and Applications of Microneedles- Micropumps- microvalves- Implantable microchips- Quantum Dot Probes- Nanorobots- Drug delivery to Central Nervous systems- Drug delivery across Blood brain barrier	

Learning Resources	1. *Drug Delivery: Engineering Principles for Drug Therapy, M. Salzman, Oxford University Press, 2001.* 2. *Drug Delivery and Targeting, A.M. Hillery, CRC Press, 2002.*	3. *Drug Delivery: Principles and Applications, B. Wang, Wiley Intersceince,2005* 4. *NanoparticleTechnologyforDrugDelivery, RamB.Gupta,UdayB.KompellaTaylor & Francis,2006*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. K. ChandruTrivitron Healthcare Pvt. Ltd. Chennai, chandru.k@trivitron.com*	1. *Dr. Asifkhan Shanavas, INST Mohali, asifkhan@inst.ac.in*	1. *Dr. G. Devanand Venkatasubbu, SRMIST*
2. *Dr. Achuth Padmanaban, Baylor College of Medicine, USA, achuthz@gmail.com*	2. *Dr.Mukesh Doble, IIT M, mukeshd@iitm·ac*	2. *Dr. K. Janani Sivasankar, SRMIST*

Course Code	21NTE317T	**Course Name**	SOCIETAL IMPLICATIONS OF NANOTECHNOLOGY	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide an insight into the fundamentals of social-economic implications of nanotechnology*
CLR-2:	*provide an insight into the fundamentals of ethical implications of nanotechnology*
CLR-3:	*understand the legal risks related with the nanotechnology*
CLR-4:	*understand the implications of nanotechnology in quality of life*
CLR-5:	*explore the matters related to risk assessment associated with nanotechnology*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*address the socioeconomic implications of nanotechnology*	*3*	-	-	-	-	-	-	*3*	-	-	-	-	*3*	-	-
CO-2:	*apply the knowledge of ethical implications pertaining to nanotechnology*	*3*	-	-	-	-	-	-	*2*	-	-	-	-	-	-	-
CO-3:	*address the legal risks related with the nanotechnology*	*2*	-	-	-	-	-	-	*2*	-	-	-	-	-	*2*	-
CO-4:	*improve the quality of life*	*3*	-	-	-	-	-	-	*3*	-	-	-	-	-	-	-
CO-5:	*handle the issues related to risk assessment associated with nanotechnology*	*3*	-	-	-	-	-	-	*2*	-	-	-	-	-	*2*	-

Unit-1 - Social-Economic Implications of Nanotechnology ***9 Hour***

Economic Impacts and Commercialization of Nanotechnology. Socio-economic impact of nanoscale science: initial results: nanobank, Managing the nanotechnology revolution, Malcolm Baldrige national quality criteria. Emergence of Nanoeconomy Key drivers, challenges and opportunities, Moore's law, Transcending Moore's law with molecular electronics, Molecular electronics – a next paradigm, Transcending Moore's law with nanotechnology, Transition from Microelectronics to nanoelectronics, Semiconductor scaling as a model for nanotechnology commercialization. Sustaining the impact of nanotechnology on productivity. Sustaining the impact of nanotechnology on sustainability

Unit-2 - Ethical Considerations Pertaining to Nanotechnology ***9 Hour***

Ethics, Law and Governance – Introduction. Ethics and law. Ethical issues in nanoscience and nanotechnology: reflections and suggestions. Concerns of Nano scientists and engineers in ethics and law. Ethics and nano: a survey. Recent developments in nanotechnology law in a new frontier. An exploration of patent matters associated with nanotechnology. U.S. Patent Statute. The ethics of ethics. Environmental Impacts of nanomaterials. Problems of governance of nanotechnology. Negotiations over quality of life in the nanotechnology initiative. Governance. Societal implications of emerging science. and technologies: a research agenda for science and technology studies (STS). Institutional impacts of government science initiatives Challenges for government and universities. Nanotechnology for national security. Nanotechnology in Defense

Unit-3 - Legal Risks Associated with Nanotechnology ***9 Hour***

Nanoparticle toxicity and risk, Navigating nanotechnology through society, Public and private goods. Nanoparticle Toxicity and risk, Nanotechnology, surveillance, and society Methodological issues. Innovations for social research, Nanotechnology: societal implications: individual perspectives, Nanotechnology: individual perspectives. Nanotechnology and social trends; Five nanotech social scenarios Technological revolutions and the limits of ethics in an age of commercialization. Implications of Experiential data recorder. Vision, innovation, and policy. Institutionalizing Multi-Disciplinary Engagement. Post-hoc Versus Therapeutic Ethics, Nano revolution implications for the artist

Unit-4 - Coverging Interdisciplinary Technologies	***9 Hour***
Converging Technologies - Introduction Integrative Technology. Nanotechnology’s implications for the quality of life. Social implications, Management of innovation for convergent technologies the “integration/penetration model" Social impacts of nano biotechnology issues. Nanobiotechnology: The Science Dimension. The Integration/Penetration Model: The Interface Range New Forms of Knowledge: Computer Simulations and Modeling. Regulatory structures and society. Social impacts of nanobiotechnology issues. The use of analogies for interdisciplinary research in the convergence of nanotechnology. Interdisciplinary research in the convergence of bio technology. Interdisciplinary research in the convergence of information technology Converging technologies: innovation, legal risks, and society. Converging technologies and their societal implications.	
Unit-5 - Risk Assessment and Management	***9 Hour***
Public Perceptions and Education. Public perceptions-societal implications of nanoscience. An agenda for public interaction research. Communicating nanotechnological risks Risk Assessment, Risk communication. Problems in Risk communication. A proposal to advance understanding of nanotechnology’s social impacts. Nanotechnology in the media: a preliminary analysis public engagement with nanoscale science and engineering, Nanophobia, Public Engagement with nanotechnology. Nanotechnology: moving beyond risk Communication streams and nanotechnology: the (Re) interpretation of a new technology nanotechnology, Societal implications- individual perspectives. The case of Cold Fusion, The case of Recombinant DNA	

Learning Resources	1. *C.R. Mihail, and S.B. William, Nanotechnology: societal implications, Springer publication, 2011 (978-1-4020- 5432-7)* 2. *Ronald Sandler, Nanotechnology the Social & Ethical Issues, Woodrow Wilson, 2009*	3. *William S. Bainbridge, Societal Implications of Nanoscience and Nanotechnology, 2010 (079237178X, 9780792371786)* 4. *Fritz Allhoff, Patrick Lin, James H. Moor, John Weckert, “Nanoethics: The Ethical and Social Implications of Nanotechnology”, John Wiley & Sons, 2007*

Learning Assessment

	Bloom’s Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr.Ajay Kumar, Avansa Technology and services, India ajaykumar@avansa.co.in*	1. *Dr. Hirendra N Ghosh, Institute of Nanoscience and Technology, Punjab, hnghosh@inst.ec.in*	1. *Dr. C. Gopalakrishnan, SRMIST*
2. *Dr.Tanvi Sharma ,Nanoshel LLC, Chandigarh, India, tanvisharma@nanoshel.com*	2. *Dr. Asish Pal, Institute of Nanoscience and Technology, Punjab.apal@inst.ac.in*	2. *Dr. P. Sivakumar, SRMIST*

