ACADEMIC CURRICULA

POST GRADUATE DEGREE PROGRAMMES

Master of Technology

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 26
Syllabi for Civil Engineering and Nanotechnology Programmes

Professional Core and Elective Courses

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

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Nanotechnology

Professional Core Courses

Regulations 2021

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Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21NTC501T	Course Name	QUANTUM 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:***
CLR-1:	*understand the postulates of quantum mechanics and the central concepts of wave functions and operators*
CLR-2:	*obtain analytical solutions of simple systems in one, two and three dimensions*
CLR-3:	*solve the time-dependent and time-independent Schrödinger equation for simple atomic systems*
CLR-4:	*learn the fundamentals of time-dependent and time-independent perturbation methods*
CLR-5:	*obtain approximate solutions of two-electron and multielectron molecular systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply principles of quantum mechanics to calculate observables in quantum measurements and uncertainty principle.*	*3*	*-*	*3*
CO-2:	*solve simple three-dimensional quantum mechanical problems exactly by using quantum mechanical framework*	*3*	*-*	*3*
CO-3:	*relate the knowledge of mathematics to the formalism of quantum mechanics*	*3*	*-*	*3*
CO-4:	*identify and solve the eigenvalue problems for energy, momentum, angular momentum and explain the idea of spin*	*3*	*-*	*3*
CO-5:	*gain experience with quantum mechanics for further studies in material science as well as nanotechnology*	*3*	*3*	*-*

Module-1 - Postulates of Quantum Mechanics and Schrodinger Equation	***9 Hour***
Inadequacy of Classical Mechanics-De Broglie waves, Wave-particle duality, Time-dependent Schrodinger equation, Time-independent Schrodinger equation, Wave function and its physical interpretation, Postulates of quantum mechanics, Problem solving-Properties of eigenfunctions, orthonormality and completeness, Linearity and superposition, Probability density and probability Curren, Continuity equation, Hermitian operators, Properties of Hermitian operators-Problem solving, Dirac notation, Uncertainty principle, Ehrenfest Theorem-Problem solving	
Module-2 - Potential Problem	***9 Hour***
Free particle in three dimensions, particle in a box-one dimension and three dimension-potential step, potential barrier, tunnel effect, square well potential, periodic potential, Barrier penetration problem for Tunnel effect, Tunneling probability for a barrier of width L and height V, Problem solving linear harmonic oscillator, rigid rotator, Stationary states and energies, Time-dependent solutions, Expectation values and comparison with classical solution (in phase space)	
Module-3 - Hydrogen Problem and Operators	***9 Hour***
Introduction to spherical symmetric potentials, hydrogen atom-Schrodinger equation, Radial and angular equations of hydrogen atom, Solutions to radial and angular equations, Energy quantization of hydrogen atom, Energies and wave functions of hydrogenic atoms-Problem solving, Angular momentum operators, Raising and lowering operators, Commutation relations between angular momentum operators, Eigenvalues and Space quantization, Conservation of angular momentum in hydrogen atom, Clebsch-Gordon coefficients	
Module-4 - Perturbation Theory and Related Phenomena	***9 Hour***
Time-independent perturbation theory, nondegenerate case-First-order correction to energy and wave function, Time-independent perturbation theory – degenerate case, Removal of degeneracy, Stark effect of hydrogen atom, Energy level splitting in Stark effect-Problem solving, Normal Zeeman effect without spin, Normal Zeeman effect with spin, Fine structure – relativistic correction, Fine structure – spin-orbit interaction, Hyperfine structure, Energy level splitting due to hyperfine interaction in hydrogen atom-Problem solving, Time-dependent perturbation theory, Fermi's golden rule.	
Module-5 - Scattering and Many Electrons System	***9 Hour***

Scattering at a central potential, Scattering amplitude and (angle-differential) cross section, Classical versus quantum interpretation, Green's functions (inclusion of boundary conditions, contour integration technique), Born series, First Born approximation cross section for Yukawa and Coulomb potentials, Partial wave expansion of scattering wavefunction, amplitude, and cross section, Scattering phase shifts and resonances, Variation theorem statement, Proof of variation theorem.

Learning Resources	*1. David J. Griffiths, "Quantum Mechanics", Pearson Educational, 2005* *2. Richard L. Liboff, "Introductory Quantum Mechanics", Pearson Education, 2003*	*3. Arthur Beiser, "Concepts of Modern Physics", McGraw Hill, 2009* *4. Y. Peleg, R. Pnini, E. Zaarur, "Schaum's outline of theory and problems of quantum mechanics", McGraw Hill, 1998*

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, NPL, dkaswal@nplindia.org	1. Dr. R. Sivakumar, Pondicherry University, rs4670@pondiuni.ac.in	1. Dr. Saurabh Ghosh, SRMIST
2. Dr. Subramanian, CLRI, subbu@clri.res.in	2. Dr. M. Pattabiraman, IITM, pattu@iitm.ac.in	2. Dr. Rohit Dhir, SRMIST

Course Code	21NTC502J	Course Name	NANOSCALE MATERIALS: SYNTHESIS AND CHARACTERIZATION	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:	*acquire knowledge on nanomaterials synthesis*
CLR-2:	*understand various concepts involved in preparation of different nanostructured materials*
CLR-3:	*acquire knowledge about size effects and reaction kinetics at nanoscale*
CLR-4:	*get acquainted with material properties and practical experience on nanomaterials synthesis*
CLR-5:	*utilize material characterization techniques and to analyze their morphological, structural, and chemical behaviour*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*analyse the chemistry based processes and able to optimize the procedures and implementations at nanoscale*	*3*	*3*	*-*
CO-2:	*fabricate different classes of materials at nanoscale*	*3*	*-*	*3*
CO-3:	*apply the chemical concepts to understand the structure and properties of various materials*	*3*	*3*	*-*
CO-4:	*characterize and to study the properties of the nanomaterials*	*3*	*3*	*-*
CO-5:	*acquire the skills required for the advanced characterization techniques*	*3*	*-*	*3*

Module-1 - Physical Routes of Synthesis — ***15 Hour***

Importance and emergence of nanotechnology, nucleation theory, surface characteristics and stabilization, Fabrication of nanomaterials by Physical Methods, High energy Ball Milling, Arc discharge method, RF- plasma technique, Vapour deposition techniques, Physical and Chemical vapour deposition techniques, Catalyst assisted chemical vapour deposition (CCVD), Pulsed Laser Deposition, Atomic Layer Deposition (ALD), Sputter deposition, Inert gas condensation

1. *Introduction to the laboratory*
2. *Mechanical ball milling technique to prepare metal and ceramic composite preparation*
3. *Determination of the crystallite size using XRD analysis*

Module-2 - Chemical Routes of Synthesis — ***15 Hour***

Nanomaterial synthesis through chemical routes, Colloidal method, Sol-gel method, Electrodeposition, Micellar growth, Vapor (or solution) – liquid – solid (VLS or SLS) growth, Langmuir-Blodgett Films,- Electrochemical Deposition, Solvothermal and hydrothermal routes, precipitation, Spray pyrolysis, Special Nanomaterials, Core/shell structures, Carbon-based Nanomaterials, Micro and Mesoporous Materials, Organic-Inorganic Hybrids, Electrophoretic deposition

4. *Preparation of organic-inorganic hybrid material*
5. *Synthesis of bimetallic nanoparticles*
6. *Preparation of metal oxide nanoparticles by sol-gel method*

Module-3 – Fabrication of Nanostructured materials — ***15 Hour***

Nanofabrication processes: Concept of Top Down and Bottom Up Fabrication approach, template assisted synthesis, epitaxial growth, Molecular beam epitaxy (MBE), Nanoimprint lithography, Electron beam lithography (EBL), Bio-mediated assembly, Scaffold Fabrication and Tailoring, Synthetic Biomaterial Scaffolds, Fabrication: Design rules, Clean rooms, Wafer cleaning and Gettering, Oxidation, Photoresist, Photolithography

7. *wet chemical etching of silicon dioxide and metal thin films*

8. Microwave assisted synthesis of zinc oxide nanowires 9. Morphological analysis using SEM image and to measure the particle size
Module-4 - Nanomaterial Characterization Techniques **15 Hour**
Characterization of nanomaterials: X-ray Diffraction, Thermal Analysis Methods, Spectroscopic techniques, UV-Visible Spectroscopy, Vibrational spectroscopy, IR Spectroscopy, Raman Spectroscopy, Electron Spin Resonance Spectroscopy, NMR Spectroscopy, Photoluminescence (PL), Cathodeluminescence (CL), Particle size characterization: Zeta Potential Measurement, Particle size Analysis, X-ray Photoelectron spectroscopy, Auger electron spectroscopy (AES) 10. Determination of the lattice strain using Williamson-Hall Plot 11. Determination of the optical band gap using UV-Visible spectrum 12. Interpretation of the XPS spectra
Module-5 - Surface Imaging Techniques **15 Hour**
Optical microscopy, Interference Microscopy, Confocal microscopy, Scanning electron microscopy, Modes of operation, Backscattered electrons, secondary electrons, X-rays, Transmission Electron Microscopy: Modes of operation, Specimen preparation, Diffraction in imperfect crystals, dislocations, precipitates, HRTEM use in nanostructures, Atomic Force Microscopy: different modes of operation, Contact mode imaging, Non-contact and tapping mode imaging, Scanning Tunneling Microscopy 13. Determination of the surface morphology by STM and roughness determination by AFM 14. Imaging analysis using transmission electron microscope 15. Revision of the experiments

Learning Resources	1. Guozhong Cao, Nanostructures and Nanomaterials : Synthesis, Properties and Applications, Imperial College Press 2004 2. CNR Rao et.al., Chemistry of Nanomaterials : Synthesis, properties and applications, John Wiley & Sons, 2006	3. Characterization of Nanophase materials – Z.L Wang (ed), Wiley-VCH, New York 2000 4. Nanobiotechnology: Concepts, Applications and Perspectives - C.M. Niemeyer, C.A. Mirkin, Wiley-VCH, ISBN: 978-3-527-30658-9, 2004 5. Nanostructures-Fabrication and analysis: Editor: H. Nejo, Springer publication, 2007

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- Practice (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, sudhakarp@clri.res.in	1. Dr. Kothandaraman Ramanujam, IITM, rkraman@iitm.ac.in	1. Dr. N. Angeline Little Flower, SRMIST
2. Dr. N. Vijayan, NPL, nvijayan@nplindia.org	2. Prof. G. Ranga Rao, IITM, grrao@iitm.ac.in	2. Dr. K. Mani Rahulan, SRMIST

Course Code	21NTC503J	Course Name	NANOSCALE SCIENCE IN BIOLOGICAL SYSTEMS	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:	provide knowledge about various biological molecules
CLR-2:	give understanding about the cell structure and organelles and transportation across membrane
CLR-3:	gain knowledge about various molecular biology principles
CLR-4:	understand about biomaterials and their interaction
CLR-5:	gain knowledge about the different applications of nanomaterials in biology

Course Outcomes (CO):	At the end of this course, learners will be able to:	Programme Outcomes (PO)		
		1	2	3
CO-1:	describe the importance of biological molecules	3	-	3
CO-2:	analyze the transportation process across membrane.	3	-	3
CO-3:	describe the molecular biology process	3	-	3
CO-4:	analyze the interaction of biomaterials with cell	3	-	3
CO-5:	use nanomaterials for biological application	3	3	-

Module-1 - Biomolecules	15 Hour
Introduction to biomolecules, Carbohydrates – Classification, structure, isomerism, Amino acids - Classification, structure, Proteins – Primary, secondary, tertiary and Quaternary Structures, Fatty acids - Classification, structure, Lipids - Classification, structure, Nucleic acids - Classification, structure of DNA and RNA 1. Introduction to the laboratory 2. Bacteria growth by plating technique 3. Estimation of membrane damage by nanoparticles	
Module-2 - Cell structure and organelles	15 Hour
Cell: Structure, organelles, function, Cell membrane: structure, components, Transport across cell membrane, Active transport, Passive transport, endocytosis, exocytosis, Cell cycle: Mitosis, Meiosis 4. Fluorescence imaging of nano bio interaction 5. Growth inhibition by nanoparticles	
Module-3 - Molecular mechanism	15 Hour
DNA replication, Transcription, Genetic codes - Codon, anti-codon, T-RNA structure, Ribosome structure, Translation, Carbohydrate metabolism – Glycolysis, Kreb's cycle, electron transport chain 6. Analysis of nanoparticle induced genotoxicity 7. Separation of proteins by SDS phage	
Module-4 - Biomaterials	15 Hour
Biomaterials – Types of biomaterials, biocompatibility, applications of biomaterials, Interaction of biomaterials with cells, blood and proteins, Protein corona, Surface modification of biomaterials 8. Estimation of drug loading in nanocarriers 9. Estimation of drug release from nano drug delivery system	
Module-5 - Nano drug delivery systems and biosensors	15 Hour

