ACADEMIC CURRICULA

UNDERGRADUATE/ INTEGRATED POST GRADUATE DEGREE PROGRAMMES

(With exit option of Diploma)

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 19

(Syllabi for Nanotechnology Programme Courses)

Revised on July 2024

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

UNDERGRADUATE/ INTEGRATED POST GRADUATE DEGREE PROGRAMMES

(With exit option of Diploma)

(Choice Based Flexible Credit System)

Regulations 2021

Volume – 19A
(Syllabi for Materials Science (Integrated) Programme Courses)

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

ACADEMIC CURRICULA

Engineering Course

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21NTS211T	Course Name	COMPUTATIONAL METHODS FOR MATERIALS SCIENCE	Course Category	S	ENGINEERING SCIENCE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*develop skills to solve problems in physics numerically*
CLR-2:	*learn advance tools for computational physics*
CLR-3:	*learn methods to solve various real-life problems numerically*
CLR-4:	*learn and apply methods used across the academics and industry*
CLR-5:	*learn to solve quantum mechanical problems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO) 1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	Program Specific Outcomes PSO-1	PSO-2	PSO-3
CO-1:	*understand the idea of modelling in small systems*	*3*	*3*	-	-	*3*	-	-	-	-	-	-	-	*3*	-	*3*
CO-2:	*solve classical molecular dynamics*	*3*	*3*	-	-	*3*	-	-	-	-	-	-	-	*3*	*2*	-
CO-3:	*solve ODE by different methods*	*3*	*3*	-	-	*3*	-	-	-	-	-	-	-	*3*	-	*3*
CO-4:	*solve quantum mechanical problems*	*3*	*3*	-	-	*3*	-	-	-	-	-	-	-	*3*	*3*	*3*
CO-5:	*solve problems using random numbers*	*3*	*3*	-	-	*3*	-	-	-	-	-	-	-	*3*	*3*	-

Unit-1 - Introduction to Computer Simulations	***9 Hour***
Motivations; Model systems and interacting potentials; Force field; Small Systems	
Unit-2 - Molecular Dynamics	***9 Hour***
Ensemble, Molecular dynamics, 2-body md with Lennard-Jones potential	
Unit-3 - Solving ODE	***9 Hour***
ODE using RK4 and Finite elements methods	
Unit-4 - Single Particle Schrodinger Equations	***9 Hour***
Particle in a box, hydrogen atom. Eigen value equations using external libraries	
Unit-5 - Random Numbers	***9 Hour***
Generation of random numbers; monte carlo integration, metropolis algorithm, calculation of pi; random walker or Ising model as an implementation	

Learning Resources		
	1. Press et. al., Numerical Recepies, 2nd ed, CUP, 1992 *2. Qingkai Kong, Timmy Siauw, Alexandre Bayen, Python Programming and Numerical Methods: A Guide for Engineers and Scientists (Elsevier),2020*	*3. Thijssen, Computational Physics, 2nd ed, CUP, 2007*

Learning Assessment							
	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	15%	-	15%	-	15%	-
Level 2	*Understand*	25%	-	20%	-	25%	-
Level 3	*Apply*	30%	-	25%	-	30%	-
Level 4	*Analyze*	30%	-	25%	-	30%	-
Level 5	*Evaluate*	-	-	10%	-	-	-
Level 6	*Create*	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Avik Chatterjee, Chief Scientist,Centre for Advanced Manufacturing and Metrology Group Advanced Design and Analysis Group- CSIR-CMERI	1. Dr. M. S. Shunmugam, Professor, Department of Mechanical Engineering, IIT Madras	1. Dr. Rudra Banerjee, SRMIST
2. Dr. Soumen Mandal, Senior Scientist, Central Mechanical Engineering Research Institute, Durgapur, WB	2. Dr. Jose Mathew, Professor, Department of Mechanical Engineering, NIT Calicut	2. Dr. Payel Bandyopadhyay, SRMIST

ACADEMIC CURRICULA

Professional Core Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21NTC211J	Course Name	ELECTRIC, ELECTRONICS AND DIELECTRIC PROPERTIES OF MATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*outline the fundamentals and applications of electric field and electric potential*
CLR-2:	*illustrate the basics of electrical conduction of metals and semiconductors, thermionic emission, photo electric emission*
CLR-3:	*introduce dielectric constant, polarization, ferroelectricity, piezoelectricity*
CLR-4:	*explain the working of various capacitors, the capacitor with dielectric and electric displacement*
CLR-5:	*introduce the concepts of energy bands in solids, intrinsic and extrinsic semiconductor, Hall effect and PN junction diode*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the concepts of electric field and electric potential to various systems of charge distribution*	*3*	-	-	2	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*analyze the electron conduction and thermal conduction in metals and semiconductors*	*3*	-	-	2	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*gain knowledge on dielectrics, frequency dependence of polarization, ferroelectricity, piezoelectricity*	*3*	2	-	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-4:	*acquire knowledge on different types of capacitors*	*3*	-	-	2	-	-	-	-	-	-	-	-	-	-	*3*
CO-5:	*utilize the concepts of energy bands to examine the metals, semiconductors for various applications*	*3*	-	-	2	-	-	-	-	-	-	-	-	-	-	*3*

Unit-1 – Electrostatics	***15 Hour***
Coulomb's law, Electric field, Electric field due to discrete and continuous charge distributions, Gauss law in integral and differential form, Applications of Gauss law for symmetric charge distributions, Electric dipole in an electric field, Torque, Electric potential - Calculating electric potential from electric field and vice–versa - Potential inside and outside of a spherical shell of charge - Equipotential lines and surfaces - Energy expended in moving a point charge in an electric field - Calculation of electric potential due to a system of discrete and continuous charge distributions. *Lab1 - Calibration of ammeter using Potentiometer,* *Lab-2 - Calibration of voltmeter using Potentiometer*	
Unit-2 - Electrical Conduction in Solids	***15 Hour***
Metals, Semiconductors, Ionic Solids; Drude Model; factors affecting the resistivity of electrical materials, motion of an electron in an electric field, Equation of motion of an electron, current carried by electrons, mobility, energy levels of a molecule, emission of electrons from metals, thermionic emission, photo electric emission, field emission, effect of temperature on electrical conductivity of metals, electrical conducting materials, thermal properties, thermal conductivity of metals, thermoelectric effect *Lab 3 - Determination of resistivity using four probe method*	
Unit-3 - Dielectric Properties	***15 Hour***
Introduction, effect of a dielectric on the behavior of a capacitor, polarization, the dielectric constant of monatomic gases, frequency dependence of permittivity, dielectric losses, significance of the loss tangent, dipolar relaxation, frequency and temperature dependence of the dielectric constant, dielectric properties of polymeric system, ionic conductivity in insulators, insulating materials, ferroelectricity, piezoelectricity, *Lab 4 - Determination of Internal resistance of the given cell using Potentiometer*	

Unit-4 - Capacitors	**15 Hour**
Calculating the capacitance of a parallel plate capacitor, a cylindrical capacitor, a spherical capacitor, and for an isolated spherical capacitor, Capacitor with a dielectric, Gauss's law in presence of linear dielectrics, Electric displacement, Lab 5 - Determination of dielectric constant	
Unit-5 - Semiconductors	**15 Hour**
Energy band in solids, conductors, semiconductors and insulators, types of semiconductors, Intrinsic semiconductors, impurity type semiconductor, diffusion, the Einstein relation, hall effect, Thermal conductivity of semiconductors, electrical conductivity of doped materials, p-n junction diode, Forward and Reverse Bias, Lab 6 - Determination of energy band gap of a semiconductor materials, Lab 7 - Determination of Hall coefficient	

Learning Resources	1. H. Goldstein, C. Poole and J. Fafko, Classical Mechanics, (Pearson Education Inc., 2002) 2. Rana & Joag, Classical Mechanics, McGraw Hill Education, 2017) 3. D.S. Mathur, Elements of Properties of Matter, (S. Chand, 2010	4. J. P. Suchet, Electrical Conduction in Solid Materials, Elsevier, 1st edition, 1975 5. R. P. Deshpande, Capacitors, McGraw-Hill 6. P C Chattopadhyay, D. Rakshit, Electronics Fundamentals and Applications, New Age International Private Limited, 2020

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (45%)		Life-Long Learning CLA-2 (15%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	20%	20%	-
Level 2	Understand	25%	-	-	20%	20%	-
Level 3	Apply	30%	-	-	40%	40%	-
Level 4	Analyze	30%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org	1. Prof. S. Ananthakumar, NIIST, Trivandrum, ananthakumars@niist.res.in	1. Dr.T.Vijayakumar, SRMIST
2. Dr. H. Sreemoolanadhan, VSSC, h_sreemoolanadhan@vssc.gov.in	2. Prof. V. Subramanian, IIT Madras, manianvs@iitm.ac.in	2. Dr.K.Kamala Bharathi, SRMIST

Course Code	21NTC212T	Course Name	ENGINEERING THERMODYNAMICS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamental laws of thermodynamics*
CLR-2:	*introduce the concept of different quasi-static process in thermodynamics*
CLR-3:	*explain the importance of Carnot cycle and Carnot engine*
CLR-4:	*understand the basic concept of quantum statistics relevant for engineers*
CLR-5:	*introduce the fundamentals of ensemble theory*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the laws of thermodynamics in real systems*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-2:	*analyze the importance of quasi-static process and adiabatic process*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*gain knowledge on different thermodynamic quantities*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-4:	*acquire knowledge on ensemble theory*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	*3*	*3*
CO-5:	*utilize the concepts of quantum statistics in future*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-	*3*	-