Course Code	21NTE401T	Course Name	NANOTECHNOLOGY IN TISSUE ENGINEERING	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***	Program Outcomes (PO)												Program Specific Outcomes		
CLR-1:	*understand the general scientific concepts of tissue engineering*	1	2	3	4	5	6	7	8	9	10	11	12			
CLR-2:	*know the various types of tissues*	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CLR-3:	*acquire knowledge about biomaterials for tissue engineering and regenerative medicine*															
CLR-4:	*get acquainted with stem cells*															
CLR-5:	*understand the process of cell therapy*															
Course Outcomes (CO):	***At the end of this course, learners will be able to:***															
CO-1:	*apply basic knowledge of tissue anatomy for tissue mimicking*	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-2:	*analyze the different tissue type*	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*apply different biomaterials in tissue engineering for biomedical applications*	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-4:	*apply stem cells in tissue engineering*	3	-	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-5:	*apply concepts in of stem cells in therapy*	3	-	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 - Introduction to Tissue Engineering	***9 Hour***
Basic definition; current scope of development; use in therapeutics, cells as therapeutic agents, cell numbers and growth rates, measurement of cell characteristics morphology, number viability, motility and functions. Measurement of tissue characteristics, appearance, cellular component, ECM component, mechanical measurements and physical properties	
Unit-2 - Types of Tissues and Interactions	***9 Hour***
Tissue types and Tissue components, Tissue repair, Engineering wound healing and sequence of events. Basic wound healing Applications of growth factors: VEGF/angiogenesis, Basic properties, Cell-Matrix& Cell-Cell Interactions, telomeres and Self-renewal, Control of cell migration in tissue engineering.	
Unit-3 - Biomaterials for Tissue Engineering	***9 Hour***
Properties of biomaterials, Surface, bulk, mechanical and biological properties. Scaffolds & tissue engineering, Types of biomaterials, biological and synthetic materials, Biopolymers, Applications of biomaterials, Modifications of Biomaterials, Role of Nanotechnology	
Unit-4 - Stem Cells in Tissue Engineering Technology	***9 Hour***
Introduction, hematopoietic differentiation pathway Potency and plasticity of stem cells, sources, embryonic stem cells, hematopoietic and mesenchymal stem cells, Stem Cell markers, FACS analysis, Differentiation,Stem cell systems- Liver, neuronal stem cells, Types & sources of stem cell with characteristics: embryonic, adult, haematopoetic, fetal, cord blood, placenta, bone marrow, primordial germ cells, cancer stem cells induced pleuripotent stem cells.	
Unit-5 - Stem Cell Therapy	***9 Hour***
Stem cell therapy, Molecular therapy, In vitro organogenesis, Neurodegenrative diseases, spinal cord injury, heart disease, diabetes, burns and skin ulcers, muscular dystrophy, orthopedicapplications, Stem cells and Gene therapy Physiological models, issue engineered therapies, product characterization, components, safety, efficacy. Preservation –freezing and drying. Patent protection and regulation of of tissue-engineered products, ethical issues.	

Learning Resources	1. Bernhard O.Palsson, Sangeeta N.Bhatia,"Tissue Engineering" Pearson Publishers 2009. 2. Meyer, U.; Meyer, Th.; Handschel, J.; Wiesmann, H.P. Fundamentals of Tissue Engineering and Regenerative Medicine.2009	3. Bernard N. Kennedy (editor). New York: Nova Science Publishers, 2008.Stem cell transplantation, tissue engineering, and cancer applications 4. Sabu Thomas, Yves Grohens, Neethu Ninan, Nanotechnology Applications for Tissue Engineering 1st Edition, Elsevier, 2015

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. K. Chandru, HCL Health care division, Chennai	1. Dr. Mukesh Doble, IIT M	1. Dr. G. Devanand Venkatasubbu, SRMIST
2. Dr. Asifkhan Shanavas, INST Mohali	2. Dr. T. Prakash, UOM	2. Dr. N. Selvamurugan,, SRMIST

Course Code	21NTE402T	**Course Name**	MICRO AND NANOFLUIDICS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on various physical principles related to liquid flows*
CLR-2:	*understand theory of fluid flow in micro and nano-size devices*
CLR-3:	*describe the concept of heat and mass transfer phenomena in channel*
CLR-4:	*unifies thermal sciences with colloidal sciences, biological sciences*
CLR-5:	*gain knowledge on electrochemical mechanisms of micro and nanofluids*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the principles of liquid flow*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-2:	*analyze flow of fluid in micro and nano-size devices*	*3*	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-3:	*apply the knowledge of micro and nanofluidic devices, their fabrication, charecterization*	*3*	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*utilize the opportunities in the emerging field of micro and nanofluids*	2	*3*	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-5:	*apply the conceptsof electrochemical mechanisms of micro and nanofluids*	*3*	2	-	-	-	-	-	-	-	-	-	-	-	-	2

Unit-1 - Introduction to Microscale Liquid Flow ***9 Hour***

Liquid flow at low dimensions-- Micro and Nanofluidics -Micro and Nanofluids devices- Design of micro and Nanofluids-Preparatory concepts-Preparatory concepts-Constitutive Laws,Determination of transport properties- viscosity,diffusion coefficients,Determination of transport properties-thermal conductivity- Continuum approximation and its limitations,Kinematics- Surface forces,Body forces,Navier-Stokes equation,Navier-Stokes Equations in Cartesian Coordinates- Energy transport,Energy transport-conduction heat transfer,Two-dimensional, Steady flow- Incompressible flow

Unit-2 - Flow Analysis in Micro and Nano Size Devices ***9 Hour***

Microscale viscous flow-Essentials,Structure of flow in a pipe or channel,Poiseuille flow in a pipe,Poiseuille flow in a pipe-derivation of maximum velocity,The velocity in slip flow of gases and liquids,Flow in a thin film under gravity-film flow rate,Fully developed suction flows,Velocity profile-suction flows,Developing suction flows,Darcy's flow,Surface tension driven flow and its quantitative approach,Stokes flow past a sphere and its drag calculation, Sedimentation of a solid particle,simple model for blood flow

Unit-3 - Heat and Mass Transger Phenomena in Channel ***9 Hour***

Heat transfer phenomena in channels and tubes,Mass transfer phenomena in channels and tubes,One-dimensional temperature distributions in channel flow,Temperature distributions in channel flow (quantitative approach),Thermal and mass transfer entrance regions,Mass transfer entrance regions,The temperature distribution in fully developed tube flow,Nusselt number,The Graetz problem for a channel and its quantitative approach,Mass transfer in thin films,A thin liquid film falling under gravity,Classical Taylor-Aris dispersion and its quantitative approach, The stochastic nature of diffusion,Brownian motion, Unsteady mass transport in uncharged membranes, Temperature and concentration boundary layers

Unit-4 - Electrochemical Mechanisms of Micro and Nanofluids	**9 Hour**
Introduction to elements of electrochemistry and the electrical double layer,The structure of water and ionic species,Chemical bons in biology and chemistry,Hydration of ions,Chemical potential and its quantitative approach,The Gibbs function, Chemical Equilibrium,Electrochemical potential,Acids bases and electrolytes,Site-binding models of the silica surface,Polymer surfaces,Qualitative description of the electrical double layer and electrical double layer-triple layer model,The electrical double layer on a cylinder and on a sphere,Electrical conductivity in an electrolyte solution,Electrophoretic effect	
Unit-5 - Opportunities in Emrging Micro and Nanofluids	**9 Hour**
Elements of cell biology and applications,Nucleic acids and polysaccharides,Proteins:Protein function and structure,Some common proteins,Few polypeptide chains are useful,Protein binding,Cells-The cell membrane,Membrane transport,Ion channels,Applications-DNA transport,DNA current,Development of an artificial kidney:Background,The nanopore membrane for filtration,Hindered transport,Biochemical sensing:Biosensor,Receptor-based classification of biosensors,Transducer-based classification of biosensors,Evaluation of biosensor performance,Nanopores and nanopore membranes for biochemical sensing	

Learning Resources	1. *TerrenceConlisk"EssentialofMicroandnanofluidics: withapplicationstobiologicalandchemical sciences" Cambridge University Press, 2018.* 2. *Joshua Edel "Nanofluidics" RCS publishing, 2016.* 3. *Henrik Bruus "Theoretical Microfluidics" Oxford Master Series inPhysics, 2007.*	4. *Patric Tabeling "Introduction to Microfluids" Oxford U. Press, 2005.* 5. *ChristofM.Niemeyer&ChadA.Mirkin, "Nanobiotechnology: Concepts, Applicationand Perspectives", Wiley VCH, 2004.* 6. *SaritK.Das, StephenU.S. Choi, WhenhuaYu&T. Pradeep, "NanofluidsScienceand Technology" Wiley Interscience,2007*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. Sameer Sharda, New Age Instruments & Materials Pvt. Ltd, Gurgaon, sameer@newagein.com*	1. *Dr. Basavaraj Madivala Gurappa, IIT Madras, Chennai, basa@iitm.ac.in*	1. *Dr. Junaid Masud Laskar, SRMIST*
2. *Mr. Mohammed Shafi, Holmarc Opto-Mechatronics Pvt. Ltd, Cochin, optics@holmarc.com*	2. *Dr. Dillip K. Satapathy, IITM, Chennai, dks@iitm.ac.in*	2. *Dr. V. Eswaraiah, SRMIST*