Drug delivery systems, Traditional drug delivery systems, controlled drug delivery systems, Targeted drug delivery system, Active targeting, passive targeting, Tissue engineering, Scaffolds, Biosensors, monoclonal antibody *10. Fabrication of scaffolds for tissue engineering* *11. Biocompatibility analysis of nanoparticles by MTT assay*

Learning Resources	1. *Donald Voet, Judith G. Voet, Biochemistry, Wiley, 2022* 2. *David Freifelder, Molecular Biology, 2nd ed., Narosa, 2022*	*3. Niemeyer, C.M. and Mirkin, C.A., Nanobiotechnology: Concepts, Applications and Perspectives, Wiley-VCH, 2020.* *4. Madhuri Sharon, Maheshwar Sharon, Sunil Pandey and Goldie Oza, Bio-Nanotechnology_ Concepts and applications. Ane Books Pvt Ltd, 1 edition 2022.*

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. Mr. P. Aravind Mukesh, United Breweries, Bengaluru	1. Prof. K. Chandraraj, IITM, kcraj@iitm.ac.in	1. Dr. G. Devanand Venkatasubbu, SRM IST
2. Mr. K. Chandru, HCL Medical devices Pvt. Ltd. Chennai	2. Dr. P. Balasubramanian, NIT Rourkela, balap@nitrkl.ac.in	2. Dr. N. Selvamurugan, SRM IST

Course Code	21NTC504J	Course Name	PHYSICS AND CHEMISTRY 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:	*acquire knowledge on Nanostructures and nanomaterials*
CLR-2:	*understand the concepts of various physical Aspects of Nano materials*
CLR-3:	*familiarize with Chemical aspects and mechanism of nanomaterial's*
CLR-4:	*explore about the fundamentals and mechanism of Nucleation and growth kinetics*
CLR-5:	*understand the concepts of Diffusion and defects*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Programme Outcomes (PO)		
		1	*2*	*3*
CO-1:	*explain the general classification and structures of nanomaterials, basic principles and properties of the most important systems structured at the nano scale*	*3*	*3*	*-*
CO-2:	*illustrate the electrical, optical, magnetic and thermal properties of nanomaterials*	*3*	*3*	*-*
CO-3:	*analyze the chemical aspects of nanomaterials and the catalytic properties of nanomaterials*	*3*	*3*	*-*
CO-4:	*evaluate the kinetic process and mechanism of nucleation*	*3*	*-*	*3*
CO-5:	*describe the diffusion and surface defects in nanostructures*	*3*	*3*	*-*

Module-1 - Nanostructured Systems ***15 Hour***

Nanostructures, Quantum phenomenon in low dimensional nanostructures, Effective mass theory, Density of states, 3-Dimensional nanostructures, Coulomb blockade and quantum computers, Surface science, 2-Dimensional nanostructures, Quantum well and super lattices, 1-Dimensional nanostructures, Quantum dots, Excitons in Quantum structures and in heterostructures, Special nanomaterials, Core-shell structures, Nanocomposite, Polymer and carbon based nanocomposite materials, Application of low dimension nanomaterials

1. *Introduction to the laboratory*
2. *Analysis and interpretation of BET graph*
3. *Atomic Force Microscopy analysis of (0,1,2-D nanostructures)*

Module-2 - Physical Aspects of Nanomaterials ***15 Hour***

Surface physics of nano materials, Surface area and aspect ratio, Adsorption at surfaces (Chemisorption, Physisorption), Mechanical properties: nanomaterials fracture and fatigue of nanomaterial, Electrical properties: Resistivity of nanomaterials (Alloys, semiconductor oxides), Magnetic properties :Magnetization& coercivity of nonmagnetic materials, Curie temperature of nano magnetic materials, Optical properties: Photonic bandgap materials, Sensors and actuators NEMS, Thermal properties, Debye temperature of nanomaterials, Specific heat of nanomaterials, Thermal expansion, Elevated and Lowered Melting Points of Nanomaterial, Melting Enthalpy and Entropy in Nanomaterials 4. *Hall – measurement of nanostructured thin films* 5. *To determine magnetic susceptibility of given nano material* 6. *Determination of optical band gap of semiconducting nanomaterial using UV-Vis absorption technique*	
Module-3 - Chemical Aspects of Nanomaterials	***15 Hour***
Introduction to chemical bonding, Surface energy, Chemical potential as a function of surface curvature, Electrostatic stabilization: Surface Charge density and Van der waals attraction potential, Interactions between two particles DLVO theory, Steric stabilization, Influence of reducing reagents, Influence of polymer stabilizer, Influence of other factors, Influence of kinetic energy on the surface of nanomaterials, Electrochemistry of metallic nanostructures, Surface segregation, Influence of hydrodynamics on nanomaterials, Nano catalysis, Chemical reactions and catalytic process on free and supported clusters 7. *Synthesis of surfactant assisted photocatalytic nanoparticles* 8. *Photo catalytic study of nanoparticles* 9. *Study on phase effect of nanoparticles on photo catalytic activity*	
Module-4 - Nucleation and Growth Kinetics	***15 Hour***
Growth-kinetic, Gibb's free energy for driving force for super saturation, The resistance force: energetic barrier, Nucleation: Thermodynamics of phase transition, Nucleation: Growth rate equation of nucleation theory, Nucleation: Stationary state, stages of nucleation condensation energy, Homogeneous, Heterogeneous, Green function at the growth stage, Kirkendal effect and inverse kirkendal effect, Driving Force, Kinetics of Ostwald Ripening, LSW theory of kinetics of particle ripening, Self-induced islands in lattice mis-matched system, Size-quantization in nanostructures, Stranski-krastanow growth-(Islands), Formation energy of growth 10. *Seed assisted growth of ZnO nanorods by hydrothermal method.* 11. *Effect of pH on Seed assisted growth of ZnO nanorods by hydrothermal method* 12. *SEM and XRD analysis of synthesised ZnO nanorods*	
Module-5 - Diffusion and Defects	***15 Hour***
Linear Diffusion, Fick's law of diffusion: Flux divergence, Tracer Diffusion, diffusivity, Non-Linear Diffusion, kinetic consideration, Thermodynamic consideration, TG-DTA analysis, Solution of diffusion equation, Diffusion on surface, Defects in nano materials, Types of defects, point, line and planar defects, Effects of low stacking fault energy in nanomaterials, Grain-Refinement Mechanism, defect structure, ultrafine grained alloys, Effect of grain size on deformation mechanism, Breakdown of Hall-Petch behavior, Defect structure & ductility of nanomaterials, Thermal stability of defect structure in nanomaterials, High temperature thermal stability of nanomaterials 13. *Study the thermal stability of nanomaterials: TG-DTA analysis.* 14. *Defect analysis of Nanomaterials: TEM images*	

Learning Resources	1. *Kenneth J. Klabunde, Ryan M. Richards - Nanoscale Materials in Chemistry, Second Edition-Wiley, 2009* 2. *Murashov, Vladimir_ Pleus, Richard C - Physico-chemical properties of nanomaterials, 2018*	3. *Jeno Gubicza - Defect structure in nanomaterials-Woodhead Publishing, 2012* 4. *Harrison, P., "Quantum Wells, Wires, and Dots: Theoretical and Computational Physics", John Wiley.2000* 5. *Joel I.Gersten, "The Physics and Chemistry of Materials", Wiley, London 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- Practice (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. Saravanan S, EMMVEE Group, Bangalore shrisharavanan@yahoo.co.uk	1.Dr. Geetha Balakrishna, Jain University, br.geetha@jainunivsity.ac.in	1.Dr. J. Archana, SRMIST
2.Mr. Sanjev N. Sharma,KNV's Incorporation, sanjeev@knvindia.com	2.Prof. G. Ravi, Alagappa University, raviganesa@rediffmail.com	2.Dr. A.Karthigeyan, SRMIST

Course Code	21NTC505J	Course Name	SPECTROSCOPIC TECHNIQUES 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:	*understand the X-ray Spectroscopic methods for nanomaterials*
CLR-2:	*know the ionic spectroscopes and their use in elemental measures*
CLR-3:	*acquire knowledge on linear and non-linear optical properties measurements*
CLR-4:	*get familiarized the vibrational spectroscope techniques*
CLR-5:	*understand the nuclear magnetic resonance-based spectroscopy*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe the Construction of X-ray spectroscopes and analyze the nanomaterials as well*	3	3	3
CO-2:	*identify various elements present in the samples, both qualitatively and quantitatively using ion mass spectrometry*	3	2	-
CO-3:	*understand the electronic band transitions and non-linear optics of the materials*	3	3	3
CO-4:	*understand the concepts involved in IR and Raman spectroscopic techniques*	3	-	3
CO-5:	*recognize the various molecular bonds and defects in the specimens*	3	-	2

Module-1 - X-ray Spectroscopes — ***15 Hour***

X-ray Spectroscopy for Elemental analysis - Comparison of K, L, and M Series - X-Ray Fluorescence Spectrometry (XRF) - Wavelength Dispersive Spectroscopy (WDS) - Energy Dispersive Spectroscopy (EDS) – Auger electron spectroscopy (AES) - X-ray Photoelectron spectroscopy (XPS) – Interpretation of XPS spectrum of nanocomposite – Qualitative and Quantitative Analysis by X-Ray Fluorescence and Electron Microscopy

1. *Introduction to the laboratory*
2. *Obtaining and analysing the metal oxide composites using X-ray Fluorescence Spectrometry*
3. *Analysing the Survey and Core level spectra of metal alloys*

Module-2 - Ions and Electron Spectroscopes — ***15 Hour***

Physics of ion-surface interactions, Secondary Ion Mass Spectrometry (SIMS):Dynamic and Static SIMS, Instrumentation, Ion Systems and Surface Structure Analysis, SIMS Spectrum Interpretation for Nanocomposites, Low energy Ion Scattering Spectroscopy (LEIS): Instrumentation, Shadowing and blocking, Relative Measurements and Surface Analysis, Qualitative and quantitative analysis in LEIS, Interpreting low energy ion scattering, Electron energy loss spectroscopy (EELS) : Background, Instrumentation, Analysis of nanomaterials with EELS

4. *Analyzing the SIMS spectrum of Multiwall carbon nanotubes*
5. *Qualified Elemental analysis of LEIS spectrum and SIMS spectrum Carbon materials*
6. *Analyzing the EELS spectra of graphene on various substrates*

Module-3 - Linear and Non-Linear Optical Spectroscopes — ***15 Hour***

UV-Vis absorption spectroscopy, Measuring the bandgap, shifts, Direct and Indirect band gaps, Surface plasmon Resonance of nanomaterials and Interpretation of Absorption of composite materials, Luminescence Excitation Spectroscopy and Decay, Luminescence in Band Scheme of various nanomaterials, Non-Linear optical properties of Nanomaterials, Parametric and Non parametric processes, Estimation of 2nd and 3rd order Nonlinearities, Enhanced NLOs in doped nanomaterials and nanocomposites, Layered Geometry and Fractal Structures

7. Obtain and analysis of absorption spectrum of nanoparticles for varying size 8. Surface charge defect analysis of CdS using the PL spectrum 9. Analysis on Spectral and third order nonlinear optical properties of binary oxide nanoparticles
Module-4 - Vibrational Spectroscopy **15 Hour**
Vibrational Spectroscopy: Theoretical Background & IR and Raman Activity, FT IR: Examination Techniques, FT IR Microspectroscopy, Raman Microscopy : Qualitative Analysis of Carbon nanostructures and layered materials, Surface Enhanced Raman Spectroscopy (SERS), Time Resolved Resonance Raman Spectroscopy (TR3 S), High Vacuum Tip Enhanced Raman Spectroscopy (HV-TERS), Confocal Raman Spectroscopy (CRM), Experimental & Analysis by CRM, Advantages of CRM – Comparison of SERS, TR3 S, HV-TERS & CRM 10. Obtain and analyze the spectrum of amino acids functionalized metal nanoparticles 11. Analysis on Raman spectrum of MoS_2 layers 12. Analysis of SERS spectrum of various metal nanoparticles decorated Si substrate
Module-5 - Nuclear Spectroscopy **15 Hour**
Nuclear Magnetic Resonance Spectroscopy, Nuclear Spin and Magnetic Response, Continuous Wave NMR Instruments, FT NMR Instruments, Chemical shift in the NMR Spectrum, Factors Affecting Chemical Shifts, NMR in Nanomaterials, Insensitive Nuclei Enhanced by polarization, Magic Angle Spinning and Cross Polarization, Dynamic Nuclear Polarization, Characterization using 1D and 2D NMR Spectroscopy : Correlation Spectroscopy, Heteronuclear Correlation Spectroscopy 13. Analysis of functionalized and non-functionalized metal oxide nanoparticles using NMR spectra 14. Compound Quantification with NMR spectra 15. Revision of Experiments

