ACADEMIC CURRICULA

Professional Elective Courses

NANOTECHNOLOGY

Regulations - 2018

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Kancheepuram, Tamil Nadu, India

Course Code	18NTE301T	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	*Nanotechnology*	Data Book / Codes/Standards		*Nil*	

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Acquire knowledge various forms of carbon*			
CLR-2 :	*Understands the use of carbon forms in applications*			
CLR-3 :	*Understands the physical and chemical properties of fullerenes*			
CLR-4 :	*Understands the physical and chemical properties of graphene*			
CLR-5 :	*Understands the physical and chemical properties of carbon nanotubes*			
CLR-6 :	*Acquire knowledge about various synthesis forms*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Analyze the geometry of various carbon nanostructures*	*2*	*80*	*75*	*H*	*H*	*H*	*H*	*M*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Differentiate the structure and properties of different carbon nanostructure*	*2*	*80*	*70*	*H*	*H*	*M*	*H*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Elucidate the uses of Fullerenes, Carbon nanotubes and Graphene in different applications*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*H*
CLO-4 :	*Analyze the geometry of various carbon nano tubes*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-5 :	*Analyze the various synthesis and characterization techniques of carbon nanostructures*	*2*	*80*	*70*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6 :	*Demonstrate the applications of carbon nanostructures*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction*	*Fullerenes*	*Carbon Nanotubes*	*Graphene*	*Introduction to thin films*
	SLO-2	*Carbon molecules*	*Structure of fullerenes*	*Structure of Carbon Nanotubes*	*Structure of Graphene*	*Carbon thin films*
S-2	SLO-1	*Nature of carbon bond*	*Bonding of fullerenes*	*Nomenclature of Carbon Nanotubes*	*Synthesis of Graphene*	*Amorphous nature*
	SLO-2	*New carbon structures*	*Nomenclature*	*Electronic properties of Carbon Nanotubes (CNTs)*	*Characterization of Graphene*	*Crystalline nature*
S-3	SLO-1	*Discovery of C60*	*C60 and higher fullerenes*	*Synthesis of Single Wall CNTs (SWCNTs)*	*Properties of Graphene*	*Chemical vapor deposition (CVD): Diamond*
	SLO-2	*Structure of C60*	*Growth mechanisms*	*Production of SWCNTs*	*Electrical properties of Graphene*	*Structure of CVD diamond*
S-4	SLO-1	*C60 crystal*	*Production*	*Synthesis of Multi Wall CNTs (SWCNTs)*	*Magnetic properties of Graphene*	*Synthesis of CVD diamond*
	SLO-2	*From graphene sheet to a nanotube*	*Purification*	*Production of MWCNTs*	*Band structure of Graphene*	*Physical properties of CVD diamond*
S-5	SLO-1	*Single wall and multi walled nanotubes*	*Fullerene preparation by pyrolysis of hydrocarbons*	*Growth mechanism of CNTs*	*Phonon modes in Graphene*	*Chemical properties of CVD diamond*
	SLO-2	*Zigzag nanotubes*	*Partial combustion of hydrocarbons*	*Analysis of Carbon Nanotubes by X-ray diffraction*	*Raman modes in Graphene*	*CVD diamond as wear resistant coating*
S-6	SLO-1	*Armchair nanotubes*	*Physical properties*	*Analysis of carbon nanotubes by Raman Spectroscopy*	*Layer dependence of Raman spectra*	*CVD diamond as bio-chemical sensors*
	SLO-2	*Chirality in nanotubes*	*Chemical properties*	*Carbon nanotubes as Transistors*	*Raman spectroscopy of Graphene under*	*Optical applications: infrared windows,*

					strain	*lenses, X-ray Windows*
S-7	SLO-1	*Structure of defective nanotubes*	*Hydrogenation*	*Carbon nanotubes as Field Effect Transistors (FET)*	*Infrared spectroscopy of Graphene*	*Amorphous carbon thin films*
	SLO-2	*Bonding of defective nanotubes*	*Applications of fullerenes*	*Carbon nanotubes as sensors*	*X-Ray diffraction of Graphene*	*Amorphous carbon films (a:C)*
S-8	SLO-1	*Cylindrical nanotubes*	*Fullerenes in solar cell*	*Carbon nanotubes as bio-sensors*	*EELS of Graphene*	*Hydrogen amorphous carbon films (a:C-H)*
	SLO-2	*Euler's theorem*	*Fullerenes as donor systems*	*Carbon nanotubes as gas sensors*	*Graphene in solar cell applications*	*Physical properties of amorphous carbon film*
S-9	SLO-1	*Euler's theorem in cylindrical nanotubes*	*Fullerenes as acceptor systems*	*Carbon nanotubes in dye degradation*	*Graphene as gas sensors*	*Chemical properties of amorphous carbon film*
	SLO-2	*Euler's theorem in defective nanotubes*	*Fullerenes as chemical sensors*	*Carbon nanotubes in photo-catalytic activities*	*Graphene in dye degradation (photo-catalytic activities)*	*Amorphous carbon film as anti-reflection and anti-corrosive coatings*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	*1. Dr. V. Subramaniyam, IIT Madras, manianvs@iitm.ac.in*	*1. Dr. M.Navaneethan, SRMIST*
2. Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in	*2. Dr. S. Balakumar, University of Madras, balakumar@iunom.ac.in*	*2. Dr. E. Senthil Kumar, SRMIST*

Course Code	18NTE302T	Course Name	PHYSICS OF SOLID STATE DEVICES	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	Get knowledge in the design and working principle of solid state devices
CLR-2 :	Understand the physics of p-n junction
CLR-3 :	Familiarize with the concept of metal/semiconductor junctions and semiconductor heterojunctions
CLR-4 :	Describe the operation of basic semiconductor diodes
CLR-5 :	Understand the theory of various types of transistors
CLR-6:	Acquire knowledge on the materials and working of solid-state optoelectronic devices like LEDs, Solar cells, Photodetectors, Lasers, etc

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning 1 (Level of Thinking (Bloom))	Learning 2 (Expected Proficiency (%))	Learning 3 (Expected Attainment (%))
CLO-1 :	Realize importance of semiconducting materials and p-n junction for development of solid state devices	2	80	75
CLO-2 :	Use knowledge of physics to understand the workingof semiconductor devices	2	80	70
CLO-3 :	Develop analytical approaches to understand semiconductor devices	2	75	70
CLO-4 :	Develop in depth understanding on the principle of working of different solid state devices	2	80	75
CLO-5 :	Distinguish the design principles of various solid state devices	2	80	70
CLO6:	Design two-terminal and three-terminal electronic devices	2	80	70

Program Learning Outcomes (PLO)	1 Engineering Knowledge	2 Problem Analysis	3 Design & Development	4 Analysis, Design, Research	5 Modern Tool Usage	6 Society & Culture	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	13 PSO - 1	14 PSO - 2	15 PSO - 3
CLO-1 :	H	H	H	H	H	H	H	H	H	H	M	H	H	H	H
CLO-2 :	H	H	H	H	M	M	M	H	H	H	L	H	M	M	M
CLO-3 :	H	L	H	H	H	H	H	H	H	H	M	H	H	H	H
CLO-4 :	H	H	H	H	M	M	H	H	H	H	M	H	H	H	H
CLO-5 :	H	M	H	H	M	M	H	H	H	H	L	H	H	H	H
CLO6:	H	H	H	H	M	M	M	H	H	H	L	H	M	M	M

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Concept of p-n junction	Understand what a metal-semiconductor contact is.	Study fundamentals of BJT operation	Principle and types of field-effect transistors	Understand optical generation of carriers in a p-n junction
	SLO-2	Physics of the p-n junction formation	Qualitative characteristics of energy band formation	Operation modes of a BJT	Principle of operation of JFET	Types of Photodiodes
S-2	SLO-1	Energy band diagram of a p-n junction	Understand the ideal junction properties	Understand the structure and working of p-n-p and n-p-n transistors	Concept of pinch-off and saturation	Solar radiation and ideal conversion efficiency of a solar cell
	SLO-2	Estimation of the electric field, electric potential, and built-in potential	Theoretical considerations in estimating the barrier height	Band diagram and static characteristics	Derive I-V characteristics of JFET	Physics of solar cell
S-3	SLO-1	Depletion approximation and estimation of space charge width	Nonideal effects on the barrier height	Factors involved in transistor amplification	GaAs epitaxial layers for MESFET – Principle of working	Device configuration and technology roadmap, solar cell materials
	SLO-2	Depletion layer capacitance and its estimation	Qualitative explanation of image-force-induced lowering of the potential barrier	BJT fabrication	Concept of high-electron mobility transistors - III-V semiconductor materials	Familiarize with the solar cell parameters and efficiency calculation
S-4	SLO-1	Linearly graded junction in thermal equilibrium	Current transport processes in metal-semiconductor contacts	Analysis of minority carrier distribution	Basic working and fabrication of MOSFET	Design principle of photodetector
	SLO-2	Arbitrary doping profile and understanding the doping profile from $1/C^2$-V plot	Comparison of the Schottky barrier diode and the p-n junction diode	Solution of the diffusion equation in the base region	Knowledge on modes of operation and short channel MOSFET	Types of photodetectors and characteristics

S-5	SLO-1	*Qualitative description of charge flow in a p-n junction*	*Metal-semiconductor Ohmic contacts*	*Evaluation of the terminal currents*	*Short channel effects in MOSFET*	*How light-emitting diodes work?*
	SLO-2	*Ideal current-voltage characteristics of a p-n junction*	*Concept of ideal nonrectifying and tunneling barriers*	*Non ideal effects in BJT*	*Advanced MOSFET structures*	*Basic device structure and the concept of radiative recombination*
S-6	SLO-1	*Derivation of Shockley equation (ideal-diode equation)*	*Methods to experimentally measure the barrier height*	*Deviations from the basic theory and indicate situations in which each effect is important*	*Metal Gate-High-k and Enhanced Channel Mobility Materials and Strained Si FETs*	*Materials of choice and technology roadmap*
	SLO-2	*Generation-recombination process and its effect*	*Current-voltage and capacitance-voltage measurements*	*The physical mechanisms of the current gain limiting factors*	*Complementary MOS structure and its formation*	*Specifications used in denoting the practical LED bulbs*
S-7	SLO-1	*Reverse bias breakdown mechanisms in a pn junction*	*Photoelectric measurements*	*The voltage breakdown mechanisms in abipolar transistor*	*CMOS process integration*	*Physics of laser action*
	SLO-2	*Zener and Avalanche breakdown*	*Figure of merit of ohmic contacts and its determination, the concept of specific contact resistance*	*The current-limiting factors from the current components in the transistor*	*Concept of modulation doping in HEMT*	*Gain knowledge of stimulated emission and population inversion*
S-8	SLO-1	*Transient behavior of a p-n junction*	*Isotype and anisotype semiconductor heterojunctions - energy band diagrams*	*Frequency limitations of transistors*	*Basic device structure of AlGaAs/GaAs HEMT and I-V characteristics*	*Fabrication of p-n junction laser*
	SLO-2	*Concept of Noise in semiconductor devices*	*Current density equations and physical interpretation*	*The voltage breakdown mechanisms in a bipolar transistor*	*Output characteristics and channel related phenomenon*	*Emission spectra*
S-9	SLO-1	*Terminal functions of a p-n junction diode, The concept of tunnel diode*	*Introduction to two-dimensional electron gas*	*Heterojunction BJT*	*Dynamic effects in MOS capacitors – The Charge-coupled device*	*Familiarize with the structure and need of heterojunction lasers*
	SLO-2	*p-n junction as rectifier, Zener diode, Varistor, and Varactor*	*Concept of quantum well and superlattice structures*	*Schottky and Photo transistors*	*Basic CCD structure and its applications*	*Materials for semiconductor lasers and quantum cascade lasers*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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

Course Code	18NTE303T	Course Name	MOLECULAR SPECTROSCOPY AND ITS APPLICATIONS	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	Nanotechnology	Data Book / Codes/Standards	Nil		

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Acquire the knowledge in the basic concepts of interaction of radiation with matter and rotational spectroscopy			
CLR-2 :	Comprehend the principles of vibrational spectroscopy			
CLR-3 :	Understand the principles and techniques involved in of Raman scattering			
CLR-4 :	Emphasize the significance of various techniques in electronic spectroscopy			
CLR-5 :	Expose to concepts and applications of magnetic resonance			
CLR-6 :	Focus on relevant theory, concepts, and techniques for understanding the spectrum of molecules			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Interpret the processes of absorption and radiation and analyse the rotational motion in molecules	2	80	75	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	Analyze the vibrational spectra of diatomic and polyatomic molecules	2	80	70	H	M	M	H	M	M	M	H	M	H	M	H	M	M	M
CLO-3 :	Analyze the Raman spectra and various non-linear Raman techniques	2	75	70	H	M	M	H	H	M	M	M	M	H	H	H	H	H	H
CLO-4 :	Elucidate the various optical processes involved in the electronic spectra.	2	80	75	M	H	M	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Apply the concept magnetic resonance in chemical analysis and structure determination.	2	80	70	H	M	M	H	H	M	M	H	M	H	M	H	H	H	H
CLO-6 :	Critique the applicability of a spectroscopic approach in the analysis of a molecular structure	2	80	75	H	M	M	H	H	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Electromagnetic spectrum, spectral regions	Vibrational energy of a diatomic molecule	Born oppenheimer approximation	Quantum theory of Raman scattering	Magnetic moments
	SLO-2	Types of molecular energies	Classical approach	Vibrational coarse structure	Classical theory of Raman scattering	Quantization
S-2	SLO-1	Interaction of light with matter	Wave mechanical approach	Band system and vibrational transitions	Rotational Raman spectra	Larmor precession
	SLO-2	Methods of obtaining a spectrum, components of a spectrometer	Morse curve and energy levels of a diatomic molecule	Progressions and sequences	Vibrational Raman spectra	Resonance condition in Nuclear magnetic resonance (NMR)
S-3	SLO-1	Spectral line width and broadening of spectral lines	Selection rules for vibration	Franck condon principle	Mutual exclusion principle	Spin –spin relaxation
	SLO-2	Intensity of spectral lines	Fundamental overtones and hotbands in the vibrational spectrum	Intensity of vibrational electronic spectra	Polarization of Raman scattered light	Spin-lattice relaxation
S-4	SLO-1	Absorption and emission of radiation	Accidental degeneracy	Rotational fine structure	Raman spectrometer	NMR spectrometer
	SLO-2	Spontaneous and stimulated processes	Diatomic vibrating rotator	Assignment of bands in a fine structure	Analysis of Raman spectra	Chemical shift
S-5	SLO-1	Einstein's co-efficients and its derivation	Selection rules for vibration-rotation	Dissociation energy and dissociation products	Structure determination using Raman spectroscopy	Factors contributing to screening
	SLO-2	Laser as a spectroscopic light source	Vibrations of polyatomic molecules	Predissociation	Raman investigation of phase transitions	Double resonance technique
S-6	SLO-1	Classification of molecules based on moment of inertia	Normal vibrations of CO_2 and H_2O molecules	Electronic absorption spectra	Resonance Raman scattering	NMR imaging
	SLO-2	Rotational spectra of rigid diatomic	Interpretation of IR spectra	Electronic angular momentum in diatomic	Surface enhanced Raman scattering	Fourier transform NMR techniques

		molecules		*molecules*		
S-7	SLO-1	*Rigid rotator*	*Group frequencies and various regions in IR spectrum*	*Dissipation of energy by excited molecule*	*Non-linear Raman phenomena-preliminaries*	*^{13}C NMR*
	SLO-2	*Isotope effect in rotational spectra, Intensity of rotational lines*	*Perturbation of group frequencies: mass effects*	*Jablonski diagram*	*Hyper Raman effect*	*Electron spin resonance*
S-8	SLO-1	*Non-rigid rotator*	*Perturbation of group frequencies: inductive effects*	*Phosphorescene*	*Stimulated Raman scattering*	*Resonance condition in Electron spin resonance (ESR)*
	SLO-2	*Vibrational excitation effect and Λ doubling*	*Fourier transform infrared spectroscopy: principle and interferometer arrangement*	*Fluorescence*	*Inverse Raman effect*	*ESR spectrometer*
S-9	SLO-1	*Microwave spectrometer*	*Elucidation of molecular structure using IR spectroscopy*	*Photoelectron spectroscopy: principle*	*Coherent Antistokes Raman scattering*	*Nuclear- electron spin coupling*
	SLO-2	*Applications of rotational spectroscopy*	*Identification of molecular constituents using IR spectroscopy*	*Photoelectron spectroscopy: instrumentation*	*Photo acoustic Raman scattering*	*Applications of ESR spectroscopy*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember / Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply / Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate / Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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

Course Code	18NTE304T	Course Name	NANOTRIBOLOGY	Course Category	E	Professional Elective Course	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Acquire knowledge on nanotribology			
CLR-2 :	Understand lubrication and related theories			
CLR-3 :	Gain insight on surfaces forces and its measurement techniques			
CLR-4 :	Know about mechanisms involved in tribology related mechanical properties			
CLR-5 :	Enhance the knowledge on friction and wear and their importance			
CLR-6 :	Attain knowledge on tribological applications in day to day life			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Strong knowledge in the basic tribological concepts required for nanotechnology	2	80	75	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	Identify, formulate, and solve engineering problem of interacting surfaces in relative motion	2	80	70	H	M	M	H	M	M	M	H	M	M	M	H	M	M	M
CLO-3 :	Emphasize the knowledge of scientific disciplines in understanding tribological phenomenon	2	75	70	H	M	H	H	H	H	H	M	H	H	H	M	H	H	H
CLO-4 :	Realize the significance of lubrication, friction and wear	2	80	75	H	H	M	M	M	H	H	H	H	M	M	H	H	H	M
CLO-5 :	Familiar in the importance of modifying surface properties	2	80	70	H	M	H	H	H	M	M	H	M	H	M	H	M	M	H
CLO-6 :	Utilize nanotribological principles for any applications	2	80	75	H	M	M	H	H	M	M	H	H	H	M	M	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	History of tribology-origin	Surface Forces	Lubrication	Scale Effects in Mechanical Properties	Applications of Tribology
	SLO-2	Significance of micro/nanotribology	Methods used to study surface forces	Lubricant States	Nomenclature	Introduction to various tribological phenomenon
S-2	SLO-1	Tribology in design-Methods of solution of tribological problems	Force laws	Viscosity of lubricant	Yield strength and Hardness	Bio-Tribology
	SLO-2	Purpose of lubrication	Surface force apparatus (SFA)	Fluid film lubrication	Shear strength at the interface	Tribology in the human body
S-3	SLO-1	Modes of lubrication- hydrodynamic	Force between dry surface	Theories of hydrodynamics lubrication	Scale dependence on surface roughness and contact parameters	Tribology in the artificial organs
	SLO-2	Hydrostaticlubrication	Force between surfaces in liquid	Lubrication design of typical mechanical elements	Dependence of contact parameters on load	Tribology in medical devices
S-4	SLO-1	Boundary lubrication	Adhesion	Transformation	Scale effects in friction	Natural human synovial joints
	SLO-2	Elastohydrodynamic lubrication	Capillary forces	Parameter of surface topography	Adhesion Friction	Total joint replacements
S-5	SLO-1	Extreme pressure lubrication	Modes of deformation	Friction- Basic laws of friction	Two body deformation	Wind turbine Tribology
	SLO-2	Lubricants - types and lubricating oils	Description of AFM/FFM	Static and kinetic friction	Three body deformation	Biorefining
S-6	SLO-1	Lubricant properties-effect of temperature and pressure	Other measurement techniques	Friction of materials	Ratchet mechanism	Coating applications- sliding bearings
	SLO-2	Oxidation stability	Surface roughness	Solid – solid contact	Meniscus Analysis	Rolling contact
S-7	SLO-1	Thermal conductivity	Friction force	Liquid mediated contact	Total value of coefficient of friction	Bearings

	SLO-2	*Type of additives*	*Scratching*	*Interfacing temperature of sliding Surfaces*	*Transformation from elastic to plastic regime*	*Gears*
S-8	SLO-1	*Bearings- classification based on mode of lubrication*	*Wear and machining*	*Wear-Laws of wear*	*Tribological properties of SAMs*	*Erosion and scratch resistant*
	SLO-2	*Bearing-Classification based on relative motion between contact surfaces*	*Surface potential measurements*	*Mild and Severe wear*	*Tailoring surfaces*	*Magnetic recording devices*
S-9	SLO-1	*Comparison of sliding and rolling contact bearing*	*Nanoindentation measurement*	*Identification of wear mechanism,*	*Modifying surface composition for application in Tribology*	*Micro components*
	SLO-2	*Solving numerical problems on above topics*	*Boundary lubrication*	*Typical test geometries*	*Modifying Structurefor application in Tribology*	*MEMS/NEMS*

Learning Resources	1. *G. Phakatkar and R.R. Ghorpade, "Tribology", Nirali publication, 2009* 2. *Bharat Bhushan, "Nanotribology and Nanomechanics", Springer Publication, Second edition,2011* 3. *Bharat Bhushan," Principles and Applications to Tribology", Wiley Publication, 2013*	4. *S. M. Sze, "Semiconductor Sensors", Wiley-Interscience,1994* 5. *C. Mathew Mate, "Tribology on the Small Scale" Oxford University Press, 2008* 6. *Nicholas D. Spencer, "Tailoring surfaces", World Scientific IISC Press, 2011*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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