Unit-1 - Microscopic and Macroscopic Point of View	***9 Hour***
Thermal equilibrium and zeroth law, Temperature, System and surrounding. Extensive and Intensive properties. Zeroth law, .Ideal gas, reversible and irreversible processes. Thermo-dynamic equilibrium, equation of states, Work, quasi- static process, pV diagram, calculation of $\int pdV$ *for hydrostatic systems*	
Unit-2 - Adiabatic Process and Work	***9 Hour***
1st law of thermodynamics; internal energy and enthalpy; heat capacities of gases, liquids and solids; application of the 1st law to isothermal, adiabatic, constant pressure and constant volume processes with ideal gas as system; thermochemistry; Kirchoff's Law, Stefan-Boltzmann Law, First law of thermodynamics and internal energy, constant pressure process	
Unit-3 - Equation of State of Gas	***9 Hour***
Internal energy of gas, quasistatic adiabatic process, work & heat conversation, 2nd law of thermodynamics, Heat Engine, refrigerator, Kelvin-Plank and Clausius statement of 2nd law, Reversibility, Carnot cycle and refrigerator, Carnot Theorem and thermodynamic temperature, absolute zero and Carnot efficiency, Entropy, Entropy of various systems, TS diagram	
Unit-4 - Enthalpy, Gibbs and Helmholtz Free Energies	***9 Hour***
T dS relations, Maxwell relations; Joule-Thomson effect; First order and Second order phase transition, Clausius-Clapeyron equation and phase diagram, Entropy of reversible and irreversible systems, Principles of increasing entropy, entropy and chaos	
Unit-5 - Statistical Mechanics	***9 Hour***
Random walk problem, Maxwell velocity, energy and momentum distribution, Statistical distribution, Maxwell Boltzmann statistics, Quantum statistics, Bose-Einstein and Fermi-Dirac Statistics, Specific heat at constant temperature and pressure, Ensemble, Introduction to micro-canonical, canonical and grand canonical ensembles, Partition function, Partition function of canonical ensemble and ideal monoatomic gas	

Learning Resources	1. *M. Zemansky, and R.Dittman, Heat and Thermodynamics, 8th Ed., McGraw- Hill Education, 2012.* 2. *BB Laud, Fundamentals of Statistical Mechanics.,New Edge International, 2009*	3. *Arthur Beiser, Concepts of Modern Physics, Sixth Edition, McGraw-Hill, 2003* 4. *Sonntag R.E., Borgnakke C. & Van Wylen C. J, Fundamentals of Thermodynamics, 6th Ed, Wiley, 2002*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Priyanks Biswas, Graphene Research Lab Pvt Ltd., RI India*	1. *Prof. B. R. K. Nanda, IIT Madras, nandab@iitm.ac.in*	1. *Dr. Rudra Banerjee, SRMIST*
2. *Dr. Pralay K. Santra, Scientist D, Centre for Nano and Soft Matter Sciences, Bengaluru*	2. *Prof. Arabinda Haldar, IIT Hyderabad, arabinda@phy.iith.ac.in*	2. *Dr. Jaivardhan Sinha, SRMIST*

Course Code	21NTC213T	Course Name	KINETICS, DIFFUSION AND MASS TRANSFER	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the fundamental of reactions*
CLR-2:	*illustrate the basics of reaction kinetic, method of analysis, reaction rate*
CLR-3:	*introduce fluxes, law of diffusion, mass transfer and theory of diffusion*
CLR-4:	*explain diffusion problems, diffusion-controlled evaporation*
CLR-5:	*introduce binary mixture, mass transfer, equation of diffusion*

		Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*demonstrate the fundamentals of reaction, order of reactions*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*analyse the basics of reaction kinetics, method of analysis, reaction rate*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*gain knowledge on ficks law of diffusion, theory and mass transfer*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-4:	*acquire knowledge on diffusion problems, diffusion controlled evaporation*	*2*	*2*	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-5:	*apply the equation of diffusion, binary mixture and mass transfer*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	*3*	-	*3*

Unit-1 - Introduction	***9 Hour***
Classification of reactions: homogeneous vs heterogeneous, single vs multiple; elementary vs non-elementary, reversible vs irreversible; molecularity and order of reactions; types of intermediates for non-elementary reactions; search for reaction mechanism.	
Unit-2 - Temperature Dependence of Reaction Rate	***9 Hour***
Arrhenius equation; activation energy; activated complex theory; collision theory; rate controlling step. Integral and differential method of analysis of batch reactor data; 1st-, 2nd-, and zero-order reaction kinetics	
Unit-3 - Diffusion	***9 Hour***
Definition of fluxes; relation of fluxes relative to stationary coordinates and average velocities; Fick's 1st law of diffusion; analogy of momentum, heat and mass transfers; temperature and pressure dependence of mass diffusivity; theory of diffusion in gases and liquids.	
Unit-4 - Boundary Conditions in Diffusion	***9 Hour***
Applications of shell mass balance and boundary conditions in solving diffusion problems: diffusion- controlled evaporation of a liquid through a stagnant gas film at steady state; mixed control oxidation of a metal plate	
Unit-5 - Fick's Law	***9 Hour***
Three-dimensional equation of diffusion with convection in a binary mixture A-B: Fick's 2nd law of diffusion. Mass transfer coefficient and concentration boundary layer on a flat plate: exact solution method and approximate integral method	

Learning Resources		
	1. Michel Soustelle, An Introduction to Chemical Kinetics, Wiley, 2011	*3. E. L. Cussler, Diffusion: Mass Transfer in Fluid Systems,Chembridge University Press, 3rd Edition, 2009*
	2. Keith J. Laidler, Pearson, Chemical Kinetics, 3rd Edition, 1987	*4. James S. Vrentas, Christine M. Vrentas, Diffusion and Mass Transfer, CRC Press, 1st Edition, 2013*

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

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. S. Ramaseshan, IGCAR, Kalpakkam	1. Prof. K.Jeganathan, School of Physics. Bharathidasan University	1. Dr.D. C.Gopalakrishnan, SRMIST
2. Dr. G. Krishnan, IGCAR Kalpakkam	2. Prof. N. Ponpandian,Bharathiyar University, Coimbatore cdramo@annauniv.edu	2. Dr.Payel Bandopadhyay, SRMIST

Course Code	21NTC214J	Course Name	OPTICAL AND PHOTONIC PROPERTIES OF MATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on various basic principles of superposition of waves*
CLR-2:	*modify properties of light using non-linear optics in metamaterials*
CLR-3:	*understand the concept of image formation and design of optical systems*
CLR-4:	*gain knowledge on techniques to measure different properties of light*
CLR-5:	*gain knowledge on optical and photonic properties of materials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO) 1	2	3	4	5	6	7	8	9	10	11	12	Program Specific Outcomes		
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the principles of 'superposition' in the design of interferometer*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	*2*	-
CO-2:	*analyze the non-linear optical properties of material surface to design a metamaterial*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-3:	*apply the knowledge of image formation to design optical systems*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-4:	*utilize the opportunities in the emerging field of photonics*	*2*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-5:	*apply the concepts of scattering to probe the material properties*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	*3*	-	*2*

Unit-1 - Introduction to Wave Propagation and Wave Superposition Principle — ***15 Hour***

Interference and Diffraction, Basics of coherence: Temporal and spatial coherence, Shape and width of spectral lines and broadening mechanisms, Michaelson and Fabry-Perot Interferometers, Introduction and analysis of speckle pattern and speckle contrast imaging,
Lab 1: Determination of wavelength using Newton's rings experiment,
Lab 2: Determination of wavelengths of mercury spectrum using diffraction grating in minimum deviation
Lab 3: Measurement of wire thickness using air wedge technique.

Unit-2 - Photonics — ***15 Hour***

Electrons in periodic structures, Photons in periodic structures, 2D and 3D photonic crystals, Photons in non-periodic structures, Photonic glass, Light-matter interactions, Regimes of light scattering through disordered media, Introduction to Random lasing ,Plasmonic materials, Surface Plasmon Resonance (SPR), SPR in nanostructures, Losses in plasmonics, Localization of light in dielectric materials, Optical properties of metal dielectric composites, Introduction to metamaterials, Electric and magnetic metamaterials, Negative index metamaterials, Non-linear optics with metamaterials

Unit-3 - Optics — ***15 Hour***

Image formation (first-order optics), Mirrors and prisms, Phenomenon of spherical and chromatic aberration, Stops and apertures, Basic optical devices and Design of optical systems, Solid immersion lens and Numerical aperture increasing lens (NAIL),
Lab 4: Determination of refractive index of material of prism by drawing the i-d curve,
Lab 5: Determination of numerical aperture and acceptance angle of optical fiber using laser Lab 6: Determination of refractive index of liquid using spectrometer

Unit-4 - Introduction to Electromagnetic Wave Theory	***15 Hour***
Maxwell's equations, Different scattering regimes, Rayleigh and Mie scattering, Geometry dependence resonance, Static and dynamic light scattering, Basic theory of optical tweezers, Introduction to Atomic Force Microscopy (AFM), AFMolloidal probe technique, Magnetic chaining technique, Beam width measurement techniques, Knife-edge scanning technique, Introduction to Snell's law, Liquid Refractometer *Lab 7: Study of laser beam parameters: (a) measurement of wavelength of He-Ne laser light using ruler (b) measurement of thickness of wire with laser (c) determination of particle size using laser*	
Unit-5 - Basics of Optical Microscopy	***15 Hour***
Bright field microscopy, Dark field microscopy, Introduction to polarization, Polarizing microscopy, Phase contrast microscopy, Concept of fluorescence, Different kinds of dyes used in microscopy, Fluorescence microscopy, Confocal fluorescence microscopy, Light sheet fluorescence microscopy, Two-photon fluorescence optical microscopy, Introduction to non-linear optical properties, Non-linear optical microscopy, *Lab 8: Optical microscopy for different samples to see the microstructural features*	