Learning Resources	1. Thomas Sabu, Raju Thomas, Ajesh K. Zachariah, And Raghvendra Kumar, Eds., “Spectroscopic Methods For Nanomaterials Characterization. Vol. 2”. Elsevier, 2017. 2. Sneha Mohan Bhagyaraj,,Oluwatobi Samuel Oluwafemi, Nandakumar Kalarikkal, And Sabu Thomas, Eds., “Characterization of Nanomaterials: Advances And Key Technologies”. Woodhead Publishing, 2018. 3. Imalka Munaweera, M.L. Chamalki Madhusha, Characterization Techniques For Nanomaterials, CRC Press· 2023	4. Sneha Mohan Bhagyaraj,,Oluwatobi Samuel Oluwafemi, Nandakumar Kalarikkal, And Sabu Thomas, Eds., “Characterization Of Nanomaterials: Advances And Key Technologies”. Woodhead Publishing, 2018. 5. Kitsakorn Locharoenrat, “Linear And Nonlinear Optics Materials, Properties, And Applications”, Jenny Stanford Publishing, 2021 6. Prabal Kumar Mallick , Fundamentals Of Molecular Spectroscopy, Springer Nature· 2023

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- Practice (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. D. K. Aswal, NPL, dkaswal@nplindia.org	1. Prof. S. Gunasekaran, Anna University, kgunasekaran@annauniv.edu	1. Dr. C.Siva, SRMIST

2. *Dr. Subramanian, CLRI, subbu@clri.res.in*	2. *Prof. Balakumar, University of Madras, balakumar@unom.ac.in*	2. *Dr. P. Sivakumar, SRMIST*

ACADEMIC CURRICULA

Nanotechnology

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	21NTE501T	Course Name	SOLID STATE NANOFABRICATION	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 overview of the techniques and processes for nanofabrication*
CLR-2:	*give understanding of the physical and chemical methods*
CLR-3:	*acquire knowledge of silicon micromachining*
CLR-4:	*get acquainted with masked and direct write lithography tools*
CLR-5:	*give overview of replication tools for nanofabrication*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand the methods of nanofabrication*	*3*	*2*	*3*
CO-2:	*apply physical and chemical methods for fabrication*	*3*	*-*	*3*
CO-3:	*apply silicon micromachining for micro/nano fabrication*	*3*	*3*	*2*
CO-4:	*understand the utility of masked and direct write lithography tools*	*3*	*2*	*3*
CO-5:	*design devices that makes use of replication tools for nanofabrication*	*3*	*2*	*2*

Unit-1: Micro and Nano Fabrication Application Areas	***9 Hour***
Solid state light emitting diodes, Diode lasers, Organic LED, Nanoelectronic devices, Micro and Nano fluidic devices, MEMS and NEMS, Semiconductor-based spintronic devices	
Unit-2: Physical and Chemical Methods for Micro and Nano Fabrication	***9 Hour***
Nanofabrication by bottom up and top down approach, Ion sputtering, Laser ablation, Ball Milling, Molecular beam epitaxy, Atomic Layer Deposition, Chemical and Physical vapor deposition Techniques, Electro deposition	
Unit-3: Silicon Micromachining	***9 Hour***
Over view of crystal and lattices , Classification of grades of silicon, Production of electronic grade silicon, Si growth methods, Wafer manufacturing steps and inspection, Necessity for different types of clean rooms- construction and periodical maintenance of a clean room, Wet and dry etching in Silicon machining, reactive ion etching	
Unit-4: Masked and Direct Lithography Tools	***9 Hour***
Optical lithography, light sources and common emission lines, mask making-Masked lithography at shorter wavelength: Deep UV, Extreme UV, X-ray lithography, Characteristics of Photoresists, Nanofabrication by e-beam: Introduction, Electron optics: Electron lens, sources and aberrations, Electron scattering, proximity effect and correction, Nanofabrication by Ion Beam, Ion scattering in solid materials, FIB direct nanofabrication, Ion beam lithography, Ion beam implantation process	
Unit-5: Replication Tools for Nanofabrication	***9 Hour***
Hot embossing- Nanoimprint lithography (NIL), UV-NIL - Soft Lithography, Moulding and Replica moulding: PDMS stamps, Surface Patterning methods - Dip-pen Nanolithography, 3D printing	

Learning Resources	*1. Zheng Cui, Nanofabrication: Principles, Capabilities and Limits, Second edition, Springer, 2017* *2. Hans H. Gatzen, Volker Saile, Jürg Leuthold, Micro and Nano Fabrication: Tools and Processes, Springer, 2015*	*3. Jiwang Yan (Editor), Micro and Nano Fabrication Technology, Springer, 2017-2018* *4. MEMS/NEMS Handbook, Techniques and Applications, Springer, 2006, ISBN : 978-0-387-24520-1* *5. Kazuaki Suzuki. Bruce W Smith. Microlithography: science and technology, CRC press 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%	-	15%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	25%	-	30%	-
Level 4	Analyze	30%	-	25%	-	30%	-
Level 5	Evaluate	-	-	10%	-	-	-
Level 6	Create	-	-	5%	-	-	-
	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. S. Balakumar, Madras University, balakumar@unom.ac.in*	*1.Dr. P. Malar, SRMIST*
2. Mr, C P Sridhar, SIMCO Groups, Bangalore, sridhar.cp@simcogroup.in	*2.Prof. Bhaskar Chandra Mohanty, Thapar University, bhaskar@thapar.edu*	*2. Dr. Abhay Sagade, SRMIST*

Course Code	21NTE502T	Course Name	VACUUM AND THIN FILM 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 and obtain knowledge on the importance of vacuum systems and technology*
CLR-2:	*gain knowledge on functionalities of various vacuum pumps and gauges*
CLR-3:	*acquire knowledge on various physical and chemical vapor deposition techniques*
CLR-4:	*understand the various thin film growth mechanisms and theories explaining them*
CLR-5:	*utilize the evaluation of properties of gas and gas mixtures*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*utilize the functionalities of vacuum systems and can operate them*	3	-	-
CO-2:	*apply the knowledge to operate vacuum pumps and measure at various regimes*	3	-	--
CO-3:	*operate various physical and chemical vapor deposition tools*	-	2	3
CO-4:	*render the physics and chemistry of growth mechanisms and measure the physical properties using various techniques*	3	-	3
CO-5:	*utilize the concept of various characterization tools and operate them*	3	2	3

Module-1 - Concepts of Gases and Vacuum Systems	***9 Hour***
Introduction to vacuum systems and technology, different vacuum regions and units, gas kinetics, Maxwell-Boltzmann distribution, molecular impingement flux, Knudsen equation, mean free path, transport properties, Different types of pumps to create vacuum, mechanical pumps, diffusion and turbo molecular pump, Ion pumps, Measurement of vacuum, Direct and indirect vacuum gauges, Safety practices in vacuum systems, Applications of vacuum technology	
Module-2 - Thin Film Growth Models	***9 Hour***
Thermodynamics of thin film growth, Different growth models, Nucleation and early stages of film growth- adsorption, surface diffusion, nucleation, structure development, interfaces, stress, Capillary theory, Volmert-Weber growth, Frank-van der Merwe (FM) growth, Stranski-Krastanov growth, substrates for thin film growth, Epitaxy, lattice mismatch, chemical processing of substrates.	
Module-3 - Physical Vapor Deposition Techniques	***9 Hour***
Physical vapor deposition overview, evaporation techniques, filaments, baskets, and boats, E-beam techniques, sputtering techniques (DC & RF Magnetron), operation of a vacuum coating system, Pulsed laser deposition (PLD): basics and operating procedure, Molecular beam epitaxy (MBE) basics and operations, Safety considerations	
Module-4 – Chemical Vapor Deposition Techniques	***9 Hour***
Chemical vapor deposition (CVD): gas supply and convection, reaction equilibrium and surface processes, diffusion limited deposition and reactor models, Metalorganic CVD (MOCVD), Plasma Assisted Chemical Vapor Deposition (PACVD), Electrodeposition, Spray pyrolysis for nano thin films, Dip coating and Spin coating for nano thin films, Safety considerations	
Module-5 - Characterization Tools	***9 Hour***
Thickness measurement techniques, Quartz crystal monitor, Mechanical method (stylus), Optical interference methods, Structural properties, X-ray diffraction (XRD), Atomic force microscopy (AFM), X-Ray Reflectivity (XRR), Reflection high energy electron diffraction (RHEED), Rutherford backscattering spectroscopy, Scanning electron microscopy, Transmission electron microscopy, Energy dispersive analysis of thin films, Auger electron spectroscopy, Electrical property measurements, two and four probe methods	

Learning Resources	1. *Peter M. Martin, Handbook of Deposition Technologies for Films and Coatings: Science, Applications and Technology, Elsevier Science, Third Edition, 2010* 2. *Kasturi Lal Chopra and Inderjeet Kaur, Thin Film Device Applications, Springer US, 2012*	3. *Milton Ohring, Materials Science of Thin Films: Deposition and Structure, Academic Press, Second Edition, 2002* 4. *Pfeiffer, The Vacuum Technology book, Pfeiffer Vacuum, volume I, 2008*

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%	-	15%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	25%	-	30%	-
Level 4	*Analyze*	30%	-	25%	-	30%	-
Level 5	*Evaluate*	-	-	10%	-	-	-
Level 6	*Create*	-	-	5%	-	-	-
	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, India, mkrishnasurendra@gmail.com	*1. Dr. Mahaveer Kumar Jain, Professor, IIT Madras, mkjain@iitm.ac.in*	*1. Dr. K. Kamala Bharathi, SRMIST*
2. Dr. Sarin Sundar J K, Applied Materials, India sarinjk@gmail.com	*2. Dr. Ramesh Babu, Bharathidasan university, Trichy, rameshbabu.r@bdu.ac.in*	*2. Dr. P. Malar, SRMIST*

Course Code	21NTE503T	Course Name	NANOSCALE MAGNETIC MATERIALS AND 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:	*understand the fundamentals of different types of magnetism*
CLR-2:	*provide in-depth knowledge of magnetic domain and magnetization reversal mechanism*
CLR-3:	*acquire understanding of magnetization dynamics in thin films*
CLR-4:	*get familiarized with different techniques for magnetic characteristic measurements*
CLR-5:	*understand relevant nanoscale magnetism concepts for device application*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain different types of magnetism*	3	-	2
CO-2:	*describe the magnetic domain formation and analyze the magnetization reversal mechanism*	3	3	2
CO-3:	*apply the knowledge of magnetization dynamics in thin films*	2		3
CO-4:	*interpret the experimental results of magnetic characteristic measurements*	3	-	-
CO-5:	*envision the application potential of different nanomagnetic devices*	3	2	-

Module-1 - Types of Magnetism	***9 Hour***
Basics of magnetism, Magnetization, Paramagnetism, Diamagnetism, Ferromagnetism, Antiferromagnetism and Ferrimagnetism, Curie law and Curie Weiss law, Magnetization vs Field/Temperature response in each type, Superparamagnetism, Hysteresis, Magnetic susceptibility versus temperature response, Magnetic Anisotropy, Various contribution to magnetic anisotropy, Magneto crystalline anisotropy, Shape anisotropy, Uniaxial and Unidirectional Anisotropy	
Module-2 - Magnetic Domain and Nanostructures	***9 Hour***
Length Scale in magnetism, Exchange length, Formation of magnetic domains, Domain walls, Domain wall width, Domain wall energy, Various type of domain walls, Bloch walls and Neel walls, Single domain and multidomain magnetic nanoparticle, Magnetization reversal, Mechanisms of magnetization reversal, Coherent rotation, Magnetization, Curling, Domain wall movement, Magnetization reversal in magnetic nanoparticles and nanowires.	
Module-3 - Magnetic Thin film and Magnetization Dynamics	***9 Hour***
Magnetic thin film, Heterostructures, Easy axis and Hard axis in ferromagnetic thin film, In-plane and out of plane magnetized thin films, Magnetic multilayers, Interface effects in magnetic multilayers, Interlayer exchange coupling, Magnetization dynamics, Time scale involved in magnetization dynamics, Ferromagnetic Landau Lifshitz Gilbert Equation, Introduction to Gilbert damping, Intrinsic and Extrinsic contribution to Gilbert damping, Ferromagnetic Resonance	
Module-4 – Experimental Techniques	***9 Hour***
Gaussmeter, Magnetic field sensor, Magnetic domain imaging, Magneto-optical Kerr effect, Longitudinal, Transverse and Polar Kerr effect, Faraday rotation, Magnetic force microscopy, Magneto-optical imaging, Scanning electron microscopy with polarization analysis, Spin-polarized scanning tunnelling microscope, Magnetization measurement using various magnetometers, Working principle, Vibrating Sample Magnetometer (VSM)	