Course Code	21NTE403T	**Course Name**	NANOROBOTICS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*provide an insight into the fundamentals of nanorobotics manipulation and assembly*
CLR-2:	*gain scientific understanding regarding the role of nanorobotics in the modern engineering applications*
CLR-3:	*understand the concept of nanomanipulation of nanostructures*
CLR-4:	*learn the techniques of automated manipulation of nanoobjects*
CLR-5:	*gain knowledge on theoretical and experimental aspects of Nanorobotics*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the scientific concepts underlying engineering and technological applications in nanorobotics*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-2:	*acquire the knowledge of nanorobotics manipulation*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*apply the knowledge of fast imaging system for advance nanotechnology applications*	-	-	*2*	*2*	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*get familiarize with the new concepts of real-time nanomanipulation and apply those concepts using CAD*	-	-	*3*	*2*	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*utilize the concept of nanobots for medical applications*	-	-	*3*	*2*	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Introduction to Nanorobotics ***9 Hour***

Types of interaction forces – nanomanipulation using interaction forces – Actuation - Electro kinetic based actuation - Carbon nanotubes - Electro kinetic manipulation of carbon nanotubes - Graphene sheets – Nanoparticles - Biological entities - Biological nanomaterials - Laser based actuation-fundamentals - Laser based actuation-applications - Optical tweezers - Applications of optical tweezers - Manipulation of biological entities - Manipulation of chemical entities – Piezoelectricity - Piezoelectric enabled actuator

Unit-2 - Role of Nanorobotics in Modern Engineering ***9 Hour***

I Dielectric materials - Dielectric polarization - Electro rotation - Theory and modelling of electro rotation - Properties of fluid medium - Dynamic effects of fluid medium – Dielectrophoretic - Nanoparticles by dielectrophoretic - CNT-definition - Manipulation of CNT - Scanning probes - Nanomanipulation by scanning probe - Atomic scale stick-definition - Reducing atomic scale stick - Slip motion - Nanomanipulation by slip motion - Feedback control - Slip motion by feedback control - nanomanipulation

Unit-3 - Nanorobotic Manipulation and Assembly ***9 Hour***

Sensors-classifications - Art of compressive sensing - Fast imaging system - Compressive sensing based fast imaging system – SPM basics - AFM based imaging - Atomic manipulation in AFM - AFM based nanorobotic system - Augmented reality - AFM based nanorobotic system enhanced by augmented reality - Hardware setup for Sensing - Software setup for Sensing – Hardware setup for fast imaging system – Software setup for fast imaging system – Examples of Experiments on nanomanipulation of nanoparticles-I

Unit-4 - Real Time Nanomanipulation Using Cad ***9 Hour***

computer-aided design (CAD) - CAD models of nanostructures - Automated manipulation of micro-nano objects - Automated manipulation of nanostructures - Automated manipulation of Nanorods Automated manipulation of Nanowires - Automated manipulation of nanotubes - Automated manipulation of nanoparticles - Augmented reality system Limitation of augmented reality system Real time fault detection - Methods of real time fault correction - Time random drift - Time random drift compensation with local scan on-line fault detection - Interpretation of on-line fault correction Implementation of the data to test the hypothesis - Experimental results of the data to test the hypothesis

Unit-5 - Applications of Nanorobotics	***9 Hour***
Nanorobotic- introduction - Nanorobotic Applications - Endoscopy imaging - Wireless capsules endoscopy imaging - Energy harvesting - Energy harvesting by nanorobotic - Gastro-intestinal tract- introduction - Capsules robot in gastro-intestinal tract - Nanorobots – introduction - Nanorobots –basic design - Cooperative control design for nanorobots - Design and application of nanorobotics in oncology - Drug delivery system - Cooperative control design for nanorobots in drug delivery - Medical applications of nanorobots - Medical applications of nanorobots: current - proposals and designs - Therapy using nanorobots - Cancer targeted therapy using nanorobots	

Learning Resources	*1. Ning Xi, Guangyoung Li, "Introduction to Nanorobotic Manipulation & Assembly" Artech House Press, 2012* *2. Yi Guo,"Selected Topics in Micro/Nano-robotic for Biomedical Applications", Springer, 2013*	*3. Klaus D. Sattler, "Hand Book of Nanophysics: Nano medicine & Nanorobotics", CRC Press, 2019* *4. Constantinos Mavroidis, Antoine Ferreira, "Nanorobotics Current Approaches and Techniques" Springer Link, 2013*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Narayanasvamy Vijayan, National Physical Laboratory, nvijayan@nplindia.org	*1. Prof. V. Subramaniam, IITM, Chennai, maninanvs@iitm.ac.in*	*1. Dr. S. Murali, SRMIST*
2. Dr. A. Pandikumar, Scientist, CSIR-CERL, pandikumar@cecri.res.in	*2. Prof. D. Arivuoli, Anna University, arivuoli@annauniv.edu*	*2. Dr. V. Kathirvel, SRMIST*

Course Code	21NTE404T	Course Name	PHOTOVOLTAIC TECHNOLOGY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the basics of solar energy and solar cells*
CLR-2:	*know about the materials properties relevant to photovoltaics*
CLR-3:	*acquire knowledge about design of photovoltaic devices*
CLR-4:	*get acquainted with different types of solar cells*
CLR-5:	*get acquainted with new concepts and developments in photovoltaics*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*differentiate between different types of photovoltaic technologies*	*2*	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*interpret important properties of semiconductors relevant to photovoltaics*	*3*	-	-	2	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*identify different photovoltaic device design concepts for different applications*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*
CO-4:	*discuss advancement of different generations of solar cells*	*3*	-	-	2	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*discuss the advanced concepts and explorations in photovoltaics*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	-

Unit-1 - Introduction to Photovoltaics	***9 Hour***
Renewable energy technologies, Challenges, History of solar cells, Commercialization/economic factors, Basics of solar cell device and mechanism, Sun as a source of energy, The solar spectrum, Measuring sun light, Atmospheric effects, Terrestrial and space spectra; Air mass (AM0, AM1.5), Classification of photovoltaic technologies, Generations of solar cells, 1st generation photovoltaics, Silicon technology, 2nd generation photovoltaics, 3rd generation photovoltaics	
Unit-2 - Photo Conversion, Seperation and Recombination	***9 Hour***
Optical absorption, Carrier generation, Band gap, Direct vs. indirect bandgaps, Minority carrier transport -Carrier recombination-lifetime and defects, Band to band and Shockley-Read-hall recombination, High injection effects Surface and interface recombination, Implications on device performance, PN homojunctions, PN junction under dark and light, Photocurrent, Spectral response, non-idealities, Real p-n diodes, Temperature effects	
Unit-3 - Characteristic Parameters and Device Studies	***9 Hour***
Solar Cell performance indicators, Device testing, Efficiency calculations, Parameters for ideal cells, Non-idealities, Series resistance, shunt resistance, Optical loss mechanisms and implications, Electrical loss mechanisms and implications, Basics of solar cell device design, Minimization of losses, Lateral design and Vertical design, Optical versus electrical tradeoffs, Device optimization, Band gap and other material properties, Spectral utilization, Light management	
Unit-4 - Various Types of Solar Cells	***9 Hour***
Si photovoltaics, Fabrication, Single crystal Si solar cells, Polycrystalline/microcrystalline Si solar cells, Amorphous Si solar cells, Heterojunctions, p-i-n and n-i-p structures, thin film II-VI solar cells, Chalcopyrites, CdTe/CdS thin film solar cells, Superstrate structure, CuInGaSe2/CdS thin film cell technologies, Earth abundant alternatives, Dye-Sensitized solar cells, QDSSCs, ETA solar cells, Organic photovoltaics, Hybrid solar cells, Perovskite solar cells	