Course Code	18NTE305T	Course Name	NANOTECHNOLOGY LEGAL ASPECTS	Course Category	E	Professional Elective Course	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Familiarize with the concept of patent and copyright laws			
CLR-2 :	Understand the concept of trade mark, trade secret and IP infringement			
CLR-3 :	Understand the government policies and rules related to nanotechnology			
CLR-4 :	Gain knowledge on environmental degradation and current regulations			
CLR-5 :	Learn the social and ethical impact of nanotechnology			
CLR-6 :	Understand the concept of taxation, trade, security, privacy, export import of nanomaterials			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Acquire the concepts of patent and copyright laws	2	80	75	H	M	H	M	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	Apply the knowledge of trade mark, trade secret and IP infringement	2	75	70	M	M	M	M	M	M	M	H	M	H	M	H	M	M	M
CLO-3 :	Get familiarize with the government policies and rules related to nanotechnology	2	75	70	M	M	H	H	H	H	H	M	H	H	H	H	M	H	H
CLO-4 :	Acquire the knowledge on environmental degradation and current regulations	2	80	75	M	H	M	M	H	H	H	H	H	H	M	H	M	M	H
CLO-5 :	Get familiarize with the current social and ethical impact of nanotechnology	2	80	75	M	M	M	M	H	M	M	H	M	H	M	H	H	M	H
CLO-6 :	Apply the knowledgeof taxation, trade, security, privacy, export import of nanomaterials	2	80	75	H	M	M	H	H	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction	Government policies and rules	Environmental degradation	Social impact of nanotechnology	Trade and business in nanotechnology
	SLO-2	Patents	Quality of information	Current environmental regulations	Economic impact of nanotechnology	Trade restrictions
S-2	SLO-1	Patentability requirements – structure of patent	Food and drugs evaluation method	Classification	Implications of nanotechnology	Taxation system
	SLO-2	Utility patent	Food and drugs research	Sources of pollutants	Effect on the quality of life	Taxation of goods too small to be seen
S-3	SLO-1	Design patent, monopoly powers	Classification of medical products	Pollution – air	Short term implications	Laws for genetic research
	SLO-2	licensing strategies and arrangements	Safe workplace	Pollution – water	Long term implications	Rights of new life form
S-4	SLO-1	Classification of patent applications	Self-regulation	Industrial waste water	Ethical issues in nanotechnology	Government surveillance
	SLO-2	Willful infringement issues, claim scope	Liability – responsibility of a scientist	Control and quality check	Social and environmental issues in nanotechnology	Privacy violations
S-5	SLO-1	Reexamination of patents	Civil laws	Dispersion methods	Artificial intellects	Security and monitoring
	SLO-2	Patent treaties	Criminal laws in nanotechnology	Monitoring	Ethics for artificial intellects	Eavesdropping
S-6	SLO-1	Copyright laws – fixation	Negligence to nanotechnology – breach of duty causation	Solid waste – homes	Nanotechnology and life extension	R&D in Nanotechnology
	SLO-2	Originality, creativity	Negligence to nanotechnology – damage and defense	Solid waste – industrial	Nanotechnology for national security	R&D regulation
S-7	SLO-1	Integrated circuit topographies	Risk associated with nanoparticles	Hospital waste	Nanotechnology for space exploration	Current industrial design laws
	SLO-2	Industrial designs, artistic work –	Nanoparticles use and effects on health	Hazardous chemical waste	Nanotechnology for medical applications	Change in industrial design laws

		arrangement of atoms				
S-8	SLO-1	*Technology transfer*	*Liability for nanoparticles side effects*	*Toxicity, health issues*	*Moral issues of Nanotechnology applications*	*Export – import regulations*
	SLO-2	*Trademarks*	*Role and responsibilities*	*Safety issues*	*Public perception of Nano-technological risk*	*Crimes using Nanoparticles*
S-9	SLO-1	*Trade secrets*	*Class action*	*Risk assessment and analysis*	*Education of public about Nanotechnology*	*Corporate criminal liability,*
	SLO-2	*Ownership of IP*	*Certification*	*Responsibility and rules*	*Training of public about Nanomaterials*	*prevention and detention*

Learning Resources	1. *Patrick M. Boucher, "Nanotechnology: Legal aspects" CRC press, 2008* 2. *Fritz Allhoff, Patrick Lin, James Moor, John Weckert, "NanoEthics: The ethical and social implications of nanotechnology" Wiley publication, 2007*	3. *Louis Theodore, Robert G. Kunz, "Nanotechnology: Environmental implications and solutions" Wiley Publication, 2005*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	*2. Prof. D. Arivuoli, Anna University, arivuoli@annauniv.edu*	*2. Dr. A. Karthigeyan, SRMIST*

Course Code	18NTE306T	Course Name	LITHOGRAPHIC TECHNIQUES AND FABRICATION	Course Category	E	*Professional Elective Course*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning		
		1	2	3
CLR-1 :	*Understand the physical significance of lithography tools in micro/nano structures creation*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-2 :	*Acquire knowledge on masked lithography, uv and deep uv lithography, its merits and demerits*			
CLR-3 :	*Understand the concept of direct lithography, its advantages; electron beam for lithography and their applications*			
CLR-4 :	*Acquiring comparative knowledge of different lithography tools*			
CLR-5 :	*Acquire knowledge on the replication tools such as nano imprint lithography, injection molding and others.*			
CLR-6 :	*Make aware of VLSI technology*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Make use of top-down approach for micro/nano fabrication*	2	80	75	H	M	H	H	H	M	M	H	H	H	M	M	H	H	H
CLO-2 :	*Analyze the limitation of masked lithography with respect to incident radiation*	2	80	70	H	M	M	H	M	M	M	H	M	H	M	H	M	M	M
CLO-3 :	*Using electron beams for the creation of nano structures*	2	75	70	H	M	H	H	H	H	H	M	H	H	H	M	H	H	H
CLO-4 :	*Know the other techniques of nano fabrication using light and heavy ion beams*	2	80	75	M	H	H	M	H	H	H	H	H	H	M	M	H	H	H
CLO-5 :	*Apply knowledge of mass production replication tools*	2	80	70	H	M	H	H	H	M	M	H	M	H	M	M	H	H	H
CLO-6 :	*Imagine importance of nanoscale devices*	2	80	75	H	M	M	H	H	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Micro/nano fabrication*	*Optical(photo) lithography*	*Introduction-maskless/direct lithography tools*	*Ion beam lithography (IBL) types*	*Micro/ Nano replication tools*
	SLO-2	*Top-down & bottom-up approach*	*Process steps*	*Difference between masked and maskless lithography*	*Heavy and light ions for lithography*	*Necessity for replication*
S-2	SLO-1	*Necessity for clean room, types of clean room*	*Optical lithography mask*	*Advantages and disadvantages of maskless lithography*	*Focused ion beam properties*	*Application areas-MEMS/NEMS, micro/nanofluidics*
	SLO-2	*Construction and maintenance of clean room,*	*Mask definition, and different materials*	*Principles of electron beam lithography (EBL) system*	*Beam scanning*	*Soft lithography*
S-3	SLO-1	*Clean room standards, protocols*	*Different light sources*	*Electron properties for lithography*	*Resists for ion beam lithography*	*PDMS Casting*
	SLO-2	*Lithography- process steps*	*Contact and proximity exposures*	*Design of electron beam lithography system*	*Electron lithography process flow*	*Mold fabrication for soft lithography*
S-4	SLO-1	*Photo resists materials, types and characteristics*	*Diffraction limit and resolutions enhancement methods*	*Operation of electron beam lithography system*	*Focused ion beam lithography- Incident ion properties*	*Micro injection molding*
	SLO-2	*Spin coating methods*	*Projection lithography*	*E-beam resists*	*Principle, design and operation*	*Hot embossing*
S-5	SLO-1	*Exposure dose*	*Extreme UV (EUV) lithography*	*E-beam resist properties*	*Masked ion beam structuring: Broad beam patterning*	*Nano imprint lithography NIL principles*
	SLO-2	*chemical development, optimization*	*EUV: Scope and demerits*	*Comparison with optical lithography resists*	*Atom lithography*	*Mold fabrication for hot embossing and NIL*
S-6	SLO-1	*Etching methods, resist and other*	*Interferometric and holographic tools*	*Dose calculation*	*Proton beam lithography*	*Mold fabrication for injection molding*

		materials				
	SLO-2	*Dry and wet methods*	*Lithography masks*	*Significance of beam blanking*	*Comparison of electron, proton and gallium for resist patterning*	*Process flow and requirements*
S-7	SLO-1	*Wet etching chemicals, Si etching*	*Laser writer: near UV and Deep UV masks*	*Patterning resolution comparison with other methods*	*Limitation and suitability of each technique in comparison with one another*	*Polymers for imprinting*
	SLO-2	*Wet etching examples*	*Synchrotron radiation for lithography processes*	*EBL for mask preparation*	*IBL resists, dose calculation and process optimization*	*Polymer characteristics and performance*
S-8	SLO-1	*Reactive ion etching*	*X-ray lithography mask*	*Nanofabrication with EBL – MEMS*	*Nanofabrication with IBL – MEMS*	*Master mold preparation for replication tools, comparison*
	SLO-2	*Isotropic and non isotropic etching*	*X-ray lithography, merits and demerits*	*Nanofabrication with EBL – NEMS*	*Nanofabrication with IBL – NEMS*	*Application-microfluidics*
S-9	SLO-1	*Types of lithography : classification*	*Comparison of all masked lithography tools*	*Nanofabrication with EBL –microfluidics applications*	*Nanofabrication with IBL –microfluidics applications*	*Application-nano fluidics*
	SLO-2	*Introduction to next generation lithography tools*	*Specific applications of different lithography tools.*	*Nanofabrication with EBL – Nanofluidics applications*	*Nanofabrication with IBL – Nanofluidics applications*	*Industrial applications*

Learning Resources	1. *Chris A. Mack, Fundamental Principles of Optical Lithography: The Science of Microfabrication, John Wiley & Sons, London 2007*	2. *Stefan Landis, "Lithography and nanolithography", Published by Wiley - ISTE, 2010*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Course Code	18NTE307T	Course Name	SENSORS AND TRANSDUCERS	Course Category	E	Professional Elective Course	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Understand basic principles and characteristics of sensors and transducers			
CLR-2 :	Gain knowledge on mechanical and electromechanical sensors			
CLR-3 :	Get acquainted with thermal sensors and its types			
CLR-4 :	Know about magnetic sensors and radiation sensors			
CLR-5 :	Gain knowledge on electrochemical sensors			
CLR-6 :	Apprehend knowledge on recent trends in sensor technologies and applications			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Analyze calibration techniques and signal types of sensors	2	80	75	H	M	H	H	H	M	M	H	H	H	M	M	H	H	H
CLO-2 :	Expertise in various types of Sensors & Transducers and their working principles	2	80	70	H	M	M	H	M	M	M	H	M	H	M	M	M	M	M
CLO-3 :	Evaluate performance characteristics of different sensors and transducers	2	75	70	H	M	H	H	H	H	H	M	H	H	H	M	H	H	H
CLO-4 :	Predict exactly the expected performance of various sensors	2	80	75	M	H	H	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Develop advance techniques in sensor technology	2	80	70	H	M	H	H	H	M	M	H	M	H	M	H	H	H	H
CLO-6 :	Devise smart sensors for real time applications	2	80	75	H	M	M	H	H	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Measurements-Basic method of measurement	Mechanical and electromechanical sensors Resistive potentiometer	Thermal sensors- Gas thermometric sensors	Magnetic sensors-Introduction	Electroanalytical sensors-introduction
	SLO-2	Errors	Strain gauge	Thermal expansion type thermometric sensors	Principles behind	Electrochemical cell
S-2	SLO-1	Classification of errors	Inductive sensors	Acoustic temperature sensor	Yoke coil sensors	Sensor electrodes-Molecular selective electrodes
	SLO-2	Error analysis	Sensitivity and linearity of sensor	Dielectric constant and refractive index of thermosensors	Coaxial type sensors-Force and displacement sensors	ChemFET
S-3	SLO-1	Statistical methods	Ferromagnetic plunger type transducers	Helium low temperature thermometer-Nuclear thermometer	Magnetoresistive sensors- Anisotropic magnetoresistive sensing	Recent trends in sensor technologies
	SLO-2	Sensors/Transducers-Introduction	Electromagnetic transducer	Magnetic thermometer	Semiconductor magnetoresistors	Film sensors- Thick and thin film sensors
S-4	SLO-1	Principles of Sensors/Transducers	Magnetostrictive transducer	Resistance change type thermometric sensors	Active semiconductor magnetic sensors	Semiconductor IC technology
	SLO-2	Classification of Sensors/Transducers	Capacitive sensors	Metal resistance thermometric sensors	Hall effect sensor-sensor geometry and fabrication	Micro electro mechanical system (MEMS)-micromachining
S-5	SLO-1	Static Characteristics of Sensors/Transducers	Parallel plate capacitive sensor	Thermistors	Variable inductance sensors	Some application examples
	SLO-2	Accuracy-Precision-Resolution-Minimum	Serrated plate capacitive sensor	Thermo emf sensors	Eddy current sensors	Nanosensors

		detectable signal				
S-6	SLO-1	*Threshold-Sensitivity-Selectivity and specificity-Non-linearity*	*Variable thickness dielectric capacitive sensor*	*Materials for thermo emf sensors*	*Radiation sensors-Introduction-basic characteristics*	*Onboard automobile sensors-flow rate sensors-pressure sensors*
	SLO-2	*Hysteresis-Output impedance-isolation and grounding*	*Stretched diaphragm variable capacitance transducer*	*E (emf)-T(Temperature) relations*	*Types of photoresistors/photodetectors*	*Temperature sensors-oxygen sensors*
S-7	SLO-1	*Dynamic Characteristics*	*Electrostatic transducer*	*Thermosensors using semiconductor devices*	*Photoemissive cell and photomutliplier*	*Torque and position sensors*
	SLO-2	*Zero order and First order sensors*	*Piezoelectric elements*	*Thermal radiation sensors*	*Photoconductive cell-LDR*	*Home appliance sensors*
S-8	SLO-1	*Second order sensors*	*Piezoelectric materials*	*Detectors*	*Photocurrent*	*Aerospace sensors-Fluid velocity sensors*
	SLO-2	*Electrical characterization*	*Deformation modes and multimorphs*	*Pyroelectric thermal sensors*	*Photoresistors and photoFETs and other devices*	*Sensing direction of air flow- Monitoring strain, force, thrust and acceleration*
S-9	SLO-1	*Mechanical and thermal characterization*	*Lead zirconatetitanate (PZT) family*	*Quartz crystal thermoelectric sensors*	*Fibre optic sensors*	*Medical diagnostic sensors*
	SLO-2	*Optical characterization-Chemical/biological characterization*	*Force/stress sensors using quartz resonators*	*Heat flux sensors*	*Temperature sensors-microbend sensors*	*Sensors for environmental monitoring*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr.Shyam Sunder Tiwari, Sensors technology Private Limited, India, sst@sensorstechnology.com	*2. Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*2. Dr. A. Karthigeyan, SRMIST*

Course Code	18NTE308T	Course Name	2-D LAYERED NANOMATERIALS	Course Category	E	*Professional Elective Course*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Understanding the electronic properties of 2D materials, especially Graphene*			
CLR-2 :	*Acquire knowledge on the different synthesis methods*			
CLR-3 :	*Describe the difference in various properties of 2D-layered structure*			
CLR-4 :	*Classification of 2D layered Nanomaterials*			
CLR-5 :	*Gain knowledge on application of layered Nanomaterials*			
CLR-6:	*Understand the principles of various characterization tools to study the properties of 2D materials*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Apply the concept of atomic and electronic structure to understand the physical and chemical properties of graphene*	*2*	*80*	*75*	*M*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Utilize the procedure to synthesize layered materials and the concept of Raman spectra over synthesized materials*	*2*	*80*	*70*	*M*	*H*	*M*	*H*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Utilize the spectroscopic concepts to analyze the properties of layered materials*	*2*	*75*	*70*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*H*
CLO-4 :	*Apply the concept and the uses of semiconducting and metal dichalcogenides based materials*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-5 :	*Utilize the application of layered materials in various fields.*	*2*	*80*	*70*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6:	*Utilize the concept of sensor to analyze the material nature.*	*2*	*80*	*75*	*M*	*H*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction of graphene*	*Introduction to Scotch-tape method (micromechanical cleavage)*	*Introduction to X-ray photoemission spectroscopy*	*Graphene and its properties*	*Introduction to Gas sensors*
	SLO-2	*Vander Walls force*	*Preparation of graphene using Scotch-tape method*	*Limitation and application of XPS*	*Penta-graphene and its properties*	*Gas sensing mechanism and types of sensor*
S-2	SLO-1	*Covalent bond*	*Introduction and principle of Chemical vapor deposition*	*Introduction to X-ray diffraction study*	*h-BN structure, synthesis and properties*	*Chemical sensors*
	SLO-2	*Dimension of carbon allotrope*	*Preparation of graphene by CVD*	*Limitation and application of XRD*	*Application of h-BN*	*Uses smart materials in sensors*
S-3	SLO-1	*Transition of metal dichalcogenides*	*Introduction to Solution-exfoliation*	*Introduction to Optical absorption spectroscopy*	*SiC structure, synthesis and properties*	*2D materials based membranes*
	SLO-2	*Manipulation of quantum degree of freedom*	*Preparation of graphene using solution-exfoliation*	*Limitation and application of optical absorption spectroscopy*	*Application of SiC*	*Application of membrance*
S-4	SLO-1	*Crystal plane of 2D graphene*	*Introduction to Solution-exfoliation*	*Introduction and limitations of Scanning Tunneling Microscopy*	*Si structure, synthesis and properties*	*Oxygen reduction reaction*
	SLO-2	*Free standing model*	*Preparation of 2D layered material by solution exfoliation*	*Measuring mechanical properties*	*Application of Silicon*	*Uses of 2D materials in enhance the activity*
S-5	SLO-1	*Electronic structure of graphene*	*Decomposition*	*Introduction and limitations to BET analysis*	*Ge structure, synthesis and properties*	*Hydrogen production, types of hydrogen production*
	SLO-2	*Band structure*	*Decomposition of silicon carbide*	*Adsorption properties*	*Application of Ge*	*Uses of 2D materials in hydrogen*

						production
S-6	SLO-1	*Fermi levels in graphene*	*Principles of Raman spectroscopy*	*Introduction and limitations to VSM analysis*	*Types of oxide materials*	*Electronic devices*
	SLO-2	*Carrier density*	*Limitations of Raman spectroscopy*	*Magnetic properties*	*Properties of oxide materials*	*Difference between electronic and electric device*
S-7	SLO-1	*Role of defect and dopant*	*Raman spectrum of graphene*	*Types of interactions*	*Introduction and types of transition metal dichalcogenides*	*Optical materials*
	SLO-2	*Electronic structure of graphene*	*Analysis of D band Raman spectra*	*Catalytic properties*	*Introduction and application of MoS_2*	*Solar absorber materials*
S-8	SLO-1	*Tensile strength*	*Analysis of G band Raman spectra*	*Metal support interactions*	*Introduction and application of VS_2*	*Magnetic devices*
	SLO-2	*Physical properties of graphene*	*Raman shift dependence on number of layer*	*Changes in the properties due to metal support interaction*	*Introduction and application of WS_2*	*Materials used*
S-9	SLO-1	*Functional properties of graphene*	*Raman shift dependence on defect*	*Non-metal support interactions*	*Introduction of Si2BN and its application*	*Types of magnetic devices*
	SLO-2	*Chemical properties of graphene*	*Raman shift dependence on doping concentration*	*Difference in properties due to non-metal support interactions*	*Introduction of BCN and its applications*	*Applications of magnetic devices*

Learning Resources	1. *Houssa, Michel, Athanasios Dimoulas, and Alessandro Molle, "2D Materials for Nanoelectronics"- CRC Press, 2016.* 2. *Banks, Craig E., and Dale AC Brownson, eds. "2D Materials: Characterization, Production and Applications"- CRC Press, 2018.*	3. *Tiwari, Ashutosh, and Mikael Syväjärvi, eds. "Advanced 2D Materials" - John Wiley & Sons, 2016.* 4. *Dragoman, Mircea, and Daniela Dragoman,"2D Nanoelectronics: Physics and Devices of Atomically Thin Materials"- Springer, 2016.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Course Code	18NTE309T	Course Name	SUPRAMOLECULAR SYSTEMS	Course Category	E	*Professional Elective Course*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Acquire the concepts of supramolecular chemistry*			
CLR-2 :	*Utilize designing new materials of metal-organic frame works*			
CLR-3 :	*Describe the concept of nanostructured objects*			
CLR-4 :	*Understand the principles of supramolecular chirality*			
CLR-5 :	*Gain knowledge on host-guest complexes*			
CLR-6 :	*Understand the principles sophisticated molecular devices and infinite multicomponent systems*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Recognize the main types of supramolecular assemblies*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Apply the importance of the bottom-up approach to prepare complex (nanoscale) systems*	*2*	*80*	*70*	*H*	*M*	*M*	*M*	*M*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Identify the main supramolecular forces involved in such systems*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*
CLO-4 :	*Analyze and understand the intermolecular forces to rationalize the formation of complex nanomaterials.*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-5 :	*Evaluate the needs of sustainable future, develop the supramolecular molecular materials for biological systems*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*M*	*H*	*H*	*H*
CLO-6 :	*Apply through feasible approaches, and assemble with the prior knowledge to fabricate novel designs/architectures*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*M*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Basic concepts and principles of supramolecular chemistry*	*Introduction to coordination chemistry*	*Biological inspiration for supramolecular chemistry*	*Supramolecular Chirality*	*Special Class Materials*
	SLO-2	*Classification of supramolecular compounds*	*Hosts for cation binding*	*Alkali metal cations in biochemistry*	*Chirality in Self-Assembled Systems*	*Birth of a new macromolecular chemistry concept*
S-2	SLO-1	*Host-guest compounds*	*Cation receptors*	*Co-ordination Polymers*	*Chirality of Host-Guest Compounds*	*Rational Design*
	SLO-2	*Receptors, coordination compounds*	*Crown ethers*	*Clathrates*	*Chirality of Interlocked Systems*	*Molecular Paneling*
S-3	SLO-1	*Lock and key analogy*	*Cryptands*	*Cavitands*	*Metal Organic Frameworks (MOFs)*	*Artifical Self Replicating Systems*
	SLO-2	*Binding constants*	*Spherands*	*Binding by cavitands*	*Covalent Organic Frameworks*	*Supramolecular reactivity and catalysis*
S-4	SLO-1	*Cooperative effect*	*Calixarens*	*Cyclodextrins*	*Polymorphism*	*The past, present and future of dendrimers and dendrons*
	SLO-2	*Chelate effect*	*Selectivity of cation complex*	*Cucurbituril*	*Solvates*	*Supramolecular assembly of dendrons and dendrimers*
S-5	SLO-1	*Thermodynamic selectivity*	*Macrocyclic effects*	*Porphyrins and tetrapyrrole macrocyles*	*Co-Crystals*	*Synthesis of dendritic polymers*
	SLO-2	*Kinetic selectivity and discriminations*	*Template effects*	*Transport processes*	*Principles of supramolecular Extraction*	*Characterization of dendritic architectural structures*
S-6	SLO-1	*Nature of supramolecular interactions*	*Host for anion binding*	*Dynamic Combinatorial chemistry*	*Extraction technique, the extraction equilibrium*	*Nanomedical and advanced materials*
	SLO-2	*Solvation effects*	*Concepts in anion host design*	*Supramolecular features of plant*	*Examples of supramolecular extraction*	*Diagnostics and advanced imaging*

				photosynthesis		
S-7	SLO-1	*Hydrophobic effects*	*Anion receptors*	*Uptake and transport of oxygen by haemoglobin*	*Binding Constant*	*Characterization of dendritic architectural structures*
	SLO-2	*Supramolecular concepts and design*	*Shape and selectivity*	*Enzymes and coenzymes*	*Binding constant determination by UV/Vis spectroscopy*	*Nanoscience applications*
S-8	SLO-1	*Hydrogen bonding and supramolecular interactions*	*Neutral receptors*	*Neurotransmitters and hormones*	*Instrumentation of mass spectrometry, Limitations of mass spectrometry*	*Molecular and Supramolecular devices*
	SLO-2	*Secondary Electrostatic Interactions in Hydrogen Bonding*	*From cation host to anion host – a simple change in pH*	*Enzymes, Metallobiosites*	*Scanning probe microscopes: - scanning electron microscopy*	*Molecular Electronic Devices*
S-9	SLO-1	*Molecular recognition*	*Hosts for binding of neutral guests*	*Heme analogues*	*Transmission electron microscopy*	*Switches*
	SLO-2	*Types of recognition*	*Inert metal- containing receptors*	*Semiochemistry in natural world, Biochemical self-assembly*	*Confocal laser scanning microscopy*	*Molecular Machines*