Learning Resources	1. *A.Ghatak, Optics, McGraw Hill, 7th Ed, 2020.* 2. *E. Hecht, Optics, Pearson, 5th Ed, 2019.* 3. *R. Boyd, Nonlinear Optics, Academic Press, 3rd Ed,* 4. *C.Dainty, Laser Speckle and Related Phenomena, Springer, 2nd Ed, 1984.* 5. *M. Bornand, E. Wolf, Principles of Optics, Cambridge University Press, 7th Ed., 1999.* 6. *S. V. Gaponenko, Introduction to Nanophotonics, Cambridge University Press, 1st Ed, 2010*	7. *V. Shalaevand W. CAI, Optical Metamaterials: Fundamentals & Applications, Springer, 2nd ed., 2010.* 8. *J. Mertz, Introduction to Optical Microscopy, Roberts & Company publishers, 1st Ed., 2010.* 9. *C.F. Bohren and D. R. Huffman, Absorption and scattering of light by small particles, Wiley-VCH, 4th Ed., 2009* 10. *J. W. Goodman,Statistical properties of laser speckle patterns,Springer-Verlag,1st Ed.1975*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (45%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (15%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	20%	20%	-
Level 2	Understand	25%	-	-	20%	20%	-
Level 3	Apply	30%	-	-	40%	40%	-
Level 4	Analyze	30%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Mr. Sameer Sharda, New Age Instruments & Materials Pvt. Ltd, Gurgaon, sameer@newagein.com*	1. *Prof. V. Subramanian, IIT Madras, Chennai, manianvs@iitm.ac.in*	1. *Dr. Junaid Masud Laskar, SRMIS*
2. *Mr. Mohammed Shafi, Holmarc Opto-Mechatronics Pvt. Ltd, Cochin, optics@holmarc.com*	2. *Prof. C Vijayan, IITM, Chennai, cvijayan@iitm.ac.in*	2. *Dr. K Shadak Alee, SRMIST*

Course Code	21NTC215J	Course Name	PHYSICAL METALLURGY	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	2	4

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*gain knowledge on Phase diagrams including Fe-C phase diagram*
CLR-2:	*discussing about nucleation and growth kinetics*
CLR-3:	*understanding electrochemical experiments and parameters*
CLR-4:	*introduction to steels and their properties*
CLR-5:	*exploring the properties of aluminums and its alloys*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*leaning the phase diagrams including the Fe-C phase diagrams*	2	-	3	-	-	-	-	-	-	-	-	-	3	-	-
CO-2:	*understanding the diffusion, nucleation and growth kinetics*	-	2	-	3	-	-	-	-	-	-	-	-	3	2	-
CO-3:	*exploring the electrochemical corrosion prevention techniques*	2	-	-	3	-	-	-	-	-	-	-	-	3	-	3
CO-4:	*introduction to steels and their properties*	3	-	-	2	-	-	-	-	-	-	-	-	-	3	3
CO-5:	*study on properties and applications of light metals and their alloys*	3	-	-	-	2	-	-	-	-	-	-	-	-	2	3

Unit-1 - Concept of Phase Diagram ***15 Hour***

Fe-C system, equilibrium and non-equilibrium cooling of Fe-C systems, Free energy composition curves for binary systems, Effects of alloying elements and cooling rate on Fe-C diagram, Ternary phase diagram
Lab1: Specimen Preparation techniques for Metallographic Analysis – Optical Microscopy
Lab2: Pb – Sn Phase diagram

Unit-2 - Diffusion and Nucleation ***15 Hour***

Diffusion in solids, Nucleation and Growth Kinetics, Solidification, TTT diagram and CCT diagram - hardenability measurement, annealing, normalising - hardening and tempering – heat treatment furnaces, Quench Cracks, case hardening techniques
Lab3: Microstructural Analysis of Carbon Steels
Lab4: Microstructural Analysis of Cast Iron

Unit-3 - Galvanic Cell ***15 Hour***

Electrode Potential, Polarization, Passivation, General methods of corrosion prevention, Cathodic protection, coatings, Corrosion prevention by alloying
Lab5: Study of the Microstructure of heat-treated plain carbon steels.
Lab6: To find out the hardness of various heat treated and untreated plain carbon steels

Unit-4 - Types of Steels ***15 Hour***

plain carbon steels, alloy steels, tool steels; stainless steels types of cast irons compositions, properties and applications, heat treatment (specific examples)
Lab7: Microstructural Analysis of Non-Ferrous Metals: Brass & Bronze

Unit-5 - Aluminum and its Alloys	**15 Hour**
physical, chemical and mechanical properties of aluminium of aluminium alloys, magnesium, titanium alloys - microstructural features, typical properties and applications - heat treatment (specific examples Lab8: Standard test Methods for Estimation of Grain Size Lab9: Determination of density of defects in given copper wire at different temperatures using resistivity measuremen	

Learning Resources	1. Raghavan, V., "Physical Metallurgy", (Prentice Hall of India, 2006) Sidney Avner, Introduction to Physical Metallurgy, McGraw Hill Education, 2nd edition, 2017	2. Herman W. Polack, Materials Science and Metallurgy, 4th Edition, A Reston Book, A Pearson Education Company, NJ, 1988: 3. Geroge L Kehl, The Principles of Metallographic Laboratory practice (1949)

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (45%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (15%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	20%	20%	-
Level 2	Understand	25%	-	-	20%	20%	-
Level 3	Apply	30%	-	-	40%	40%	-
Level 4	Analyze	30%	-	-	20%	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D. Sivaprahasam, ARCI, Chennai, sprakash@arci.res.in	1. Prof. M. Anbarasu, IIT Madras, anbarasu@ee.iitm.ac.in	1. Dr. Suresh Perumal, SRM IST
2. Dr. Ajay Singh, BARC, Mumbai, ajay@barc.ac.in	2. Prof. R. Ranjith, IIT Hyderabad, ranjith@msme.iith.ac.in	2. Dr. Ravikirana, SRM IST

Course Code	21NTC216T	Course Name	POLYMER MATERIALS AND COMPOSITES	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

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

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

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the basic concepts to understand the functionality of the polymers*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*analyze the mechanism of different polymerization reactions*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-3:	*express the various methods and approaches employed in the molecular weight of the polymer*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*acquire knowledge on crystal strucuture and mechanical propertiesof the polymer*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*analyze the types of matrix, reinforcements and nanoadditives available for the preparation of nanocomposites*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	-

Unit-1 - Fundamentals of Polymers ***9 Hour***

Basic concepts & definitions: monomer & functionality, polymer, repeating unites, degree of polymerization, molecular weight & molecular weight distribution. Natural Polymers: Chemical & Physical structure, properties, source, important chemical modifications, applications of polymers

Unit-2 - Concepts about Polymerization Reactions ***9 Hour***

Polymerization: Classification of polymers, thermoplastic and thermosetting, different types of polymerization mechanism, Step reaction polymerization: mechanism and kinetics, Radical chain polymerization: mechanism and kinetics, Ionic and coordination chain polymerization: mechanism and kinetics, Copolymerization: mechanism and kinetics motor

Unit-3 - Polymers in Nanotechnology ***9 Hour***

Characterization: Criteria for solubility, Thermodynamics and phase equilibrium of polymer solution, Measurement of molecular weight, Chemical analysis, thermal analysis, End group analysis, colligative property measurement, ultra centrifugation, light scattering, gel permeation chromatography

Unit-4 - Physical and Mechanical Properties of Polymer ***9 Hour***

Configuration of polymer chain, Crystal structure, crystallization and melting, factors affecting Crystallization and melting, viscous flow, viscoelasticity, Mathematical models for viscoelasticity, Glassy state and glass transition, Mechanical properties of crystalline polymers

Unit-5 - Preparation and Properties of Nanocomposites ***9 Hour***

Commonly used matrix reinforcement system, Fiber, Flake and particulate reinforced composites, Nano particle dispersion in polymer matrix, Polymer- nanoclay composites and polymer-carbon nanotubes composites

Learning Resources	1. *Fred W Billmeyer, Textbook of Polymer Science, Wiley, 3rd Edition, 1984* 2. *Anil Kumar, Rakesh K Gupta, Fundamentals of Polymer Engineering, Marcel Dekker Inc., 2nd Edition, 2003* 3. *Mc Crum, Principles of polymer Engineering, 2nd Edition, Oxford, 2001*	4. *HullD., and Clyne W., An Introduction to Composite Materials, Cambridge University Press, 2nd Edition, 2017* 5. *Jones R.M., "Mechanics of Composite Materials", Taylor & Francis, 2nd Edition, 2018*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	15%	-	15%	-	15%	-
Level 2	*Understand*	25%	-	20%	-	25%	-
Level 3	*Apply*	30%	-	25%	-	30%	-
Level 4	*Analyze*	30%	-	25%	-	30%	-
Level 5	*Evaluate*	-	-	10%	-	-	-
Level 6	*Create*	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

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

Course Code	21NTC311L	Course Name	MATERIAL CHARACTERISATION LABORATORY	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							0	0	6	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*utilize X ray material characterization techniques to analyze their morphological, structural and chemical behavior*
CLR-2:	*introduce spectroscopy techniques and understand electronic transition*
CLR-3:	*introduce advance spectroscopy techniques*
CLR-4:	*utilize Characterization techniques for thermal analyses*
CLR-5:	*explain the working of microscopy*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*acquire knowledge on different types of crystal structure and analyze it through X- Ray techniques*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	*3*	-
CO-2:	*analyze materials using spectroscopy technique*	*3*	*3*	-		-	-	-	-	-	-	-	-	-	*2*	-
CO-3:	*gain knowledge on advance spectroscopy techniques*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-4:	*acquire knowledge on glass transition temperature*	*3*	-	-	-	-	-	-	-	-	-	-	-	*2*	-	*3*
CO-5:	*utilize microscopy techniques for structural and image analyses*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-	*3*