Unit-5 - Next Generation Photovoltaic Cells	***9 Hour***
III-V photovoltaics, multi-junction solar cells, Spectral splitting, GaInP/GaAs/Ge triple junction solar cell, Bandgap profile optimization, Solar spectrum matching, Tunnel junctions, Current matching limitations, Concentrator photovoltaics (CPV)-, Concentrator optics, CPV cells, Terrestrial CPV systems, Space photovoltaics, Radiation effects in semiconductors and solar cells, new concepts, Quantum dots, wires, Intermediate band solar cells, Multiple exciton generation	

Learning Resources	*1. Solanki C.S., "Solar photovoltaics - fundamentals, technologies and applications", 3rd edition, PHI LearningPvt Ltd, New Delhi, India* *2. Fonash S.J., "Solar Cell Device Physics", Academic, 2010* *3. Moller H.J., "Semiconductors for Solar Cells", Artech House, 1993.*	*4. Green M.A., "Third Generation Photovoltaics: Advanced Solar Energy Conversion", Springer, 2006Fundamentals of Solid-State Engineering, Manijeh Razeghi, Kluwer Academic Publishers, 2002*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	*1. Dr. Sudhakar Chandran, IIT Madras, csudhakar@iitm.ac.in*	*1. Dr. S Venkataprasad Bhat, SRMIST*
2. Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in	*2. Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*2. Dr. P. Malar, SRMIST*

							L	T	P	C
Course Code	21NTE405T	**Course Name**	ADVANCED COMPUTATIONAL TECHNIQUES	**Course Category**	E	PROFESSIONAL ELECTIVE	3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*know the physical effects at the nanometer and sub-nanometer scales: how computational methods can help to understand the properties and at nanoscale*
CLR-2:	*acquire knowledge on molecular and optical computing*
CLR-3:	*know the basis of Biomedical Computing and its application*
CLR-4:	*understand the concepts and applications of quantum computing*
CLR-5:	*acquire knowledge on parallel information processing mechanism and architecture*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the knowledge of the properties of nanomaterial in Quantum computing*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*understand the design principles of molecular and optical devices through computation*	-	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-3:	*apply the knowledge of Biomedical Computing*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	*2*	-	-
CO-4:	*execute the basic of Qubit problems and gain depth knowledge about Quantum Computing*	-	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*apply knowledge of computing architecture in efficient optimization of the materials problems*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Computational Methods for Nanoscale Understanding ***9 Hour***

History of computing –Quantum Computing - Quantum Computing – Materails for Quantum Computing - Nano Information Processing - Prospects and Challenges - Digital Signals- Digital Gates - Introduction of Nanoelectronics - Application of Nanoelectronics –to Carbon Nanotube Electronics - Application of CNT electronics - Concept of Silicon Nanoelectronics - Application of Silicon Nanoelectronics - Simulation of hole and electron mobility in Si Introduction- Concept of Carbon Nanotube Electronics - Application of Carbon Nanotube Electronics - Modeling of Carbon Nanotube - Field Effect Transistors based on CNT

Unit-2 - Molecular and Optical Computing ***9 Hour***

Molecular Computing - Applications of Molecular Computing - Modeling molecules - Modeling clusters of atoms - Overview of various first-principles methods - Discussion on Limitation and Application -- Density Functional Theory (DFT) - HK and KS equations – Kohn Sham equation- Discussion on LDA and GGA - Structural, Electronic of nanomaterials from DFT calculations (Examples only) - Magnetic properties (examples only) - Concept of Optical Computing - Application of Optical Computing - Current use of optics for Computing in Industry - Optics for Computing: Future Applications - Optical Computing Paradigms - Optical Computing Paradigms: Examples - Working concept of Photonic Switches - Application of Photonic Switches.

Unit-3 - Biochemical Computing and Examples ***9 Hour***

Introduction to Biochemical Computing - Examples of Biochemical Computing - Application of DFT in biological system – Bsics of Molecular Dynamics Simulation (MD) – Block Diagram of MD- Constant Tempature MD - Application of MD in biological system - Genetic Algorithm - Application of GA to Biological Systems - Biological Neurons - Biological Neurons in information processing - Function of neuron cell on silicon - Function of neuron cell on silicon for Signal processing - Modeling of neuron cells by VLSI circuits - Problems on Modeling of neuron cells by VLSI circuits - Neural networks and distributed data processing - Problems on Neural networks and distributed data processing - Working concept of DNA Computer - Application of a DNA Computer - Information Processing with Chemical reactions: Working Concept - Information Processing with Chemical reactions: Example.

Unit-4 - Concepts and Applications of Quantum Computing	***9 Hour***
Bit and Qubit - Coherence and Entanglement - Concept of Coherence - Concept of Entanglement with Examples - Theory of Quantum Parallelisms - Application of Quantum Parallelisms - Classical Gates – Reversible Operations - Sqrt (NOT) Operation - Concept of Quantum Algorithm - Application of Quantum Algorithms - Challenges to large Quantum Computers - Fabrication, Testing Architectural Challenges - Working Concept of Quantum dot cellular automata - Application with Example of Quantum dot cellular automata - Introduction and Working principle of Computing with QCA - Application of Computing with QCA - QCA Clocking - QCA Design Rules- Electronic Strcuture Calculations on Quantum Computers- Magnetic calculations	
Unit-5 - Parallel Information Processing and Architecture	***9 Hour***
Parallel computing - Shared and Distributed Memory Clusters - Parallel algorithm - MPI based algorithm as example - Working Concept of Mono and Multiprocessor Systems - Applications: Mono and Multiprocessor Systems - Some considerations to Parallel Processing - Usefulness of Parallel processing in various device applications - Influence of Delay Time - Performance efficiency on Delay time - Power Dissipation - Power Dissipation in different system - Architecture for Processing in Nanosystems - Classic Systolic Arrays - Processor with large memory - Application of Processor with large memory - Processor array with SIMD - PIP Architectures- Optimize choice of processors to solution- Comparisim between Parallel and Quantum Computer in terms of performance	

Learning Resources	*1. Vishal Sahni et.al, Nanocomputing: The Future of Computing, Tata McGraw-Hill Education, 2008.* *2. Feliciano Giustino, Materials Modelling using Density Functional Theory: Properties and Predictions, Oxford: Oxford University Press, 2014.*	*3. J.M. Thijssen, Computational Physics, Cambridge University Press, 2007.* *4. AndrewR.Leach, Molecularmodelling: principlesandapplication, PearsonEducation,2001*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Hemant Dixit, GlobalFoundaries, aplahemant@gmail.com	*1. Dr. Ranjit Kumar Nanda, IITM Chennai, nandab@iitm.ac.in*	*1. Dr. C. Preferencial Kala, SRMIST*
2. Dr. Murali Kota, Global Foundaries, USA, kvrmmurali@gmail.com	*2. Dr.Biswarup Pathak, IIT Indore, biswarup@iiti.ac.in*	*2. Dr. Saurabh Ghosh, SRMIST*

Course Code	21NTE406T	**Course Name**	NANOTECHNOLOGY LEGAL ASPECTS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*readers would be comfortable moving across the fields of science, ethics, and law and be able to fill a void in addressing the legal, social, and policy implications of nanotechnology from a global governance*
CLR-2:	*familiarize with the concept of patent, copyright laws trade mark, trade secret and IP infringement*
CLR-3:	*gain sound knowledge on environmental degradation and current regulations*
CLR-4:	*understand the government policies and rules pertaining to nanotechnology*
CLR-5:	*learn the social and ethical impacts of nanotechnology and its allied fields*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*acquire the knowledge the regulatory policies of social and legal aspects*	*3*	-	-	-	-	*2*	*3*	*2*	-	-	-	-	-	-	*3*
CO-2:	*understand the concepts of patents, copyright laws and apply the knowledge of trademark, trade secret and IP infringement*	*2*	-	-	-	-	*2*	*3*	*3*	-	-	-	-	-	-	*3*
CO-3:	*acquire the knowledge on environmental degradation and current regulations*	*2*	-	-	-	-	*3*	*2*	*2*	-	-	-	-	-	-	*3*
CO-4:	*get familiarize with the current trends in legal and ethical impacts of nanotechnology*	*2*	-	-	-	-	*3*	*2*	*2*	-	-	-	-	-	-	*3*
CO-5:	*fuel with the government policies and rules related to taxation, trade, security, privacy, export import of nanomaterials*	*2*	-	-	-	-	*3*	*3*	*3*	-	-	-	-	-	-	*3*