Module-5 – Nanomagnetic Devices	***9 Hour***
Interaction of charge current with magnetization, Spin polarization, Magnetoresistance (MR), Anisotropic Magnetoresistance (AMR), Giant Magneto-Resistance (GMR), Current perpendicular to plane GMR device, Factors affecting GMR, Magnetic Tunnel Junction (MTJ), Tunnel Magneto-Resistance (TMR), Magnetic Recording, Different Types of Magnetic Storage Devices, Magnetic Hard Disc Drive, Magnetic Resonance Imaging	

Learning Resources	*1. J.M. D Coey, Magnetism and Magnetic Materials, Cambridge University Press, USA, 2010* *2. B. D. Cullity and C. D. Graham, Introduction to magnetic materials, Wiley, USA, 2009*	*3. J. M.D. Coey and Stuart Parkin, Handbook of Magnetism and Magnetic Materials, Springer Cham (2020)* *4. Anjan Barman and Jaivardhan Sinha, Spin dynamics and damping in ferromagnetic thin films and nanostructures, Springer, Switzerland, 2018*

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*	*15%*	-	*15%*	-	*15%*	-
Level 2	*Understand*	*25%*	-	*20%*	-	*25%*	-
Level 3	*Apply*	*30%*	-	*25%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*25%*	-	*30%*	-
Level 5	*Evaluate*	-	-	*10%*	-	-	-
Level 6	*Create*	-	-	*5%*	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Sukumar Rajauria, Western Digital, USA, sukumar.rajauria@wdc.com	*1. Dr. Arabinda Haldar, IIT Hyderabad, arabinda@phy.iith.ac.in*	*1. Dr. Jaivardhan Sinha, SRM IST*
2. Dr. Sanjay Panduranga Setty, Quantum Design, India, sanjay@qd-india.com	*2. Dr. P. K. Muduli, IIT Delhi, muduli@physics.iitd.ac.in*	*2. Dr. K. Kamala Bharathi, SRM IST*

Course Code	21NTE504T	Course Name	NANOTOXICOLOGY	Course Category	E	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 nanoparticle exposure and distribution*
CLR-3:	*learn about nanoparticle interaction with placental barrier*
CLR-4:	*know about various methods of toxicity assessment*
CLR-5:	*learn various in vivo toxicity methods*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*aware about toxicity caused by nanomaterials*	*3*	*-*	*3*
CO-2:	*explain the exposure assessment pathways*	*3*	*-*	*3*
CO-3:	*analyze the transport of nanoparticles across placental barrier*	*3*	*-*	*3*
CO-4:	*apply the various methods of toxicity assessment*	*3*	*-*	*3*
CO-5:	*analyze the in vivo toxicity data*	*3*	*3*	*-*

Module-1 - Introduction to Nanotoxicology	***9 Hour***
Introduction to toxicity, Size-specific toxicity of nanomaterials, Entry Routes of nanomaterials into the Human Body, Physicochemical properties of Nanomaterials related to toxicity, significance of nanomaterial characterization after administration, Source of Nanoparticles	
Module-2 - Toxicity Mechanism	***9 Hour***
Mechanism of nanotoxicity, ROS mediated toxicity, Interactions between Nanoparticles with organisms, Need for appropriate model, Exposure assessment, Types of exposure pathways, Significance of exposure assessment, nature of exposures, Bio-distribution of nanoparticles, Localization of particles in tissues	
Module-3 - Interaction of Nanomaterial with cells	***9 Hour***
Interaction of nanoparticles with lipid bilayers, Nanoparticle-induced membrane permeability, Biological barrier for nanoparticle transfer, Placental Barrier, Transport across placental barrier, Biological mechanism of nanoparticle disposition, toxicity based on route of entry	
Module-4 - Toxicokinetics	***9 Hour***
Toxicokinetics, Absorption, distribution, metabolism excretion studies (ADME), Effects of Nanoparticle on the Cardiovascular System, Thrombosis, Fibrinolysis, Coagulation, Effect of nanoparticles on Nervous system, Effect of nanoparticles on Respiratory system	
Module-5 - Toxicity to Organs	***9 Hour***
Dermal toxicity, Hepato toxicity, Nephrotoxicity, Assessment of oxidative stress, Genotoxicity, carcinogenicity, In vivo Analysis, Histopathology studies, Clinical studies in nanotoxicology	

Learning Resources		
	1. Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2021. *2. Nanotoxicology: Characterization, Dosing and Health Effects- Nancy. A, Monteiro-Riviere, Lang Tran. C Informa healthcare, 2022*	*3. Nanotoxicology - Interactions of Nanomaterials with Biological Systems. Yuliang Zhao and Hari Singh Nalwa, 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. P. Aravind Mukesh, United Breweries, Bengaluru, aravind.mukesh@gmail.com	*1. Dr. Asif Khan Shanavas, INST, Mohali, asifkhan@inst.ac.in*	*1. Dr. G. Devanand Venkatasubbu, SRM IST*
2. Mr. K. Chandru, HCL Medical devices Pvt. Ltd. Chennai, acewhentura@gmail.com	*2. Dr. P. Balasubramanian, NIT Rourkela, balap@nitrkl.ac.in*	*2. Dr. S. Sahabudeen, SRM IST*

Course Code	21NTE505T	Course Name	NANOELECTRONICS	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 on quantum confinement and low-dimensional nanostructures*
CLR-2:	*grasp the key aspects of electron tunnelling and its application in operating nanodevices.*
CLR-3:	*get acquainted with the concept of magnetic tunnel junctions to enter the field of spintronics*
CLR-4:	*acquire the knowledge on molecular electronics*
CLR-5:	*cognize the charge transport mechanism and fabrication processes for simulation of nanodevices*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand the physics of electrons in highly scaled dimensions to get hold of semiconductor nanostructures*	2	2	2
CO-2:	*apply the knowledge of quantum tunnelling to understand the operation of nanoscale semiconductor devices*	2	3	3
CO-3:	*understand the mechanism of magnetic tunnel devices to design sustainable organic semiconductor sensors*	3	3	3
CO-4:	*understand the suitability of organic small molecules and polymers for developing flexible-hybrid electronics*	2	3	2
CO-5:	*apply the knowledge of quantum transport and nano fabrication to design and simulate semiconducting and nanoelectronic devices*	2	3	3

Module-1 - Quantum Confinement and Tunneling Phenomena in Nanoelectronics	***9 Hour***
Electrons as Particles and Waves; Free and Confined Electrons, Quantum Dots, Quantum Wires and Quantum Wells, Charge and Spin in Single Quantum Dots, Electrons in Mesoscopic Semiconductors, CMOS – Limitations and Solutions, Emergence and Future Prospects of Nanoelectronics Devices and Architecture, Single Electron Tunneling and Coulomb blockade, Nonlinear Current-Voltage Characteristic of a Tunnel Diode, Working Principles of a Single Electron Transistor (SET), Resonant Tunneling Diodes (RTDs), Tunnel FETs, Quantum Interference Transistors (QUITs), Novel Organic-Molecules in Nanoelectronics: Pentacene, Fullerenes and Porphyrins, Quantum Bit (Qubit) and Its Requirements, Quantum Dot Cellular Automata (QCA)	
Module-2 - Nanoscale Electron Transport and Nanostructure Field-Effect Transistors	***9 Hour***
Classical and Semi-Classical Transport, Ballistic Transport, Electron Transport in Semiconductor Nanostructures, Drude Model, Characteristic Lengths, Phase Coherence Effect, Mesoscopic Quantum Phenomena, Charge Transport at the Nanoscale: Landauer Formalism and Multimode Transport, Electron Transport in p-n Junctions, Short Channel Nano-Transistor, Advanced MOSFETs, Hot electron effects in MOSFETs, Gate-oxide tunneling, Trigate Field-Effect Transistors (TGFETs), FinFETs	
Module-3 - Magnetic Tunnel Junctions and MRAM Technologies	***9 Hour***
Spin Tunneling Devices, Magnetic Tunnel Junctions (MTJs), Tunneling Spin Polarization, Tunneling Magnetoresistance (TMR), Spin Injection and Spin Transport in Hybrid Nanostructures, Spin Filters and Spin Diodes, Spintronics: Spin propagation and detection, spinFETs , Julliere Model, Spin Interactions in Semiconductors, Exchange Interaction and Exchange Anisotropy, Slonczewski's Model, Magnetic Field Dependence of TMR, Bias Voltage Dependence of TMR, Magnetic RAM (MRAM) and Magnetoresistive Biosensors, Fluxtronics: Fluxon, Ratchet effect, Flux Qubit	
Module-4 - Single-Molecule Devices and Molecular Electronics	***9 Hour***
Electrodes and Contacts; Fabrication of Atomic-size Contacts, Mechanically Controllable Break Junction (MCBJ), STM Break Junction (STM-BJ), Molecular Functionalities; Metal-Molecule Interfaces, Deposition of Molecules, Techniques for Contacting Molecules, Atomistic View of Electrical Resistance, Conductance of Atomic-scale Contacts, Coherent Transport through Molecular Junctions, Molecular Contacts as Tunnel Junctions, Molecular Electronic Devices, Conducting Mechanism of Single-Molecule Junctions, Elementary Circuits using Organic Molecules, Organic Field-Effect Transistor (OFET), Thermoelectricity of Molecular Junctions	

Module-5 - Computational Modeling and Virtual Nano Fabrication	***9 Hour***
Electron Transport in Atomistic Nanojunctions, Non-Equilibrium Green's Function (NEGF) Approach to Nano-Device Simulation, Monte Carlo Method for Device Simulations, Non-equilibrium Molecular Dynamics (NEMD) Method for Modeling Heat Transport in Semiconductor Nanodevices, Modeling and Optimization of Metal-Semiconductor Contacts, Simulating Phonon-limited Electron Mobility in FinFETs, Optimization of Material Stacks for Spintronic Memory Devices, Modeling of 2D-Material FETs, Simulating the Resistive Switching in Non-Volatile Memory (NVM) Devices.	