Practice	***90 Hour***
Lab 1:	*XRD to determine lattice parameters for 3 different crystals*
Lab 2:	*Determination of mineral concentration using XRF spectrometer for metal oxide / sulfide nanoparticles synthesized by chemical precipitation method*
Lab 3:	*Determination of the wavelength absorbance, particle size, and band gap using UV-Vis spectroscopy of metal oxide nano thin film fabricated using dip coating / spin coating technique.*
Lab 4:	*Identification of functional group using FTIR of different polymer materials*
Lab 5:	*Thermal characterization: DSC, TGA, DTA, Determination of glass transition temperatures of polymer materials.*
Lab 6:	*Raman Spectroscopy*
Lab 7:	*Preparation of metal/alloy/metal oxide samples and determination of microstructure using SEM.*
Lab 8:	*Preparation of metal/alloy/metal oxide samples and determination of composition using TEM*
Lab 9:	*Preparation of metal/alloy/metal oxide thin films and determine the surface roughness using AFM.*
Lab 10:	*Preparation of metal/alloy/metal oxide samples and determination of composition using EDS*

Learning Resources	1. *Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques,Taylor and Francis, 1st Edition, 2008* 2. *Colin Banwell, Elaine McCash, Fundamentals for Molecular Spectroscopy,4th ed., Mc Graw 2016*	3. *Introduction to Thermal Analysis, Michael Ewart Brown, Springer, 2nd Edition, 2001* 4. *Robert Pecora, Dynamic Light Scattering, Springer, 1985* 5. *Jürgen H Gross, Mass Spectrometry, Springer, 3rd Edition, 2017*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Soumee Chacroborty, Scientific Officer, IGCAR (soumee@igcar.in)*	1. *Dr. Sudhashu Sekar Pati, NIT Jamshedpur (sspati.chem@nitjsr.ac.in)*	1. *Dr. S. Anbumozhi Angayarkanni, SRMIST*
2. *Dr. Ranjini. P. Antony, IGCAR (raji.anna@gmail.com)*	2. *Dr. Shima dhamodharan, Kannur University, Kerela. (shimachem@kannuruniv.ac.in)*	2. *Dr.Payel Bandapodaya, SRMIST*

Course Code	21NTC312T	Course Name	MECHANICAL BEHAVIOR OF MATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*outline the fundamentals of elasticity and plasticity*
CLR-2:	*introduce stress, strain, strengthening mechanisms*
CLR-3:	*Learn different mechanism of mechanical testing including fracture*
CLR-4:	*explain the fracture and toughening mechanisms in ceramics, creep*
CLR-5:	*introduce the fatigue of engineering materials, fatigue calculations and models*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	Program Outcomes (PO) 1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	Program Specific Outcomes PSO-1	PSO-2	PSO-3
CO-1:	*apply the concepts of deformation behavior of materials to understand the mechanical behavior of materials*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	*3*	-
CO-2:	*appreciate the concept of stress and strain in evaluating the strength of materials, and hardening mechanisms*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-3:	*analyze the mechanical properties of materials using various testing methods*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	*2*
CO-4:	*acquire knowledge on fracture mechanics, toughening mechanisms in ceramics and creep*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-5:	*obtain the knowledge on fatigue of engineering materials, strain-controlled fatigue and fatigue failure models*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*

Unit-1 - Introduction ***9 Hour***

overview of the subject and fundamentals of the atomic structure and types of bonding in different classes of materials and its relation to the physical and mechanical properties, Elasticity - Analysis of stress, State of stress at a point, Normal and shear stress components, Stress components on an arbitrary plane, Principal stresses, Plane stress & Plane strain

Unit-2 - Hooke's Law and Elastic Behaviour ***9 Hour***

Generalized Hooke's law, Atomic equivalent of Hooke's law, Elastic behavior of anisotropic and isotropic materials.Plastic deformation in single & polycrystalline, semi crystalline materials, strengthening mechanisms in solids, Work hardening, Solid solution strengthening, Grain boundary strengthening, Particle hardening, High temperature deformation of amorphous; crystalline materials

Unit-3 - Mechanical Testing ***9 Hour***

A review, Common states of stress in real life, Tension, Indentation, Compression, Torsion, Bending. Fracture of solids/Fracture mechanics - Linear elastic stress field in cracked bodies – Crack deformation modes, - Singular stress field and displacement fields Stress intensity factor solutions - Crack growth based on energy balance - Griffith's criterion for brittle fracture - Strain energy release rate, Stress intensity factor equivalence - Crack stability, R curves

Unit-4 - J Integral Concepts ***9 Hour***

Critical stress intensity factor fracture criterion -Fracture criterion - Experimental determination of fracture toughness (KIC) - Non-linear fracture - Toughening mechanisms (in ceramics). Creep, mechanisms of creep, Creep of pure metals, solid solutions, MMCs, Creep of ceramics and polymers, creep asymmetry. Superplasticity in materials

Unit-5 - Fatigue of Engineering Materials ***9 Hour***

Characteristics of fatigue fracture -Fatigue crack propagations laws, Strain controlled fatigue, Fatigue failure models - Fatigue life calculations, High cycle fatigue design- Surface fatigue failure models- dynamic contact

Learning Resources	1. *Thomas H Courtney, Mechanical behavior of materials, Waveland Press, 2nd Edition, 2005.* 2. *R. W. Hertzberg, Deformation Behaviour and Fracture Mechanics of Engineering Materials, John Wiley & Sons, 2020* 3. *Marc Meyers, and Krishna Chawla, Mechanical behavior of materials, Cambridge, University Press, 2009.*	4. *William F. Hosford, Mechanical Behavior of Materials, Cambridge, University Press, 2010* 5. *D. Hull and D.J. Bacon, Introduction to Dislocations, Butterworth-Heinemann; 5th ed., 2011* 6. *G.W. Dieter, Mechanical Metallurgy, TMH, 3rd ed, 2017*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr.Gaurav Singh, Engineering Lead, Infosys, gauravsingh90@gmail.com*	1. *Dr.Eswara Prasad, IIT Indore, eswar@iitm.ac.in*	1. *Dr. Kiran Mangalampalli, SRMIST*
2. *Dr. Sunil Varughese, CSIR-NIIST, Tridendrum, s.varughese[at]niist.res.in*	2. *Dr. Rajesh K, rajeshk@iith.ac.in*	2. *Dr.Payel Bandyopadhyay, SRMIST*

Course Code	21NTC313T	Course Name	ELECTROCHEMISTRY AND CORROSION	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*outline the fundamentals of electrochemistry and corrosion*
CLR-2:	*illustrate the kinetics of corrosion*
CLR-3:	*introduce different forms of corrosion*
CLR-4:	*explain the principles of prevention & protection of corrosion*
CLR-5:	*introduce the concepts of corrosion and electrochemistry in biological systems*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the principles of electrochemistry*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*analyze the corrosion process with emphasis on its kinetics*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-3:	*gain knowledge on different forms of corrosion*	*3*	-	-	-	-	-	-	-	-	-	-	-	*3*	-	*3*
CO-4:	*acquire knowledge on prevention & protection of corrosion*	*3*	2	*2*	-	-	-	-	-	-	-	-	-	-	*3*	*3*
CO-5:	*utilize the concepts of corrosion and electrochemistry for bio applications*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	-	*3*	*3*

Unit-1 - Principles of Electro-Chemistry ***12 Hour***

Electrode Potential, Reference Electrode, Half-cell reaction, Nernst's equation, Application of Thermodynamics to Feasibility of corrosion of metals and alloys in various environments, Pourbaix diagram of common metals, Electrolytes, potentiometric and conductometric titration, Debye-Huckel theory of strong electrolytes, transport of ions in solution: electrolytic conduction, Debye-Huckel-Onsager treatment of the conductance of strong electrolyte and its limitations, the electrical double layer,

Unit-2 - Kinetics of Corrosion ***12 Hour***

Polarization: Activation, Concentration and Resistance Polarization, Overvoltage, Basics of electrodics, rates of simple electrode reactions, elementary electron electrode process, Butler-Volmer equation, exchange current density and symmetry factor, polarisable and non-polarisable electrodes Tafel's Equation, Corrosion rate determination by Tafel extrapolation and Linear polarization methods, Passivity and passivity breakdown, Cyclic polarization, Evan's diagram, Practical applications of polarization diagrams

Unit-3 - Forms of Corrosion ***12 Hour***

Uniform attack, Galvanic, Crevice, pitting, Intergranular, Erosion corrosion, Stress induced Corrosion: SCC, CF, HIC, Testing slow strain rate and Fracture mechanics K 1C

Unit-4 - Principle of Prevention and Protection of Corrosion ***12 Hour***

Anodic protection, Cathodic Protection, Application of Inhibitors, Organic coating and paints, Metallic coating, Anodizing, phosphating, Chromate coating, Atmospheric corrosion & Oxidation at elevated temperature, Factors affecting atmospheric corrosion and remedy, doping of p and n type metallic oxide, various kinetic laws of Oxidation,

Unit-5 - Microbial Corrosion ***12 Hour***

Accelerated degradation of metals in presence of Aerobic and Anaerobic microorganisms, Corrosion for Beneficial purpose: Introduction to Fuel cell and Battery. Bioelectrodics - membrane potentials, electrochemical communication in biological organisms, enzymes as electrodes, electrochemical sensors, electrochemical biosensors.