Learning Resources	*1. Jonathan W. Steed and Jerry L. Atwood, "Supramolecular Chemistry"J. Wiley and Sons; 1st Ed. 2000* *2. J.M. Lehn, Supramolecular Chemistry, VCH, Wiley and Sons, 1st Ed. Weinheim, 1995*	*3. Donald A. Tomalia, Jørn B. Christensen, Ulrik Boas, "Dendrimers, Dendrons, and Dendritic Polymers: Discovery, Applications and the Future", MPG books group, UK, 2012*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Course Code	18NTE310T	Course Name	MEMS and NEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Learn what are MEMS? and where they are useful?*			
CLR-2 :	*Understand the basics of fabrication of electromechanical systems at micro and nanoscale and modeling*			
CLR-3 :	*Understand the principles of sensing and actuation in electromechanical systems*			
CLR-4 :	*Explore magnetic materials for suitable for magnetic MEMS*			
CLR-5 :	*Gain knowledge on thermal, micro-opto-MEMS materials*			
CLR-6 :	*Acquire knowledge on the fabrication, characterization and applications of RF, optical, MEMS Understand the*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Utilize mechanics principles to analyze the mechanical performance of microsystems.*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Utilize optics, electrical and mechanical principles to analyze optoelectro mechanical performance of MOEMS*	*2*	*80*	*70*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Use the radio frequency and thermal principles to analyze the performance of RF and thermal MEMS*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*
CLO-4 :	*Use magnetic and fluid principles to analyze the performance of magnetic MEMS and microfluidic devices*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-5 :	*Analyze the tools and processes used in micromaching of MEMS*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6 :	*Apply the principles of physics to analyze and design MEMS, including sensors and actuators.*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Micro and nanoelectro mechanical systems (MEMS and NEMS)*	*Photolithography*	*Principles of sensing and actuation*	*Magnetic materials: properties,*	*Principles of MOEMS technology, Applications*
	SLO-2	*Importance of MEMS in daily life*	*Surface machining, bulk machining, etching*	*Role of microsensors and microactuator with examples*	*Magnetoresistive materials, magnetostrictive materials,*	*Hybrid systems, application, advantages*
S-2	SLO-1	*MEMS and NEMS - Scaling Laws*	*Structural materials*	*Components of mechanical MEMS*	*hard magnetic materials, design considerations in magnetic materials*	*MOEMS components*
	SLO-2	*Conventional electromechanical systems*	*Sacrificial materials*	*Beam, cantilever, microplates*	*Magnetic sensing and design*	*Light modulators, beam splitters, Micro lens,*
S-3	SLO-1	*Mathematical Modeling*	*Thin film deposition, Impurity doping, etching*	*diaphragm structures theory, corrugated diaphragms*	*Presence and direction detection of large object – an example*	*micro mirror, digital micromirror device*
	SLO-2	*Important steps for analysis and design of engineering steps*	*Bulk and surface micromachining*	*Components in sensors*	*Magneto resistive sensor*	*MOEMS devices*
S-4	SLO-1	*Microsensors and microactuators*	*Physical and chemical vapor deposition methods,*	*Capacitive effects, piezo element, piezo mechanics,*	*Principle of magnetoresistive sensor, hall effect, magntrotransitor*	*Optical switch, wave guide and tuning,*
	SLO-2	*Principle of sensing and actuation, capacitive sensors, pressure sensors*	*P and N-type doping in semiconductors, surface machining at macro and microscales.*	*Measurement methods*	*MEMS magnetic sensors and actuators*	*shear stress measurement*
S-5	SLO-1	*Mechanical MEMS, Thermal MEMS*	*Wafer bonding and LIGA, MEMS*	*Strain measurement, pressure*	*Construction of a MEMS magnetic sensor,*	*Lab-on-a-chip, Important considerations on*

			Assembling and Packaging	*measurement*	*principle of operation, sensitivity of the sensor*	*microscale fluid*
	SLO-2	*Strain measurement*	*Anodic bonding, fusion bonding, Lithography, electroforming and molding.*	*Flow measurement using integrated paddle-cantilever structure*	*Review of RF based Communication syste-I*	*Properties of fluids, density, viscosity, nature of flow, surface tension*
S-6	SLO-1	*MEMS gyroscope, Inchworm technology*	*Basic Modeling elements in mechanical and electrical systems*	*MEMS Gyroscopes*	*Tuners, resonators, switches,*	*Fluid actuation methods,*
	SLO-2	*Thermistors, thermal flow sensors, shape memory alloys*	*Ampler element, mass/inertia element, capacitor, resistor and inductor*	*Shear mode MEMS, principle*	*phase shifters, RF MEMS application area, advantages*	*Dilectrophoresis, electrowetting*
S-7	SLO-1	*MOEMS, Magnetic MEMS, NEMS Architectures*	*Basic Modeling elements in fluid systems*	*Compensation in gyroscope, gripping piezoactuator, design and working principle,*	*Review of RF based Communication system-II*	*Electrothermal flow*
	SLO-2	*Properties of light and their exploitation with respective to MOEMS*	*Inertance, fluid resistance, fluid capacitor*	*Inchworm technology, principle, controlling signal*	*Design scenarios, planer inductor*	*Thermo capillary effect*
S-8	SLO-1	*optical switching, beam splitters and microlenses*	*Thermal systems modeling*	*Thermal sensors and actuators*	*RF MEMS, varactors, tuner/filter*	*Electroosmosis flow*
	SLO-2	*Introduction to RF Communication systems and applications.*	*Thermal capacitance, thermal resistance*	*Thermal energy basics and heat transfer processes,*	*Fabrication process, varactors,*	*Optoelectrowetting*
S-9	SLO-1	*Varactors, RF tuners, filters, switches, phase shifters*	*Translational and rotational pure mechanical systems with spring*	*thermistors, thermocouple, Thermal actuators*	*Tuner/filter, resonator, Resonators*	*Micropumps: design consideration, Microneedle,*
	SLO-2	*Microfluidic systems, Concept of lab-on-a-chip, properties of fluids*	*damper and mass*	*Thermodevices, micromachine thermocouple probe, thermal flow sensors*	*Switches, Phase shifter*	*Construction of a micropump, modeling, working principle*

Learning Resources	*1. Mahalik N P, "MEMS", Tata McGraw-Hill Education, 2008* *2. Sergey Edward Lyshevski, "Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering", CRC Press, 2005*	*3. C. T. Leondes, MEMS/NEMS Handbook Techniques and Applications, Vol. 1, Sringer, 2006.* *4. Mohamed Gad-el-Hak, MEMS- Introduction and Fundamentals, 2nd Edition, Taylor and Francis Group, LLC, 2006.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember / Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply / Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate / Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Hemant Dixit, GlobalFoundaries,USA, aplahemant@gmail.com	*1. Prof. V. Subramaniam, IITM, Chennai, manianvs@iitm.ac.in*	*1. Dr. M. Kiran, SRMIST*
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	*2. Prof. M. Ghanashyam Krishna, UOHYD, mgksp@uohyd.ernet.in*	*2. Dr. A. Karthigeyan, SRMIST*

Course	18NTE311T	Course	SURFACE AND INTERFACES	Course	*E*	*Professional Elective*	L	T	P	C

Code		Name		Category			3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	*Understand why/how surfaces are important in nanotechnology*
CLR-2 :	*Explain various mechanisms involved in surfaces/interfaces and fundamentals of various types of bonding at surfaces/interfaces*
CLR-3 :	*Describe strategies for manipulating the surfaces and how those strategies help them depending upon the application of such modified surface*
CLR-4 :	*Be familiar with property equations and thermodynamic properties of gas-surface interactions along with the concepts of phase equilibrium of multi component systems*
CLR-5 :	*Acquire the knowledge in Adsorption and desorption kinetics*
CLR-6 :	*Equip with surface-analytical tools such as photoemission spectroscopy, Kelvin probe microscopy, spectroscopy ellipsometry and its significances*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Apply the knowledge in surfaces; their structure and physical-chemical properties, and interfaces between solids*	*2*	*85*	*70*	*H*	*M*	*M*	*M*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-2 :	*Analyze a surface reconstruction & anticipate the stability of a given interface.*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*H*
CLO-3 :	*Decide what the necessary (statistical) thermodynamics concepts to describe an interface are.*	*2*	*70*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*M*
CLO-4 :	*Develop qualitative understanding of theories involved and general concepts*	*2*	*75*	*75*	*H*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*H*	*M*	*M*	*L*	*H*	*M*
CLO-5 :	*Validate sound understanding in collective phenomena at the surfaces/interfaces*	*2*	*75*	*70*	*H*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*
CLO-6 :	*Compare different surface characterization techniques in terms of their performance, sample introduction of methods and sensitivity*	*2*	*80*	*75*	*H*	*M*	*M*	*M*	*M*	*M*	*H*	*H*	*M*	*H*	*M*	*H*	*M*	*H*	*M*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Definition of a Surface and an Interface - its importance/significance*	*The Hierarchy of Equilibrium*	*Adsorption and Desorption Kinetics*	*Structure of Surfaces*	*Electronic Properties at the surfaces*
	SLO-2	*Liquids and Liquid Surfaces*	*Thermodynamics of Flat Surfaces and Interfaces*	*Physiosorption and Chemisorption*	*Surface Crystallography*	*Beyond the Surface Selection Rule*
S-2	SLO-1	*Surface Area to Volume Ratio*	*The Interface Free Energy*	*General Issues of Isotherms*	*Surface stress, Surface energy*	*Correlation between Propagation Length and Surface Roughness*
	SLO-2	*Solids and Solid Surface Roughness*	*Surface Excesses*	*Isosters, and Isobars*	*Relaxation, Reconstruction - Defects*	*Many Body effects*
S-3	SLO-1	*Chemical Heterogeneity of Solid Surfaces - Molecular Interactions*	*Charged Surfaces at Constant Potential*	*The Langmuir Isotherm*	*General Aspects of Surface Lattice Dynamics*	*Surface Plasmons*
	SLO-2	*General concepts of Internal Energy and Free Energy*	*Charged Surfaces at Driven potential*	*Lattice Gas with Mean Field Interaction*	*Diffraction at Surfaces - Surface Superlattices*	*Surface Plasmon/phonon Dispersion and Multipole Excitations*
S-4	SLO-1	*Intramolecular Forces: Formation of a Molecule by Chemical Bonding*	*Maxwell Relations*	*The Fowler-Frumkin Isotherm*	*Defects at surfaces/interfaces – line & point defects*	*Electromagnetic Field Enhancement – Conservation laws for atomic collisions*
	SLO-2	*Interatomic forces, bonds - Molecular geometry*	*Their Applications*	*Reduction to the Langmuir Isotherm*	*Vibrational Excitations at Surfaces - Surface Phonons of Solids*	*Empty and image – potential surface states*
S-5	SLO-1	*Dipole moments*	*Solid and Solid interfaces*	*Experimental Determination of the Heat*	*Surface Stress and the Nearest Neighbor*	*Scattering of Light at Rough Surfaces-*

				of Adsorption	*Central Force Model*	*From Nanowires to Quantum Conduction*
	SLO-2	*Intermolecular Forces and Potential Energies*	*Solid-Liquid Interfaces*	*Underpotential Deposition*	*Surface Phonons in the Acoustic Limits*	*Classical limit of particle scattering*
S-6	SLO-1	*Coulomb Interactions*	*Step Line Tension*	*Symmetry of Adsorption Sites -*	*Diffusion at Surfaces*	*Linear Optical Techniques at Surfaces and Interfaces*
	SLO-2	*Polar Interactions*	*Stiffness at its interfaces*	*Vibrational Frequencies of Isolated Adsorbates*	*Observation of Single Atom Diffusion Events-Statistics of Random Walk*	*Spectroscopic Ellipsometry (SE)*
S-7	SLO-1	*van der Waals Interactions*	*Equilibrium Fluctuations of Line Defects and Surfaces*	*Desorption - Desorption Spectroscopy*	*Absolute Rate Theory*	*Reflection Difference Techniques (Surface Differential Reflectivity (SDR)*
	SLO-2	*Induction effects*	*The Terrace-Step-Kink Model - Basic Assumptions and Properties*	*Theory of Desorption Rates*	*Calculation of the Pre-factor*	*Reflection Anisotropy Spectroscopy (RAS))*
S-8	SLO-1	*Collective phenomena at interfaces – Superconductivity*	*Step-Step Interactions on Vicinal Surfaces*	*Specific Adsorption of Ions*	*The Ehrlich-Schwoebel Barrier- The Concept of the Ehrlich-Schwoebel Barrier*	*Probing occupied and unoccupied states - Photoemission spectroscopy, surface states*
	SLO-2	*Superconductivity at interfaces – A simple model for transport through normal-superconductor interface*	*The Ising-Model*	*Specific Adsorption of molecules*	*Mass Transport on Stepped Surfaces*	*General Aspects of inverse photoemission*
S-9	SLO-1	*Collective phenomena at interfaces - Ferromagnetism*	*Application to the Equilibrium Shape of Islands*	*The Chemical Bond of Adsorbates of Hydrogen, Oxygen molecules*	*The Kink Ehrlich-Schwoebel Barrier*	*Work Function changes induced by the adsorbates – 2D phase transition*
	SLO-2	*Ferromagnetism at interfaces- Magnetic layer coupling*	*Simple Solutions for the Problem of Interacting Steps*	*The Chemical Bond of Adsorbates of Water, Hydrocarbons*	*The Atomistic Picture of the Ehrlich-Schwoebel Barrier*	*Kelvin Probe measurements for the study of work-function changes*

Learning Resources	1. *G. Bordo Vladimir and Horst-Günter Rubahn, Optics and Spectroscopy at Surfaces and Interfaces, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim 2005* 2. *Harald Ibach, Physics of Surfaces and Interfaces, Springer-Verlag Berlin Heidelberg 2006* 3. *H. Yıldırım Erbil, Surface Chemistry Of Solid and Liquid Interfaces, First published in 2006 by Blackwell Publishing Ltd, Oxford, UK*	4. *John C. Riviere, Sverre Myhra, Handbook of Surface and Interface Analysis: Methods for Problem-Solving, 2nd Edition, CRC Press Taylor & Francis Group 2009* 5. *Klaus Wandelt, Surface and Interface Science, Volume 6: Solid-Gas Interfaces II, Wiley VCH Verlag, Weinheim, Germany 2015*

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember / Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply / Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate / Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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

Course Code	18NTE312T	Course Name	NANOTECHNOLOGY IN FOOD PRODUCTION	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	Nanotechnology	Data Book / Codes/Standards		Nil	

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Know the various types of interactions at molecular scale			
CLR-2 :	Understand the effect of nanoparticles on agricultural methodology and food technology			
CLR-3 :	Gain knowledge of the types diagnostic tools using nanotechnology			
CLR-4 :	Acquire knowledge about the newer technologies in the food production			
CLR-5 :	Get familiarized with the new concepts of Nano Science in the packaging industries and food production			
CLR-6 :	Know the toxic effect of nanomaterials used in food processing and food technology			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)													
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Apply the concept of interactions with in the supramolecular structures at molecular scale	2	80	75	M	M	H	M	M	H	H	H	H	H	H	H	H	H	H
CLO-2 :	Utilize the assay techniques in agricultural and food diagnostics	2	80	70	M	H	M	M	M	H	H	H	M	H	H	H	M	M	M
CLO-3 :	Apply the concepts of nanotechnology in food products	2	75	70	H	M	M	M	M	H	H	M	H	H	H	H	H	H	H
CLO-4 :	Engineer food ingredients which are capable to improve the bioavailability	2	80	75	H	H	H	M	M	M	H	H	M	H	H	H	H	H	H
CLO-5 :	Select the preferred packaging materials for various food products	2	80	70	M	H	M	M	M	M	M	H	M	H	H	H	H	H	H
CLO-6 :	Assess the toxic effects of the nanomaterials used in the food processing and technology	2	80	75	M	H	M	M	M	M	M	H	M	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Intermolecular interactions and supermolecular structures – Introduction	Nanotechnology in Agriculture and Food diagnostics	Food products and its production – Introduction	Nanotechnology in Crop management - Introduction	Toxicology of Nanomaterials in food - Introduction
	SLO-2	Water - hydrophobic and hydrophilic interactions	Nanodiagnostic approaches in detecting microbial agents	Food and new ways of food production	Crop improvement - reasons to package food products	Characterization of engineered nanomaterials
S-2	SLO-1	dispersion interaction, electrostatic interactions	Biosensors, Enzyme biosensors and diagnostics	Need for new food processing methods	Physical properties of packaging materials	Unique issues for characterization of engineered nanomaterials for food applications
	SLO-2	Atoms and small molecules	DNA-based biosensors and diagnostics	Efficient fractionation of crops	Strength	Safety assessment of oral-exposure engineered nanomaterials for food application
S-3	SLO-1	Polymers, particles, and surfaces	Radiofrequency identification	Efficient product structuring	Barrier properties	Experimental design considerations for toxicology studies
	SLO-2	Introduction to Steric interactions	Integrated nanosensor networks: Detection and Response	Optimizing Nutritional value	light absorption	Life cycle of nanotechnology food products
S-4	SLO-1	Steric interactions involving soluble polymers	Electrochemical biosensors – Gold Nanoparticles	Nanotechnology in Food Production	structuring of interior surfaces	Environmental behavior of nanoparticles - Toxicology of nanoparticles
	SLO-2	Aggregation	Magnetic Nanoparticles in diagnostics	Applications of nanotechnology in foods	Antimicrobial functionality	Molecules in foods involved in triggering allergies

S-5	SLO-1	*Depletion aggregation of particles by non-adsorbing polymers*	*Fluorescent Nanoparticles in diagnostics*	*Sensing, packaging*	*Visual indicators*	*Impact of nanoscale structures on allergenic potential of foods*
	SLO-2	*Bridging aggregation of particles by adsorbing polymers*	*Silica Nanoparticles in diagnostics*	*Encapsulation*	*Quality assessment*	*Toxicokinetics*
S-6	SLO-1	*Stabilization of dispersed particles by adsorbing polymers*	*Safety of nanotechnology in food and the impact in consumer health*	*Nano Engineering food ingredients to improve bioavailability*	*Food safety indication*	*Adme (absorption)*
	SLO-2	*Polymer brushes to prevent particle aggregation and particle deposition at surfaces*	*Transduction Principles*	*Nanocrystalline food ingredients*	*Product properties*	*Adme (distribution)*
S-7	SLO-1	*Self Assembly*	*Microfluidic Assays*	*Nano-emulsions*	*Information and Communication technology*	*Adme (metabolism)*
	SLO-2	*Organized self-assembled structures*	*Lateral flow (immuno) assay*	*Nano-engineered protein fibrils as ingredient building blocks*	*Sensors*	*Adme (excretion)*
S-8	SLO-1	*Langmuir layers*	*Nucleic acid lateral flow (immuno) assay*	*Preparation of food matrices*	*Radiofrequency identification technology*	*Toxicodynamics*
	SLO-2	*Lipid bilayers*	*Flow-through (immuno) assays*	*Risks of Nanotechnology*	*Health Risks*	*In vivo toxicity*
S-9	SLO-1	*Solid-supported lipid bilayers*	*Antibody microarrays*	*Concerns about using nanotechnology in food production*	*Environmental Risks*	*In vitro toxicity*
	SLO-2	*Micelles, Vesicles*	*Surface plasmon resonance spectroscopy*	*Rational argumentation versus Human feelings*	*Consumer and societal acceptance*	*Study Reliability*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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