Learning Resources	*1. Supriyo Dutta, Lessons from Nanoelectronics: A New Perspective on Transport Part B: Quantum Transport: World Scientific: 2nd Edition (2023)* *2. Hassan. Raza. Nanoelectronics fundamentals: materials, devices and systems. Springer; 2020* *3. J. Hoekstra, Introduction to Nanoelectronic Single-Electron Circuit Design, Jenny Stanford Publishing; 2 edition (2016)*	*4. Rutu Parekh, Rasika Dhavse; Nanoelectronics: Physics, Technology and Applications, IOP Publishing Ltd (2024)* *5. Joachim Knoch, Nanoelectronics: From Device Physics and Fabrication Technology to Advanced Transistor Concepts, De Gruyter: 2nd Edition (2024)*

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%*	-	*20%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*20%*	-	*30%*	-
Level 5	*Evaluate*	-	-	*10%*	-	-	-
Level 6	*Create*	-	-	*10%*	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Prof. Sarin Sundar JK, Applied Materials (India) sarinjk@gmail.com	*1. Prof. Somnath Chanda Roy, IIT Madras, Chennai somnath@iitm.ac.in*	*1. Dr. Arijit Sen, SRMIST*
2. Mr . R.Karthick GM Operations Flexiflo India Pvt Limited Alwarpet Chennai,karthik@flexiflo.ae	*2. Dr. Shovit Bhattacharya, BARC, Mumbai shovitb@barc.gov.in*	*2. Dr. Preferencial Kala, SRMIST*

Course Code	21NTE506T	Course Name	2D LAYERED 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:	*apply theory of atomic arrangements in atomically-thin solids to understand layered materials*
CLR-2:	*apply the chemical and physical methodologies for the synthesis of 2D materials*
CLR-3:	*apply various characterization principles to investigate the thin layered materials*
CLR-4:	*analyze exotic physical properties originated from thin layered 2D materials*
CLR-5:	*analyze various device structures and their potential applications in energy, electronics and environment*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*classify various types of 2D layered materials*	3	2	2
CO-2:	*apply synthesis procedure for the production of 2D materials*	2	3	3
CO-3:	*determine characterization tools for 2D layers*	3	3	3
CO-4:	*perform physical property analysis of Graphene and TMDs*	2	3	2
CO-5:	*utilize 2D layers for various applications*	3	2	3

Module-1 - Introduction to 2D Layered Materials	***9 Hour***
Introduction to 2D Layered Materials, different types of 2D Materials, Density of states (DOS) of 2D Materials, Van der Waals bonding and interaction in 2D layered materials, Graphene, atomic structure of graphene, electronic band-structure of graphene, Dirac-cone, 2D Hexagonal Boron Nitride (h-BN), Black Phosphorous, 2D Transition Metal Dichalcogenides (TMDS), Crystal Structure of TMDs, 1T, 2H and 3R phases of TMDs, MXenes, 2D Layered Oxides, Graphene oxide, MnO_2, Hydroxides	
Module-2 – Production of 2D Materials	***9 Hour***
Exfoliation of graphene, Mechanical exfoliation (Scotch-tape method) and Liquid-phase exfoliation, Intercalation exfoliation, Chemical Vapor Deposition (CVD),CVD growth of graphene, Single crystalline and polycrystalline Graphene, Epitaxial growth of Graphene, Plasma enhanced CVD (PECVD) for graphene growth, Vapor Phase Transport (VPT) CVD and Metalorganic CVD (MOCVD) for the synthesis of TMDs, Atomic Layer & Molecular Layer Deposition of 2D Materials, Chemical routes for the synthesis of 2D layered Materials, Hydrothermal method, Synthesis of MXenes, Single layer hBN growth using CVD, Physical Vapor Deposition for the production of graphene and TMDs, Sputtering and pulsed laser deposition (PLD).	
Module-3 – Characterization of 2D Materials	***9 Hour***
Raman spectroscopy, Principle of Raman spectroscopy, Raman spectrum of Graphene, D and G bands in monolayer, bilayer and trilayer graphene, Defect bands of graphene, Raman spectra of 2D TMDs, Effect of thickness (layer number) on the Raman modes, Estimation of layer number using Raman spectra, Imaging of 2D layers, Atomic Force microscopy (AFM) for morphology and thickness measurement, High resolution transmission electron microscopy of graphene, point and line defects, defects in TMDs, electron beam damage of 2D layers, Scanning Tunneling Microscopy (STM) analysis of local defects and surfaces of 2D layers, Chemical compositional analysis of Graphene and TMDs via X-Ray Photoelectron spectroscopy.	
Module-4 – Physical Properties of 2D Materials	***9 Hour***
Optical properties of 2D materials, Absorption, optical transmittance and photoluminescence of graphene and TMDs, Valley states in 2D TMDs, Electrical transport properties of Graphene, Sheet resistance and mobility of graphene, Quantum Hall Effect in graphene, Electronic band structure of single layer and bilayer TMDs, Electrical properties of TMDs, Mechanical properties of Graphene, h-BN and TMDs, Graphene electromechanical resonators, Thermal conductivity of Graphene, h-BN and TMDs, Magnetism in Graphene and TMDs.	

Module-5 – Devices and Applications of 2D Materials	**9 Hour**
Twisted bilayer graphene, magic angle, phase transition, magnetism and superconductivity in twisted bilayer graphene, Van der Waals (VdW) Heterostructures, Moire excitons, Interlayer excitons in TMD heterostructures, Graphene and TMD based Field Effect Transistors (FETs), Applications of 2D Materials, Graphene and TMDs for photodetection, Gas sensors, Graphene for flexible and transparent conducting applications, 2D Materials for quantum technology, 2D Materials for energy storage applications, Graphene oxide and composites for water purification	

Learning Resources	1. *Phaedon Avouris., Tony F. Heinz and Tony Low, 2D Materials: Perspectives and Devices, Cambridge University Press, 2017* 2. *Saptarshi Das, 2D Materials for Electronics, Sensors and Devices Synthesis, Characterization, Fabrication and Application, 1st ed., Elsevier, 2022* 3. *Paolo Bondavalli, 2D Materials and Their Exotic Properties, De Gruyter, 2022*	4. *Tianrong Zhang, Graphene From Theory to Applications, Springer, 2022* 5. *Mikhail I. Katsnelson., Graphene Carbon in Two Dimensions, Cambridge University Press, 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*	15%	-	15%	-	15%	-
Level 2	*Understand*	25%	-	20%	-	25%	-
Level 3	*Apply*	30%	-	25%	-	30%	-
Level 4	*Analyze*	30%	-	25%	-	30%	-
Level 5	*Evaluate*	-	-	10%	-	-	-
Level 6	*Create*	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. M. Krishna Surendra, Saint-Gobain, Chennai, mkrishnasurendra@gmail.com	*1.Dr M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*1. Dr E. Senthil Kumar, SRM IST*
2. Dr. Saranya Mohan, Motherson Electronics Pvt. Ltd., Chennai, saranya.sambathkumar@motherson.com	*2.Dr Abhishek Misra, IIT Madras, abhishek.misra@iitm.ac.in*	*2. Dr S. Chandramohan, SRM IST*

Course Code	21NTE507T	Course Name	MICRO/NANO SYSTEMS AND SENSORS	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:	*gain understanding of the fundamentals of micro/nano systems technology*
CLR-2:	*acquire knowledge of fabrication process involved in microsystem technology*
CLR-3:	*understand different conversion phenomena involved in sensors*
CLR-4:	*acquire knowledge on different sensors and its working mechanisms*
CLR-5:	*gain knowledge on micro total analysis system technology*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand basics of micro/nano systems technology*	3	3	2
CO-2:	*apply suitable process technique for producing electromechanical structures*	3	3	2
CO-3:	*develop understanding of sensor characteristics and principles for different applications*	3	3	3
CO-4:	*apply suitable sensors for different applications*	3	3	3
CO-5:	*understand concepts and techniques involved in Micro Total Analysis System*	3	3	2

Module-1 - Micro and Nano Systems Technology	***9 Hour***
Microsystem technology (MST), Microelectronics and Microsystem Technology, MEMS and NEMS: Overview and applications, Miniaturization and Examples: Scaling Law of Spring Constant and Area to-Volume Ratio, Microelectronics integration, Monolithic integration of MST and IC, MEMS and NEMS Architectures, Taxonomy of Nano/Microsystem Synthesis and Design, Stages of MEMS Product Development	
Module-2 - MEMS Fabrication Technologies	***9 Hour***
Basic Processes in Microfabrication: Wafer, Level Processes and Pattern Transfer, A Simple Process Flow of simple diode, Silicon-Based MEMS Processes: Bulk Micromachining and Surface Micromachining, High-Aspect-Ratio LIGA like Technology, Process flow of a Bulk-Micromachined Diaphragm Pressure Sensor, Process flow of a Surface, Micromachined Suspended Filament, Fabrication of Microfluidic components- Quartz/Glass/Polymer substrates processes	
Module-3 - Sensor Characteristics-Thermal, Radiation and Mechanical Sensor	***9 Hour***
Nanotechnology Enabled Sensors, Sensors and actuators: Energy Domains and Transducers, Sensor Characteristics, Dynamic Characteristics, Signal Transduction Principles: Physical Effects, Thermocouple, Resistive Temperature sensors, Photodiodes, Phototransistors, Pyroelectric Sensors Mechanical Sensors: Piezoresistors, Capacitive Sensors, Accelerometers, Nano-mechanical cantilever-based sensors	
Module-4 - Magnetic, Bio(Chemical) and SAW Sensors	***9 Hour***
Magnetic Effects: Hall Effect, Magneto resistive Effect, Magnetic Sensor: Hall Plat sensor , Hall FET sensors, Magneto resistive Devices, Magneto diodes and transistors, Bio (Chemical) Sensors, Classification of the bio(chemical)sensors, Conductimetric Devices: Taguchi type tin oxide gas sensors, CHEMFET sensors, The ion-sensitive field-effect transistor, Surface Acoustic Wave (SAW) Devices - Piezoelectric Effect based SAW devices, Interdigital Transducers (IDT) in SAW Devices	
Module-5 – Microactuators and Micro Total Analysis Systems	***9 Hour***
Electrostatic Actuators, Magnetic Actuators, Piezoelectric Actuators, Thermal Actuators, Multilayer Bonded Devices, Basic fluid mechanics concepts, methods for fluid movement in channels, Electrophoretic separation, design and fabrication of selective components, Substrate Materials for Microfluidic Chip, Lab-on Chip, Detection Technique for Microfluidic Chips, Liquid Pumping and Controlling Technology in μTAS, Microsystems packaging, Essential packaging technologies including 3D Integration.	

Learning Resources		
Learning Resources	1. *Sergey Edward Lyshevski, Lyshevski Edward Lyshevski, Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering– 2nd Ed., CRC Press, 2005* 2. *Nadim MalufKirt Williams, An Introduction to Micro electromechanical Systems Engineering 2nd Edition, Artech House, Inc, 2004* 3. *Kalantar–Zadeh. K, Nanotechnology Enabled Sensors, Springer, 2008*	4. *Karl Goser . Peter Glösekötter. Jan Dienstuh, Nanoelectronics and Nanosystem, Springer, 2004* 5. *Advanced Micro & Nanosystems,Volume 1, Enabling Technology for MEMS and Nanodevice, WILEY-VCH Verlag GmbH & Co. KGaA, 2004* 6. *Alina Voda, Micro, Nanosystems and Systems on Chips Modeling, Control and Estimation, John Wiley & Sons, 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	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	20%	-	25%	-
Level 3	Apply	30%	-	25%	-	30%	-
Level 4	Analyze	30%	-	25%	-	30%	-
Level 5	Evaluate	-	-	10%	-	-	-
Level 6	Create	-	-	5%	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Saravanan S, EMMVEE Group, Bangalore shrisharavanan@yahoo.co.uk	*1. Prof. S. Balakumar, University of Madras, balakumar@unom.ac.in*	*1. Dr. A. Karthigeyan, SRMIST*
2. Dr. Shanmugasundaram Sakthivel, ARCI, Hyderabad, ssakthivel@arci.res.in	*2. Prof. V Subramanian, IIT Madras, manianvs@iitm.ac.in*	*2. Dr. Elangovan Elamurugu, SRMIST*

Course Code	21NTE508T	Course Name	INDUSTRIAL APPLICATIONS 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:	*gain knowledge on the principles and applications of nanotechnology in electronics*
CLR-2:	*understand the principles of nanotechnology in biomedical industry*
CLR-3:	*understand the significance of nanotechnology in agriculture and food industry*
CLR-4:	*explore the possibilities of nanotechnology in textile and cosmetic sector*
CLR-5:	*utilize the knowledge on nanotechnology for energy storage systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand the importance of nanotechnology in electronics and energy sectors*	3	2	3
CO-2:	*apply the principles of nanotechnology in biomedical industry*	2	3	3
CO-3:	*realizing the importance of nanotechnology in agriculture and food processing*	3	3	3
CO-4:	*apply the principles of nanotechnology for the manufacturing process in textile industries*	-	3	2
CO-5:	*use nanotechnology for the design of efficient energy storage system*	2	3	3