Learning Resources	1. *E.E. Stansbury, R.A. Buchanan, Fundamentals of Electrochemical Corrosion,ASM International, 2000* 2. *Nestor Perez, Electrochemistry and Corrosion Science, Springer, 1st edition, 2004* 3. *D. R. Crow, Principles and Applications of Electrochemistry, 4th edition, 2017*	4. *Physical Electrochemistry: Fundamentals, Techniques, and Applications, Noam Eliaz, Eliezer Gileadi, 2nd Edition, 2018* 5. *E McCafferty, Introduction to Corrosion Science, Springer-Verlag New York, 1st Edition, 2010* 6. *Zaki Ahmad, Principles of Corrosion Engineering and Corrosion Control, Elsevier, 2006*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Anju VP, Carborandum Universal Ltd., Cochin	1. Prof. Santosh Haram, Savitribai Phule Pune University, Pune	1. Prof. Sasidharan, SRMIST
2. Dr. Santoshkumar D. Bhat, CSIR-CECRI	2. Prof. Kodandaraman, IIT Madras	2. Dr. Venkatesh Prasad Bhat, SRMIST

Course Code	21NTC315J	Course Name	MAGNETISM AND MAGNETIC MATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							2	0	2	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*outline the fundamentals of magnetostatics and magnetism in materials*
CLR-2:	*illustration and overview of the basics of theories and postulates in magnetism*
CLR-3:	*introduce about the various phenomena in magnetism and magnetic materials*
CLR-4:	*explaining magnetization and magneto transport phenomena*
CLR-5:	*introduce on various magnetic property measurement techniques toward applications*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO) 1	2	3	4	5	6	7	8	9	10	11	12	Program Specific Outcomes		
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*gaining knowledge about the fundamentals of magnetostatics and magnetism in materials*	*3*	2	-	-	-	-	-	-	-	-	-	-	*3*	*2*	-
CO-2:	*developing through understanding on the basics of theories and postulates involved in magnetism*	*3*	2	-	-	-	-	-	-	-	-	-	-	*3*	*2*	-
CO-3:	*gaining knowledge about the phenomena involved in magnetism and magnetic materials*	*3*	2	-	-	-	-	-	-	-	-	-	-	*3*	*2*	*3*
CO-4:	*acquiring knowledge and sound understanding about advanced magnetization and magneto transport characterization techniques*	*3*	-	-	2	-	-	-	-	-	-	-	-	*2*	*2*	*3*
CO-5:	*utilizing knowledge and understanding of magnetic properties for innovative applications viz. Spintronics and Magnetic recording*	*3*	2	-	2	-	-	-	-	-	-	-	-	*2*	*2*	*3*

Unit-1 - ***12 Hour***

Magnetic force and fields, Fields due to current, Magnetic dipole moment of a magnetic dipole, Lorentz Law of force, Magnetic field intensity – Biot–savart Law Application of Biot–savart Law: Magnetic field (i) Due to steady current in long straight wire, (ii) Near a straight current filament of finite length, (iii) Interaction between two parallel long current wires, (iv) Along the axis of circular coil, and (v) Helmholtz galvanometer; Ampere's Law – Magnetic field due to straight conductors, circular loop, infinite sheet of current – Magnetic flux density (B) – B in free space; Magnetization –Boundary conditions for Magnetic field Magnetic Potentials (Scalar and Vector Potential), Magnetic dipole moment, Maxwell's equations and magnetic field calculations, Magnetostatic energy and forces

Lab 1: Introduction to the laboratory, Lab 2: Determination of horizontal component of earth magnetic field–field along the axis of the coil

Unit-2 - ***12 Hour***

Classical and quantum mechanical model of magnetic moment of electrons, Magnetic properties of free atoms, Classification of magnetic materials, Theories of Diamagnetism, Theories of Paramagnetism, Theories of Ferromagnetism, Theories of Antiferromagnetism, Theories of Ferrimagnetism, Theories of ordered magnetism, Quantum theory of magnetism: electron-electron interactions, Localized electron theory, Itinerant electron magnetism

Lab 3: Magnetic domain imaging using magnetic force microscopy (MFM), Lab 4: Determination of magnetic moment and ratio of magnetic moments by Searles vibration magnetometer method

Unit-3 - ***12 Hour***

Magnetic Interactions and Magnetic Couplings. Origin of exchange interaction, Direct exchange interactions, Indirect exchange interactions, Double exchange interaction, Anisotropic exchange interaction, Magnetization Reversal by Spin Rotation, Magnetization Reversal by Wall Motion Magnetic Annealing, Magnetic Irradiation, Magnetostatic Energy and Domain Structure (Uniaxial and Cubic Crystals), Magnetization in Low Fields, Magnetization in High Fields

Lab 5: Magnetization Reversal curve recording using magneto- optical Kerr effect (MOKE) Lab 6: Magnetic susceptibility measurement of nanomaterials

Unit-4 -	*12 Hour*
Magnetic Domain theory, Bloch and Neel Wall theory, Magnetic Domain wall pinning, Spin Waves and Magnons, Magnetic anisotropy, Exchange Anisotropy, Thin Film and Multilayers Magnetoresistance (MR), Giant Magnetoresidence (GMR), Tunnel Magnetoresistence (TMR), Superparamagnetism, Single-Domain vs Multi-Domain Behavior, Zero-field-cooled (ZFC), field-cooled (FC) curves and Blocking temperature Spintronics, Magnetorestriction; Spin glass, Heisenberg and Ising models, Magnetic Resonance, Ferromagnetic Resonance, Nuclear Magnetic Resonance, Magnetic Recording, Perpendicular Recording	
Lab 7: Magnetization Reversal curve recording using Vibrating sample magnetometer (VSM)	
Unit-5 -	***12 Hour***
Magnetic shielding, Faraday cage, Faraday balance magnetometer, AC susceptometry (ACS), Torque magnetometry, Vibration sample magnetometer (VSM), Magneto-optical Kerr effect (MOKE), Magnetic Forcer Microscopy (MFM), Magnetic circular dichroism (MCD), Superconducting quantum interference device (SQUID) magnetometer, Experimental method in low temperature.	
Lab 8: Magnetic Anisotropy measurement using magneto- optical Kerr effect (MOKE)	

Learning Resources	*1. S. Blundell, Magnetism in Condensed Matter (OUP,2001)* *2. J. M. D. Coey, Magnetism and Magnetic Materials (CUP,2012)* *3. N. Spaldin, Magnetic Materials: Fundamentals and Applications (CUP,2012,2nd ed)*	*4. B.D. Cullity, C.D. Graham, Introduction to Magnetic Materials (Wiley, 2nd ed.,2008)* *5. H. Zabel and S. D. Bader (Eds.), Magnetic Heterostructures (Springer,2008)* *6. A Planes L.Ma˜nosa ASaxena (Eds.),Magnetism and Structure in Functional MaterialsSpringer,2005*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Muhammad Shahid Anwar, CSIR - Institute of Minerals and Materials Technology, Bhubaneswar,shahid@immt.res.in	1. Prof. K. Sethupathi, IITM, ksethu@iitm.ac.in	1. Dr.Jitendra Kumar Tripathi, SRMIST
2. Dr. Ashutosh Rath, CSIR - Institute of Minerals and Materials Technology, Bhubaneswar, ashutosh@immt.res.in	2. Dr. Dinesh Kumar Shukla, UGC-DAE CSR, Indore, dkshukla@csr.res.in	2. Dr. Jaivardhan Sinha, SRMIST

Course Code	21NTC316T	Course Name	GLASS AND CERAMIC MATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*gain knowledge on importance of Glasses and their formation*
CLR-2:	*emphasize the significance of transport and mechanical properties of Glasses*
CLR-3:	*explore the ceramic-based materials and their characteristics*
CLR-4:	*understanding the microstructures of Ceramics*
CLR-5:	*study of functional properties of ceramics*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	Program Outcomes (PO) 1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	Program Specific Outcomes PSO-1	PSO-2	PSO-3
CO-1:	*introduce the structure and formation for glasses*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*explore the functional properties of glass-based materials*	-	*2*	-	*3*	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*learning about ceramic-based materials and their structures*	*2*	-	*3*	-	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*knowing the importance of microstructures on Ceramics*	*3*	-	-	2	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*understand the functional and mechanical properties of Ceramics*	*3*	-	-	2	-	-	-	-	-	-	-	-	-	-	-

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

Definition and Historical Summary, Structure of Glass, glass melting, Structure of Special Melts and Glasses, Composition of Glass, Glass Formation, Crystallization and Liquid Immiscibility, Viscosity of Glass Forming Melts, Density and Thermal Expansion

Unit-2 - Transport Properties of Glasses ***9 Hour***

Transport Properties, Mechanical Properties, Optical and Magnetic Properties, Water in Glasses and Melts, Thermal Analysis of Glasses, Glass Technology, Compositions and Properties of Commercial Glasses, Doped Vitreous Silica, Oxyhalide Glasses

Unit-3 - Structural Properties of Glasses ***9 Hour***

Introduction, Ceramic Processes and Products, Characteristics of Ceramic Solids, Structure of Crystals, Structure of Glasses, Structural Imperfections, Surfaces, Interfaces, and Grain Boundaries, Atom Mobility

Unit-4 - Microstructure of Glasses ***9 Hour***

Development of Microstructure in Ceramics, Ceramic Phase Equilibrium Diagrams, Phase, Transformation, Glass Formation and Glass-Ceramics, Reactions with and between Solids. Grain Growth, Sintering and Vitrification, Microstructure of Ceramics.