Course Code	18NTE313T	Course Name	ADVANCED DRUG DELIVERY SYSTEMS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Understand the concept of drug delivery*
CLR-2 :	*Acquire knowledge on controlled drug delivery*
CLR-3 :	*Learn the concept of targeted drug delivery*
CLR-4 :	*Know about the methods of drug delivery*
CLR-5 :	*Learn about various nanocarriers*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Explain various drug delivery systems*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*L*	*H*	*H*	*H*	*H*
CLO-2 :	*Analyse a controlled drug release profile*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*M*	*M*	*M*	*H*	*M*	*H*	*L*	*H*	*M*	*M*	*M*
CLO-3 :	*Formulate different drug delivery systems*	*2*	*75*	*70*	*H*	*L*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*L*	*H*	*H*	*H*	*H*
CLO-4 :	*Apply the concept of drug targeting*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*L*	*H*	*H*	*H*	*H*
CLO-5 :	*Differentiate among various nanocarriers*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*L*	*H*	*H*	*H*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Drug delivery systems*	*Targeted drug delivery system*	*Metal nanoparticles for drug delivery*	*Cancer therapy*	*Theranostic metal nanoshells*
	SLO-2	*Traditional drug delivery*	*Site specific drug release*	*Gold based drug delivery systems*	*Drug delivery to cancer*	*Photothermally-modulated drug delivery using nanoshell*
S-2	SLO-1	*Advantages and disadvantages of various traditional drug delivery systems*	*Types of drug targeting*	*Multifunctional nanoparticles*	*Targeted drug delivery to cancer*	*Hydrogels*
	SLO-2	*Modes of drug delivery*	*Active targeting*	*Multifunctional gold nanoparticles for drug delivery and imaging*	*Enhanced permeability and retention*	*Nanoporous systems for drug delivery*
S-3	SLO-1	*Routes of administration*	*Passive targeting*	*Virus based drug delivery system*	*Cancer markers*	*Molecularly-derived therapeutics*
	SLO-2	*Novel drug delivery system*	*Barriers for drug targeting*	*Polymeric nanoparticles*	*Folate receptor*	*transdermal drug delivery*
S-4	SLO-1	*Pharmacokinetics*	*Strategies for site specific drug delivery*	*Classifications of polymers*	*Angiogenesis*	*low-frequency sonophoresis*
	SLO-2	*ADME studies*	*Receptors*	*Polymer micelles*	*Leaky vasculature*	*implants for controlled drug delivery*
S-5	SLO-1	*Kinetics of drug delivery*	*Ligands*	*Synthesis of polymeric nanoparticles for drug delivery*	*Cancer specific targeting*	*Responsive release system*
	SLO-2	*Zero order kinetics*	*Antibodies based drug delivery*	*Dentrimers*	*Combinational therapy*	*Fabrication and Applications of Microneedles*
S-6	SLO-1	*First order kinetics*	*Metabolism based drug delivery*	*Magnetic nanoparticles for drug delivery*	*Neutron capture therapy*	*Micropumps*
	SLO-2	*Mixed order kinetics*	*Surface modification of nanoparticles*	*Nanoscaffolds*	*Targeting tumor vasculature for imaging*	*microvalves*
S-7	SLO-1	*Controlled drug delivery*	*Bioconjugation of nanoparticles*	*CNT in drug delivery*	*Anticancer drugs*	*Implantablemicrochips*

	SLO-2	*Mechanism of controlled drug release*	*PEGylation of nanoparticles*	*Liposomes*	*Pharmacodynamics*	*Quantum Dot Probes*
S-8	SLO-1	*Therapeutic index*	*reticuloendothelial system*	*Protein drug delivery*	*Photothermal therapy*	*Applications Nano biotechnologies for Single-Molecule Detection*
	SLO-2	*Drug release profile*	*Opsonaization*	*Gene delivery*	*Cancer imaging*	*Nanorobots*
S-9	SLO-1	*Rate controlled drug delivery*	*Renal clearance*	*Gene transfection*	*Nanoparticle–Aptamer Conjugates for Cancer Cell Targeting and Detection.*	*Drug delivery to Central Nervous systems*
	SLO-2	*Time controlled drug delivery*	*Steric repulsion*	*Methods of gene transfection*	*Fluorescent Silica Nanoparticles for Tumor Imaging-*	*Drug delivery across Blood brain barrier*

Learning Resources	1. Drug Delivery: Engineering Principles for Drug Therapy, M. Salzman, Oxford University Press, 2001. 2. Drug Delivery and Targeting, A.M. Hillery, CRC Press, 2002.	3. Drug Delivery: Principles and Applications, B. Wang, Wiley Intersceince, 2005. 4. Nanoparticle Technology for Drug Delivery, Ram B. Gupta, Uday B. Kompella Taylor & Francis, 2006

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. K. ChandruTrivitron Healthcare Pvt. Ltd. Chennai, chandru.k@trivitron.com	*1. Dr. AsifkhanShanavas, INST Mohali, asifkhan@inst.ac.in*	*1. Dr. G. Devanand Venkatasubbu, SRMIST*
2. Dr. AchuthPadmanaban, Baylor College of Medicine, USA, achuthz@gmail.com	*2. Dr.MukeshDoble, IIT M, mukeshd@iitm·ac*	*2. Dr. Selvamurugan, SRMIST*

Course Code	18NTE314T	Course Name	NANOMEDICINES	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	Nanotechnology	Data Book / Codes/Standards		Nil	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	Understanding the basis of medicine
CLR-2 :	Know the various classification of nanomedicine
CLR-3 :	Getting knowledge about interaction of nanomaterials with biological environment
CLR-4 :	Gain a broad understanding about the nanosystems for the diagnosis and therapy
CLR-5 :	Get acquainted with future aspects of nanoimprinted biosensor
CLR-6:	Comprehend the principles behind nanomedicine

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Apply the principles of medicine in nanomedicine	2	80	75	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	Analyze the shortcomings of conventional medicine	2	80	70	H	M	M	H	M	M	M	H	M	H	M	H	M	M	M
CLO-3 :	Apply concepts of nanomedicine to a focused clinical area of their choice	2	75	70	H	M	H	H	H	H	H	M	H	H	H	H	H	H	H
CLO-4 :	Apply these nanosystems for the diagnosis and therapy	2	80	75	M	H	H	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Utilize the current techniques for novel applications of bioimaging	2	80	70	H	M	H	H	H	M	M	H	M	H	M	H	H	H	H
CLO-6 :	Apply the principles of 3D printing for future aspects of nanoimprinted biosensor	2	80	75	H	M	M	H	H	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Carbon nanotubes for Bone regeneration	Biocompatibility of traditional medical implants	Introduction to biomedical imaging	Drug delivery to CNS	3D Bioprinting – introduction
	SLO-2	Carbon nanotubes for Electroporation	Adhesive interactions with implant surfaces	Types of biomedical imaging	Drug delivery across blood brain barrier (BBB)	3D Bioprinting uses
S-2	SLO-1	Hexagonal array of gold nanorods	Nanorobot immunoreactivity	The emergence of nanoparticles as imaging platform in biomedicine	EEG for monitoring brain activity	Types of 3D bioprinting
	SLO-2	Gold nanorods in sensing	Nanopyrexia	Magnetic resonant imaging- principle and techniques	Nanowires for monitoring brain activity	3D Bioprinting technologies: ink jet based
S-3	SLO-1	Isohelical DNA-binding oligomers	Mutagenicity	Magnetic resonant imagingworking methodology	Neuroregeneration	Pressure assisted
	SLO-2	Nanospearing- multifunctional glyco-nanoparticles	Carcinogenicity	Magnetic resonant imaging-Paramagnetic contrast agents	Neurosurgery	Laser assisted
S-4	SLO-1	Nanoarchitecures	Thermocompatibility	USPIOS for imaging	Nanoneurosurgery	Solenoid valve based
	SLO-2	Nanoconstructions based on spatially ordered nucleic acid molecules	Mechanocompatibility	SPIOS for imaging	Lipoblockers	Acoustic jet based
S-5	SLO-1	DNA self assembly	Cell membrane disruption	MPIOS for imaging	Nanolipoblockers - antirestenosis drugs	Challenges of 3D bio printing
	SLO-2	DNA self-assembling nanostructures	Systemic nanoparticle distribution	Magnetic nanosensors	Myocardial Infraction conventional therapy	Future development of 3D bio printing

		induced by trivalent ions				
S-6	SLO-1	*Assembling by polycations*	*Nanoparticle phagocytosis*	*Nanosensors- radio labeled nanoparticles*	*Cell therapy for myocardial infarction*	*Nanoparticles sensors*
	SLO-2	*Wang tiles*	*Nanomaterial volumetric intrusiveness*	*Ultrasound imaging*	*Stem cell types*	*Calorimetric sensing*
S-7	SLO-1	*Biological examples of Nanomotors and devices*	*Intusiveness of Nanobots*	*Acoustically reflective nanoparticles*	*Regeneration of the cardiovascular system*	*Vapor phase sensing*
	SLO-2	*ATPase motor*	*Nanobiotechnology in tissue engineering*	*Acoustically reflective nanoparticles: application in ultrasound imaging*	*Nanobone implants*	*Raman sensing at surfaces*
S-8	SLO-1	*Kinesine motor*	*Nanobiotechnology for organ replacement*	*Iodinated liposomes*	*Nanobone scaffolds*	*Electro analytical sensing*
	SLO-2	*Dynein motor*	*Liver and kidney transplant*	*Application of Iodinated liposomes*	*Nanoparticle drug formulations for spray inhalation - wound healing*	*Plasma sensing*
S-9	SLO-1	*Polymer-based capsules*	*Nanobiotechnology for assisted function*	*Quantum dots*	*Nanogeriatrics*	*Optical sensing*
	SLO-2	*Oral drug delivery*	*Organ assists*	*Quantum dots in optical imaging*	*Orthodontal application*	*Sensors for cancer detection*

Learning Resources	*1. Understanding Nanomedicine: An Introductory Textbook by Rob Burgess. 2012 CRC Press* *2. Nanomedicine for Drug Delivery and Therapeutics, Editor(s): Ajay Kumar Mishra, 2013, Wiley*	*3. Medical Nanotechnology and Nanomedicine by Harry F. Tibbals. 2010 by CRC Press* *4. Introduction to Nanomedicine and Nanobioengineering, by Paras N. Prasad. 2012, Wiley*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. K. Chandru Trivitron Healthcare Pvt. Ltd. Chennai, chandru.k@trivitron.com	*1. Dr.Amit Kumar Mishra , IIT Jodhpur, amit@iitj.ac.in*	*1. Dr. Devanandh venkata subhu, SRMIST*
3. Dr.Nagesh Kini,Thermax,Pune,Maharastra,nagesh.kini@gmail.com	*2. Dr.Sampath Kumar T.S,IIT Madras, tssk@iitm.ac.in*	*2. Dr. Selvamurugan, SRMIST*

Course Code	18NTE315T	Course Name	MICROELECTRONICS AND VLSI	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	The purpose of learning this is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Acquire knowledge on importance of microelectronics			
CLR-2 :	Understand the physical effects of semiconductor-semiconductor junction, its electrostatics, device and circuit level operation			
CLR-3 :	Acquire knowledge on digital language of Boolean algebra, basics of logic gates for advanced memory applications			
CLR-4 :	Learn process flow of CMOS IC fabrication, circuit formation and its operation			
CLR-5 :	Understand intricacies of designing micro/nanoscale rules, flow of fabrication and IC testing principles			
CLR-6 :	Acquire knowledge on power consumption and optimization of on-chip devices, its analysis on performance			

Learning Outcomes (CLO):	At the end of this , learners will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	Interpret difference between macro and micro electronics	2	80	75
CLO-2 :	Apply basic semiconductor physics which is important to understand the working of semiconductor-semiconductor junctions, device and circuit level operation	2	80	70
CLO-3 :	Analyze various number systems of Boolean algebra, operation of logic gates and memory circuits	2	75	70
CLO-4 :	Elucidate process flow of CMOS based logic devices, circuit formation and its operation	2	80	75
CLO-5 :	Designing steps in VLSI, rules, flow of fabrication and IC testing at high frequency	2	80	70
CLO-6 :	Analyze power consumption and need for optimization in on-chip devices, its effect on switching speed	2	80	75

Program Learning Outcomes (PLO)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	H	M	M	H	M	M	M	H	M	H	M	H	M	M	M
CLO-3 :	H	M	H	H	H	H	H	M	H	H	H	M	H	H	H
CLO-4 :	M	H	H	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	H	M	H	H	H	M	M	H	M	H	M	H	H	H	M
CLO-6 :	H	M	M	H	M	M	M	H	H	M	M	H	M	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction to classification of materials	Number systems	Introduction to IC Technologies	Overview of VLSI design methodologies	Usage of power in IC
	SLO-2	Types of semiconductors	Binary and octal numbering	Needs of VLSI	Needs of designing	Overview of power consumption, low and high power in VLSI chips
S-2	SLO-1	Concept of energy band gap	Hexadecimal numbering	VLSI design styles	Steps in designing	On-chip capacitors
	SLO-2	Doping in semiconductors	Conversions between number systems	Layout rules	Cascading of process	Charging and discharging of capacitor
S-3	SLO-1	Formation of p-n junction	Boolean algebra	Introduction to Complementary Metal Oxide Semiconductor (CMOS)	Introduction to MOFET	Currents and voltages in CMOS short circuits
	SLO-2	Electrostatics of junction operation	Logic gates	VLSI for CMOS	VLSI for MOSFET	Leakage current, static current
S-4	SLO-1	Diode as circuit element	Truth tables for AND, OR, NOT gates	Positive channel MOS (PMOS) and negative channel MOS (NMOS)	DC operation of MOSFET	Gate-level- architecture
	SLO-2	Basics of bipolar and unipolar junction transistors	Truth tables for NAND, NOR gates	BiCMOS and applications	AC operation of MOSFET	transistor and gate sizing
S-5	SLO-1	Current-voltage characteristics and operation of transistors	Circuits with logic gates	CMOS inverter	Modelling of MOSFET	Power analysis
	SLO-2	Ebers-Moll representation of transistor for circuit element	combinational circuits and sequential circuits	CMOS logic circuits	Small signal model	Data correlation analysis

S-6	SLO-1	*AC operation of transistor*	*Flip-flops*	*Combinatorial CMOS Logic*	*Need of high frequency operation*	*Random logic signals, signal entropy*
	SLO-2	*Small signal model*	*SR and JK flip-flops*	*pMOS and nMOS in logic operation*	*high frequency MOSFET models*	*Switching activity analysis*
S-7	SLO-1	*Small signal model for bipolar junction transistor (BJT)*	*Basics of counters*	*D-latch*	*Testing of transistor*	*Parallel architecture*
	SLO-2	*Small signal model for junction field effect transistor (JFET)*	*Asynchronous and synchronous counters*	*CMOS for D-latch*	*Need for testing*	*Digital CMOS circuits*
S-8	SLO-1	*Amplifiers*	*Overview of memory devices*	*Triggering of flip-flops*	*Testing principles*	*CMOS amplifiers*
	SLO-2	*Transistor connections in various modes*	*Logic gates for memory applications*	*Edge triggered Flip Flops*	*design for testability*	*CMOS amplifier topologies*
S-9	SLO-1	*Feedback concept*	*Read only memory*	*Transistor logic*	*Error analysis*	*Common-Source topologies*
	SLO-2	*Ideal F/B amplifiers*	*Random access memory*	*Pass transistor circuits*	*Safety in testing*	*Parallel architecture with voltage reduction*

Learning Resources	1. *Behzad Razavi, Fundamentals of Microelectronics/Edition 1, Wiley, 2008* 2. *Millman and Grabel, "Microelectronics", 2nd Ed. Tata McGraw-Hill, 1999*	3. *Weste N.H., "Principles of CMOS VLSI Design", Pearson Education, India, 2002*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in	*2. Prof. S. Balakumar, University of Madras, balakumar@iunom.acs.in*	*2. Dr. P. Malar, SRMIST*

Course Code	18NTE316T	Course Name	PHYSICS OF ELECTRONIC MATERIALS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	The purpose of learning this is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Understand the physics of electronic materials			
CLR-2 :	Familiarize different physical properties of electronic materials			
CLR-3 :	Know-how the various processes in electronic materials			
CLR-4 :	Understand the physics behind the working of electronic materials based devices			
CLR-5 :	Gain a fundamental understanding of the emerging electronic materials			
CLR-6:	Know new materials other than Si etc and future technology roadmap			

Learning Outcomes (CLO):	At the end of this , learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Use knowledge of physics to understand the properties of electronic materials	2	80	75	M	M	H	H	M	H	H	M	M	H	M	H	H	H	H
CLO-2 :	Analyze different mechanisms that determine the properties of electronic materials	2	80	70	H	M	H	H	M	M	M	M	M	H	L	H	M	M	M
CLO-3 :	Determine the applications of electronic materials based on their properties	2	75	70	M	L	H	H	H	H	H	H	M	H	M	H	H	H	H
CLO-4 :	Evaluate the material characteristics by applying laws of physics	2	80	75	H	H	H	H	H	H	H	M	M	H	M	H	H	M	M
CLO-5 :	Develop in depth understanding of the physical processes of electronic materials	2	80	70	H	M	H	H	H	H	H	H	M	H	M	H	H	M	M
CLO-6 :	Distinguish how materials are classified and their applications				M	M	M	M	L	M	M	H	H	H	H	M	H	M	M

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Defining characteristics and classification of semiconductors	Concept of relative permittivity	Definition of magnetic dipole moment	Optical properties of materials	Thermal properties of materials
	SLO-2	Fundamentals of band theory of semiconductors	Electric dipole moment and polarizability	Orbital and spin magnetic moment of an electron	Refractive index, Refractive index-wavelength behavior	Atomistic theory of heat capacity
S-2	SLO-1	Intrinsic semiconductors	Polarization vector and charge density	Magnetization vector	Snell's law and total internal reflection	Quantum mechanical considerations
	SLO-2	Energy band diagram and carrier movement	Electric susceptibility and relative permittivity	Definition of magnetic susceptibility and magnetic permeability	Case study: fiber optics and LEDs	Einstein and Debye model
S-3	SLO-1	Conductivity of a semiconductor	Lorentz field in dielectrics	Magnetic materials classification	Interaction of photons with materials	Electronic contribution to the heat capacity
	SLO-2	Electron and hole concentrations	Clausius-Mossotti equation	Dia-, para-, ferro-, antiferro-, and ferrimagnetism	Absorption, transmittance and reflection	Heat capacity and specific heat
S-4	SLO-1	Extrinsic semiconductors	Electronic polarization in covalent solids	Origin of ferromagnetism and exchange interaction	Antireflection coatings on solar cells	Thermal expansion and thermal conductivity
	SLO-2	Concepts of p-type, n-type and compensation doping	Ionic, dipolar, interfacial and total polarization	Saturation magnetization and curie temperature	Dielectric mirrors	Thermal conductivity in metals, alloys, and dielectrics

S-5	SLO-1	*Energy band diagram and electron and hole concentrations*	*Concept of dielectric loss*	*Magnetic domains and domain walls*	*Band to band absorption*	*Thermoelectricity in metals*
	SLO-2	*Estimation of the position of the Fermi energy and the resistivity*	*Dielectric studies and the Cole-Cole plot*	*Magnetostriction and domain wall motion*	*Direct and indirect transitions*	*Seebeck effect and the figure-of-merit*
S-6	SLO-1	*The temperature dependence of carrier concentration*	*Dielectric strength and insulation breakdown*	*Magnetic domains in polycrystalline materials*	*Light scattering in materials, attenuation in optical fibers*	*Thermoelectricity in semiconductors*
	SLO-2	*The temperature dependence of drift mobility*	*Dielectric breakdown mechanisms*	*Understanding the M versus H hysteresis curve*	*Luminescence, phosphors, and white LEDs*	*Overview of thermoelectric devices*
S-7	SLO-1	*Degenerate and nondegenerate semiconductors*	*Capacitor dielectric materials*	*Demagnetization*	*Spontaneous and stimulated emission*	*Two-dimensional electronic materials*
	SLO-2	*Direct and indirect recombination*	*Typical capacitor constructions*	*Soft and hard magnetic materials: Examples and uses*	*Laser materials and laser action*	*The Era of graphene and related materials*
S-8	SLO-1	*Minority carrier life time*	*Piezoelectricity*	*Superconductivity, Type I and Type II superconductors*	*Concept of photoluminescence and electroluminescence*	*Electronic properties at 2D limit*
	SLO-2	*Carrier injection and diffusion*	*Piezoelectric spark generator and quartz crystal*	*Critical current density and superconducting solenoids*	*Examples for devices working on the principles of PL and EL*	*Optical properties- layer dependence*
S-9	SLO-1	*Optical absorption in semiconductors*	*Ferroelectricity and pyroelectricity*	*Josephson effect*	*Electro-optic effects and applications*	*2D materials based metal, semiconductor and dielectrics*
	SLO-2	*Direct and indirect band gap semiconductors and the E-k diagram*	*Practical Applications*	*Introduction to anisotropic and giant magnetoresistance*	*Magneto-optic effects and applications*	*Applications and future perspectives*

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

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

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

Course Code	18NTE317T	Course Name	NANOCATALYSTS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	The purpose of learning this is to:
CLR-1 :	Aquire the concepts of chemistry of nanocatalyst
CLR-2 :	Understand the catalytic kinetics
CLR-3 :	Describe the reaction kinetics of adsorption and desorption processes
CLR-4 :	Understand the principles behind the synthesis of nanocatalyst
CLR-5 :	Gain knowledge about the working mechanism of nanocatalytic materials
CLR-6 :	Describe catalytic processes at nano-levels