Module-1 - Nanotechnology in Electronics	***9 Hour***
Miniaturization, Nano electronic devices and circuits, Semiconductor Memories, Applications of Semiconductor Memories, Dynamic Radom Access Memory, Nonvolatile Semiconductor Memories, Quantum Dot based Memory Cell, physical and chemical Sensors, Electronic noses, Actuators, Micro and Nano-Electromechanical systems, Lighting and Displays, Quantum optical devices, Applications of Quantum optical devices, Heterostructure semiconductor laser	
Module-2 - Nanotechnology in Biomedical Industry	***9 Hour***
Biosensors & Applications, Bioreceptors and their properties, Biochips, Integrated nanosensor networks for detection and response, DNA and protein based biosensors and diagnostics, materials for biosensor applications, quantum dot based bioimaging, Natural nanocomposite systems, bones, shells, Nanomaterials in bone substitutes, Nanomaterials in dentistry, Tissue Engineering, Nanotechnology in diagnostics, Nanopharmacology and drug targeting, Nanotoxicology, Drug delivery systems, Cancer therapy and other therapeutic applications	
Module-3 - Nanotechnology in Agriculture and Food Sector	***9 Hour***
History of agriculture and the role of chemicals in modern agriculture, Precision farming, Smart delivery systems, Insecticides using nanotechnology ,Potential of nano-fertilizers, Nanofertigation, Nanopesticides, Nanoseed Science, Nanotechnology in Food industry, Potential benefits in Nanotechnology in Food industry, Food processing, Packaging, Packing materials; physical properties, improvements of mechanical and barrier properties, Antimicrobial functionality, Active packaging materials, Nanopackaging for enhanced shelf life,	
Module-4 - Smart/Intelligent Packaging	***9 Hour***
Discuss on basic functions of packaging; Different forms of packaging - Rigid, semirigid and flexible, Primary, secondary and tertiary, Food safety, Nano hazards Germ proof Cloths, Cleaner kids Clothes, Wired and Ready to Wear textiles- Cosmetics; Nanomaterials in Sun-screen UV protection, Color cosmetics	
Module-5 - Energy Challenges	***9 Hour***
development and implementation of renewable energy technologies, nanotechnology enabled renewable energy technologies, Issues and Challenges of functional Nanostructured Materials for electrochemical Energy, Fuel cells, Principles and nanomaterials design for Proton exchange membrane fuel cells (PEMFC), Direct methanol fuel cells (DMFC),Solid-oxide fuel cells (SOFC), Solar energy, Hydrogen energy and Nano-materials, Carbon nanotube fuel cells, Hydrogen storage, Thermoelectricity, Super capacitors, Applications of Super capacitors	

Learning Resources		
	1. Nanoelectronics- principles and devices, M. Dragoman and D. Dragoman, Artech House publishers, 2008. 2. Neelina. H, Malsch (Ed.), "Biomedical Nanotechnology", CRC Press 2005. 3. Jennifer Kuzma and Peter Ver Hage, "Nanotechnology in agriculture and food production", Woodrow Wilson International Center, 2006. .	4. Brown. P. J and Stevens. K "Nanofibers and Nanotechnology in Textiles", Woodhead Publishing Limited, Cambridge, 2007. 5. Electrochemical methods: Fundamentals and Applications, Allen J.Bard, Larry R. Faulkner and Henry S. White, 3rd Edition John Wiley & Sons. Inc (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	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	20%	-	25%	-
Level 3	Apply	30%	-	25%	-	30%	-
Level 4	Analyze	30%	-	25%	-	30%	-
Level 5	Evaluate	-	-	10%	-	-	-
Level 6	Create	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D. K. Aswal, NPL, dkaswal@nplindia.org	1. Dr. Kothandaraman Ramanujam, IITM, rkraman@iitm.ac.in	1. Dr. Ravikirana, SRMIST
2. Dr. Subramanian, CLRI, subbu@clri.res.in	2. Prof. G. Ranga Rao, IITM, grrao@iitm.ac.in	2. Dr. A. Karthigeyan, SRMIST

Course Code	21NTE509T	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:	*gain a fundamental knowledge on various forms of carbon nanomaterials*
CLR-2:	*understand the structure-property correlation in carbon materials*
CLR-3:	*know various properties of fullerenes, carbon nanotubes, diamond, and graphene materials*
CLR-4:	*familiarize with different synthesis methods in making carbon nanomaterials*
CLR-5:	*understand the importance of carbon nanotechnology in various sectors*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*evaluate the potential of fullerene for various applications*	3	3	
CO-2:	*define different carbon nanotubes and evaluate their applications*	2	3	3
CO-3:	*analyze the importance of diamond thin films in tribological applications*	2	3	3
CO-4:	*design and fabricate graphene materials*	2	3	2
CO-5:	*apply novel synthesis routes to obtain carbon quantum dots and carbon-based hybrid electrodes*	3	3	2

Module-1 – Introduction to Carbon Allotropes and Fullerenes	***9 Hour***
Introduction, Allotropes of Carbon, Hybridization in carbon, Properties of Sigma and pi bonds, Structure and bonding of fullerenes, C60 and higher fullerenes, Synthesis and purification, Growth Mechanisms, Physical properties of fullerene, Chemical properties of fullerene, Functionalization of fullerenes, Bio-medical applications of fullerenes, Fullerenes in photovoltaics, Fullerene derivatives in energy harvesting and storage devices	
Module-2 - Carbon Nanotubes	***9 Hour***
Nomenclature, the structure and types of carbon nanotubes, Electronic band structure of Carbon nanotubes, Arc-discharge method, Chemical Vapor Deposition, Laser Ablation methods and growth mechanisms, Electro-chemical separation of carbon nanotubes, Spectroscopic and microscopic evaluation of CNTs, SWCNT based FETs, CNT for field emission, Aligned CNT membranes and electrodes, Application of CNTs in sensing and photocatalysis, Carbon nanotubes as reinforcing element.	
Module-3 - Nanodiamond and Diamond Thin Films	***9 Hour***
Crystal structure and physical properties, Advances in CVD of diamond thin films, Production of ultrananocrystalline diamond (UNCD), Natural verses synthetic diamond, Boron-doped diamond, Properties and applications, Applications of diamond films in tribology and electronic cooling, Diamond-like carbon coating, Amorphous carbon (a-C) thin films, Hydrogenated amorphous carbon films (a:C-H), PECVD of a:C-H, Amorphous carbon films as anti-reflection and anti-corrosive coatings	
Module-4 - Graphene	***9 Hour***
Structure and electronic properties, Quantum Hall effect in graphene, Graphene twistronics, Moiré superlattices, Graphene production by exfoliation, chemical vapor deposition, and epitaxy, Large-area graphene transfer, Optical microscopy and Raman spectroscopy of graphene, Graphene-based electrodes and interconnects, Graphene photodetectors, Functionalization of graphene and graphene oxide, Graphene bio-sensors, Graphene in high-speed analog electronics	

Module-5 - Carbon Quantum Dots and Carbon-Based Hybrid Materials	***9 Hour***
Carbon and graphene quantum dots, Synthesis routes, Photophysical properties, Functionalization and surface modification, Applications in sensing, bio-imaging and catalysis, Carbon Fibers, Nanotextured carbon materials for electrochemical energy storage, Carbon-based hybrid anode materials for Li-ion and Na-ion batteries, Carbon-carbon composites, carbon aerogels and foams	

Learning Resources	*1. Anke Krueger, Carbon Materials and Nanotechnology, Wiley-VCH, 2010* *2. R. B. Mathur, B. P. Singh, S. Pande, Carbon Nanomaterials: Synthesis, Structure, Properties and Applications, CRC Press, 2017.* *3. Yury Gogotsi, Carbon Nanomaterials, Taylor and Francis, Second edition, 2014*	*4. C. N. R. Rao, Ajay K. Sood, Graphene: Synthesis, Properties, and Phenomena- Wiley-VCH, 2013* *5. 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%*	-	*20%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*20%*	-	*30%*	-
Level 5	*Evaluate*	-	-	*10%*	-	-	-
Level 6	*Create*	-	-	*10%*	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Tamilarasan, CSIR-CECRI, tamilan@cecri.res.in	*1. Prof. Ramaprabhu, IITM Chennai, ramp@iitm.ac.in*	*1. Dr. S. Chandramohan, SRMIST*
2. Dr. M. Sathish, CSIR-CECRI, msathish@cecri.res.in	*2. Dr. Maneesh Chandran, NIT Calicut, maneesh@nitc.ac.in*	*2. Dr. Eswaraiah Varrla, SRMIST*

Course Code	21NTE601T	Course Name	MODELLING AND COMPUTATION	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:	*know GNU OCTAVE*
CLR-2:	*acquire detailed knowledge of Density Functional Theory*
CLR-3:	*get acquainted with the calculation of electronic property of a material using DFT code*
CLR-4:	*learning Molecular Dynamics simulation*
CLR-5:	*learn python coding and predictive Machine Learning*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*make use of GNU OCTAVE programming to solve numerical and physics problem*	3	-	3
CO-2:	*utilize the concept of DFT to analysis structural property of a material*	3	-	3
CO-3:	*applying computational modeling tools to determine basic electronic structure of a given solid*	3	-	3
CO-4:	*determination dynamics of an ion-electron system using simulation*	3	-	3
CO-5:	*make use of Python programming, Monte Carlo and ML for materials*	3	3	-

Module-1: GNU OCTAVE and Computing Clusters	***9 Hour***
Introduction to GNU OCTAVE, Arrays, Matrices, Matrix operation, Inverse of a Matrix, Eigen value problem, Diagonalization of a Matrix, example force constant matrix, Logical operation using GNU OCTAVE, Loop control statements, Functions-data visualization in 2D, Examples on data visualization in 2D, Functions-data visualization in 3D, Examples on data visualization in 3D, High-Performance Parallel Computing, Programming for Parallel Computing, Shared memory parallel computers and programming with OpenMP, Distributed memory parallel computers and message passing basics with MPI	
Module-2: Density Functional Theory	***9 Hour***
Schrodinger equation, Schrodinger equation for Many Body problem, Born-Oppenheimer approximation, 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), GGA (Basic concept), DFT self-consistence field (SCF) cycle, Working algorithm of SCF method (illustration), Various Implementations of DFT, Illustration, -Discussion on Electronic Structure Density of States, Band Structure, Geometry Optimization, Electronic Structure and Magnetic Properties.	
Module-3: Pseudopotential and Exchange Correlation functional	***9 Hour***
Pseudopotential model external potential (electron-ion) interaction in a Solid, The underline concept, The Ultrasoft pseudopotential, PAW potential, Pseudowave function to model the basis sent of the many body wave function, The underline concept, Parodic boundary condition, Bloch function, Reciprocal Space, K-mesh, Brillion Zone integration, Irreducible K, points-K-mesh for modeling 3D, 2D, 1D and 0D systems, Discussion on various input parameters, Setting of structural inputs, Encut, k-points LDA/GGA-Discussing on the output, electronic and ionic minimization	
Module-4: Molecular Dynamics Simulation and Phase-Filed Modeling	***9 Hour***
Classical molecular dynamics, The basics of molecular dynamics (MD) algorithm, Discussions with examples on MD algorithm, Microstructure evolution, Continuum vs sharp interface description, The Ginzburg-Landau free energy functional, Equilibrium interfaces and surface tension, Conserved and non-conserved order parameters, Driving forces, fluxes, Spinodal decomposition in a binary alloy.	

Module-5: Python programming, Monte Carlo and predictive Machine Learning	***9 Hour***
Introduction to Python programming, Python Basic, Control Statements, Functions, Python Basic, Functions, Mathematical operations, Basic Numerical tools, Differentiation and Integration, Solution of Ordinary Differential Equation using Python, Monte-Carlo method: Introductory examples, Integration, Random Number generation, Determination of π-Concept of Acceptance and rejection rate, Detail Balance Condition, Discussions on Importance sampling, Metropolis algorithm, Introduction to the predictive Machine Learning, Random Forest Classification and Regression model, concept of feature importance, Predictive Machine Learning a few example from materials science.	