Unit-5 - Physical Properties of Glasses ***9 Hour***

Thermal Properties, Optical Properties, Plastic Deformation, Viscous Flow and Creep, Elasticity, Anelasticity and Strength, Thermal and Compositional Stresses, Electrical Conductivity, Dielectric Properties, Magnetic Properties

Learning Resources	1. *Textbook of Polymer Science, Fred W Billmeyer, Wiley, 3rd Edition, 1984* 2. *Fundamentals of Polymer Engineering, Anil Kumar, Rakesh K Gupta, Marcel Dekker Inc., 2nd Edition, 2003* 3. *Mc Crum, Principles of polymer Engineering, 2nd Edition, Oxford, 2001.* 4. *Fundamentals of Inorganic Glasses, Arun Varshneya John Mauro, Elsevier, 3rd Edition, 2019* 5. *Introduction to Ceramics, William David Kingery, H. K. Bowen, Wiley, 2nd edition, 1976*	6. *Introduction to Glass Science and Technology, James E Shelby, Royal Society of Chemistry, 3rd edition, 2020* 7. *Fundamentals of Ceramics, Michel Barsoum, CRS press, 2nd edition, 2020* 8. *HullD., and Clyne W., An Introduction to Composite Materials, Cambridge University Press, 2nd Edition, 2017* 9. *Jones R.M., "Mechanics of Composite Materials", Taylor & Francis, 2nd Edition, 2018*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	15%	-	15%	-	15%	-
Level 2	*Understand*	25%	-	25%	-	25%	-
Level 3	*Apply*	30%	-	30%	-	30%	-
Level 4	*Analyze*	30%	-	30%	-	30%	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

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

Course Code	21NTC411L	Course Name	NANOINDENTATION AND NANOTRIBOLOGY	Course Category	C	PROFESSIONALCORE	L	T	P	C
							0	0	6	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*outline the fundamentals of elastic and plastic deformations*
CLR-2:	*introduce the nanoindentation and theory*
CLR-3:	*learn the data analysis and factors affecting indentation results*
CLR-4:	*explain the time-dependent deformation mechanisms, and mechanical behavior of soft materials*
CLR-5:	*introduce the tribology principles at nanoscale contacts and applications*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO) 1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	Program Specific Outcomes PSO-1	PSO-2	PSO-3
CO-1:	*apply the concepts of deformation behavior of materials to understand the mechanical behavior of materials*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-2:	*appreciate the instrumented nanoindentation technique in quantifying the mechanical properties of materials*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-3:	*analyze the indentation data and identify the factors affecting mechanical properties*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-4:	*acquire knowledge on mechanical deformation of polymers and the importance of time-dependent mechanical characterization*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	*3*	-
CO-5:	*obtain the knowledge on nanoscale tribology contacts and utilize it in various applications*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-

Practice	***90 Hour***
Lab 1:	*Evaluation of mechanical properties of glass and ceramics - ph curve analysis (ISO 14577/ASTM E 2546)*
Lab 2:	*Evaluation of mechanical properties of polymer - ph curve analysis (ISO 14577/ASTM E 2546)*
Lab 3:	*Evaluation of mechanical properties of metal - ph curve analysis (ISO 14577/ASTM E 2546*
Lab 4:	*Evaluation of mechanical properties of thin film - ph curve analysis (ISO 14577/ASTM E 2546*
Lab 5:	*Demonstration of indentation size effects*
Lab 6:	*Demonstration of effect of indenter geometry on mechanical properties*
Lab 7:	*Demonstration of loading rate effect on mechanical properties*
Lab 8:	*Demonstration of substrate effect on mechanical properties in case of thin films*
Lab 9:	*Extraction of stresses-strain curves from nanoindentation data*
Lab 10:	*Study of creep and relaxation from quasi-static nanoindentation technique*
Lab 11	*Nano DMA analysis to find storage and loss modulus*
Lab 12	*Nano/micro scratch experiment to measure coefficient of frinction*
Lab 13	*Quantification of wear volume using nano/micro tribology (ASTM G 99*

Learning Resources	1. *Introduction to contact mechanics, Anthony C Fischer-Cripps, Springer, 2nd Edition, 2007* 2. *Nanotribology and Nanomechanics: An Introduction, Bharat Bhushan, Springer, 2nd Edition, 2008*	3. *Nanoindentation, Anthony C Fischer-Cripps, Springer, 2nd Edition, 2004.* 4. *C. Mathew Mate, "Tribology on the Small Scale" Oxford University Press, 2008.Bharat Bhushan," Principles and Applications to Tribology", Wiley Publication, 2013.*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Gaurav Singh, Engineering Lead, Infosys, gauravsingh90@gmail.com*	1. *Dr. Eswara Prasad, IIT Indore, eswar@iitm.ac.in*	1. *Dr. Kiran Mangalampalli, SRMIST*
2. *Dr. Krishna Muvvala, Saint Gobain*	2. *Dr. Rajesh K, rajeshk@iith.ac.in*	2. *Dr. Payel Bandyopadhyay, SRMIST*

Course Code	21NTC412T	Course Name	SOFT MATTER	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*introduction to soft matter*
CLR-2:	*explaining the concept of basics of polymer materials*
CLR-3:	*introduce the ways to characterize the polymer matters for various applicarionsnd understand the various semiconductor devices*
CLR-4:	*explain the concept of solution processed thin film formation and their characterizations*
CLR-5:	*introduce the physical properties of the soft matter for various practical applicataions*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***
CO-1:	*understanding the basic concept and mechanism soft matter materials properties*
CO-2:	*understanding soft matter based thin film for various applications*
CO-3:	*gain knowledge on various state of soft matter and their application to various practical applications*
CO-4:	*acquire knowledge on various physical properties of the soft matter*
CO-5:	*utilize the concepts solution based thin film formation in the soft matter materials for commercial applications*

	Program Outcomes (PO)												**Program Specific Outcomes**		
	1	2	3	4	5	6	7	8	9	10	11	12			
	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1	2	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2	3	-	1	-	-	-	-	-	-	-	-	-	-	2	-
CO-3	-	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-4	3	-	1	-	-	-	-	-	-	-	-	-	-	2	-
CO-5	2	3	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 – Definition	***9 Hour***
Soft matter definition, Overview of the main classes, Self-assembly versus self-organization, Dynamic versus static self-assembly, Central role of Entropy, Energy scales compared to covalent bonding energies, Van der Waals interactions: three types of attractive interactions and steric repulsion, Hamaker constant and its application, Hydrogen bonds, Hydrophobic effect, Aromatic interactions, Ionic interactions and ion dissolution, Electric double layer, Models for the electric double layer, ζ potential and the hydrodynamic radius, Hamaker constant, Entropy, Poisson-Boltzmann theory and concepts Debye screening length and ionic strength, Definition of colloids and overview of main classes, Preparation of colloids, Stability of colloidal liquids: Brownian motion vs. gravity and viscosity, Exercise on hydrogen bonds, hydrophobic effect charged surfaces and ions in solution.	
Unit-2 - Sedimentation and Centrifugation	***9 Hour***
Sedimentation and Centrifugation, Stabilization of colloids, Colloid flocculation/coagulation, DLVO Theory-introduction, Casimir Force, Poisson-Boltzmann, Colloid Synthesis, Jamming and Gelation, Percolation and its applications, Wetting/ dewetting and hydrophobicity/hydrophilicity, Capillary phenomena, Synthetic opals, Marangoni effect and Coffee Ring Effect, Life at low Reynolds number, Granular matter, Depletion attraction, Surface/interfacial tension and Ostwald ripening, Surfactant self-assembly (beginning), Supramolecular Self-Assembly of surfactants, Micelle formation and the packing parameter, Colloid crystallization, Colloid preparation and stabilization/destabilization.	
Unit-3 - Colloid Preparation	***9 Hour***
Lab on colloid preparation and the properties of colloids, Liquid crystal's introduction, Phases (nematics, smectics, columnar phases) and their building blocks. Typical molecule structures, Nematic elasticity and director field deformations in nematics and smectics, Topological defects-introduction, Mixtures and phase diagrams, Phase transitions, Surfactant self-assembly, Topological defects, The Volterra process, Phase transitions, Landau expansion, Landau rules and symmetry considerations in liquid crystals, Glass transition, Mixtures and phase diagrams, Colloid crystallization, Optical anisotropy, Characterization: polarizing optical microscopy, Fundamentals of the microscope, Michel-Levy diagram and determination of birefringence. Use of phase plates.	

Unit-4 - Viscous, Elastic and Viscoelastic Behaviour	9 Hour
Viscous, Elastic & viscoelastic behaviour and connection to glass transition, Nucleation and growth, Spinodal decomposition, Anisotropic viscous properties of liquid crystals, Miesowicz and rotational viscosities of nematics, Response of nematic liquid crystals to electric fields and elastic relaxation after field removal, Liquid crystal displays, Polarizing microscopy, Nematic elasticity, Liquid crystal topology, Liquid crystal viscosity, Optics of the Twisted Nematic explained using the Poincaré sphere, Cholesteric phases and their peculiar optical properties: Mauguin-type polarization guiding, Optical activity and selective reflection.	
Unit-5 - Liquid Crystals	**9 Hour**
Surface anchoring of liquid crystals & control of the bulk director field via boundary conditions, Langmuir films, Self-assembled Monolayers, More on lyotropic liquid crystals, Vesicles, Bio membranes, Block co-polymers and their self-assembly in water & without solvent, Liquid Crystal Displays (LCDs), Poincaré sphere, Twisted nematics, Cholesterics, Liquid crystal polymers/elastomers and their applications, Biological soft matter: nucleic acids and their self- assembled structures, Natural and artificial Biological soft matter, Protein self-assembly, Self-assembled monolayers, Bio membranes, Block co-polymers, Liquid crystal elastomers, Biological soft matter.	