Unit-1 - Policies of Social and Legal Aspects — ***9 Hour***

Big Questions about defining little Nanoparticles- simple applications of Nanotechnology of day-to-day life- Labels: how Big is nano, how small is not nano,- capturing the discovery: the limits of lists and numbers as regulatory criteria- sample legal definitions- the lessons learned from the legend of Asbestos- components of international regulation exposure of legend Asbestos- Rethinking traditional policies- Integrating nanotechnology into international laws- abundance of laws- WHO constitution – codifying precautionary principles- synthesizing NT advances into harmonized legislative texts- Nanotechnology revolutionizing risk communications – due diligence is your best friend- the Question is knowledge and consent, not the magnitude of risks- revolutionary promises of nanoparticles, nanomedicine- nanoworld cancer day, benefits to patients: new bones, new teeth, and new organs- Stakeholders, one and all- Hamilton's legacy – Governmental obligations

Unit-2 - Intellectual Property and Copyright — ***9 Hour***

Technical knowledge of patents- Patentability requirements – structure of patents- classification of patent applications- design patent, monopoly powers- Reexamination of patents - licensing strategies and arrangements- Willful Patent treaties infringement issues, claim scope- Patent treaties- Copyright laws – fixation, Originality, creativity- Government policies and rules- Integrated circuit topographies- Technology transfer - Civil laws- Criminal laws in nanotechnology- Trade secrets- Ownership of IP

Unit-3 - Environmental Degradation and Regulations — ***9 Hour***

Environmental degradation and its consequences- Current environmental regulations- Classification of pollutants- Sources/origins of pollutants- Pollution – air- Pollution – water- Industrial waste water treatment- Control and quality check - Dispersion methods – aerobic and non-aeroobic- Monitoring and its regulatory boards- House-hold- Solid wastes – Solid waste – industrial/commercial type- Hospital waste and recycling methods- Hazardous chemical waste- Toxicity, health issues- Safety and health issues- Risk assessment and analyses- Tracking, responsibility and rules

Unit-4 - Social Impacts of Nanotechnology	***9 Hour***
Social impacts of nanotechnology- Economic impacts of nanotechnology- Implications of nanotechnology- Effect on the quality of life- Short term and long-term implications- Legal, societal implications in Nanotechnology- Ethical issues in nanotechnology- Social and environmental issues in nanotechnology- Artificial intellects- Ethics, for artificial intellects- Nanotechnology and life extension- Nanotechnology for national security- Nanotechnology for space exploration- Nanotechnology for medical applications- Moral issues of nanotechnology applications- Public perception of nano-technological risks- Education of public about nanotechnology- Training to the public about nanomaterials	
Unit-5 - Trade and Business in Nanotechnology	***9 Hour***
Trade and business in nanotechnology- Trade restrictions and barriers- Taxation system – national and international regulatory bodies- Taxation of goods: - too small to be seen- Laws for genetic research- Rights of new life form- Governmentsurveillance and monitoring- Privacy violations- Security and monitoring Eavesdropping – case studies- R&D in nanotechnology- R&D regulation- Current industrial design laws-Change in industrial design laws- Export – import regulations- Crimes involved in nanoparticles- Corporate criminal liability, intentions- prevention and detention	

Learning Resources	1. *Patrick M. Boucher, "Nanotechnology: Legal aspects" CRC press, 2008* 2. *Fritz Allhoff, Patrick Lin, James Moor, John Weckert, "Nanoethics: The ethical and social implications of nanotechnology" Wiley publication, 2007*	3. *Louis Theodore, Robert G. Kunz, "Nanotechnology: Environmental implications and solutions" Wiley Publication, 2005* 4. *Ilise Feitshans, Global Health Impacts of Nanotechnololaw, Taylor and Francis group, 2018Espresso) and Page 300-307 (VASP)*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Narayanasvamy Vijayan, National Physical Laboratory, nvijayan@nplindia.org*	1. *Prof. V. Subramaniam, IITM, Chennai, manianvs@iitm.ac.in*	1. *Dr. Alagiriswamy A A, SRMIST*
2. *Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com*	2. *Prof. D. Arivuoli, Anna University, arivuoli@annauniv.edu*	2. *Dr. P. Malar, SRMIST*

Course Code	21NTE407T	Course Name	MICRO AND NANO EMULSIONS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co- requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on micro and nano emulsion and its stability*
CLR-2:	*understand the various properties of emulsion*
CLR-3:	*describe the concept of Mechanism of Emulsification*
CLR-4:	*understand the formulation of Nano emulsion*
CLR-5:	*learn the applications of emulsion for various fields*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*explore basic principles in chemistry of microemulsions*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*explain properties of emulsion by concept of phase diagram*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*analyze the stabilization mechanism in emulsions*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-4:	*apply the formulation of micro and nano emulsions*	-	-	*2*	-	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*elucidate importance of emulsions in various technological applications*	-	-	-	*2*	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 - Introduction to Micro and Nano Emulsions ***9 Hour***

Emulsion definition and characteristics- Definition of micro emulsion- Definition of nano emulsion- Theory of emulsion and methods- Theory of Micro emulsions- Theory nano emulsions- Preparation of microemulsion - Preparation of nano emulsion- Winsor's classification of microemulsions- Stability of micro emulsions- Rheology of microemulsion drops- Applications of emulsions- Ostwald ripening- Flocculation- Coalescence of drops- Applications of emulsions - Different application of micro and Nano emulsions

Unit-2 - Microemulsions and its Properties ***9 Hour***

phase diagram approach to microemulsion- Partial generic phase diagram- Microemulsion formation- Ordering and disordering- Temperature Dependence of microemulsion ordering- Vapor Composition from Microemulsions- Ekwall on the association structures- Water–surfactant combination- Physicochemistry of W/O microemulsion formation- Stability of emulsions- Droplet clustering- Energetics of Droplet Clustering- Phenomenon in microemulsion- Percolating phenomenon in microemulsion- Scaling Laws- Effect of external entity-Microemulsions with mixed nonionic surfactants- Organ chalcogenides,Aromatic Heterocyclic Compounds- Properties of microemulsions with mixed nonionic surfactants

Unit-3 - Mechanism of Emulsification ***9 Hour***

Mechanism of Emulsification- Surface forces- Van der walls interactions- Electrical interactions- Phase inversion phenomena- Phase behaviorsof emulsions- Standard inverse boundary- Dynamic inversion- Dynamic behavior of emulsion- Spontaneous emulsification- Recent development with emphasis on self-emulsification- Self-emulsification process- Organic Reactions in Emulsions- Microemulsions- Symmetric thin liquid film with Fluid interfaces- Formation emulsified microemulsion- Microemulsion properties- Characterization of emulsified microemulsion

Unit-4 - Nanoparticle Formation in Microemulsions ***9 Hour***

Nanoparticle formation in microemulsion- Concept of formation in microemulsion- Chemical Reaction- Nucleation- Exchange mechanism in emulsions- Autocatalysis- Mechanism of microemulsion- Critical Nucleus Size- Chemical Reaction Rate- Nanoparticles uptake from W/O emulsion- W/O emulsion process- Nanoparticle Uptake in Reactive Surfactant Systems- Nanoparticle Uptake in Nonreactive Surfactant Systems- TiO2 nanoparticle in micro-emulsion and photophysical properties- Optical Absorption and Emission of TiO2 Nanoparticles in Microemulsion- Electron Transfer Dynamics in CatecholSensitized TiO2 Nanoparticles- Properties of interfacial electron transfer dynamics- Interfacial electron transfer dynamics

Unit-5 - Characterization and Applications of Microemulsions	***9 Hour***
Characterization and Application of Microemulsion- Introduction in basics and principles of NMR- NMR technique for measurement emulsion- Relaxation measurements on emulsions via CPMG experiments- Diffusion measurements on emulsions via PGSE andPGSTE experiments- Introduction and basics of ultrasound- Ultrasound characterization for emulsion- Ultrasound characterization for microemulsion- General features of acoustic measurement- Acoustic measurements on emulsions- Physicochemical characterization and characterization techniques types- Pharmaceutically applicable microemulsions- Places of microemulsion and emulsion in cancer therapy- In vitro and in vivo evaluation- Biocatalysis in microemulsion- Biofluidic Matrices- Microemulsions as Decontamination Media for Chemical weapons- Microemulsions as toxic Industrial Chemicals	