Learning Outcomes (CLO):	At the end of this , learners will be able to:	Learning 1 Level of Thinking (Bloom)	Learning 2 Expected Proficiency (%)	Learning 3 Expected Attainment (%)	PLO 1 Engineering Knowledge	PLO 2 Problem Analysis	PLO 3 Design & Development	PLO 4 Analysis, Design, Research	PLO 5 Modern Tool Usage	PLO 6 Society & Culture	PLO 7 Environment & Sustainability	PLO 8 Ethics	PLO 9 Individual & Team Work	PLO 10 Communication	PLO 11 Project Mgt. & Finance	PLO 12 Life Long Learning	PLO 13 PSO - 1	PLO 14 PSO - 2	PLO 15 PSO - 3
CLO-1 :	Describe the mechanisms of nanomaterials for using as catalyst	2	80	75	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	Apply the importance of the bottom-up approach to prepare nanomaterials	2	80	70	H	M	M	H	M	M	M	H	M	H	L	H	M	M	M
CLO-3 :	Identify the photocatalyst for environmental remediation	2	75	70	H	M	H	H	M	H	H	M	H	H	H	H	H	H	H
CLO-4 :	Analyze the working of noble metal nanocatalyst	2	80	75	M	H	H	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Evaluate the needs and future possibilities of nanocatalyst	2	80	70	H	M	H	H	H	M	M	H	M	H	L	H	H	H	H
CLO-6 :	Apply isotherms for different micro and nano porous catalytic materials	2	80	75	H	M	M	H	M	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction to catalysis	Adsorption and Desorption Processes	Kinetics and photocatalytic activity	Catalyst in Nanoscale	Applications of Nano-Catalyst
	SLO-2	Classifications	Adsorption Rate	Introduction to photocatalyst	Noble metals nanocatalyst (Ru, Rh, Pd, Pt, etc)	Toxic Gases conversion using nanocatalyst: NOx
S-2	SLO-1	heterogeneous catalysis	Desorption Rate	Basics of electrochemistry	Polymer stabilized Rh and Ru nanoparticles	CO oxidation using nanocatalyst
	SLO-2	Reaction on the solid surfaces	Catalytic activity (bulk and nanoscale)	Photochemistry	Oxide supports for nano-catalysts; carbon supports for nano-catalysts	Hydrogenation of compounds with C≡C bonds, hydrogenation of aromatic compounds
S-3	SLO-1	Active sites- Activation energy	Catalytic activity determination for metal/metal oxide nanostructures	Electronic structure and photoabsorption	Gold nanoparticle-based catalyst	Green house gases: CO2 conversion
	SLO-2	Adsorption isotherms	Langmuir-Hinshelwood mechanism for nanocatalyst	Jablonskii diagram	Gold vs. Palladium catalysts for the aerobic oxidation of alcohols	Dissociative mechanism: oxygen reduction reaction using nanocatalyst
S-4	SLO-1	Physisorption and chemisorptions	Mass transport	Structure of photocatalysts	Oxide based catalyst	Associative mechanism: oxygen reduction reaction using nanocatalyst
	SLO-2	Brunauer-Emmett-Teller (BET) theory	Diffusion controlled process	Solar spectrum	Metal free catalyst (CNT, Graphene based Catalyst)	Hydrogen Production using oxide and dichalcogenides based catalyst
S-5	SLO-1	Total surface area	Adsorption equilibrium on uniform	Fundamental understanding of	Transition metal dichalcogenides based	Energy processing: Processes involved in

			surfaces-Langmuir isotherms single-site (non-dissociative) adsorption	*semiconductor interfaces*	*catalyst*	*crude oil refinery*
	SLO-2	*Pore volume and pore size distribution*	*Dual-site (dissociative) adsorption*	*Principles and relevance to photoelectrochemical mechanism*	*Microporous materials: Zeolites- Zeotypes*	*Gasoline production*
S-6	SLO-1	*Hg porosimetry method*	*Derivation of the Langmuir isotherm*	*Photocatalysis mechanism*	*Overall steps in zeolite crystallization*	*Cracking*
	SLO-2	*N2 adsorption-desorption method*	*Adsorption equilibrium on non-uniform surfaces-Langmuir isotherms*	*Properties of good photocatalysts*	*Zeolite synthesis via.- dry gel route*	*Fuel cell*
S-7	SLO-1	*Reaction mechanism*	*The Freundlich isotherm*	*Advantages of photocatalysts*	*Zeolite Y- determination of surface acidity-*	*Biomass gasification*
	SLO-2	*Kinetics of the heterogeneous catalytic reactions*	*The Temkin Isotherm*	*Types of photocatalysts*	*Shape-selectivity*	*Biodiesel*
S-8	SLO-1	*Activation energy (Arrhenius equation, Eyring equation)*	*Activated adsorption*	*Homogeneous and heterogeneous photocatalyst*	*Synthesis of Mesoporous Silica MCM-41*	*Photocatalyst for self cleaning*
	SLO-2	*Terminology in catalysis, TO(Turnover),TON(Turnover number), TOF(Turnover frequency)*	*Catalytic efficiency*	*Carbonaceous photocatalysts.*	*Mesoporous Carbon*	*Purification of water and air*
S-9	SLO-1	*Sequences involved in a catalysed reaction*	*Application of metal nanoparticles in organic reactions*	*Plasmonic photocatalysts.*	*Sulfated Zirconia*	*Environmental remediation*
	SLO-2	*Asymmetric synthesis using a catalyst*	*Environmental remediation*	*Application of photocatalyst*	*Ag/SiO_2 composite nanocatalysts*	*Future possibilities*

Learning Resources	1. *M. Albert Vannice, Kinetics of Catalytic Reactions, Springer, 2008.* 2. *Nick Serpone and Ezio Pelizzetti, Photocatalysis: Fundamentals and Application, Wiley Interscience, 1st Edition, 1989*	3. *Kurt W. Kolasinaski, Surface Science: Foundations of Catalysis and Nanoscience , John Wiley & Sons, England, 2nd Edition , 2005* 4. *Nanoporous Materials: Synthesis and Applications, Edited by Qiang Xu, CRC Press, 1st Edition, 2013*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.

Course Designers		
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Course Code	18NTE318T	Course Name	NANO AND MICRO EMULSIONS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Acquire knowledge on micro and nano emulsion and its stability*
CLR-2 :	*Understand the various properties of emulsion*
CLR-3 :	*Describe the concept of Mechanism of Emulsification*
CLR-4 :	*Understand the formulation of Nano emulsion*
CLR-5 :	*Learn the applications of emulsion for various fields*
CLR-6 :	*Understand the principles of NMR and Ultrasound characterization*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual &Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Explore basic principles in chemistry of microemulsions*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-2 :	*Explainproperties of emulsion by concept of phase diagram*	*2*	*80*	*70*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Analyze the stabilization mechanism in emulsions*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*	*H*
CLO-4 :	*Apply the formulation of micro and nano emulsions*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-5 :	*Elucidate importance of emulsions in various technological applications*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6 :	*Utilize the knowledge on formulation and characterization of microemulsions*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*M*	*H*	*H*	*M*	*H*	*H*	*M*	*M*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Introduction to Emulsion*	*A phase diagram approach to microemulsion*	*Mechanism of Emulsification*	*Nanoparticle formation in microemulsion*	*Characterization and Application of Microemulsion*
	SLO-2	*Introduction to Micro and Nano Emulsion*	*Partial generic phase diagram*	*Surface forces*	*Concept of formation in microemulsion:*	*Introduction in basics and principles of NMR*
S-2	SLO-1	*Definition of micro emulsion*	*Microemulsion formation*	*Van der walls interactions*	*Chemical Reaction*	*NMR technique for measurement emulsion*
	SLO-2	*Definition of nano emulsion*	*Ordering and disordering*	*Electrical interactions*	*Nucleation*	*Relaxation measurements on emulsions via CPMG experiments*
S-3	SLO-1	*Theory of emulsion and methods*	*Temperature Dependence of microemulsion ordering*	*Phase inversion phenomena*	*Exchange mechanism in emulsions*	*Diffusion measurements on emulsions via PGSE andPGSTE experiments*
	SLO-2	*Theory of Micro emulsions*	*Vapor Composition from Microemulsions*	*Phase behaviorsof emulsions*	*Autocatalysis*	*Introduction and basics of ultrasound*
S-4	SLO-1	*Theory nano emulsions*	*Ekwall on the association structures*	*Standard inverse boundary*	*Mechanism of microemulsion*	*Ultrasound characterization for emulsion*
	SLO-2	*Preparation of microemulsion*	*Water–surfactant combination*	*Dynamic inversion*	*Critical Nucleus Size*	*Ultrasound characterization for microemulsion*
S-5	SLO-1	*Preparation of nano emulsion*	*Physicochemistry of W/O microemulsion formation*	*Dynamic behavior of emulsion*	*Chemical Reaction Rate*	*General features of acoustic measurement*
	SLO-2	*Winsor's classification of microemulsions*	*Stability of emulsions*	*Spontaneous emulsification*	*Nanoparticles uptake from W/O emulsion*	*Acoustic measurements on emulsions*
S-6	SLO-1	*Stability of micro emulsions*	*Droplet clustering*	*Recent development with emphasis on self*	*W/O emulsion process*	*Physicochemical characterization and*

				emulsification,		*characterization techniques types*
	SLO-2	*Rheology of microemulsion drops*	*Energetics of Droplet Clustering*	*Self-emulsification process*	*Nanoparticle Uptake in Reactive Surfactant Systems*	*Pharmaceutically applicable microemulsions*
S-7	SLO-1	*Applications of emulsions*	*Phenomenon in microemulsion*	*Organic Reactions in Emulsions*	*Nanoparticle Uptake in Nonreactive Surfactant Systems*	*Places of microemulsion and emulsion in cancer therapy*
	SLO-2	*Ostwald ripening*	*Percolating phenomenon in microemulsion*	*Microemulsions*	*TiO_2 nanoparticle in micro-emulsion and photophysical properties*	*In vitro and in vivo evaluation*
S-8	SLO-1	*Flocculation*	*Scaling Laws*	*Symmetric thin liquid film with Fluid interfaces*	*Optical Absorption and Emission of TiO_2 Nanoparticles in Microemulsion*	*Biocatalysis in microemulsion*
	SLO-2	*Coalescence of drops*	*Effect of external entity-Microemulsions with mixed nonionic surfactants*	*Formation emulsified microemulsion*	*Electron Transfer Dynamics in Catechol-Sensitized TiO_2 Nanoparticles*	*Biofluidic Matrices*
S-9	SLO-1	*Applications of emulsions*	*Organ chalcogenides,Aromatic Heterocyclic Compounds*	*Microemulsion properties*	*Properties of interfacial electron transfer dynamics*	*Microemulsions as Decontamination Media for Chemical weapons*
	SLO-2	*Different application of micro and Nano emulsions*	*Properties of microemulsions with mixed nonionic surfactants*	*Characterization of emulsified microemulsion*	*Interfacial electron transfer dynamics*	*Microemulsions as toxic Industrial Chemicals*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	*2. Dr. S. Ramaprabhu,IITM, ramp@iitm.ac.in*	*2. Dr. N. Venkatramaiah, SRMIST*

Course Code	18NTE401T	Course Name	NANOROBOTICS	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Provide an insight into the fundamentals of nanorobotics manipulation and assembly*
CLR-2 :	*Gain scientific understanding regarding the role of nanorobotics in the modern engineering applications*
CLR-3 :	*Understand the concept of nanomanipulation of nanostructures*
CLR-4 :	*Learn the techniques of automated manipulation of nanoobjects*
CLR-5 :	*Gain knowledge on theoretical and experimental aspects of Nanorobotics*
CLR-6 :	*Understand the principles of nanomicroscopy*

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Apply the scientific concepts underlying engineering and technological applications in nanorobotics*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Acquire the knowledge of nanorobotics manipulation*	*2*	*80*	*75*	*H*	*M*	*M*	*M*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Apply the knowledge of fast imaging system for advance nanotechnology applications*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*
CLO-4 :	*Get familiarize with the new concepts of real-time nanomanipulation*	*2*	*75*	*70*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*H*
CLO-5 :	*Apply the concept of nanorobotics assembly using CAD*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-6 :	*Utilize the concept of nanobots for Medical applications*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*M*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Types of interaction forces*	*Dieelectric materials*	*Sensors-classifications*	*computer-aided design (CAD)*	*Nanorobotic- introduction*
	SLO-2	*Interaction forces in nanomanipulation*	*Dielectric polarization*	*Art of compressive sensing*	*CAD models of nanostructures*	*Nanorobotic Applications*
S-2	SLO-1	*Actuation*	*Electro rotation*	*Fast imaging system*	*Automated manipulation of micro-nano objects*	*Endoscopy imaging*
	SLO-2	*Electro kinetic based actuation*	*Theory and modelling of electro rotation*	*Compressive sensing based fast imaging system*	*Automated manipulation of nanostructures*	*Wireless capsules endoscopy imaging*
S-3	SLO-1	*Carbon nanotubes*	*Properties of fluid medium*	*SPMbasics*	*Automated manipulation of Nanorods*	*Energy harvesting*
	SLO-2	*Electro kinetic manipulation of carbon nanotubes*	*Dynamic effects of fluid medium*	*AFM based imaging*	*Automated manipulation of Nanowires*	*Energy harvesting by nanorobotic*
S-4	SLO-1	*Graphene sheets*	*Dielectrophoretic*	*Atomic manipulation in AFM*	*Automated manipulation of nanotubes*	*Gastro-intestinal tract- introduction*
	SLO-2	*Nanoparticles*	*Nanoparticles by dielectrophoretic*	*AFM based nanorobotic system*	*Automated manipulation of nanoparticles*	*Capsules robot in gastro-intestinal tract*
S-5	SLO-1	*Biological entities*	*CNT-definition*	*Augmented reality*	*Augmented reality system*	*Nanorobots - introduction*
	SLO-2	*Biological nanomaterials*	*Manipulation of CNT*	*AFM based nanorobotic system enhanced by augmented reality*	*Limitation of augmented reality system*	*Nanorobots –basic design*
S-6	SLO-1	*Laser based actuation-fundamentals*	*Scanning probes*	*Hardware setup for Sensing*	*Real time fault detection*	*Cooperative control design for nanorobots*
	SLO-2	*Laser based actuation-applications*	*Nanomanipulation by scanning probe*	*Software setup for Sensing*	*Methods of real time fault correction*	*Design and application of nanorobotics in oncology*

S-7	SLO-1	*Optical tweezers*	*Atomic scale stick-definition*	*Hardwaresetup for fast imaging system*	*Time random drift*	*Drug delivery system*
	SLO-2	*Applications of optical tweezers*	*Reducing atomic scale stick*	*Softwaresetup for fast imaging system*	*Time random drift compensation with local scan*	*Cooperative control design for nanorobots in drug delivery*
S-8	SLO-1	*Manipulation of biological entities*	*Slip motion*	*Experiments on nanomanipulation of nanoparticles-I*	*on-line fault detection*	*Medical applications of nanorobots*
	SLO-2	*Manipulation of chemical entities*	*Nanomanipulation by slip motion*	*Experiments on nanomanipulation of nanoparticles-II*	*Interpretation of on-line fault correction*	*Medical applications of nanorobots: current proposals and designs*
S-9	SLO-1	*Piezoelectricity*	*Feedback control*	*Experiments on nanomanipulation of nanoparticles-III*	*Implementation of the data to test the hypothesis*	*Therapy using nanorobots*
	SLO-2	*Piezoelectric enabled actuators*	*Slip motion by feedback control nanomanipulation*	*Experiments on nanomanipulation of nanoparticles-IV*	*Experimental results of the data to test the hypothesis*	*Cancer targeted therapy using nanorobots*

Learning Resources	*1. Ning Xi, Guangyoung Li, "Introduction to Nanorobotic Manipulation & Assembly" Artech House Press, 2012* *2. Yi Guo,"Selected Topics in Micro/Nano-robotic for Biomedical Applications", Springer, 2013*	*3. Klaus D. Sattler, "Hand Book of Nanophysics: Nano medicine & Nanorobotics", CRC Press, 2010*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. A. Pandikumar, Scientist, CSIR-CERL, pandikumar@cecri.res.in	*2. Prof. D. Arivuoli, Anna University, arivuoli@annauniv.edu*	*2. Dr. V. Kathirvel, SRMIST*

Course Code	18NTE402T	Course Name	MICRO AND NANOFLUIDS	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	*Nanotechnology*	Data Book / Codes/Standards		*Nil*	

Learning Rationale (CLR):	*The purpose of learning this is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Acquire knowledge on various physical principles related to liquid flow*			
CLR-2 :	*Understand theory of fluid flow in micro and nano-size devices.*			
CLR-3 :	*Describe the concept of heat and mass transfer phenomena in channel*			
CLR-4 :	*Unifies thermal sciences with colloidal sciences, biological sciences*			
CLR-5 :	*Gain knowledge on electrochemistry*			
CLR-6 :	*Understand the applications of micro and nanofluidics*			

Learning Outcomes (CLO):	*At the end of this , learners will be able to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Apply the principles of liquid flow*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Analyze flow of fluid in micro and nano-size devices*	*2*	*80*	*70*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Apply the knowledge of micro and nanofluidic devices, their fabrication, charecterization*	*2*	*75*	*70*	*H*	*M*	*H*	*M*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*H*
CLO-4 :	*Utilize the opportunities in the emerging field of micro and nanofluids*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-5 :	*Apply the concept electrochemistry*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6 :	*Utilize the new concepts of real-time nanomanipulation & assembly*	*2*	*80*	*75*	*H*	*M*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*H*	*M*	*H*	*H*	*M*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Microscale liquid flow - Introduction*	*Microscale viscous flow - Essentials*	*Heat transfer phenomena in channels and tubes*	*Elements of electrochemistry and the electrical double layer - introduction*	*Elements of cell biology and applications*
	SLO-2	*Micro and Nanofluidics*	*Structure of flow in a pipe or channel*	*Mass transfer phenomena in channels and tubes*	*The structure of water and ionic species*	*Nucleic acids and polysaccharides*
S-2	SLO-1	*Micro and Nanofluidics devices*	*Poiseuille flow in a pipe*	*One-dimensional temperature distributions in channel flow*	*Chemical bonds in biology and chemistry*	*Proteins : Protein function*
	SLO-2	*Design of micro and Nanofluidics devices*	*Poiseuille flow in a pipe – derivation of maximum velocity*	*Temperature distributions in channel flow (Quantitative approach)*	*Hydration of ions*	*Protein structure*
S-3	SLO-1	*Preparatory concepts*	*The velocity in slip flow - gases*	*Thermal and mass transfer entrance regions*	*Chemical potential*	*Some common proteins*
	SLO-2	*Constitutive Laws*	*The velocity in slip flow - Liquids*	*Mass transfer entrance regions*	*Chemical potential (Quantitative approach)*	*Few polypeptide chains are useful*
S-4	SLO-1	*Determination of transport properties – viscosity, diffusion coefficients*	*Flow in a thin film under gravity*	*The temperature distribution in fully developed tube flow*	*The Gibbs function*	*Protein binding*
	SLO-2	*Determination of transport properties – thermal conductivity*	*Flow in a thin film under gravity – film flow rate*	*Nusselt number*	*Chemical equilibrium*	*Cells - The cell membrane*
S-5	SLO-1	*Classification of fliud flows*	*Fully developed suction flows*	*The Graetz problem for a channel*	*Electrochemical potential*	*Membrane transport*

	SLO-2	*Continuum approximation and its limitations*	*Velocity profile – suction flow*	*The Graetz problem for a channel (Quantitative approach)*	*Acids, bases, and electrolytes*	*Ion channels*
S-6	SLO-1	*Kinematics - Surface forces*	*Developing suction flows*	*Mass transfer in thin films*	*Site-binding models of the silica surface*	*Applications - DNA transport*
	SLO-2	*Body forces*	*Darcy's law*	*A thin liquid film falling under gravity*	*Polymer surfaces*	*DNA current*
S-7	SLO-1	*Navier-Stokes equation*	*Surface tension driven flow*	*Classical Taylor–Aris dispersion*	*Qualitative description of the electrical double layer -*	*Development of an artificial kidney : Background*
	SLO-2	*Navier–Stokes equations in Cartesian coordinates*	*Surface tension driven flow (Quantitative approach)*	*Classical Taylor–Aris dispersion (Quantitative approach)*	*Qualitative description of the electrical double layer - triple layer model*	*The nanopore membrane for filtration, Hindered transport*
S-8	SLO-1	*Energy transport*	*Stokes flow past a sphere*	*The stochastic nature of diffusion*	*The electrical double layer on a cylinder*	*Biochemical sensing : Biosensor, Receptor -based classification of biosensors*
	SLO-2	*Energy transport - conduction heat transfer*	*Stokes flow past a sphere – drag calculation*	*Brownian motion*	*The electrical double layer on a sphere*	*Transducer-based classification of biosensors*
S-9	SLO-1	*Two-dimensional, Steady flow*	*Sedimentation of a solid particle*	*Unsteady mass transport in uncharged membranes*	*Electrical conductivity in an electrolyte solution.*	*Evaluation of biosensor performance*
	SLO-2	*Incompressible flow*	*Simple model for blood flow*	*Temperature and concentration boundary layers*	*Electrophoretic effect*	*Nanopores and nanopore membranes for biochemical sensing.*

Learning Resources	1. *Terrence Conlisk "Essential of Micro and nanofluidics: with applicationsto biological and chemical sciences" Cambridge University Press, 2018.* 2. *Joshua Edel "Nanofluidics" RCS publishing, 2016.*	3. *Henrik Bruus "Theoretical Microfluidics" Oxford Master Series in Physics,2007.* 4. *Patric Tabeling "Introduction to Microfluids" Oxford U. Press, 2005.* 5. *Christ of M. Niemeyer & Chad A. Mirkin, "Nanobiotechnology: Concepts, Application and Perspectives", Wiley VCH, 2004.* 6. *Sarit K.Das, Stephen U.S. Choi, Whenhua Yu & T. Pradeep, "Nanofluids Science and Technology" Wiley Interscience, 2007.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
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2. Mr. Mohammed Shafi, Holmarc Opto-Mechatronics Pvt. Ltd, Cochin, optics@holmarc.com	*2. Dr. Dillip K. Satapathy, IITM, Chennai, dks@iitm.ac.in*	*2. Dr. Surya K Ghosh, SRMIST*

Course Code	18NTE403T	Course Name	NANOTECHNOLOGY FOR ENERGY SYSTEMS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	The purpose of learning this is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Learn the importance of renewable energies for the safe survival of human kind on the earth			
CLR-2 :	Understand the basics of green energy production, storage and transport			
CLR-3 :	Understand how nanotechnology can improve the green energy production from various sources			
CLR-4 :	Explore the methods of hydrogen production and storage			
CLR-5 :	Acquire knowledge on the fabrication, characterization of nanomaterials useful for energy production, transportation and storage			
CLR-6 :	Acquire knowledge on design, fabrication, characterization of advanced energy systems			