Learning Resources	1. Alan S. Wineman and K. R. Rajagopal, Mechanical Response of Polymers: An Introduction, Cambridge University Press, 2000 (1st Edition) 2. R. Byron Bird, Robert C. Armstrong and Ole Hassager, Dynamics of Polymeric Liquids, Volume 1:	3. Fluid Mechanics, 2nd Edition, Wiley & Sons Ltd, 1987. (2nd Edition) 4. Richard A.L. Jones, Soft Condensed Matter, OUP Oxford, 2002 (1st Edition). 5. Nhan Phan-Thien, Nam Mai-Duy, Understanding Viscoelasticity: An Introduction to Rheology, Third Edition, Springer 2017

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	25%	-	25%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr Bhaskar Sahu, Schneider Electric Ltd, bhaskar.sahu@se.com	1. Dr. Satyajith Gupta, IIT Bhilai, satyajit@iitbhilai.ac.in	1. Dr. K. Arul varman, SRMIST-KTR
2. Dr.S.Paramasivam, ESAB, paramsathya@yahoo.com	2. Dr. Vijay Shinde, IIT (BHU), vijay.che@iitbhu.ac.in	2. Dr.K.Mohanraj, SRMIST

Course Code	21NTC413T	Course Name	ALLOYS: FERROUS AND NON-FERROUS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*gain knowledge on the fundamentals of alloy theory and introduce iron –Iron carbide Phase diagram*
CLR-2:	*emphasize the significance of phase transformation in metals and alloys*
CLR-3:	*introduce the necessary theories on the phase transformation process in metals and alloys*
CLR-4:	*explain the microstructure and Mechanical properties of different types of steels*
CLR-5:	*acquire knowledge non non ferrous alloys*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*introduce the concept of alloy theory and apply it to Fe-C system*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*analyse the mechanism of solidification and solid-state transformation in metals and alloys*	*3*	*3*	-	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*gain knowledge on diffusion process and various phase transformation involving diffusion process*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*acquire knowledge on microstructural and Mechanical properties of different types of Steels*	*3*	-	-	-	*2*	-	-	-	-	-	-	-	-	-	-
CO-5:	*introduce the different types of non ferrous alloys, production microstructure and applications*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Alloy Theory	***12 Hour***
Alloy theory-Definition of mode of alloying, solid solutions, terminal solid solutions and intermediate phases,chemical compounds in metallic alloys, eutectic and eutectoid phase and microstructural elements in metallic alloys, Free energy-composition diagrams,Ideal and non-ideal behaviour of alloy systems, Binary and ternary phase diagrams examples, introduction to high entropy alloy Fe-C system: The Fe-Fe3Cphase diagram, Classification of Iron-Carbon alloys based on equilibrium phase diagram,	
Unit-2 - Transformation in Metals and Alloys	***12 Hour***
solidification and solid-state transformation, Solidification of a pure metal, continuous growth, lateral growth, Alloy solidification –Solidification of single phase alloys-cellular and dendritic solidification; eutectic solidification, off-eutectic solidification, Peritectic solidification, Kinetics of solid-state transformation, C-curve, segregation, precipitation reaction	
Unit-3 - Diffusional Transformations in Solids	***12 Hour***
Homogeneous and heterogenous nucleation, Precipitate growth, overall transformation kinetics – TTT and CCT diagrams, Precipitation in age hardening alloys (Aluminium-Copper alloys, Aluminium-Silver alloys), Age hardening, Spinodal decomposition, Particle coarsening, Precipitation of ferrite from austenite, cellular precipitation, eutectoid transformations- Pearlite reaction, Bainite transformation, Massive transformation, Order-disorder transformations	
Unit-4 - Steel	***12 Hour***
Plain carbon steels , Terminology of plain carbon steels, Mechanical properties, Classification and main types of plain carbon steels, Characteristic microstructure of plain carbon steels, Alloyed steels, The main alloying elements of steel and their effects, effects of alloying elements on the phase diagram, the effect of alloying element on the non-equillibrium phase transformations, Main types of alloyed steels, Manganese steels, Chromium steels, Nickel steels, Recent development trends in steel, Methods to increase the strength of steels, Heat treatment principles	
Unit-5 - Non-ferrous Metals and Alloys	***12 Hour***
Aluminium and its alloys, –, Classification of main types of aluminium alloys, Magnesium and its alloys, beryllium and its alloys, Titanium and its alloys, Copper and its alloys, Brasses and Bronze, Lead and its alloys, Solder Alloy, Ni and Co based superalloys	

Learning Resources	1. David A Porter; K E Easterling; Mohamed Y Sherif, Phase transformations in metals and alloys, CRC Press, [2009] 2. Sydney H. Avner, Introduction To Physical Metallurgy, Mcgraw-Hill Book Company [2017]	3. Tisza, Miklós, ed. Physical metallurgy for engineers. ASMInternational, 2001. 4. R. E. Smallman, A. H.W. Ngan, Physical Metallurgy and Advanced Materials, (Elsevier Ltd., 2007) ISBN: 978 0 7506 6906 1

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	25%	-	25%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. R. Mythili, SO/E, IGCAR, rm@igcar.gov.in	1. Dr. Srinivasa Rao Bakshi, Assosiate professor, IIT Madras, sbakshi@iitm.ac.in	1. Dr.Ravikirana, SRMIST
2. Dr. Pramod S L, Lead Engineer	2. Dr.Anuradha M Ashok, Associate professor, PSGIAS,anu@psgias.ac.in	2. Dr.Suresh Perumal, SRMIST

Course Code	21NTC414T	Course Name	ENGINEERING BIOMATERIALS	Course Category	C	PROFESSIONAL CORE	L	T	P	C
							3	1	0	4

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learning importance of biomaterials*
CLR-2:	*introduce processing and study of biomaterials*
CLR-3:	*explain cell material interaction*
CLR-4:	*introduce polymeric and degradable biomaterials*
CLR-5:	*introduce tissue engineering and applications*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*significance of biomaterials*	*3*	-	*1*	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*familiar with preparation and characterization of bio materials*	*3*	2	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*gain knowledge on cell-biomaterials interaction*	*3*	-	2	-	-	-	-	-	-	-	-	-	2	-	-
CO-4:	*acquire knowledge on evolving polymeric and biodegradable materials*	*3*	-	2	-	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*understand tissue engineering and applications*	*3*	2	-	-	-	-	-	-	-	-	-	-	2	-	-

Unit-1 - Introduction to Biomaterials	***12 Hour***
Introduction to biomaterials; Background History; importance of biomaterials; Essential Properties of biomaterials; Materials for Biomedical Applications; essential properties of biomaterials; Metallic ceramic and polymeric implant materials; Practical Guidelines for the Experimental Measurements; Orthopedic, dental applications and Future of biomaterials	
Unit-2 - Physical Properties	***12 Hour***
Processing and properties of different bio ceramic materials; evaluation of physical properties biomaterials; Mechanical Properties of biomaterials; novel materials for biomedical applications; Design concept of developing new materials for bio-implant applications; Nanomaterials and nanocomposites for medical applications; Corrosion Behaviour of a biomaterials invitro; Bacterial growth and Biofilm Formation, Sintering Reactions and HA Stability, Cytocompatibility Property, Implication of Cell Proliferation	
Unit-3 - Cell Materials	***12 Hour***
cell-material interactions and foreign body response; Cell signalling mechanism; Cell-environment interactions; affect cellular functions; Eukaryotic cell fate processes; Fibrous encapsulation; compatibility of biomaterials; In-vitro and In- vivo evaluation; Dissolution study, Antibacterial assessment: Kirby–Bauer disc diffusion method or antibiotic sensitivity test and spread plate method.	
Unit-4 - Polymeric Biomaterials	***12 Hour***
Polymeric biomaterial, biodegradable polymeric biomaterial, Biodegradation properties of synthetic bio gradable polymers, Blood compatible materials; Surface-induced thrombosis Biomimetics; Advantages of biomimetics Bone biology: bone architecture, Bone as a Tissue, collagen, osteoblasts, osteoclasts, etc; Protein mediated cell adhesion, The blood-material interface in medical devices	
Unit-5 - Tissue Engineering	***12 Hour***
Introduction to tissue engineering; Applications of tissue engineering; tissue compatibility assessment; Ethical issues; Animals experiments on biomaterials; Clinical Trials on Tissue Engineering; Scaffolding Strategies for Tissue Engineering; Biomaterials worldwide market; technology transfer and ethical issues; Standards for biomaterials and devices.	

Learning Resources	1. *Hench L. Larry, and Jones J., (Editors), Biomaterials, Artificial organs and Tissue Engineering, Woodhead Publishing Limited, 2005.* 2. *Biomaterials: The Intersection of Biology and Materials Science, Johnna Temenoff, Antonios Mikos (Pearson; 1st edition (5 February 2008)* 3. *Biomaterial's principles and applications biomaterials edited by joon b. park joseph d. bronzino, edited by joon b. park*	4. *joseph d. bronzino (CRC, 2003)* 5. *Foundations of biomaterials engineering 1st edition by Maria- Cristina Tanzi, Silvia Fare and Gabriele Candiani (Elsevier 2019)* 6. *Biomaterials Science, Buddy Ratner & Allan Hoffman & Frederick Schoen & Jack Lemons (Academic Press, 3rd Edition,2012)*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*15%*	-	*15%*	-	*15%*	-
Level 2	*Understand*	*25%*	-	*25%*	-	*25%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. K. Chandru, Medical Device Domain, HCL Technologies*	1. *Dr. Asifkhan Shanavas, INST, Mohali, asifkhan@inst.ac.in*	1. *Dr.P. Malar, SRMIST*
2. *Mr. P. Aravind Mukesh, United Breweries, Bengaluru*	2. *Dr.Biman B. Mandal, IIT G, biman.mandal@iitg.ac.in*	2. *Dr. G. Devanand, SRMIST*

ACADEMIC CURRICULA

Professional Elective Courses

Regulations 2021

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Chengalpattu District 603203, Tamil Nadu, India

Course Code	21NTE221T	Course Name	CONCEPT OF NANOSCIENCE FOR ENGINEERS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the basic concepts and phenomenon of nanoscience*
CLR-2:	*demonstrate the different routes to synthesize various nanomaterials*
CLR-3:	*explain the different principles to understand the materialistic properties*
CLR-4:	*introduce the various characterization methods to determine the physical, chemical and biological properties of the nanomaterials*
CLR-5:	*demonstrate the current real time applications using nanomaterials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the basic concepts and principles of nanoscience*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*acquire knowledge on different synthesis process to prepare and fabricate nanomaterials*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*utilize the important concepts and phenomenon related to improve the materialistic properties of nanomaterials*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	*2*
CO-4:	*apply different characterization techniques to determine the properties of nanomaterials*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*acquire knowledge about the real time, commercial and futuristic applications of nanomaterials*	*3*	-	-	-	*1*	-	-	-	-	-	-	-	-	-	-