Learning Resources	*1. Fanun, Monzer. Microemulsions: properties and applications, CRC press, 2008.* *2. Sjoblom, Johan. Emulsions and emulsion stability: Surfactant science series/61. CRC Press, 2005.*	*3. Berg J. C., An Introduction to Interfaces and Colloids: The Bridge to Nanoscience, World Scientific, 2010*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Krishna Surendra, SAINT GOBAIN, Krishna.muvvala@saintgobain.com	*1. Dr. Vinu, IITM, vinu@iitm.ac.in*	*1. Dr. Junaid MasudLaskar, SRMIST*
2. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	*2. Dr. S. Ramaprabhu,IITM, ramp@iitm.ac.in*	*2. Dr. V. Eswaraiah, SRMIST*

Course Code	21NTE408T	**Course Name**	SUPRAMOLECULAR SYSTEMS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire the concepts of supramolecular chemistry*
CLR-2:	*utilize designing new materials of metal-organic frame works*
CLR-3:	*describe the concept of nanostructured objects*
CLR-4:	*understand the principles of supramolecular chirality*
CLR-5:	*gain knowledge on host-guest complexes*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*analyze the main types of supramolecular assemblies and molecular recognition*	*3*	-	-	2	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*evaluate the host-guest chemistry in supramolecules*	*2*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-3:	*analyze the nature of bindings involved in biological systems*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	-	2	-
CO-4:	*analyze and understand the intermolecular forces to rationalize the formation of complex nanomaterials*	*3*	-	*2*	*2*	-	-	-	-	-	-	-	-	-	-	*2*
CO-5:	*demonstrate the applications of supramolecules in miniaturization of molecular devices*	-	*2*	*3*	-	*1*	-	-	-	-	-	-	-	2	-	-

Unit-1 - Basic Concepts of Supramolecular Systems ***9 Hour***

Basic concepts and principles of supramolecular chemistry - Classification of supramolecular compounds - Host-guest compounds - Molecular recognition, Hydrogen Bonds: Definition, Structure and Stability-strength, Secondary Electrostatic Interactions in hydrogen bonding arrays -Non-covalent interactions: Ion pairing - Ion-Dipole Interactions- Dipole-Dipole interactions - Dipole-Induced Dipole and Ion-Induced Dipole interactions - van der Waals or Dispersion Interactions, Cation- interaction- Anion-pi interactions, pi - pi interactions - Closed shell interactions, Aromatic-Aromatic Interactions: Benzene Crystals, Edge-to-face vs. pi-pi Stacking Interactions, N-H- pi interactions, Sulfur-aromatic interactions, Benzene-Hexafluorobenzene pi-stacking

Unit-2 - Coordination Chemistry ***9 Hour***

Introduction to coordination chemistry - Hosts for cation binding - Cation receptors - Crown ethers – Cryptands – Spherands – Calixarens - Selectivity of cation complex - Macrocyclic effects - Template effects - Host for anion binding - Concepts in anion host design - Anion receptors - Biological Receptors - Conversion of Cation Hosts to Anion Hosts - Neutral Receptors - Metal-Containing Receptors - Cholapods

Unit-3 - Biological Inspiration for Supramolecular Chemistry ***9 Hour***

Biological inspiration for supramolecular chemistry - Alkali metal cations in biochemistry - Co-ordination Polymers – Clathrates – Cavitands - Binding by cavitands – Cyclodextrins – Cucurbituril - Porphyrins and tetrapyrrole macrocyles - Transport processes - Dynamic Combinatorial chemistry - Supramolecular features of plant photosynthesis - Uptake and transport of oxygen by haemoglobin - Enzymes and coenzymes - Neurotransmitters and hormones - Enzymes, Metallobiosites - Heme analogues - Semiochemistry in natural world, Biochemical self-assembly

Unit-4 - Chirality, Metal Organic Frameworks-Characterization ***9 Hour***

Supramolecular Chirality - Chirality in Self-Assembled Systems - Chirality of Host-Guest Compounds - Chirality of Interlocked Systems - Metal Organic Frameworks (MOFs) - Covalent Organic Frameworks – Polymorphism – Solvates - Co-Crystals - Principles of supramolecular Extraction - Extraction technique, the extraction equilibrium - Examples of supramolecular extraction - Binding Constant - Binding constant determination by UV/Vis spectroscopy - Instrumentation of mass spectrometry, Limitations of mass spectrometry - Scanning probe microscopes: - scanning electron microscopy - Transmission electron microscopy - Confocal laser scanning microscopy

Unit-5 - Application of Supramolecules	***9 Hour***
Special Class Materials - Birth of a new macromolecular chemistry concept - Rational Design - Molecular Paneling - Artifical Self Replicating Systems - Supramolecular reactivity and catalysis - The past, present and future of dendrimers and dendrons - Supramolecular assembly of dendrons and dendrimers - Synthesis of dendritic polymers - Characterization of dendritic architectural structures - Nanomedical and advanced materials - Diagnostics and advanced imaging - Characterization of dendritic architectural structures - Nanoscience applications - Molecular and Supramolecular devices - Molecular Electronic Devices – Switches - Molecular Machines	

Learning Resources	*1. Jonathan W. Steed and Jerry L. Atwood, "Supramolecular Chemistry"J. Wiley and Sons; 2011* *2. J. M. Lehn, Supramolecular Chemistry, VCH, Wiley and Sons, 1st Ed. Weinheim,1995*	*3. Donald A. Tomalia, Jørn B. Christensen, Ulrik Boas, "Dendrimers, Dendrons, and Dendritic Polymers: Discovery, Applications and the Future", MPG books group, UK, 2012*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. P. Sudhakara, CLRI – CSIR, Jalandhar, sudhakarp@clri.res.in	*1. Dr. Kothandaraman Ramanujam, IITM Chennai, rkraman@iitm.ac.in*	*1. Dr. N. Angeline Little Flower. SRMIST*
2. Dr. Sudhakar Selvakumar, CSIR-Central Electrochemical Research Institute, ssudhakar79@gmail.com	*2. Dr.Arthanreeswaran, NIT, Trichy,arthanareeg@nitt.edu*	*2. Dr. C. Siva, SRMIST*

Course Code	21NTE409T	**Course Name**	CANCER NANOTECHNOLOGY	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understanding the basis of cancer biology*
CLR-2:	*know the various types of cancer biomarkers*
CLR-3:	*getting knowledge about ways to treat cancer growth*
CLR-4:	*get acquainted with nanomaterial based current therapies available for cancer treatment*
CLR-5:	*get acquainted with the current trend in cancer theranostics*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*analyze the nature of cancer*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*analyze the concepts of cancer nanotechnology*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-3:	*apply concepts of cancer nanotechnology to a focused clinical area of their choice*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	*2*
CO-4:	*apply these nanosystems for the diagnosis and therapy*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-5:	*apply the concepts of nano theronostic strategy*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	*1*

Unit-1 - Basis of Cancer Biology ***9 Hour***

Nature of cancer, Tumor viruses, Oncogenes, growth factors, Tumor Suppressor genes, Characteristics of pRb, Characteristics of p53, Mutation of p53 and apoptosis, Role of p53 in cell cycle progression, Tumorigenesis, Cancer development, Angiogenesis, Invasion, Metastasis

Unit-2 - Types of Cancer and Mutations ***9 Hour***

Types of cancers, Stem cells and cancer, Molecular genetics of cancer, Genetic alterations in cancer cells: mutations, types of mutation

Unit-3 - Cancer Biomarkers and Imaging for Therapy ***9 Hour***

Theranostic cancer biomarkers, Molecular imaging in cancer theranostics, Targetted cancer theranostics, Molecular imaging in cancer theranostics, Imaging-guided cancer therapy, Nanomaterials for theranostics, Proteomics-based theranostics, Radionuclide imaging of cancer therapy, Bioluminescence imaging of cancer therapy, Magnetic resonance imaging of cancer therapy, CT based imaging of cancer therapy