Learning Outcomes (CLO):	At the end of this , learners will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Identify the urgency of energy solutions and the expectations of Nanotechnology in providing long term solutions to these problems	2	80	75	H	M	H	H	H	H	M	H	H	H	M	H	H	H	H
CLO-2 :	Describe the concepts of heterogeneous catalysis, and further apply in the designing of various nanocatalysts for energy applications	2	80	70	H	M	M	H	M	M	H	H	M	M	H	H	M	M	M
CLO-3 :	Apply Nanotechnology and nanomaterials in the designing of solar energy conversion systems and fuel cell technologies	2	75	70	H	M	H	H	H	H	H	M	H	M	H	H	H	H	H
CLO-4 :	Apply the Nanotechnology and nanomaterials for energy storage technologies	2	80	75	M	H	H	M	H	H	H	H	H	M	M	H	H	H	H
CLO-5 :	Apply the thermoelectric principles and nanotechnology to design high figure-of-merit thermoelectric devices	2	80	70	H	H	H	H	H	M	M	M	M	H	H	H	H	H	H
CLO-6 :	Apply Nanotechnology in the sensing and remediation of pollutants in air and water	2	80	75	H	H	M	H	H	M	M	M	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Energy Challenge in the 21st Century	Terawatt challenges in photovoltaics	Bulk thermoelectric materials	Low temperature fuel cells	Introduction to contribution of nanotechnology to hydrogen production
	SLO-2	Fuel share of world total primary energy supply	How can photovoltaics meet a significant fraction of energy demand?	Basics of thermoelectricity, Seebeck effect, Peltier effect, Figure of merit, Wiedemann-Franz relationship	Impact on nanostructured materials, development of low-temperature fuel cells	Methods of hydrogen production, Importance of hydrogen energy
S-2	SLO-1	Nanotechnology in energy research	Limits in conversion efficiency	Bulk thermoelectric materials- size effects, Selection criteria for bulk thermoelectric materials	Cathode and anode reaction	Nanomaterial based photoelectron chemical cell
	SLO-2	The importance of nanotechnology in improving the nanoscale energy devices	Theoretical limits of photovoltaics efficiency and possible improvements by different approaches	Important three guidelines	Oxygen reduction reaction, cathodic reactions, reactions at anode surface	Nanocrystalline thin films of metal oxides in PEC solar cells, Water splitting for producing hydrogen
S-3	SLO-1	Conventional fossil fuels Unconventional fossil fuels	Hybrid concepts	Effect of size of the quantum dots, nanowires on the conversion efficiency, classical and quantum size effects	Practical fuel cell catalysts and Electrolytes	Semiconductors with specific morphology such as nanotubes and discs for production of hydrogen
	SLO-2	Discussion about greenhouse gases,	Combining organic and inorganic cells,	Thermoelectric properties on nanoscale:	Nanostructured materials in low-	Sensitization, Hydrogen storage:

		Clean energy sources and advantages	*concept of heterojunction-type photoactive layer, hole-electron pair*	*modeling*	*temperature cell, Non-precious catalysts, electrolytes*	*technological barriers*
S-4	SLO-1	*Nanotechnology in fuel production*	*Semiconductors optical properties*	*Understanding thermoelectric properties on the nanoscale using modeling*	*High-temperature polymer electrolyte membranes, membrane-electrode assembly*	*Methods of improving efficiency of cells, HOMO-LUMO gap, several examples of sensitization*
	SLO-2	*Making efficient and economical engines*	*Basics of semiconductors, bandgap*	*Importance of characteristic length scale, Bi nanostructures*	*High temperature fuel cells*	*Hydrogen storage technology –potential storage materials hydrogen sorption*
S-5	SLO-1	*Renewable energy sources-Photovoltaics*	*charge carrier transport in semiconductors*	*Importance of Bi nanowire and its diameter in thermoelectricity*	*Development of cells that operate up to 700^{o}C*	*Hydrogen storage by Physiosorption and chemisorption methods*
	SLO-2	*Emission spectra and color as a function of particle size of a quantum dot*	*Optical properties of semiconducting thin films, Optical absorption*	*Silicon nanowire and importance at nanoscale*	*High temperature ceramic electro catalysts*	*Properties of materials: physical storage, thermodynamic and kinetics*
S-6	SLO-1	*Example of nc-CdTe film on ITO-coated glass solar cell*	*Narrow and wide band gap materials, importance of optical absorption*	*How surface roughness effects thermal conductivity. Phonon effects on the Seebeck coefficient and thermal conductivity*	*Electrochemical reaction at high temperatures, triple phase boundary*	*Bond strengths for Physiosorption and chemisorption, The desirable range of bonding energies*
	SLO-2	*Gratzel Cell Examples of nanostructured films used for PV cells*	*Selection of Dye sensitizer for better optical absorption, n-CdS band gap*	*Thermionics nanocomposites*	*Porous Ni-Ceramic electrolyte (YSZ), LaSrMnOe ceramic electrolyte*	*Nanostructured carbon*
S-7	SLO-1	*Hydrogen production*	*Dye molecular engineering*	*Description of electron motion across the barrier*	*Application of high temperature ceramic electro catalysts*	*MWNT, SWNT, carbon nanorods and aerogels etc.*
	SLO-2	*Mechanisms of dye sensitization and sensitization by composite semiconductors*	*HOMO-dye, LUMO gap*	*Si/SiGe superlattice nanowire, prototype InP/InAs superlattice nanowire*	*Various examples of high temperature fuel cells where ceramic electro catalysts are used*	*zeolites- clathrates- polymers*
S-8	SLO-1	*Hydrogen energy system. Advantages of hydrogen fuel*	*Stable self-assembling dye. Monomolecular layer*	*Thermoelectric nanocomposites*	*Solid oxide fuel cells (SOFCs)*	*Reversible occlusion of gases. Metal-organic frame works and their storage efficiency*
	SLO-2	*Fuel cells, REDOX potentials, electrochemical reactions in different types of fuel cells*	*Structure of the Z-907 amphiphilic Dye*	*PbTe-PhSeTe quantum dot*	*Mechanical properties, Efficiency, operating temperatures*	*Metals and complex hydrides- chemical hydrides nanocomposites*
S-9	SLO-1	*Microbial fuel cells, polymer electrolyte fuel cells*	*Electron transfer mechanism from TiO2 to Dye, Dye excitation and relaxation mechanisms*	*PbTe-PbSe bulk alloys, superlattice systems*	*Dry hydrocarbons in SOFC*	*Hydrogen storage by chemisorption, basic structures of metal and complex hydrides, chemical hydrides, Nanocomposites*
	SLO-2	*Introduction to Thermoelectricity*	*The nanostructured semiconductors*	*Application of thermionic and thermoelectric nanocomposites*	*Applications of Fuel cells*	*Some examples of storing hydrogen with the above materials*

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

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Course Code	18NTE404T	Course Name	PHOTOVOLTAIC TECHNOLOGY	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Learn the basic principles and design of photovoltaic cell technology			
CLR-2 :	Understand the key properties of semiconductors used in photovoltaic technology			
CLR-3 :	Learn about basic photovoltaic device structure and design			
CLR-4 :	Develop an understanding of the primary photovoltaic device technologies and their design			
CLR-5 :	Gain exposure to the various applications of photovoltaics			
CLR-6 :	Acquire knowledge on advanced concepts explored in photovoltaics			

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Differentiate between different types of photovoltaic technologies	2	80	75	H	H	H	H	H	H	M	H	H	H	H	H	H	H	H
CLO-2 :	Interpret important properties of semiconductors relevant to photovoltaics	2	80	70	H	H	M	H	M	H	M	H	M	H	H	H	M	M	M
CLO-3 :	Apply different photovoltaic device design concepts for different applications	2	75	70	H	H	H	H	H	H	H	M	M	H	H	H	H	H	H
CLO-4 :	Appreciate advancement of different generations of solar cells	2	80	75	M	H	H	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Appreciate the advanced concepts and explorations in photovoltaics	2	80	70	H	M	H	H	H	M	M	H	M	H	H	H	H	H	H
CLO-6 :	Perform photovoltaic device testing and calculations	2	80	75	H	M	M	H	H	M	M	H	M	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Renewable energy technologies	Optical absorption	Solar Cell parameters	Si photovoltaics	III-V photovoltaics
	SLO-2	Present and future global issues	Carrier photogeneration	Device testing	Fabrication of Si solar cells	Multi-junction solar cells
S-2	SLO-1	Historical development of PV; drivers-	Band gap	Efficiency calculations	High efficiency single crystal Si solar cells	Spectral splitting
	SLO-2	Commercialization/economic factors	Direct vs. indirect bandgaps	(EFF, VOC, JSC) for ideal cells	Si PV designs	GaInP/GaAs/Ge triple junction solar cell
S-3	SLO-1	Basic components of PV systems	Minority carrier transport properties-	Non-idealities	Polycrystalline/microcrystalline Si solar cells	Bandgap profile optimization
	SLO-2	Mechanism of PV	Carrier recombination-lifetime and defects	Series resistance, shunt resistance	Amorphous Si solar cells	Solar spectrum matching
S-4	SLO-1	Sun as a source of energy	Band to band and Shockley-Read-hall	Optical loss mechanisms	Heterojunctions – review	Tunnel junctions
	SLO-2	The solar spectrum	High injection effects	Implications on device performance	p-i-n and n-i-p structures	Current matching limitations
S-5	SLO-1	Measuring sun light	Surface and interface recombination	Electrical loss mechanisms	Thin film II-VI solar cells	Concentrator photovoltaics (CPV)-
	SLO-2	Atmospheric effects	Implications on device performance	Implications on device performance	Chalcopyrite photovoltaics	Concentrator optics,
S-6	SLO-1	Terrestrial and space spectra;	PN homojunctions	Basics of solar cell device design	CdTe/CdS thin film solar cells	CPV cells
	SLO-2	Air mass (AM0, AM1.5)	Carrier transport under broad spectrum illumination	Minimization of losses	Superstrate structure	Terrestrial CPV systems
S-7	SLO-1	Classification of photovoltaic	Photocurrent	Lateral design and Vertical design	CuInGaSe2/CdS thin film cell technologies	Space photovoltaics

		technologies				
	SLO-2	*Generations of solar cells*	*Spectral response*	*Cyclotron frequency*	*Earth abundant alternatives*	*Radiation effects in semiconductors and solar cells*
S-8	SLO-1	*1st generation photovoltaics*	*Current transport models*	*Optical versus electrical tradeoffs and optimization*	*Dye-Sensitized solar cells*	*New concepts*
	SLO-2	*Silicon technology*	*Non idealities*	*Band gap and other material properties*	*QDSSCs*	*Quantum dots, wires*
S-9	SLO-1	*2nd generation photovoltaics*	*Real p-n diodes*	*Spectral utilization*	*Organic photovoltaics*	*Intermediate band solar cells*
	SLO-2	*3rd generation photovoltaics*	*Temperature effects*	*Light management*	*Hybrid solar cells*	*Multiple exciton generation*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
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Course Code	18NTE405T	Course Name	NANOTECHNOLOGY IN COSMETICS	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	The purpose of learning this is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Understand the basis of cosmeceuticals			
CLR-2 :	Know the classification and various types of cosmetics			
CLR-3 :	Acquire knowledge about ingredients and effect of inclusion of nanoparticles in cosmetics			
CLR-4 :	Get acquainted with current trends in the field of nano based cosmetics			
CLR-5 :	Get acquainted with future aspects of cosmetics			
CLR-6 :	Get acquainted with future aspects of aesthetic implants			

Learning Outcomes (CLO):	At the end of this , learners will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Apply basic concepts of nanotechnology in cosmetics	2	80	75	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	Distinguish effects of using nanoparticles over conventional methods in cosmetics	2	80	70	H	M	H	H	M	M	M	H	M	H	M	H	M	M	M
CLO-3 :	Analyze about current trends in the field of cosmetics	2	75	70	H	M	H	H	H	H	H	M	H	H	H	H	H	H	H
CLO-4 :	Apply basic cosmetic concepts in making nanoformulation	2	80	75	M	H	H	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Apply knowledge in making organosilicone formulation	2	80	70	H	M	H	H	H	M	M	H	M	H	M	H	H	H	H
CLO-6 :	Apply knowledge in making aesthetic implants	2	80	75	H	M	M	H	H	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Introduction to cosmetics	Oily materials: introduction, oils and fats, wax	Film formers	Multiple emulsions as novel delivery systems	Dual nanodelivery systems
	SLO-2	Purpose of cosmetics	Hydrocarbons	Polymers as film formers	Nanoemulsion in cosmetics	Dual nanodelivery systems-Introduction
S-2	SLO-1	Meaning of cosmetics	Higher fatty acids	Thickeners	Nanocrystals in cosmetics	Synthesis of dual nanodelivery systems containing vitamin e for cosmetics
	SLO-2	Classification of cosmetics	Higher alcohols, esters, silicones	Types of thickners	Silicones and beyond	Synthesis of dual nanodelivery systems containing vitamin e for pharmaceuticals
S-3	SLO-1	Cosmeceuticals	Surface active agents : introduction	Polymers in hair colouring	Organomodified silicones	Characterization of dual nanodelivery systems containing vitamin e
	SLO-2	Pharmaceuticals in cosmetics	Anionic surfactant	Types of polymers in hair colour	New esters mimicking property for organomodified silicones	Various characterization techniques used
S-4	SLO-1	Quality characteristics	Cationic surfactants	Conditioning polymers	Silicones in shampoo	Orthopedic implant
	SLO-2	Quality assurance	Amphoteric surfactant	Surfactants in conditioners	Minimalizing undesirable side effects	Conventional types of Orthopedic implant
S-5	SLO-1	Development process of cosmetics	Non-ionic surfactant	Cleansing agents	Substantive silicones	Orthopedic implant titanium rods
	SLO-2	Cosmetics for Skin	Other surfactants	Ethoxylated alcohols	Effect of substantive silicones	Advantages of Orthopedic implant of titanium rods
S-6	SLO-1	Cosmetics for hair	Humectants : introduction	Silicones	Organo-modified delivery systems	Preparation of keratin coatings for

						orthopedic implant titanium rods
	SLO-2	*Cosmetics for nails*	*Choice of humectants*	*Emulsions*	*Types of Organo-modified delivery systems*	*Characterization of keratin coatings*
S-7	SLO-1	*Cosmetics colour materials*	*Unusual humectants*	*Types of polymeric systems*	*Silicones personal care delivery system*	*Nanotherapeutics as a treatment for inflammation*
	SLO-2	*Cosmetics and fragrances*	*Special uses of humectants*	*Natural polymers*	*Liposomes in cosmetics*	*Cosmetic repair and restoration*
S-8	SLO-1	*Oral care cosmetics*	*Antioxidants : introduction*	*Stimuli responsive polymeric systems*	*Niosomes in cosmetics*	*Moisturization of skin*
	SLO-2	*Body cosmetics*	*General oxidative theory, measurement of oxidation*	*pH-responsive*	*Microemulsion in cosmetics*	*Fortification of the skin barrier*
S-9	SLO-1	*Physical chemistry of cosmetics*	*Assessment of oxidant efficiency*	*Thermal responsive*	*Nanoemulsion in cosmetics*	*Contact lenses types*
	SLO-2	*Stability of cosmetics*	*Choice of antioxidant*	*Photo responsive*	*Cyclodextrin complexes in cosmetics*	*Beauty from contact lenses beyond vision correction*

Learning Resources	1. *New Cosmetic Science, Mitsui T. , Elsevier, 1998* 2. *CosmeticNanotechnology: Polymers and Colloids in Cosmetics, Sarah E.M., Kathleen O.H., Robert Y.L.,American Chemical Society, 2006*	3. *Delivery System Handbook for Personal Care and Cosmetic Products, Meyer R.R. ,William Andrew ASP, 2005.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1.Mr.Solomon Jonnes,Bengaluru,solomon@terracarb.com	*1. Dr. Amit Kumar Mishra , IIT Jodhpur, amit@iitj.ac.in*	*1. Dr. Devanandh venkata subhu, SRMIST*
2. Dr. Nagesh Kini,Thermax,Pune,Maharastra,nagesh.kini@gmail.com	*2. Dr. Sampath Kumar T.S, IIT Madras, tssk@iitm.ac.in*	*2. Dr. Selvamurugan, SRMIST*

Course Code	18NTE406T	Course Name	GREEN NANOTECHNOLOGY	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	The purpose of learning this is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Familiarize with the field of traditional manufacturing to green manufacturing			
CLR-2 :	Understand the various p techniques for sustainable green manufacturing			
CLR-3 :	Able to green nanotechnology concepts in Industrial process			
CLR-4 :	Gain knowledge on industrial policies and operations in industry			
CLR-5 :	Understand the list of metrics in the industry			
CLR-6 :	Familiarize the life cycle process of industrial production			

Learning Outcomes (CLO):	At the end of this , learners will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Apply the concepts of green manufacturing in industry	2	80	75	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-2 :	Solve the general problems associated with the sustainable green manufacturing	2	80	70	H	M	M	H	M	M	M	H	M	H	M	H	M	M	M
CLO-3 :	Utilize and reuse the resources effectively in industrial process	2	75	70	H	M	H	H	H	H	H	M	H	H	H	H	H	H	H
CLO-4 :	Follow the policies & metrics in industrial process	2	80	75	M	H	H	M	H	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Analyze the life cycle production systems using analyzing machine tools	2	80	70	H	M	H	H	H	M	M	H	M	H	M	H	H	H	H
CLO-6 :	Utilize green manufacturing in semiconductor manufacturing process	2	80	75	H	M	M	H	H	M	M	H	H	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Green manufacturing	Social, business & policy environment	Metrics for green manufacturing	Closed loop production systems	Semiconductor manufacturing
	SLO-2	Sustainability	Need for change	Current metrics	Life cycle production systems	Semiconductor fabrication
S-2	SLO-1	Regulation pressure	Internal stake holders	Financial metrics	Economic and ecological benefits	Micro fabrication process
	SLO-2	Economic incentives	External stake holders	Metrics for ecology	Reduction of investment & increase of resources	Lithography
S-3	SLO-1	Comprehensive advantages	Components of next transition	Metrics for society	Machine tools	Oxidation & annealing
	SLO-2	Barriers	Linear to circular transition	Multiple metrics	Energy consumption	Cleaning
S-4	SLO-1	Environment impact on waste generation	Product production to service provision	Impact assessment	Life cycle assessment machine tools	Facility systems – resource use
	SLO-2	Toxic chemical releases	Integrated, information – Rich Communication	Risk assessment	Methods & results	Abatement
S-5	SLO-1	Energy consumption and carbon emission	Policy environment – Changing policy trends	Material flow analysis	Process parameter optimization	Green manufacturing in industry
	SLO-2	Strategies for green manufacturing	Fostering co-operation	Energy flow analysis	Constant feed per tooth	Concepts & challenges
S-6	SLO-1	Green supply chain	Principles of green manufacturing	Metric development methodologies	Constant spindle speed	Use phase issues
	SLO-2	Motivation for green supply chain (GSC)	Technology – wedgels	Ecological metric choice model	Conventional vs high speed machining	Analysis phase of semiconductor manufacturing
S-7	SLO-1	Definition of GSC	1st principle of green manufacturing	Decision tree model for equipment's	Dry machining and minimum quantity	Upstream materials

				Supply	*lubrication*	
	SLO-2	*Issues in GSC*	*2nd principle of green manufacturing*	*Metrics development for component systems*	*Health & environmental hazards*	*Chemicals, silicon, water*
S-8	SLO-1	*Level of approach*	*3rd principle of green manufacturing*	*Green energy supply*	*Remanufacturing – product recovery & industrial practice*	*Infrastructure & equipment*
	SLO-2	*General problems in GSC*	*4th principle of green manufacturing*	*Green energy technologies*	*Challenges & opportunities*	*Electricity*
S-9	SLO-1	*Techniques of GSC*	*Mapping of principles*	*Solar photovoltaics, wind energy*	*Reuse*	*Semiconductor manufacturing*
	SLO-2	*Future of GSC*	*Solutions*	*Application potentials of green energy*	*Approaches for sustainable factory design*	*Transportation & use phase*

Learning Resources	1. *Green Manufacturing- Fundamentals and Applications, David A Dornfeld, Springer science publishing, 2013*	2. *Green Nanotechnology: Solutions for Sustainability and Energy in the Built Environment, Geoffrey B. Smith, Claes-Goran S. Granqvist, CRC Press, 2010*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

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

Course Code	18NTE407T	Course Name	ADVANCED COMPUTATIONAL TECHNIQUES	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	Nanotechnology	Data Book / Codes/Standards		Nil	

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	Know the physical effects at the nanometer and sub-nanometer scales: how computational methods can help to understand the properties and at nanoscale
CLR-2 :	Acquire knowledge on molecular and optical computing
CLR-3 :	Know the basis of Biomedical Computing and its application
CLR-4 :	Develop concept on the physics and application of quantum computing
CLR-5 :	Acquire knowledge on parallel information processing mechanism and architecture
CLR-6 :	Understanding the various computing techniques in advance level

Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Apply the knowledge of the properties of nanomaterial in advance computing	2	80	75	H	M	H	H	H	H	H	H	M	H	M	H	H	H	H
CLO-2 :	Determine design principles through computation	2	80	70	H	M	H	H	M	M	M	H	H	H	M	H	M	M	M
CLO-3 :	Apply the knowledge of Biomedical Computing	2	75	70	H	L	H	H	H	H	H	H	H	H	M	H	H	H	H
CLO-4 :	Execute the basic of Qubit problems and gain depth knowledge about Quantum Computing	2	80	75	H	M	H	H	H	M	M	H	H	H	M	H	H	H	H
CLO-5 :	Apply knowledge of computing architecture in efficient optimization of the materials problems	2	80	70	H	M	H	H	H	M	M	H	M	H	M	H	H	H	H
CLT-6:	Demonstration of the ability to design new functional materials	2	80	70															

Duration (hour)		9	9	9	9	9
S-1	SLO-1	History of computing – Nanocomputing	Molecular Computing	Introduction to Biochemical Computing	Bit and Qubit	Parallel computing
	SLO-2	Nanocomputing Technologies – Alternative to Transistor Technology	Applications of Molecular Computing	Examples of Biochemical Computing	Coherence and Entanglement	Shared and Distributed Memory Clusters
S-2	SLO-1	Quantum Computing	Modeling molecules	Application of DFT in biological system	Concept Coherence	Parallel algorithm
	SLO-2	Quantum Computing: Applications	Modeling clusters of atoms	Application of MD in biological system	Concept of Entanglement with Examples	MPI based algorithm as example
S-3	SLO-1	Nano Information Processing	Overview of various first-principles methods	Genetic Algorithm	Theory Quantum Parallelisms	Working Concept of Mono and Multiprocessor Systems
	SLO-2	Prospects and Challenges	Discussion on Limitation and Application	Application of GA to Biological Systems	Application of Quantum Parallelisms	Applications: Mono and Multiprocessor Systems
S-4	SLO-1	Digital Signals	Density Functional Theory (DFT)-	Biological Neurons	Classical Gates – Reversible Operations	Some considerations to Parallel Processing
	SLO-2	Digital Gates	Density Functional Theory (DFT)- HK and KS equations	Biological Neurons in information processing	Sqrt (NOT) Operation	Usefulness of Parallel processing in various device applications
S-5	SLO-1	Concept Silicon Nanoelectronics	Structural, Electronic of nanomaterials from DFT calculations (Examples only)	Function of neuron cell on silicon	Concept of Quantum Algorithm	Influence of Delay Time
	SLO-2	Application of Silicon Nanoelectronics	Magnetic properties (examples only)	Function of neuron cell on silicon for	Application Quantum Algorithms	Performance efficiency on Delay time