Learning Resources	1. *Jörg-Rüdiger Hill, Lalitha Subramanian, Amitesh Maiti, Molecular modeling techniques in material 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. *Feliciano Giustino, Materials Modelling using Density Functional Theory: Properties and Predictions, Oxford University Press, 2014* 6. *Eric Ayars, Computational Physics with Python, 2013* 7. *Andreas C. Muller and Sarah Guido, Introduction to Machine Learning with Python, A guide for Data Scientists, OREILLY publications, 2017*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) (60% weightage)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life Long Learning CLA-2 Practice (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, NPL, dkaswal@nplindia.org*	1. *Dr. G. P. Das, IIT Kharagapur, gpdas@metal.iitkgp.ac.in*	1. *Dr. Saurabh Ghosh, SRMIST*
2. *Dr. Subramanian, CLRI, subbu@clri.res.in*	2. *Dr. Ranjit Nanda, IIT Madras, nandab@iitm.ac.in*	2. *Dr. Arijit Sen, SRMIST*

Course Code	21NTE602T	Course Name	TISSUE ENGINEERING AND REGENERATIVE MEDICINE	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 utility and potential of tissue engineering principles.*
CLR-2:	*analyse different types of stem cells and its application in tissue engineering*
CLR-3:	*be aware of the materials used in tissue engineering*
CLR-4:	*know the current trend in tissue engineering and regenerative technology*
CLR-5:	*understand the clinical applications of tissue engineering*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*describe the basis of cell structure and function*	*3*	*-*	*3*
CO-2:	*get familiarized with different types stem cells*	*3*	*-*	*3*
CO-3:	*develop different biomaterials used in tissue engineering*	*3*	*-*	*3*
CO-4:	*fabricate tissue engineering products*	*3*	*-*	*3*
CO-5:	*exposure to clinical applications in organogenesis*	*3*	*3*	*-*

Module-1 - Fundamental of Tissue Engineering	***9 Hour***
Tissue Types, Epithelial, connective and muscular tissue, Germ layers, Ectoderm, endoderm and mesoderm, Fundamentals of Stem Cell Tissue Engineering, Growth Factors, Extracellular Matrix: Structure, Function And Tissue Engineering Application, Mechanical Forces On Cells, Cell Adhesion, Cell Migration	
Module-2 - Stem Cells in Tissue Engineering	***9 Hour***
Introduction of Stem cells, Hemopoietic Stem cells, Embryonic Stem cells, Adult stem cells, Cancer Stem cells, Cord Blood cells, Induced Pluripotent Stem cells, Stem cell identification, Differentiation, Dedifferentiation and Immortalization, Application of stem cells in tissue Engineering	
Module-3 - Tissue Engineering Technologies	***9 Hour***
Polymer Scaffold for Tissue Engineering, Biomimetic Materials; Nanocomposite Scaffolds, Bioreactors, Cell interaction with scaffold, Matrix effects, Polymer scaffold fabrications, Biodegradable polymers, 3 D scaffolds, mechanical properties of biomaterials (tensile, shear, bending and time-dependent properties)	
Module-4 - Tissue Engineering Application	***9 Hour***
Bioengineering Of Human Skin Substitute, Nerve Tissue Engineering, Musculoskeletal Tissue Engineering, Bone Tissue Engineering, Cartilage Tissue Engineering, Dental Tissue Engineering, Cardiac Tissue Engineering, Heart Valve Tissue Engineering	
Module-5 - Clinical Applications	***9 Hour***
Stem cell therapy, Molecular therapy, In vitro Organogenesis, Neuro degenerative diseases, spinal cord injury, heart disease, diabetes, burns and skin ulcers, muscular dystrophy, orthopedic applications, Patent protection and regulation of tissue engineered products, ethical issues	

Learning Resources	1. Clemens van Blitterswijk (2008), Tissue Engineering, Academic Press 2. R.Lanza, J.Gearhart et.al,(Eds), Essential of Stem cell Biology, Elsevier Academic Press, 2020	3. Principles of Tissue Engineering, 4th Edition (2021) Edited by Lanza, R; Langer, R; and Vacanti, J Academic Press 4. Introduction to Tissue Engineering: Applications and Challenges (IEEE Press Series on Biomedical Engineering) Ravi Birla.

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. P. Aravind Mukesh, United Breweries, Bengaluru, aravind.mukesh@gmail.com	1. Dr. Vignesh Muthu Vijayan, IITM, vigneshm@iitm.ac.in	1. Dr. G. Devanand Venkatasubbu, SRM IST
2. Mr. K. Chandru, HCL Medical devices Pvt. Ltd. Chennai, acewhentura@gmail.com	2. Dr. P. Balasubramanian, NIT Rourkela, balap@nitrkl.ac.in	2. Dr. N. Selvamurugan, SRM IST

Course Code	21NTE603T	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 principles of advanced topics in nanophotonics*
CLR-2:	*acquire knowledge in the principles and applications of plasmonics*
CLR-3:	*understand the principles and applications of all-dielectric nanophotonics*
CLR-4:	*develop knowledge in Silicon Nanophotonics*
CLR-5:	*develop knowledge about Integrated Nanophotonics*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*explain the fundamentals of photonic crystals*	*3*	*3*	*-*
CO-2:	*apply the concept of metal optics and plasmonics*	*-*	*3*	*3*
CO-3:	*describe the concept of all-dielectric nanophotonics*	*3*	*3*	*-*
CO-4:	*utilize the concepts of silicon nanophotonics*	*3*	*-*	*3*
CO-5:	*apply the knowledge of integrated nanophotonics*	*3*	*-*	*3*

Module-1 –Photonic Crystals	***9 Hour***
Electromagnetic waves, photons, an overview, Wavelengths and dispersion laws, Density of states, Maxwell and Helmholtz equations, Phase space, Light in periodic structures. Introduction to photonic crystals (structured dielectrics), Photonic bandgap, 1D, 2D and 3D photonic crystals (PCs), Bloch waves and band structure in one-dimensionally periodic structures, Band gaps and band structures in two-dimensional lattices, Band gaps and band structure in three-dimensional lattices, Applications of photonics crystals	
Module-2 - Plasmonics	***9 Hour***
Introduction to plasmonics (structured metals), Electromagnetic Wave Propagation, The Dielectric Function of the Free Electron Gas, The Dispersion of the Free Electron Gas and Volume Plasmons, The Energy of the Electromagnetic Field in Metals, Surface plasmon resonance (SPR) and Localized surface plasmon resonance (LSPR), Excitation techniques of surface plasmon resonance, Near field, prism and grating coupling of SPR, Dispersion of surface plasmon and Surface plasmon wavelength, Applications of SPR and LSPR	
Module-3 – All-Dielectric Nanophotonics	***9 Hour***
General concepts of scattering theory, Multipole decompositions of electromagnetic modes, Taylor series expansion, Visualizing multipoles (computation exercise), Dielectric materials, Directional scattering of dielectric nanoantennas, Generalized Kerker effect, First and second Kerker conditions, Lattice resonance effect, Directional scattering facilitated by lattice, Applications of All-Dielectric Nanophotonics	
Module-4 - Silicon Nanophotonics	***9 Hour***
Silicon Nanocrystals Enabling Silicon Photonics, Silicon Nanostructures for Photonics and Photovoltaics, Modeling Nonlinear Optical Phenomena in Silicon-Nanocrystal Structures, Band Structure of Silicon Nanocrystals, Engineering the Optical Response of Nanostructured Silicon, Room Temperature Light Emission from Silicon Nanowires Fabricated by a Metal-Assisted Wet Etching Process, All-Inorganic Colloidal Silicon Nanocrystals, Engineering Nonlinear Sources with Silicon-Compatible Optical Materials, Light Emission from Silicon-Based Materials: From Silicon Nanostructures to Rare Earth Ions	
Module-5 – Integrated Nanophotonics	***9 Hour***

Platforms for integrated nanophotonics- lithium niobate nanophotonics, indium phosphide nanophotonics, silicon nanophotonics, Nonlinear optics for integrated photonics, The devices and technologies for integrated nanophotonics in on-chip light sources, Optical packaging of photonic integrated circuits, Optical interconnects, Light processing devices, Applications on neuromorphic computing, biosensing, Light Detection and Ranging (LIDAR), Computing for AI and artificial neural network and deep learning

Learning Resources	*1.Sergey V. Gaponenko, Introduction to Nanophotonics, Cambridge University Press, 2010.* *2.Sergey V. Gaponenko and Hilmi Volkan Demir, Applied Nanophotonics, Cambridge University Press, 2018.* *3.Jonah Holmes, Handbook of Nanoplasmonics, NY Research Press, 2023*	*4.Alexander S. Shalin, Adrià Canós Valero, Andrey Miroshnichenko, All-Dielectric Nanophotonics, Elsevier, 2023* *5. Leonid Khriachtchev, Silicon Nanophotonics: Basic Principles, Present Status, and Perspectives, Routledge- Taylor and Francis Group, 2016* *6. Peng Yu, Hongxing Xu, Zhiming Wang, Integrated Nanophotonics - Platforms, Devices, and Applications, Wiley-VCH Verlag GmbH, 2023*

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. Renilkumar M, Lionix International, Netherlands, nair.renil@gmail.com	*1. Prof. V Subramanian, IIT Madras, manianvs@iitm.ac.in*	*1. Dr Junaid Masud Laskar, SRMIST*
2. Mr. M. Shafi, Holmarc Opto-Mechatronics Ltd., Cochin, shafiinlight@gmail.com	*2. Prof. Sandip Dhara, IGCAR Kalpakkam, dhara@igcar.gov.in*	*2. Dr. K. Shadak Alee, SRMIST*

Course Code	21NTE604T	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 of nanotribology.*
CLR-2:	*understand lubrication and related theories.*
CLR-3:	*gain insight into surface forces and their measurement techniques.*
CLR-4:	*know about mechanisms involved in tribology-related mechanical properties.*
CLR-5:	*enhance the knowledge of friction and wear and their importance.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*understand the basic tribological concepts required for nanotechnology*	*3*	*3*	-
CO-2:	*identify, formulate, and solve engineering problem of interacting surfaces in relative motion*	*3*	*3*	-
CO-3:	*emphasize the knowledge of scientific disciplines in understanding the tribological phenomenon*	*3*	*3*	*3*
CO-4:	*demonstrate the significance of lubrication, friction, and wear*	*3*	*3*	-
CO-5:	*understand the importance of modifying surface properties*	*3*	*3*	-

Module-1 - Fundamentals of Tribology	***9 Hour***
Introduction to Tribology, Significance of Micro/Nanotribology, Methods of Solution of Tribological Problems, Lubrication Fundamentals, Modes of lubrication (hydrodynamic, hydrostatic, boundary, elasto hydrodynamics, extreme pressure), Properties of lubricants and their effects on tribological performance, Additives in Tribology, Bearings and Lubrication Systems	
Module-2 – Surface Forces	***9 Hour***
Introduction to Surface Forces, Methods Used to Study Surface Forces, Force Laws, Adhesion and Capillary Forces, Surface Roughness and Frictional Force, Wear and Machining, Surface Potential Measurements, Nanoindentation Method and Mechanical Properties	
Module-3 - Lubrication	***9 Hour***
Introduction to Lubrication, Lubricant States and Viscosity, Fluid Film Lubrication, Lubrication Design of Mechanical Elements, Friction Basics Wear Mechanisms, Surface Contact and Temperature, Typical Test Geometries	
Module-4 – Mechanical Properties	***9 Hour***
Scale Effects in Mechanical Properties, Importance of Mechanical Properties, Fracture Toughness, Interface Properties, Concept of Friction, Adhesion Friction and its Significance, Deformation Between Bodies, Tribological Properties of Self-assembled Monolayers and their Applications in Tribology	
Module-5 - Applications	***9 Hour***
Introduction to Tribology and its Applications, Various Tribological Phenomena, Bio-Tribology: Tribology in the Human Body and Artificial Organs, Tribology in Medical Devices and Electronic Devices, Natural Human Synovial Joints and Total Joint Replacements, Wind Turbine Tribology and its Working Principle, Coating Applications: Sliding Bearings and Rolling Contact, Bearings: Types, Working Principle, and Applications, Gears: Types, Working Principle, and Applications	

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%*	-	*15%*	-	*15%*	-
Level 2	*Understand*	*20%*	-	*20%*	-	*25%*	-
Level 3	*Apply*	*30%*	-	*25%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*25%*	-	*30%*	-
Level 5	*Evaluate*	-	-	*10%*	-	-	-
Level 6	*Create*	-	-	*5%*	-	-	-
	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.com	*1. Prof. D. Pamu, IIT Guwahati, pamu@iitg.ac.in*	*1. Dr. Kiran Mangalampalli, SRM IST*
2.Dr. Sridhar M. R, Senior Engineer, GE Global Research, Bangalore, India, Sridhar.mr@ge.com	*2. Prof. S. Balakumar, University of Madras, balakumar@unom.ac.in*	*2. Dr. S. Yuvaraj, SRM IST*

Course Code	21NTE605T	Course Name	NANOCOMPOSITES	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:	*grasp different manufacturing techniques to produce real-life components such as vacuum infusion and injection molding*
CLR-2:	*understand characterization techniques of nanocomposites under mechanical, electrical, optical and thermal loadings and exposure to fire environments*
CLR-3:	*study different manufacturing techniques of dispersion of nanoparticles such as sonication, high shear mixing, centrifugal mixer, twin-screw extrusion.*
CLR-4:	*know classification of various nanofillers for reinforcement effect in polymers and multilayer structures*
CLR-5:	*know about aerogels, biodegradable and formation of different combination of aerogel-based nanocomposites*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*apply the importance of various nanomaterials-based fillers in matrix for synergistic effect in polymer nanocomposites.*	*3*	*-*	*3*
CO-2:	*discuss various applications of nanocomposites including for biomedical applications*	*3*	*-*	*2*
CO-3:	*discuss metal matrix nanocomposites and metallic clusters*	*2*	*-*	*3*
CO-4:	*use metal matrix nanocomposites and metallic clusters in various applications*	*3*	*3*	*-*
CO-5:	*apply different methods of making metallic, polymeric nanocomposites*	*3*	*-*	*3*