Unit-4 - Nanoparticles for Diagnosis qnd Therapy ***9 Hour***

Magnetic nanoparticles as contrast agents, Ultrasound-responsive nanoparticles, Noble metal nanoparticle, Metal oxide nanoparticles for cancer theranostics, Carbon based nanoparticles, Polymer- -based nanoparticles for cancer theranostics, Boron capture therapy and imaging,

Unit-5 - Conceprs of Theronostics Strategy ***9 Hour***

Nanomedicine approaches for cancer cell targeting, Drug delivery systems for cancer therapy, targeting cancer cells with nanoparticles, nanosystem for delivery of siRNA

Learning Resources	*1. The Biology of Cancer, Robert A. Weinberg, Garland Science, 2010.* *2. Cancer Biology, Raymond W. Ruddon, Oxford University press, 2007.*	*3. Cancer Theranostics, Chen &Wong, Academic Press, 2014.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	20%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. K. Chandru, HCL Health care division, Chennai	1. Dr. Mukesh Doble, IIT M	1. Dr. G. Devanand venkatasubbu, SRMIST
2. Dr. Asifkhan Shanavas, INST Mohali,	2. Dr. T. Prakash, UOM	2. Prof. N. Selvamurugan, SRMIST

Course Code	21NTE410T	**Course Name**	ATOMISTIC MODELING	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	Nil	**Co- requisite Courses**	Nil	**Progressive Courses**	Nil
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	Nil		

Course Learning Rationale (CLR):	**The purpose of learning this course is to:**
CLR-1:	*learn about basic modeling*
CLR-2:	*understand the DFT for materials modeling*
CLR-3:	*understand the MD simulation*
CLR-4:	*gain knowledge about Monte Carlo Simulation*
CLR-5:	*learn advance-modeling technique*

		Program Outcomes (PO)												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	**At the end of this course, learners will be able to:**	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*acquire the basics of design and materials modeling*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*gain knowledge on DFT and the approximations in the context of materials modeling*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*obtain the knowledge on Molecular Dynamics and its application to solve materials problem*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*improve their knowledge on materials modeling with Monte Carlo Simulation*	*3*	-	-	-	*2*	-	-	-	-	-	-	-	-	-	-
CO-5:	*solve problems to understand the electronic, mechanical and optical properties of Materials using advance-modeling technique*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Basics for Modeling ***9 Hour***

Classical mechanics, Hamiltonians- Coordinate systems in the context of solving the physical problems- Potential energy-Definition and Concept – Calculation of elastic constants from potential function- Potentials for ionic systems- Potentials for ceramics Systems- Concept of Many-body potential -Many -body potentials for metals- Many-body potentials for covalently bonded systems - Comparative Study- Energy optimization - Significance of Lowest energy structure- Molecular statistics - Problems on Molecular Statistics

Unit-2 - Density Functional Theory ***9 Hour***

Born-Oppenheimer approximation- Limitations of BO approximation - Introduction to DFT- Hohenberg-Kohn Theorems- Kohn-Sham Equation- Interpretation of KS equations- Exchange-correlation functions and LDA/GGA- Accuracy of LDA/GGA- PW91 method, PBE method -Pseudopotentials - Types of Pseudopotentials - Brillouin zone- K-points, Concept of Basis Set- The need for self-consistency- Setting up structures, key parameters, Volume optimization Metals vs.insulators- Basis sets, energy cutoff, exchange-correlation function, K-points- Convergence and scaling with lattice parameters

Unit-3 - Molecular Dynamics Simulations ***9 Hour***

The basic MD algorithm- The MD steps- Taylor expansion- Verlet algorithms - choosing the time step- Predictor-corrector algorithm - Discussion with Examples- MD in different ensembles- MD in constant temperature- Molecular dynamics in constant pressure- Energies: molecular statics- Problems on Molecular Statistics- MD Simulation analysis- Limitations of MD- Application of MD as Case Study: 3D system- Application of MD as Case Study: 2D system

Unit-4 - Monte Carlo Simulations ***9 Hour***

Introduction of Monte Carlo simulation - Monte Carlo simulation analysis- Limitations of Monte Carlo simulations- Introducing ensembles in MC- Kinetic Monte Carlo- Key concepts: starting structure in MD- Key concepts: starting structure in KMC- Convergence criteria- Scaling with lattice parameters- Understanding the electronic structure- Electrical conductivity, Excited electron states- Application of MC method as Case Study

Unit-5 - Various Dft Codes for Advanced Modeling	***9 Hour***
Introduction to various DFT codes - Basic DFT outputs - Basic output of QM code - Energies, electronic structure - Using the energies: molecular statics, MD, MC - Using the energies: MC - Using the electronic structure: optical properties - Transitions between electronic states- Electrical conductivity - Mobility of electrons, scattering of electrons between states - Excited electron states due to thermal (or optical) excitations - Type of bonding - tunneling rates - Excited electron states due optical excitations - Understanding the electronic structure from different Methods, Comparative study- Wave functions, charge density, band structure, density of states- Confinement effect on Electronic Structure-3D, 2D, 1D Carbon based materials as example	

Learning Resources	*1. Jörg-Rüdiger Hill,Lalitha Subramanian and Amitesh Maiti, Molecular modeling techniques in materialsciences,Taylor & Francis/CRC Press: Boca Raton,2006* *2. AndrewR.Leach,Molecular modelling: principlesandapplication, Pearson Education,India,2001*	*3. R. Martin, Electronic Structure: Basic Theory and Practical Methods, 2nd Edition, Cambridge University Press, 2020* *4. J.M. Thijssen, Computational Physics, Cambridge, UK: Cambridge University Press,2007*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Hemant Dixit, GlobalFoundaries, aplahemant@gmail.com	*1. Dr. Ranjit Kumar Nanda, IITM Chennai, nandab@iitm.ac.in*	*1. Dr. C. Preferencial Kala, SRMIST*
2. Dr. Murali Kota, Global Foundaries, USA, kvrmmurali@gmail.com	*2. Prof. G.P. Das, IIT M, KGP, msgpd@iacs.res.in*	*2. Dr. Saurabh Ghosh, SRMIST*

Course Code	21NTE411T	**Course Name**	NANOTECHNOLOGY IN TEXTILES	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on nanotechnology for textile applications*
CLR-2:	*learn the smart materials and devices for textile industry*
CLR-3:	*study the various nanostructures for improving the textile yarn and fabric*
CLR-4:	*understand the nanomaterials processing for textile industry*
CLR-5:	*learn various nanodevices for improving the textile fabrics*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*demonstrate the applications of nanotechnology in textile industry*	*3*	-	*1*	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*incorporate the responsive polymers in textile fabric designs*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	-
CO-3:	*incorporate nanocomposite-based sensors in textile fabrics*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*produce the nanocoatings in textile fabrics*	*3*	-	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*create the nanogenerators incorporated nanofabrics*	-	*2*	-	-	*3*	-	-	-	-	-	-	-	-	-	-

Unit-1 - Introduction to Smart Textiles	***9 Hour***
Introduction to smart nanotextiles, Nanotechnology & nanomaterials – Nanofibers, Advantages of nanofibers - Nanofibers fabrication, Electrospinning - Enhancing the mechanical properties, Large scale production of fibers - Formation of yarn & fabric, Moisture management & waterproof – Thermoregulation, Personal protection - Wearables and sensors, Medical care of nanofibers - Nanosols as coating agent, Applications of nanosols in textiles - Photocatalytic and light responsivity of nanosols, Antimicrobials and bioactive systems	
Unit-2 - Smart Materials for Textile Industry	***9 Hour***
Responsive Polymers, Classification of stimuli-responsive polymers - Responsive polymers as sensors, Responsive polymers in drug delivery systems - Responsive polymers in cell application, Responsive polymers-based filters, Nanowires for textiles, Properties of nanowires in textiles - Balancing transparency and conductance, High specific surface area, Direct charge transport path - Oriented assembly of nanowires, Metal conducting nanowires - Conducting polymer nanowires, Oxide semiconducting nanowires - Sulphide semiconducting nanowires, Other semiconducting nanowires - Current and future perspective of nanowires	
Unit-3 - Improvements to Textile Yarn and Fabric	***9 Hour***
Nanocomposites for textiles, Classifications - Structure & properties, Production methods of nanocomposites - Carbon structures, Nanocellulose - Conducting polymers, Nanoparticles, clays & wires - Laminated nanocomposites and fibers, Membranes, coatings, & Hydrogels - Sensing of nanocomposites Actuators of nanocomposites, Antibacterial activity of nanocomposites - Defense applications of nanocomposites Fire protection, Fire retardant materials - Self-cleaning, Energy harvesting of nanocomposites	
Unit-4 - Nanotechnology Processes for Self-Cleaning	***9 Hour***
Photocatalytic self-cleaning, Super hydrophobic self-cleaning - Antibacterial coating, UV-Protection coating -Impregnation, Cross linking method - Flame retardant coatings, Carbon materials - Phase change materials in thermal regulation, Nanowires in thermal regulation - Carbon based conducting coating -Metal based conducting coating - Textiles for flexible solar cells - 3D printable flexible materials	