				Signal processing		
S-6	SLO-1	*Introduction to Carbon Nanotube Electronics*	*Concept of Optical Computing*	*Modeling of neuron cells by VLSI circuits*	*Challenges to large Quantum Computers*	*Power Dissipation*
	SLO-2	*Application of CNT electronics*	*Application of Optical Computing*	*Problems on Modeling of neuron cells by VLSI circuits*	*Fabrication, Testing Architectural Challenges*	*Power Dissipation in different system*
S-7	SLO-1	*Concept of Silicon Nanoelectronics*	*Current use of optics for Computing in Industry*	*Neural networks and distributed data processing*	*Working Concept of Quantum dot cellular automata*	*Architecture for Processing in Nanosystems*
	SLO-2	*Application of Silicon Nanoelectronics*	*Optics for Computing: Future Applications*	*Problems on Neural networks and distributed data processing*	*Application with Example of Quantum dot cellular automata*	*Classic Systolic Arrays*
S-8	SLO-1	*Concept of Carbon Nanotube Electronics*	*Optical Computing Paradigms*	*Working concept of DNA Computer*	*Introduction and Working principle of Computing with QCA*	*Processor with large memory*
	SLO-2	*Application of Carbon Nanotube Electronics*	*Optical Computing Paradigms: Examples*	*Application of a DNA Computer*	*Application of Computing with QCA*	*Application of Processor with large memory*
S-9	SLO-1	*Modeling of Carbon Nanotube*	*Working concept of Photonic Switches.*	*Information Processing with Chemical reactions: Working Concept*	*QCA Clocking.*	*Processor array with SIMD*
	SLO-2	*Field Effect Transistors based on CNT*	*Application of Photonic Switches.*	*Information Processing with Chemical reactions: Example*	*QCA Design Rules.*	*PIP Architectures.*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember / Understand	*40 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply / Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate / Create	*20 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Hemant Dixit, GlobalFoundaries, aplahemant@gmail.com	1. Dr. Ranjit Kumar Nanda, IITM Chennai, nandab@iitm.ac.in	1. Dr. C. Preferencial Kala, SRMIST
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Course Code	18NTE408T	Course Name	NANOTECHNOLOGY IN TEXTILES	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	*The purpose of learning this is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Acquire knowledge on nanotechnology for textile applications*			
CLR-2 :	*Learn the smart materials and devices for textile industry*			
CLR-3 :	*Study the various nanostructures for improving the textile yarn and fabric*			
CLR-4 :	*Understand the nanomaterials processing for textile industry*			
CLR-5 :	*Learn various nanodevices for improving the textile fabrics*			
CLR-6 :	*Get familiarize with the integration of nanodevices in textiles*			

Learning Outcomes (CLO):	*At the end of this , learners will be able to:*	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	*Utilize the scientific concepts of nanotechnology in textile applications*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Apply the nanoparticles & nanofibers in textile fabric designs*	*2*	*80*	*70*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*M*	*M*	*M*
CLO-3 :	*Familiarize the characteristics and classification of the nanomaterials for nanofabrics*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*
CLO-4 :	*Apply various nanocoating methodologies for improving textile fabrics*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-5 :	*Familiarize with new concepts of Nanotechnology based product in Textiles*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*M*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6 :	*Apply the various nanostructures and materials in textiles fabrics*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*M*	*M*	*H*

Duration (hour)		9	9	9	9	
S-1	SLO-1	*Introduction to smart nanotextiles*	*Responsive Polymers*	*Nanocomposites for textiles*	*Nanocoatings for textiles*	*Nanogenerators for textiles*
	SLO-2	*Nanotechnology & nanomaterials*	*Classification of stimuli-responsive polymers*	*Classifications*	*Various methods of nanocoating*	*Working of nanogenartors*
S-2	SLO-1	*Nanofibers*	*Responsive polymers as sensors*	*Structure & properties*	*Sol-gel Processing*	*Classification of nanogenerators*
	SLO-2	*Advantages of nanofibers*	*Responsive polymers in drug delivery systems*	*Production methods of nanocomposites*	*Sol-gel coating methodology*	*Piezoelectric Nanogenerators (PENG)*
S-3	SLO-1	*Nanofibers fabrication*	*Responsive polymers in cell application*	*Carbon structures*	*Photocatalytic self-cleaning*	*Triboelectric Nanogenerators (TENG)*
	SLO-2	*Electrospinning*	*Responsive polymers based filters*	*Nanocellulose*	*Super hydrophobic self-cleaning*	*Theoretical origin of Nanogenerators*
S-4	SLO-1	*Enhancing the mechanical properties*	*Nanowires for textiles*	*Conducting polymers*	*Antibacterial coating*	*Fiber based PENGs*
	SLO-2	*Large scale production of fibers*	*Properties of nanowires in textiles*	*Nanoparticles, clays & wires*	*UV-Protection coating*	*Textile based PENGs*
S-5	SLO-1	*Formation of yarn & fabric*	*Balancing transparency and conductance*	*Laminated nanocomposites and fibers*	*Impregnation*	*TENGs Classifications*
	SLO-2	*Moisture management & waterproof*	*High specific surface area*	*Membranes, coatings, & Hydrogels*	*Cross linking method*	*Fibers based TENGs*
S-6	SLO-1	*Thermoregulation*	*Direct charge transport path*	*Sensing of Nanocomposites*	*Plasma surface activation*	*Textiles based TENGs*
	SLO-2	*Personal protection*	*Oriented assembly of Nanowires*	*Actuators of Nanocomposites*	*Surface modification process*	*1D materials based TENGs*
S-7	SLO-1	*Wearables and sensors*	*Metal conducting Nanowires*	*Antibacterial activity of Nanocomposites*	*Flame retardant coatings*	*2D fabrics for TENGs*
	SLO-2	*Medical care of nanofibers*	*Conducting polymer Nanowires*	*Defense applications of Nanocomposites*	*Carbon materials*	*3D woven textile TENGs*
S-8	SLO-1	*Nanosols as coating agent*	*Oxide semiconducting Nanowires*	*Fire protection*	*Phase change materials in thermal*	*Integrating energy harvesting devices*

					regulation	
	SLO-2	*Applications of nanosols in textiles*	*Sulphide semiconducting Nanowires*	*Fire retardant materials*	*Nanowires in thermal regulation*	*TENGs with solar cells*
S-9	SLO-1	*Photocatalytic and light responsivity of nanosols*	*Other semiconducting Nanowires*	*Self-cleaning*	*Carbon based conducting coating*	*Integrating energy storage devices*
	SLO-2	*Antimicrobials and bioactive systems*	*Current and future perspective of Nanowires*	*Energy harvesting of Nanocomposites*	*Metal based conducting coating*	*Future prospects of Nanogenerators*

Learning Resources	1. *Nazire D. Yilmaz, Smart Textiles, Wearable Nanotechnology, Ist Ed., Scrivener Publishing, 2019* 2. *P. J. Brown and K. Stevens, Nanofibers and nanotechnology in textiles, CRC Press, 2007*	3. *Nanotechnology in Textiles: Theory and Application, Jiří Militký and Rajesh Mishra, Elsevier Publications, 2018*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers

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

Course Code	18NTE409T	Course Name	CANCER NANOTECHNOLOGY	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	*The purpose of learning this is to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-1 :	*Understanding the basis of cancer biology*																		
CLR-2 :	*Know the various types of cancer biomarkers*																		
CLR-3 :	*Getting knowledge about ways to treat cancer growth*																		
CLR-4 :	*Get acquainted with nanomaterial based current therapies available for cancer treatment.*																		
CLR-5 :	*Get acquainted with the current trend in cancer theranostics*																		
CLR-6:	*Know about the market requirements for nanomaterial based therapies*																		
Learning Outcomes (CLO):	*At the end of this , learners will be able to:*																		
CLO-1 :	*Analyze the nature of cancer*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Analyze the concepts of cancer nanotechnology*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*M*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Apply concepts of cancer nanotechnology to a focused clinical area of their choice*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*H*
CLO-4 :	*Apply these nanosystems for the diagnosis and therapy*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-5 :	*Apply the concepts of nano theronostic strategy*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6 :	*Apply concept of gene silencing for cancer therapy*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*The biology and genetics of cells and organisms*	*Cell immortalization*	*Theranostic cancer biomarkers*	*Magnetic nanoparticles as contrast agents for MRI application*	*Pancreatic cancer stem cells as new targets for diagnostics*
	SLO-2	*The nature of cancer*	*Tumorigenesis*	*Targetted cancer theranostics*	*Magnetic nanoparticles as contrast agents for therapeutic application*	*Pancreatic cancer stem cells as new targets for therapy*
S-2	SLO-1	*Tumor viruses*	*Cancer development*	*Molecular imaging in cancer theranostics*	*Ultrasound-responsive nanoparticles as drug delivery carriers*	*Nanomedicine approaches for cancer stem cell targeting*
	SLO-2	*DNA oncoviruses*	*The biology of angiogenesis*	*Imaging-guided cancer therapy*	*Ultrasound-responsive nanoparticles as gene delivery carriers*	*Personalized cancer treatment*
S-3	SLO-1	*RNA oncoviruses*	*Invasion*	*Theranostic platforms*	*Noble metal nanoparticle platform*	*Methods adopted for Personalized cancer treatment*
	SLO-2	*Non-human oncoviruses*	*Metastasis*	*Nanomaterials for theranostics of gastric cancer*	*Cancer theranostics with Gold nanoparticle*	*Lipid based nanosystem for theranostictics*
S-4	SLO-1	*Cellular oncogenes*	*Types of cancers*	*Photo triggered drug delivery strategies For cancer theranostics*	*Cancer theranostics with Silver nanoparticle*	*Lipid based nanosystem for delivery of siRNA*
	SLO-2	*Growth Factors*	*Liver cancer*	*Proteomics-based theranostics*	*Metal oxide for cancer theranostics*	*Gene therapy for cancer*
S-5	SLO-1	*Growth Factor receptors*	*Lung cancer*	*Radionuclide imaging of cancer therapy*	*Cancer theranostics with carbon-based*	*Gene silencing by DNAzymes*

					nanoplatforms	
	SLO-2	*Cytoplasmic signal circuitry program*	*Skin cancer*	*Nanotargetted radionuclide imaging*	*CNT and grapheme based theranostics*	*Gene silencing ribozymes*
S-6	SLO-1	*Traits of Cancer*	*Colon cancer*	*Bioluminescence imaging of cancer therapy*	*Cancer theranostics with silica nanoparticle platform*	*Gene silencing by antisense DNA*
	SLO-2	*Tumor Suppressor genes*	*Stem cells and cancer*	*Imaging in luciferase labeled cancer cells*	*Silica tethered particles for cancer theranostics*	*Gene silencing by microRNA*
S-7	SLO-1	*Types of Tumour Suppressor genes*	*Molecular genetics of cancer*	*Magnetic resonance imaging of cancer therapy*	*Polymer- -based nanotechnologies for cancer theranostics*	*Rationale for immunotherapy*
	SLO-2	*Characteristics of pRb*	*Chemical modifications of chromatin-associated proteins*	*CT based imaging of cancer therapy*	*Protein-based nanotechnologies for cancer theranostics*	*Adoptive immunotherapy*
S-8	SLO-1	*pRb gene-Control of cell cycle clock*	*Genetic alterations in cancer cells: mutations*	*Boron capture therapy and imaging*	*Production of theranostic nanoparticles*	*Antibody based therapy*
	SLO-2	*Characteristics of p53*	*Three types of mutation*	*Ultrasound imaging of cancer therapy*	*Scale-up of theranostic nanoparticles*	*Galectins as targets for novel and specific antibody therapies in gynecologic cancer therapies*
S-9	SLO-1	*Mutation of p53 and apoptosis*	*Chromosomal abnormalities*	*Gene expression microarrays*	*Market considerations*	*Glycans and mucins as targets for novel and specific antibody therapies in gynecologic cancer therapies*
	SLO-2	*Role of p53 in cell cycle progression*	*Acquired abnormalities*	*Tissue arrays*	*Nanotechnology and nanomedicine patenting systems*	*Commercial development of antibodies as drugs*

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

Learning Assessment											
	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	30 %	-	30 %	-	30 %	-	30 %	-	30%	-
	Understand										
Level 2	Apply	40 %	-	40 %	-	40 %	-	40 %	-	40%	-
	Analyze										
Level 3	Evaluate	30 %	-	30 %	-	30 %	-	30 %	-	30%	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. Nagesh Kini,Thermax,Pune,Maharastra,nagesh.kini@gmail.com	*2. Dr. Sampath Kumar T.S,IIT Madras, tssk@iitm.ac.in*	*2. Selvamurugan, SRMIST*

Course Code	18NTE410T	Course Name	VACUUM AND THINFILM 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	Nanotechnology	Data Book / Codes/Standards		Nil	

Learning Rationale (CLR):	The purpose of learning this is to:	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	Acquire knowledge on vacuum systems and technology			
CLR-2 :	Understand the functionalities of various vacuum pumps and gauges			
CLR-3 :	Gain Knowledge on various physical and chemical vapor deposition techniques			
CLR-4 :	Understand the various thin film growth mechanisms and theories explaining them			
CLR-5 :	Gain knowledge on various characterization techniques tools to characterize thin films			
CLR-6 :	Acquire knowledge on various physical, optical and chemical properties of thin films			

Learning Outcomes (CLO):	At the end of this , learners will be able to:	Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Program Learning Outcomes (PLO)														
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
					Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLO-1 :	Apply the functionalities of vacuum systems and can operate them	2	80	75	H	M	H	H	H	M	M	H	H	H	H	H	H	H	H
CLO-2 :	Utilize the knowledge acquired to operate vacuum pumps and create vacuum and measure at various regimes	2	80	70	H	H	H	H	H	H	M	H	H	H	M	H	M	M	M
CLO-3 :	Grow thin films using various physical and chemical vapor deposition techniques	2	80	70	H	M	H	H	H	H	H	M	H	H	H	H	H	H	H
CLO-4 :	Construe the physics and chemistry of growth mechanisms and measure the thickness using various techniques	2	80	75	H	M	H	H	H	H	H	H	H	H	H	H	H	H	H
CLO-5 :	Apply the concept of various characterization tools and operate them	2	80	70	H	H	H	H	H	M	M	H	H	H	H	H	H	H	H
CLO-6 :	Elucidate various properties of thin films and measure them using different tools	2	80	75	H	M	H	H	H	M	M	H	H	H	H	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Over view of vacuum systems and technology	Over view of Physical vapor deposition techniques	Introduction to chemical deposition	Basic physics and chemistry behind thin films layer formation	Thin films characteristics
	SLO-2	Units and different regions of vacuum	Thermal evaporation, Resistive heating and RF-heating	Electrodeposition	Nucleation and early stages of film growth	Topography
S-2	SLO-1	Kinetic theory of gases	Flash evaporation	Electrolytic deposition	Thermodynamic aspects of nucleation	Structure integrity- X-ray diffraction (XRD)
	SLO-2	Gas flow and Mean free path	Laser evaporation	Electro less deposition	Thin film growth modes	Scanning electron microscopy
S-3	SLO-1	Conductance	Co-evaporation	Anodic oxidation	Capillary theory	Transmission electron microscopy
	SLO-2	Different types of pumps	Electron bombardment heating	Spray pyrolysis	Volmert-Weber growth	Energy dispersive analysis of thin films
S-4	SLO-1	Mechanical pumps	Sputtering plasma, discharges and arc	Dip coating and Spin coating	Frank-van der Merwe (FM) growth	Auger electron spectroscopy
	SLO-2	Diffusion and turbo molecular pump	Sputtering variants, yield and low pressure sputtering	Chemical vapor deposition (CVD)	Stranski-Krastanov growth	X-ray photoelectron spectroscopy
S-5	SLO-1	Ion pumps	RF-sputtering	Homogenous and heterogeneous process	Thickness dependent properties of thin films	Rutherford backscattering spectroscopy
	SLO-2	Measurement of vacuum	Reactive sputtering	CVD reactions	Thickness measurements	Secondary ion mass spectrometry
S-6	SLO-1	Direct and indirect gauges	Magnetron sputtering	Hydrogen reduction	Roughness	Resistance – 2-point probe
	SLO-2	Pirani gauge	Magnetron configurations	Halide disproportionation, transfer reactions	Electrical methods	Resistance – 4-point probe

S-7	SLO-1	*Capacitance gauge*	*Bias sputtering*	*CVD processes and systems*	*Microbalance monitors*	*Optical properties*
	SLO-2	*Penning gauge*	*Evaporation versus sputtering*	*Low pressure CVD*	*Quartz crystal monitor*	*Characterization of layered structures*
S-8	SLO-1	*Vacuum system*	*Pulsed laser deposition (PLD) design and basics*	*Laser enhanced CVD*	*Mechanical method (stylus)*	*Atomic force microscopy (AFM)*
	SLO-2	*Components and operation of vacuum system*	*PLD operating procedure and its various application*	*Metalorganic CVD (MOCVD)*	*Optical interference methods*	*X-Ray Reflectivity (XRR)*
S-9	SLO-1	*Safety practices in vacuum systems*	*Molecular beam epitaxy (MBE) basics*	*Plasma Assisted Chemical Vapor Deposition (PACVD)*	*Ellipsometry*	*Reflection high energy electron diffraction (RHEED)*
	SLO-2	*Applications of vacuum technology*	*MBE operating procedure*	*Safety considerations*	*Interference fringes*	*In-situ RHEED*

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	*1. Dr. Kasiviswanathan, IIT Madras, kasi@iitm.ac.in*	*1. Dr. K. Kamala Bharathi, SRMIST*
2. Mr. Ramanujam, HHV, India	*2. Dr. M. S. Ramachandra Rao, IIT Madras, msrrao@iitm.ac.in*	*2. Dr. E. Senthil Kumar, SRMIST*

Course Code	18NTE411T	Course Name	ATOMISTIC MODELING	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLR-1 :	*Learn about basic modeling*			
CLR-2 :	*Understand the DFT for materials modeling*			
CLR-3 :	*Understand the MD simulation*			
CLR-4 :	*Gain knowledge about Monte Carlo Simulation*			
CLR-5 :	*Learn advance-modeling technique.*			
CLR-6 :	*Learn materials modeling to understand materials properties*			

Course Learning Outcomes (CLO):	*At the end of this course, learners will be able to:*	Learning		
		1	2	3
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)
CLO-1 :	*Acquire the basics of design and materials modeling*	2	*80*	75
CLO-2 :	*Gain knowledge DFT and related methods in the context of materials modeling*	2	*80*	70
CLO-3 :	*Obtain the knowledge on Molecular Dynamics and its application ot solve materials problem*	2	*75*	70
CLO-4 :	*Improve their knowledge on materials modeling with Monte Carlo Simulation*	2	*80*	75
CLO-5 :	*Solve problems to understand the electronic, mechanical and optical properties of Materials*	2	*80*	70
CLR-6 :	Explain the structural, electronic and magnetic properties of a given material	2	80	70

Program Learning Outcomes (PLO)														
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
H	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
H	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*H*	*M*	*M*	*M*
H	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
H	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
H	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Classical mechanics, Hamiltonians*	*Born-Oppenheimer approximation*	*Integrating F=ma*	*Introduction - key concepts*	*Introduction to various DFT codes*
	SLO-2	*Coordinate systems in the context of solving the physical problems*	*Limitations of BO approximation*	*Detail time steps*	*Starting structure - energy cutoff*	*Basic DFT outputs*
S-2	SLO-1	*Potential energy-Definition and Concept*	*Introduction to DFT*	*The basic MD algorithm*	*State space sampling*	*Basic output of QM code*
	SLO-2	*Basic pair potentials and their limitations*	*Hohenberg-Kohn Theorems*	*The MD steps*	*Classical momentum*	*Energies, electronic structure*
S-3	SLO-1	*Definition - Elastic constant*	*Kohn-Sham Equation*	*Taylor expansion,*	*Metropolis algorithm*	*Using the energies: molecular statics, MD, MC*
	SLO-2	*Calculation of elastic constants from potential function*	*Interpretation of KS equations*	*Verlet algorithms - choosing the time step*	*Examples with a problem*	*Using the energies: MC*
S-4	SLO-1	*Potentials for ionic systems*	*Exchange-correlation functions and LDA/GGA*	*Predictor-corrector algorithm*	*Monte Carlo simulation analysis*	*Using the electronic structure: optical properties*
	SLO-2	*Potentials for ceramics Systems*	*Accuracy of LDA/GGA*	*Discussion with Examples*	*Limitations of Monte Carlo simulations*	*Transitions between electronic states*
S-5	SLO-1	*Concept of Many-body potential*	*Pseudopotentials*	*MD in different ensembles*	*Introducing ensemble sin MC*	*Electrical conductivity*
	SLO-2	*Many -body potentials for metals*	*Types of Pseudopotentials*	*MD in constant temperature*	*Kinetic Monte Carlo*	*Mobility of electrons, scattering of electrons between states*