Module -1: Fundamentals of Nanocomposites	***9 Hour***
Definition of nanofiller and matrix, Classification of nanofillers and their physical properties, Functionalization of nanofillers, Concept of reinforcement, Interface and interphase, Physical Vapour Deposition, Chemical methods for novel nanomaterials, Advantages and challenges.	
Module -2: Synthesis and Characterization of Nanocomposites	***9 Hour***
Stability of nanoparticles in solutions, Solvent solubility parameters, Van der Waals interactions, Intermolecular forces in solid-liquid media, Stability of nanoparticles by polymers, Role of nano filler in nanocomposites, Rule of mixture, Electrical and thermal percolation in polymer nanocomposites, Electromagnetic percolation theory, shear stress transfer, Insitu polymer, nanocomposites and Polymerization, Melt mixing of polymers and working principle, Single and Twin screw extruder, Barbender extruder technique, Thermogravimetry, Microscopy and Composition.	
Module -3: Types of Nanocomposites	***9 Hour***
Nanocomposites by mechanical alloying, Nanocomposites from sol-gel synthesis, Porous materials, Aerogels and properties, Nanocomposite for hard coatings, Hardness and mechanical properties of hard coatings, Carbon nanotube nanocomposites, Ceramic nanocomposites, Elastic behavior and deformation, Functional nanocomposites, Encapsulated nanocomposites, Metals filled carbon nanocomposites, Binary nanocomposites, Tertiary nanocomposites	
Module 4: Nanocomposites and their Diverse Applications	***9 Hour***
Inorganic nanocomposites for electrical applications, Nanocomposite membranes, Nanocomposites for magnetic applications, Memory devices, Magnetic multilayer nanocomposites, Flammability of nanocomposites, Low and high thermal conductivity nanofillers, Dielectric properties of nanocomposites, Breakdown strength, Optical properties of nanocomposites, Nanocomposites for LEDs.	
Module 5: Bio-Nano Composites	***9 Hour***

Biocompatibility, Biodegradable materials, Polylactic acid based bio nanocomposites, Synthesis of nanobioceramics, Chemical composition in nanobioceramics, Polyolefin based nanocomposites, Polymer matrix structurization in biocompatible nanocomposite materials, DNA, spider, silk, Biomimetic Nanocomposites, Biological macromolecules, Biologically Synthesized Nanostructures, Protein based Nanostructures. Trend in materials science and polymer/metal nanocomposites, Emerging bio nanocomposites.

Learning Resources	*1.Pulickel M. Ajayan Linda S. Schadler Paul V. Braun, Nanocomposite Science and Technology, Wiley 2003.* *2.Anatolii D. Pomogailo Vladimir N. Kestelman, Metallopolymer Nanocomposites, Springer 2005.*	*3.Visakh P.M. Maria José Martínez Morlanes, Nanomaterials and Nanocomposites: Zero- to Three-Dimensional Materials and Their Composites, Wiley 2016.* *4.Sati N. Bhattacharya, Musa Rasim Kamal, Rahul K. Gupta, Carl Hanser, Polymeric Nanocomposites: Theory and Practise Publishers, 2008.* *5. Kamal K. Kar, Jitendra K. Pandey, Sravendra Rana Handbook of Polymer Nanocomposites. Processing, Performance and Application, Springer, Ebook, 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, NPL, dkaswal@nplindia.org	*1. Prof. Ramaprabhu, IITM, ramp@iitm.ac.in*	*1. Dr. Eswaraiah Varrla SRMIST*
2. Dr. Subramanian, CLRI, subbu@clri.res.in	*2. Dr. Ramakrishna Matte, CeNS, matte@cens.res.in*	*2. Dr. Angeline Little Flower SRMIST*

Course Code	21NTE606T	Course Name	NANOTECHNOLOGY IN ENERGY CONVERSION AND STORAGE	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 energy challenges and the possible role of Nanotechnology in tackling the same.*
CLR-2:	*grasp the role of Nanotechnology in fossil fuel technology and some chemical energy conversion processes.*
CLR-3:	*acquire knowledge on the use of nanomaterials for various light energy conversion processes.*
CLR-4:	*identify the use of nanomaterials for thermoelectrics, wind, biomass and nuclear energy technologies.*
CLR-5:	*acquire knowledge on the role of Nanotechnology in various kinds of energy storage.*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*identify the need for solving the energy problems and the expectations from nanotechnology for same*	-	3	2
CO-2:	*discuss the use nanomaterials for fossil fuels and various chemical energy conversion processes*	-	3	2
CO-3:	*discuss the application of nanotechnology in the development of light energy conversion technologies such as photovoltaics and solid state lighting*	-	3	2
CO-4:	*analyze the role of nanotechnology in the development of other alternative energies such as thermoelectrics, wind, biomass and nuclear*	-	3	2
CO-5:	*realize the use of nanomaterials in the designing of different innovative energy storage technologies*	-	3	2

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Module-1 – Introduction to Nano and Energy	***9 Hour***
Energy conversion, Direct and indirect energy conversion, Current energy demands and consumption, Energy and climate, Greenhouse effect, Conventional Vs non-conventional energy sources, Renewable energy Prospects and implementation, Nanomaterials for energy, Unique properties of nanomaterials for energy conversion and energy storage.	
Module-2 - Nano for Energy Conversion-Conventional and Chemical	***9 Hour***
Conventional energy sources, Fossil fuels, Nano catalyst for petroleum and natural gas, clean energy with hydrogen and methane, Nanomaterials for catalytic and photo-electrochemical hydrogen generation, Nanomaterials for CO2 to methane conversion, Fuel cell, Nanostructured materials for fuel cells, Miniaturization of fuel cells, Micro fuel cells.	
Module-3 - Nano for Energy Conversion-Light	***9 Hour***
Solar Cells, Nanomaterials for solar cells, Nanostructured coatings, patterning for light trapping, antireflection and self-cleaning coatings, Nanomaterials for carrier management, Nanomaterials for dye & quantum dot sensitized solar cells, and other advanced concepts, Solar thermal energy conversion and nanostructured coatings, Light emitting diodes, Nanomaterials for light emitting diodes.	
Module-4 - Nano for Energy Conversion-Other	***9 Hour***
Thermoelectric energy conversion, Requirements for thermoelectric materials, Nanomaterials for thermoelectrics, Biogas energy recovery, Nanotechnology in biogas energy recovery, Miniaturization of energy conversion technology, Nano motors, Micro heat engine, Piezoelectric energy harvesting and Nano generators.	
Module-5 - Nano for Energy Storage	***9 Hour***
Nanomaterials for energy storage devices, Batteries, Li-ion battery and other types of batteries, Capacitors and Supercapacitors, Miniaturized energy storage, micro channel batteries, nanobatteries, Hydrogen storage and nanomaterials for hydrogen storage, Nano-materials for CO2 capture, Thermal energy storage and phase change nanomaterials.	

Learning Resources	1. Baldev Raj, Marcel Van de Voorde, Yashwant Mahajan, "Nanotechnology for energy sustainability", "Wiley-VCH Verlag GmbH", 3 volume set, 2017 2. Javier Garcia-Martinez, "Nanotechnology for the energy challenge", "Wiley-VCH Verlag GmbH", 2013.	3. Basu, S., "Recent Trends in Fuel Cell Science and Technology", "Springer and Anamaya", 2007. 4.Hari Singh Nalwa, "Encyclopedia of Nanoscience and Nanotechnology", "American Scientific Publishers", 2004.

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. Vijay K Toutam, NPL Delhi, toutamvk@nplindia.org	1.Dr. Jatin K Rath, IIT Madras, jkr@iitm.ac.in	1.Dr. S Venkataprasad Bhat, SRMIST
2. Dr. Dattatreya J Late, Brane Enterprises Private Ltd., Hyderabad, datta099@gmail.com	2. Dr. Adithya Sadhanala, IISc, Bangalore, sadhanala@iisc.ac.in	2. Dr. P. Malar, SRMIST

Course Code	21NTE607T	Course Name	NANOMATERIALS FOR ELECTROCHEMICAL STORAGE 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 and obtain knowledge on the importance of nanomaterials for energy conversion and storage*
CLR-2:	*gain knowledge on energy storage devices and technology*
CLR-3:	*acquire knowledge on various materials characteristics for energy storage*
CLR-4:	*understand the advantages and challenges of nanomaterials for electrochemical storage technology*
CLR-5:	*acquire knowledge on current trends in nanomaterials for electrochemical energy storage*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	***Programme Outcomes (PO)***		
		1	***2***	***3***
CO-1:	*utilize the nanomaterials for electrochemical energy technology*	3		
CO-2:	*apply the knowledge to understand and handle the energy storage devices*	3		
CO-3:	*render various properties of nanomaterials employed for energy storage technology*			3
CO-4:	*apply the knowledge acquired on advantages and disadvantages of the nanomaterials to fabricate energy storage devices*			3
CO-5:	*utilize the knowledge of current updates and scenario of nanomaterials for energy storage technology*			3

Module-1 - Nanostructured Materials for Energy Storage and Conversion	***9 Hour***
Introduction to nanomaterials - Comparison between bulk and nanomaterials - Types of nanomaterials and their applications in energy storage and conversion - carbon nanostructures - oxide nanostructures - metallic nanostructures - polymer nanostructures – nanocomposites - 0D, 1D, 2D, 3D nano-architectures.	
Module-2 - Energy Storage Devices	***9 Hour***
Introduction to energy storage devices - Working principles and importance of advanced electrochemical energy storage and conversion devices - Li-ion batteries, Na-ion batteries – Fuel cells - Supercapacitors	
Module-3 - Nanomaterials Characteristics for Energy Storage	***9 Hour***
Structural, electrical, mechanical properties of materials required to use as cathode, electrolyte and anode - Effects of crystal structures - crystallographic orientations - Issues related to diffusivity, relevant mechanical and physical properties including electrical conductivity -Effects of nanoscaled dimensions, dimensional/structural stability during operation, surface areas/properties	
Module-4 – Advantages and Challenges of Nanomaterials for Energy Storage	***9 Hour***
Advantages of nanomaterials in terms of energy densities, power densities, cycle life, design considerations - Special beneficial aspects of nanostructured materials for performance of Li batteries, Fuel cells and Super capacitors- Problems associated with the synthesis of nanomaterials and their use in electrochemical energy storage and conversion devices - Ways to overcome such limitations	
Module-5 - Current Scenario of Nanomaterials for Energy Conversion and Storage	***9 Hour***
Nanomaterials presently used in the energy storage and conversion devices - Potential nanomaterials and nanostructures deemed to further enhance the functionalities significantly - Current state and necessities for continuing fundamental research on fabricating nanomaterials for such applications	

Learning Resources	1. *Ishani Chakrabartty, Khalid Rehman Hakeem, Green Nanomaterials in Energy Conversion and Storage Applications, Apple Academic Press, 2024* 2. *Leite, Edson Roberto, Nanostructured materials for electrochemical energy production and storage, New York: Springer, 2009* 3. *E.Buck, Fundamental studies connected with electrochemical energy storage, Washington, DC: NASA, 1975*	4. *W. Wakihara, and O. Yamamoto, Lithium-Ion Batteries Fundamentals and Performance, Kodansha-Wiley-VCH, Weinheim (1998)* 5. *B. E. Conway, Electrochemical Supercapacitors, Kluwer Academic/Plenum, New York, 1999* 6. *Supramaniam Srinivasan, Fuel cells: from fundamentals to applications, Springer Science + Business Media, New York, 2006*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	20%	-	15%	-	20%	-
Level 2	*Understand*	20%	-	20%	-	20%	-
Level 3	*Apply*	30%	-	25%	-	30%	-
Level 4	*Analyze*	30%	-	25%	-	30%	-
Level 5	*Evaluate*	-	-	10%	-	-	-
Level 6	*Create*	-	-	5%	-	-	-
	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, India*	1. *Prof. S. Balakumar, Professor, University of Madras*	1. *Dr. K. Kamala Bharathi, SRMIST*
2. *Dr. Sarin Sundar J K, Applied Materials, India*	2. *Prof. Kothandaraman Ramanujam,, IIT Madras*	2. *Dr. T. Vijayakumar, SRMIST*

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

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