Unit-5 - Nanogenerators in Textiles	***9 Hour***
Nanogenerators for textiles, working of nanogenartors - Classification of nanogenerators, Piezoelectric, nanogenerators (PENG) - Triboelectric nanogenerators (TENG), Theoretical origin of nanogenerators - Fiber based PENGs, Textile based PENGs - TENGs Classifications, Fibers based TENGs - Textiles based TENGs, 1D materials based TENGs - 2D fabrics for TENGs, 3D woven textile TENGs - Integrating energy harvesting devices, TENGs with solar cells -Magnetic Textile-Solid phase extraction.	

Learning Resources	*1. Nazire D. Yilmaz, Smart Textiles, Wearable Nanotechnology, Ist Ed., Scrivener Publishing, 2019* *2. P. J. Brown and K. Stevens, Nanofibers and nanotechnology in textiles, CRC Press, 2007*	*3. Nanotechnology in Textiles: Theory and Application, Jiří Militký and Rajesh Mishra, Elsevier Publications, 2018* *4. Nanosensors and Nanodevices for Smart Multifunctional Textiles, Andrea Ehrman, Tuan Nguyen, Phuong Nguyen Tri, Elsevier Publications, 2020*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*20%*	-	*20%*	-	*20%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*20%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr.Hitesh Rathore, SHT Distributors – Salem, TN, hiteshrathore@gmail.com	*1. Dr. M. Madhusoothanan, Anna University-Chennai, mmadhu@annauniv.edu*	*1. Dr. C.Siva, SRMIST*
2. Mr. T.Raajasekar, Allwin Exports, fabric@allwinexport.com	*2. Dr.T.S. Natarajan, IIT Tirupati, tsniit@iittp.ac.in*	*2. Dr. K. Mani Rahulan, SRMIST*

Course Code	21NTE412T	**Course Name**	NANOPHOTONICS	**Course Category**	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co- requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes / Standards**	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamentals of light interaction with nanoscale materials*
CLR-2:	*learn the basic concepts of quantum confined materials*
CLR-3:	*understand the principles of photonic crystals*
CLR-4:	*enrich their knowledge on plasmonics and near field optics*
CLR-5:	*familiarize themselves with nanophotonic fabrication*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	**Program Outcomes (PO)**												**Program Specific Outcomes**		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the principles of Quantum confinement effects to understand Nanoscale interaction dynamics*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	*2*	-	-
CO-2:	*utilize the photonic crystals in various applications*	*3*	*2*	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*explore the principles of plasmonics to study Near field scanning optical microscopy*	*3*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	*3*	-
CO-4:	*utilize the Near field scanning optical microscopy in data storage applications*	*2*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	*2*	-
CO-5:	*apply the fundamental principles of Near field optical chemical vapor deposition technique for the fabrication of nanophotonic materials*	*3*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*

Unit-1 – Light Interaction with Nanoscale Materials	***9 Hour***
Photons and electrons - Similarities and differences - Free space propagation - Confinement of photons and electrons - Propagation through a classically forbidden zone – Electrons Propagation through a classically forbidden zone – Photons Tunnelling Localization under a periodic potential – Electrons Tunnelling Localization under a periodic potential – Photons Band gap and cooperative effects of photons - Band gap and cooperative effects of Electrons - Nanoscale optical interactions - Axial and lateral nanoscopic localization - Nanoscale confinement of photonic interactions - Nanoscale confinement of electronic interactions - Quantum confinement effects - Nanoscale interaction dynamics Nanoscale electronic energy transfer - Cooperative emissions.	
Unit-2 - Quantum Confined Materials	***9 Hour***
Quantum confined materials - Inorganic quantum confined structures - Manifestation of quantum confinement - Quantum confined Stark effect - Dielectric confinement effect - Super lattices - Core-shell quantum dots - Quantum wells - Quantum confined structures as lasing media - Organic quantum confined structures - Photonic crystals - Important features of photonic crystals - Applications of Photonic crystals - Dielectric mirrors - Interference filters - Photonic crystal laser - Photonic crystal sensing Photonic crystal fibers (PCFs) - Introduction to metamaterials.	
Unit-3 - Plasmonics Principles	***9 Hour***
Plasmonics - Internal reflection - Evanescent waves - Plasmons and surface plasmon resonance - Attenuated total reflection - Grating SPR coupling - Optical waveguide SPR coupling - SPR dependencies and materials - Plasmonics and nanoparticles - Near-Field Optics - Aperture less near field optics - Near field scanning optical microscopy - (NSOM or SNOM) – Principle Near field scanning optical microscopy - Design and Technique of SNOM - SNOM Applications - SNOM based visualization of waveguide structures - SNOM based energy transport - SNOM based optical data storage - SNOM based optical data recovery.	

Unit-4 - Nanophotonic Fabrication	**9 Hour**
Nanophotonic Fabrication - Adiabatic nanofabrication - Non adiabatic nanofabrications - Conditions for non-adiabatic nanofabrications - Near field optical Chemical Vapour Deposition NFO CVD - Near field optical Chemical Vapour Deposition Philosopy– Design and Technique - Near field photolithography – Philosophy - Near field photolithography Design and Technique - Self-assembling method - Self-assembling method via optical near field interactions - Regulating the size of nanoparticles - Size dependent resonance - Controlling size of nanoparticles - Alignment of Size controlled nanoparticles - Controlling position of nanoparticles - Alignment of position controlled nanoparticles - Separation of nanoparticles - Alignment of Separated and controlled nanoparticles.	
Unit-5 - Nano Biophotonics and Applications	**9 Hour**
Biophotonics – Nanobiophotonics - The cell and scale - The cell and constituents - Origin of contrast mechanisms - Optical contrast mechanisms - Classical contrast mechanisms - Bright field and dark field contrast - Phase contrast - Inter ferrometric contrast - Fluorescence contrast mechanism - Confocal Microscopy - Nonlinear microscopy based on second harmonic generation - Coherent anti-stokes Raman scattering (CARS) - Reduction of the observation volume - Far field method - 4Pi microscopy Microscopy on a mirror - Stimulated emission depletion (STED).	

Learning Resources	*1. M.Ohtsu, K.Kobayashi, T.Kawazoe and T.Yatsui, Principals of Nanophotonics, (Optics and ptoelectronics), CRC press, 2008.* *2. Joseph W. Haus, Fundamentals and Applications of Nanophotonics, Elsevier Science, 2007.*	*3. BEA Saleh and AC Teich, Fundamentals of Photonics, John Wiley and Sons,2007* *4. Y. V. G.S. Murthy and C. Vijayan, Essentials of Nonlinear Optics, Wiley, 2014*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
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Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. Sameer Sharda, New Age Instruments & Materials Pvt. Ltd., Gurgaon, sameer@newagein.com	*1. Prof. C. Vijayan, IIT Madras, cvijayan@iitm.ac.in*	*1. Dr. D. John Thiruvadigal, SRMIST*
2. Mr. Muhammed Shafi, Holmarc Opto-Mechatronics Pvt. Ltd, Cochin, optics@holmarc.com	*2. Prof. S. Balakumar, Univ. of Madras, balakumar@unom.ac.in*	*2. Dr. Junaid Masud Laskar, SRMIST*

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