S-6	SLO-1	*Many-body potentials for covalently bonded systems*	*Brillouin zone*	*Molecular dynamics in constant pressure*	*Key concepts: starting structure in MD*	*Excited electron states due to thermal (or optical) excitations*
	SLO-2	*Comparative Study*	*K-points, Monkhorst-Pack mesh, Gama point*	*Examples of MD in constant temperature and pressure*	*Key concepts: starting structure in KMC*	*Type of bonding - tunneling rates*
S-7	SLO-1	*Energy optimization*	*Concept of Basis Set*	*Energies: molecular statics*	*Convergence criteria*	*Excited electron states due optical excitations*
	SLO-2	*Significance of Lowest energy structure*	*The need for self-consistency*	*Problems on Molecular Statistics*	*Scaling with lattice parameters*	*Example with a Material problem*
S-8	SLO-1	*Molecular statistics*	*Setting up structures, key parameters, Volume optimization Metals vs. insulators*	*MD Simulation analysis*	*Understanding the electronic structure*	*Understanding the electronic structure from different Methods, Comparative study*
	SLO-2	*Problems on Molecular Statistics*	*Basis sets, energy cutoff, exchange-correlation function, K-points*	*Limitations of MD*	*Electrical conductivity, Excited electron states*	*Wave functions, charge density, band structure, density of states*
S-9	SLO-1	*Thermo statistics*	*Convergence and scaling with lattice parameters,*	*Application of MD as Case Study: 3D system*	*Application of MC method as Case Study: Temperature effect*	*Confinement effect on Electronic Structure*
	SLO-2	*Problems on Thermo statistics problems*	*DOS and BAND Structure*	*Application of MD as Case Study: 2D system*	*Determination of Tc*	*3D, 2D, 1D Carbon based materials as example*

Learning Resources	1. *Jörg-Rüdiger Hill, Lalitha Subramanian and AmiteshMaiti, Molecular modeling techniques inmaterial sciences, Taylor & Francis/CRC Press: Boca Raton, 2005* 2. *Andrew R. Leach, Molecular modelling: principles and application, Pearson Education, India, 2001*	3. *R. Martin, Electronic Structure: Basic Theory and Practical Methods, Cambridge University Press, 2004* 4. *J.M. Thijssen, Computational Physics, Cambridge, UK: Cambridge University Press, 2000*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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2. Dr. Murali Kota, Global Foundaries, USA, kvrmmurali@gmail.com	*2. Prof. G.P. Das, IIT M, KGP, msgpd@iacs.res.in*	*2. Dr. Saurabh Ghosh, SRMIST*

Course Code	18NTE412T	Course Name	SOCIETAL IMPLICATIONS OF NANOTECHNOLOGY	Course Category	E	Professional Elective	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	The purpose of learning this course is to:	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-1 :	Provide an insight into the fundamentals of ethical implications of nanotechnology																		
CLR-2 :	Provide an insight into the fundamentals of social-economic implications of nanotechnology																		
CLR-3 :	Understand the implications of nanotechnology in quality of life																		
CLR-4 :	Understand the legal risks related with the nanotechnology																		
CLR-5 :	Explore the matters related to patents associated with nanotechnology																		
CLR-6 :	Understand the problems of governance of nanotechnology																		
Course Learning Outcomes (CLO):	At the end of this course, learners will be able to:																		
CLO-1 :	Apply the knowledge of ethical implications pertaining to nanotechnology	2	80	75	H	H	H	H	H	H	H	H	H	H	M	H	H	H	H
CLO-2 :	Address the socioeconomic implications of nanotechnology	2	80	70	H	H	M	H	H	H	H	M	M	H	M	H	M	M	M
CLO-3 :	Improve the quality of life	2	75	70	M	M	H	H	H	H	H	M	M	H	M	H	H	H	H
CLO-4 :	Address the legal risks related with the nanotechnology	2	80	75	H	H	M	H	M	H	H	H	H	H	M	H	H	H	H
CLO-5 :	Handle the issues related to patents associated with nanotechnology	2	80	70	H	M	H	H	H	M	M	M	M	H	H	H	H	H	H
CLO-6 :	Address the problems of governance of nanotechnology	2	80	75	M	M	M	H	M	H	H	M	M	H	M	H	H	M	H

Duration (hour)		9	9	9	9	9
S-1	SLO-1	Economic Impacts and Commercialization of Nanotechnology	Ethics, Law and Governance – Introduction	Social Scenarios - Introduction	Converging Technologies - Introduction	Public Perceptions and Education
	SLO-2	Introduction to societal implications of nanotechnology	Ethics and law	Nanoparticle toxicity and risk	Integrative Technology	Public perceptions-societal implications of nanoscience
S-2	SLO-1	Socio-economic impact of nanoscale science : initial results	Ethical issues in nanoscience and nanotechnology: reflections and suggestions	Navigating nanotechnology through society	Nanotechnology's implications for the quality of life	An agenda for public interaction research
	SLO-2	Socio-economic impact of nanoscale science : nanobank	Concerns of Nano scientists and engineers in Ethics and law	Public and private goods	Social implications	Communicating nanotechnological risks
S-3	SLO-1	Managing the nanotechnology revolution	Ethics and nano: a survey	Nanoparticle Toxicity and risk	Management of innovation for convergent technologies	Risk Assessment
	SLO-2	Malcolm Baldrige national quality criteria	Recent developments in nanotechnology	Nanotechnology, surveillance, and society	The "integration/penetration model"	Risk Communication
S-4	SLO-1	Emergence of Nanoeconomy	law in a new frontier	Methodological issues	Social impacts of nano biotechnology issues	Problems in Risk Communication
	SLO-2	Key drivers, challenges and opportunities	An exploration of patent matters associated with nanotechnology	Innovations for social research	Nanobiotechnology: The Science Dimension	A proposal to advance understanding of nanotechnology's social impacts

S-5	SLO-1	*Moore's law*	*U.S. Patent Statute*	*Nanotechnology: societal implications: individual perspectives*	*The Integration/Penetration Model: The Interface Range*	*Nanotechnology in the media: a preliminary analysis*
	SLO-2	*Transcending Moore's law with molecular electronics*	*The Ethics of Ethics*	*Nanotechnology: individual perspectives*	*New Forms of Knowledge: Computer Simulations and Modeling*	*Public engagement with nanoscale science and engineering*
S-6	SLO-1	*Molecular electronics – a next paradigm*	*Environmental Impacts of nanomaterials*	*Nanotechnology and social trends;*	*Regulatory structures and society*	*Nanophobia*
	SLO-2	*Transcending Moore's law with nanotechnology*	*Problems of governance of nanotechnology*	*Five nanotech social scenarios*	*Social impacts of nanobiotechnology issues*	*Public Engagement with nanotechnology*
S-7	SLO-1	*Transition from Microelectronics to nanoelectronics*	*Negotiations over quality of life in the nanotechnology initiative. Governance*	*Technological revolutions and the limits of Ethics in an age of commercialization*	*The use of analogies for interdisciplinary research in the convergence of nanotechnology*	*Nanotechnology: moving beyond risk*
	SLO-2	*Semiconductor scaling as a model for nanotechnology commercialization*	*Societal implications of emerging science and technologies: a research agenda for science and technology studies (STS)*	*Implications of Experiential data recorder*	*Interdisciplinary research in the convergence of bio technology*	*Communication streams and nanotechnology: the (Re) interpretation of a new technology nanotechnology*
S-8	SLO-1	*Sustaining the impact of nanotechnology on productivity*	*Institutional impacts of government science initiatives*	*Vision, innovation, and policy*	*Interdisciplinary research in the convergence of information technology*	*Societal implications- individual perspectives*
	SLO-2	*Sustaining the impact of nanotechnology on sustainability, and equity*	*Challenges for government and universities*	*Institutionalizing Multi-Disciplinary Engagement*	*Converging technologies: innovation, legal risks, and society*	*The case of Cold Fusion*
S-9	SLO-1	*Implications of Information*	*Nanotechnology for national security*	*Post-hoc Versus Therapeutic Ethics*	*Converging technologies and their societal implications*	*The case of Recombinant DNA*
	SLO-2	*Non-Nano effects of nanotechnology on the economy*	*Nanotechnology in Defense*	*Nano revolution implications for the artist*	*Short-term implications of convergence for scientific and engineering disciplines*	*Historical comparisons for anticipating public reactions to nanotechnology*

Learning Resources	1. *C.R. Mihail, and S.B. William, Nanotechnology: societal implications, Springer publication, 2011 (978-1-4020-5432-7)* 2. *Ronald Sandler, Nanotechnology the Social & Ethical Issues, Woodrow Wilson, 2009*	3. *Mihail C. Roco and William Sims Bainbridge, Societal Implications of Nanoscience and Nanotechnology, National Science Foundation, 2001.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember Understand	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
Level 2	Apply Analyze	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
Level 3	Evaluate Create	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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Course Code	18NTE413T	Course Name	NANOTECHNOLOGY IN TISSUE ENGINEERING	Course Category	E	*Professional Elective*	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	*The purpose of learning this is to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-1 :	*Understand the general scientific concepts of tissue engineering*																		
CLR-2 :	*Know the various tissue culture techniques*																		
CLR-3 :	*Acquire knowledge about the role of nanotechnology in tissue engineering and regenerative medicine*																		
CLR-4 :	*Get acquainted with the current trend in tissue engineering and regenerative technology*																		
CLR-5 :	*Understand the tissue responses to biomaterial*																		
CLR-6 :	*Acquire knowledge on various methods adopted tissue scaffold generation*																		
CLO-1 :	*Apply basic knowledge of tissue anatomy for tissue mimicking*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Analyze the basic challenges of tissue engineering*	*2*	*80*	*70*	*H*	*M*	*M*	*H*	*M*	*M*	*M*	*H*	*M*	*H*	*M*	*M*	*M*	*M*	*M*
CLO-3 :	*Apply concepts of tissue engineering in biomedical applications*	*2*	*75*	*70*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*
CLO-4 :	*Apply these nanosystems for the therapy*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-5 :	*Apply concepts in making nanoscaffold and bioactive substrates*	*2*	*80*	*70*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*M*	*H*	*M*	*M*	*H*	*H*	*H*
CLO-6 :	*Apply the tissue engineering principles to future therapy*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*H*
Learning Outcomes (CLO):	*At the end of this , learners will be able to:*																		

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*The Cell*	*First Cultures: culture containers*	*Characteristics of biomaterials*	*Electrospinning*	*Electrospun Nanofibers for Neural Applications*
	SLO-2	*The cell as a functional unit*	*First Cultures: culture media*	*Design of biomaterials*	*Experimental setup and basic principle*	*Nanofiber-Based Integrative Repair of Orthopedic Soft Tissues*
S-2	SLO-1	*Tissue types*	*Serum free culture media*	*Fundamental aspects of tissue responses to biomaterials*	*Effects of parameters on electrospinning*	*Nanotechnologies for Peripheral Nerve Regeneration*
	SLO-2	*Soft and Hard tissue*	*Growth factors*	*Types of tissue responses*	*Solution parameters*	*Nanofibrous Materials for Vascular Tissue Engineering and Regeneration*
S-3	SLO-1	*Extracellular matrix*	*Cell Culture Techniques*	*Repair and regeneration*	*Environmental parameters*	*Engineering Soft Nanostructures for Guided Cell Response*
	SLO-2	*Extracellular matrix components and function*	*Hybridomas*	*Evaluation of biomaterial behavior*	*Biomedical Applications of electrospun nanofibres*	*Nanoparticles-Incorporated Scaffolds for Tissue Engineering Applications*
S-4	SLO-1	*Emergence of tissue*	*Cardiomyocites cultivation*	*Adhesion, migration and survival*	*Nanofibres as 3D scaffold for tissue regeneration*	*Electrospun Pseudo Poly (Amino Acids) for Tissue Engineering Applications*
	SLO-2	*Germ layers and Ground tissue*	*Cryopreservation*	*Properties of biomaterials assessed through in vivo experiments*	*Nanofibre scaffolds for interface regeneration*	*Nano-enabled Platforms for Metastatic Malignant Melanoma*

S-5	SLO-1	*Regeneration*	*Slow programmable freezing*	*Hydrogels*	*Techniques to improve porosity*	*Immune Response to Implanted Nanostructured Materials*
	SLO-2	*Various phase of regeneration*	*Vitrification*	*Types of hydrogels used in tissue engineering*	*Techniques to improve cell infiltration*	*3D Bioprinting – introduction*
S-6	SLO-1	*Concept of tissue construction*	*Persufflation*	*Chitosan as biomaterial for tissue engineering*	*Hybrid fibres for bone regeneration*	*3D Bioprinting-priciples*
	SLO-2	*Three steps of tissue development*	*Tissue culture: Migration*	*Nanobiomaterials for regeneration*	*Hybrid fibres for ligament regeneration*	*CAD based bioprinting*
S-7	SLO-1	*Stem cells- types*	*Tissue culture: new formation*	*Carbon Nanobiomaterial*	*Hybrid fibres for tendon regeneration*	*CAM based bioprinting*
	SLO-2	*Embryonic stem cell*	*Dedifferentiation*	*Self assembling nanobomaterials*	*Bioactive nanofibres*	*Laser based bioprinting*
S-8	SLO-1	*Mesenchymal stem cell*	*Organ culture: principles*	*Polymeric Nanobiomaterials*	*Types of Bioactive nanofibres*	*Bioprinted scaffolds*
	SLO-2	*Adult stem cells*	*Plasma clot method*	*Types of Polymeric Nanobiomaterials*	*Application of Bioactive nanofibres*	*Challenges and future development of 3D bio printing*
S-9	SLO-1	*Stem cells properties and source*	*Agar gel method*	*Ceramic nanobiomaterials*	*Biomolecules on nanofibers*	*Materials used for bio printing*
	SLO-2	*Responsible use of stem cells*	*Formation of organ from tissue*	*Types of Ceramic nanobiomaterials*	*Methods for immobilizing biomolecules*	*Bioprinting based tissue engineering applications*

Learning Resources	1. *W.M.Will, Raimund Strehl, Karl Schumacher, Tissue Engineering: From Cell Biology to Artificial Organs, WileyVCH, 2005.* 2. *Ketul Popat, Nanotechnology in Tissue Engineering and Regenerative Medicine, CRC Press/Taylor and Francis, 2011*	3. *Lijie Grace Zhang, John P Fisher, Kam Leong, 3D Bioprinting and Nanotechnology in Tissue Engineering and Regenerative medicine, Elsevier, 2015*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. K. Chandru Trivitron Healthcare Pvt. Ltd. Chennai, chandru.k@trivitron.com	*1. Dr.Amit Kumar Mishra , IIT Jodhpur, amit@iitj.ac.in*	*1. Dr. Devanandh Venkata Subbu, SRMIST*
2. Dr.Nagesh Kini,Thermax,Pune,Maharastra,nagesh.kini@gmail.com	*2. Dr. T.S Sampath Kumar, IIT Madras, tssk@iitm.ac.in*	*2. S. Anandhakumar, SRMIST*

Course Code	18NTE414T	Course Name	NANOMAGNETISM AND SPINTRONICS	Course Category	E	*Professional Elective Course*	L	T	P	C
							3	0	0	3

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

Learning Rationale (CLR):	*The purpose of learning this is to:*	Learning			Program Learning Outcomes (PLO)														
		1	2	3	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
		Level of Thinking (Bloom)	Expected Proficiency (%)	Expected Attainment (%)	Engineering Knowledge	Problem Analysis	Design & Development	Analysis, Design, Research	Modern Tool Usage	Society & Culture	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO - 1	PSO - 2	PSO - 3
CLR-1 :	*Understand the basic concepts related various type of magnetism and magnetic properties of materials*																		
CLR-2 :	*Provide in-depth knowledge about low dimensional magnetic materials*																		
CLR-3 :	*Understand the magnetization behavior of magnetic nanostructures and thin films*																		
CLR-4 :	*Give an overview of different Experimental Approaches to characterize magnetic nanostructures*																		
CLR-5 :	*Acquire knowledge about fundamentals in spintronics with glimpse of contemporary topics in this field*																		
CLR-6 :	*Provide in-depth knowledge of spin polarized current and spin transfer torque*																		
Learning Outcomes (CLO):	*At the end of this , learners will be able to:*																		
CLO-1 :	*Realize the importance of "magnetism" in contributing to past and for the advancement of new technology*	*2*	*80*	*75*	*H*	*M*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-2 :	*Appreciate the significance of in-depth understanding of magnetic properties in low dimension*	*2*	*80*	*70*	*H*	*H*	*M*	*H*	*M*	*M*	*H*	*H*	*M*	*H*	*M*	*H*	*M*	*M*	*M*
CLO-3 :	*Obtain the knowledge about fabrication of magnetic nanostructures and properties of the magnetic nanostructures*	*2*	*75*	*70*	*H*	*H*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*	*H*
CLO-4 :	*Know various sensitive characterization techniques for magnetic nanostructures.*	*2*	*80*	*75*	*M*	*H*	*H*	*M*	*H*	*H*	*H*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*H*
CLO-5 :	*Analyze the mechanism of spin transport in magnetic nanostructures and its relevance in advancing the existing magnetic recording technology*	*2*	*80*	*70*	*H*	*H*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*H*	*M*	*H*	*H*	*H*	*H*
CLO-6 :	*Gain the conceptual knowledge related to nanomagnetism and spintronics for energy efficient devices*	*2*	*80*	*75*	*H*	*M*	*M*	*H*	*H*	*M*	*M*	*H*	*H*	*H*	*M*	*H*	*H*	*M*	*H*

Duration (hour)		9	9	9	9	9
S-1	SLO-1	*Basics of magnetism, Units in magnetism*	*Concept of Magnetic ordering*	*Magnetism in thin films*	*Introduction to various magnetometers*	*Introduction to spin transport*
	SLO-2	*Introduction to ferromagnetism, paramagnetism, diamagnetism*	*Magnetic ordering in low dimensions*	*Magnetism in multilayers*	*Working principle of magnetometers*	*Spin angular momentum*
S-2	SLO-1	*Introduction to Ferrimagnetism and Anti-ferromagnet*	*Physical origin of Magnetic anisotropy*	*Fabrication of nanomagnets using various techniques*	*Vibrating Sample Magnetometer*	*Spin Current*
	SLO-2	*Origin of various type of magnetization behavior*	*Shape anisotropy and Magnetocrystalline anisotropy*	*Top down and bottom up approach*	*Superconducting Quantum Interference Device*	*Spin valve devices*
S-3	SLO-1	*Magnetization curves and hysteresis loops, Saturation magnetization,*	*Dipolar anisotropy, Interface magnetic anisotropy*	*Single domain versus multi domain behavior*	*Magnetic imaging techniques*	*Giant magneto resistance (GMR)*
	SLO-2	*Coercive field, Magnetic susceptibility*	*Competing energy scale determining magnetic anisotropy*	*Chemical synthesis of magnetic nano-particles*	*Magneto-optical Kerr effect*	*Spin dependent scattering*
S-4	SLO-1	*Formation of magnetic domains*	*Mechanisms of magnetization reversal,*	*Self assembly of magnetic nanoparticles*	*Longitudinal, Transverse and Polar Kerr effect*	*Valet-Fert model for GMR*
	SLO-2	*Domain walls, Domain wall width*	*Coherent rotation*	*Magnetic nanowires*	*Faraday effect*	*Magnetic tunnel junction*
S-5	SLO-1	*Various type of domain walls*	*Fanning, curling*	*Physical vapor deposition of magnetic thin films*	*Magnetic force microscopy*	*Tunnel magneto resistance (TMR)*

	SLO-2	*Bloch walls and Neel walls*	*Domain wall movement*	*Physical vapor deposition of multilayers*	*Scanning electron microscopy with polarization analysis*	*Application of GMR and TMR*
S-6	SLO-1	*Quantum mechanical picture of Heisenberg exchange interaction*	*Introduction to Gilbert damping*	*DC and RF Sputter deposition of Magnetic materials*	*Interpretation of magnetic contrast from thin films and nanostructures*	*Spin transfer torque*
	SLO-2	*Role of Heisenberg exchange interaction in magnetism*	*Significance of Gilbert damping in choosing magnetic material for application*	*Magnetic Material deposition using E-beam evaporation technique*	*Magnetic contrast from nanostructures*	*Spin-orbit coupling induced phenomena*
S-7	SLO-1	*Energy scales involved in magnetism*	*In-plane magnetic anisotropy*	*Magnetization reversal in magnetic thin films*	*Spin-polarized scanning tunneling microscope (SP-STM)*	*Spin dynamics*
	SLO-2	*Zeeman energy*	*Magnetic domains in in-plane magnetized materials*	*Domain walls and magnetization reversal nanostructures*	*Interpretation of SP-STM results*	*Advanced spintronics based devices*
S-8	SLO-1	*Magnetic anisotropy energy, exchange energy*	*Perpendicular magnetic anisotropy*	*Magnetic properties of nanostructured soft magnetic materials NiFe*	*Introduction to magnetic recording*	*Domain wall based memory*
	SLO-2	*Discussion on Magnetostatic energy*	*Magnetic domains in out-of-plane magnetized materials*	*Magnetic properties of nanostructured soft magnetic materials CoFeB*	*Magnetic recording principles*	*Magnetic random access memory*
S-9	SLO-1	*Introduction to hard magnetic materials*	*Formation of magnetic vortex*	*Magnetic properties of nanostructured hard magnetic materials FePt*	*Nanomagnetic disks*	*Heat assisted magnetic recording*
	SLO-2	*Introduction to soft magnetic materials*	*Formation of antivortex and Skyrmions*	*Magnetic properties of nanostructured hard magnetic materials CoPt*	*Read and write head*	*Microwave assisted magnetic recording*

Learning Resources	*1. Principles of Nanomagnetism, by Alberto P. Guimaraes, XII, Springer Berlin Heidelberg New York, 2009* *2. Advanced Magnetic Nanostructures, by David Sellmyer, Ralph Skomski, Springer Heidelberg, 2010*	*3. Spin dynamics and damping in ferromagnetic thin films and nanostructures, by Anjan Barman and Jaivardhan Sinha, Springer, Switzerland, 2018*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (50% weightage)								Final Examination (50% weightage)	
		CLA – 1 (10%)		CLA – 2 (15%)		CLA – 3 (15%)		CLA – 4 (10%)#			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Understand										
Level 2	Apply	*40 %*	-	*40 %*	-	*40 %*	-	*40 %*	-	*40%*	-
	Analyze										
Level 3	Evaluate	*30 %*	-	*30 %*	-	*30 %*	-	*30 %*	-	*30%*	-
	Create										
	Total	100 %		100 %		100 %		100 %		100 %	

CLA – 4 can be from any combination of these: Assignments, Seminars, Tech Talks, Mini-Projects, Case-Studies, Self-Study, MOOCs, Certifications, Conf. Paper etc.,

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
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