Unit-1 - Introduction	***9 Hour***
Scientific Revolution; Feynman's Vision – Nanoscience – Nanotechnology; Ancient Nanotechnology – Lycurgus Cup – Damascus swords – Stained Glass Windows – Nanotechnology in Nature – Insect Colours – Geckos –Hydrophobic Surfaces – Photonic Phenomena – Nanomaterials - Classification of Nanomaterials – Various Morphologies – Nanowires – Nanotubes – Nanorods – Nanofibres – Nanosphers – Quantum dots – Quantum confinement- Surface to volume ratio - Energy at bulk and nano scale – Band Structure of Nanomaterials - Size dependent variation in Optical, Mechanical, Physical- Chemical- electronics and catalytic properties.	
Unit-2 - Top down and Bottom-Up Approaches	***9 Hour***
Top down and Bottom Up approaches – Chemical Vapor Deposition- High-energy balling – Mechanical alloying –Nanostructure through Lithography – Different types of lithography techniques – Arc discharge – Physical vapour deposition - Bottom up approach: Polyol route – Colloidal precipitation – Sol-Gel process– Chemical precipitation – Hydro/solvothermal routes – Different coating techniques – Dip – Spray and layer by layer methods - Sonochemical– Microbial routes – Biosynthesis – Electrospinning method - Special Nanostructures - Quantum dots – Magnetic Nanoparticles – metal nanoparticles- Carbon Nanomaterials – Polymer based Nanocomposites.	
Unit-3 - Electromagnetic Radiation	***9 Hour***
Electromagnetic radiation – Wave nature of light – Photoelectric effect – Band Structure – Band diagram – Fermi level – The Bohr – Exciton radius – Structure of Atoms – Oxidation and reduction – Subatomic particles – Chemical bonding– Chemical reactions – Atomic orbitals – Molecular orbitals – Intermolecular forces – hydrogen bonding – Van der Waals force – dangling bonds – electron tunning effect – Interfacial charge transfer – Surface plasmon resonance –Hydrophilic and hydrophobic effect – Nanomagnets – Superparamagnetic effect – Giant Magnetoresistance	

Unit-4 - Characterization	9 Hour
Characterization of electrical- optical- mechanical and magnetic properties of nanomaterials. Electrical conductivity and permittivity- magnetic permeability- Structural characterization: X-ray diffraction- Electron microscopy – Scanningelectron and Transmission electron microscopies – UV-Vis-NIR – FTIR - Raman – X-ray Photoelectron Spectroscopies. Surface characterization: atomic force microscopy – Nano indentation. Characterization of porous structures. Characterization of quasi-static and dynamic elastic properties. Mechanical testing.	
Unit-5 - Nanocomposite Materials for Diagnosis	**9 Hour**
Nanocomposite materials for diagnosis - therapy and food packaging - Functional graphene- carbon nanostructures and polymer composite applications in defence and aerospace. Nanomaterials for energy sectors - solar Cells –hydrogen storage and production - Rechargeable batteries – supercapacitors for vehicular and portable electronic applications - Nanomaterials for electrodes and wearable electronics- Nano based coating and paints -Nano catalysts for environmental cleaning and disinfection of pathogens – Implications of nanoscience and nanotechnology on society.	

Learning Resources	1. T. Pradeep, Nano: The essentials, Tata McGraw-Hill Publishing Company Limited, 2010 2. Wesley C. Sanders, Basic Principles of Nanotechnology, CRC Press, 2018	3. Y. Dahman, Nanotechnology and Functional Materials for Engineers. A volume in 4. Micro and Nano Technologies, Elsevier, 2017. 5. B.S. Murty, P. Shankar, Baldev Raj, B B Rath, James Murday (auth.) Textbook of Nanoscience andNanotechnology, Springer, 2013.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	25%	-	25%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr.Priyanka Biswas, Graphene Research Lab Pvt Ltd	1. Dr.Pijush Ghosh, IIT Madras	1. Dr R.Ajay Rakkesh, SRMIST
2. Dr.Pralay K. Santra, Scientist D, Centre for Nano and Soft Matter Sciences,Bengaluru	2. Dr.Somnath Chandra Roy, IIT Madras	2. Dr.Payel Bandyopadhyay, SRMIST

Course Code	21NTE222T	Course Name	SYNTHESIS OF NANOSTRUCTURED MATERIALS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the basics of Nanostructured materials*
CLR-2:	*know the basics of Physical synthesis method*
CLR-3:	*introduce chemical synthesis method and understand the different synthesis routes*
CLR-4:	*understanding the working principle and fabrication of 2-D materials*
CLR-5:	*introduce the concepts of fabrication and application of 1-D materials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the concept of top-down and bottom-up method and understand the physical and chemical properties of nanostructured materials*	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*apply the concept and prepare the nanostructured materials for physical method*	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*gain knowledge on various chemical synthesis method*	2	-	2	-	-	-	-	-	-	-	-	-	-	2	-
CO-4:	*acquire knowledge on different types of fabrication of 2-D thin film materials*	3	-	-	2	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*utilize the concept and preparation of 1-D nanostructured materials to analyze the material nature*	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 - Introduction ***9 Hour***

Introduction of Nanostructured materials- Scientific Revolution-Atomic Structure and atomic size, emergence and challenges of nanoscience and nanotechnology, top-down, bottom-up approaches-carbon age-new form of carbon (CNT to Graphene), influence of nano over micro/macro, size effects and crystals, large surface to volume ration, surface effects on the properties.

Unit-2 - Synthesis ***9 Hour***

Synthesis and preparation of Nanomaterials: Vacuum: Different levels – Pumps: Rotary- Diffusion- Turbomolecular- Ion and Sublimation– Gauges: Penning- Pirani and Bayard-Alpert – Inert gas condensation: Low resistive boats – Joule heating process- Role of inert gases- Post oxidation process – Sputtering processes–Rapid solidification-Synthesis of bulk nanostructured materials, solid- state, processing- bulk and nano composite materials - Grinding - high energy ball milling – injection moulding - extrusion - melt quenching and annealing - PVD - PLD - Ultra high vacuum synthesis - Arc discharge, RF-plasma, Plasma arc techniques - Laser ablation - Spray Pyrolysis - Sputtering
- Direct current sputtering (DC sputtering), Radio frequency sputtering (RF sputtering) - -Advantages and disadvantages.

Unit-3 - Dimensions ***9 Hour***

Zero dimensional, one dimensional and two dimensional nanostructures, Nucleation theory, Homogeneous and heterogeneous nucleation, Metal nanocrystals by reduction, Sol- gel, Hydrothermal-Salvothermal–Sonochemical– Microbialroutes –Biosynthesis –Template route: DC and Pulsed electrodeposition and Electroless deposition – Combustion route, Photochemical synthesis, Electrochemical synthesis, Thermolysis routes, microwave routes, Sonochemical routes, Hybrid methods, Micelles and microemulsions, Bio-Synthesis-Polyol route – Colloidal precipitation – Chemical precipitation: Normal and Reverse reactions- Role of surfactant – Hydrolysis: Reaction kinetics.

Unit-4 - Synthetic Technique	**9 Hour**
Synthetic Technique (Physical and Chemical): Self-Assembly-Self Assembled Monolayers (SAM) - Vapour Liquid Solid (VLS) approach - Chemical Vapour Deposition (CVD) - MOCVD technique- Langmuir-Blodgett (LB) films - Spin coating- Templated self-assembly electrochemical approaches: thin films -Epitaxy -Lithography. Vacuum thermal evaporation, Electron beam evaporation, Laser beam evaporation, Ion plating evaporation-Inert gas condensation, aerosol method, Gas-phase synthesis, -Advantages and disadvantages.	
Unit-5 - One Dimensional Nanostructure	***9 Hour***
One dimensional nanostructured: Nanowires and Nanotubes- Evaporation-condensation – Electrospinning-Vapor- liquid - solid (VLS) - surface and bulk diffusion – kinetics – growth of various nanowires –control of size – precursors and catalysts - single- and multi- wall CNT - Si nanowires – density and diameter – doping in nanowires	

Learning Resources	1. *W. Gaddand, D. Brenner, S. Lysherski and G. J. Infrate (Eds), Handbook of nanoscience,Engg. and Technology, CRC Press, 2012.* 2. *G. Cao, Naostructures and Nanomaterials: Synthesis, properties and applications, imperical college press, 2004.*	3. *J. George, Preparation of thin films, Marcel Dekker, InC., NewYork, 2005.* 4. *C. N. R. Rao, A. Muller, A. K. Cheetham (Eds), The chemistry of nanomaterials: Synthesis, properties and applications, Wiley VCH Verlag Gmbh & Co, Weinheim, 2004.*

Learning Assessment

	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				*Summative Final Examination (40% weightage)*	
		Formative CLA-1 Average of unit test (50%)		*Life-Long Learning CLA-2 (10%)*			
		Theory	*Practice*	*Theory*	*Practice*	*Theory*	*Practice*
Level 1	*Remember*	*15%*	-	*15%*	-	*15%*	-
Level 2	*Understand*	*25%*	-	*25%*	-	*25%*	-
Level 3	*Apply*	*30%*	-	*30%*	-	*30%*	-
Level 4	*Analyze*	*30%*	-	*30%*	-	*30%*	-
Level 5	*Evaluate*	-	-	-	-	-	-
Level 6	*Create*	-	-	-	-	-	-
	Total	*100 %*		*100 %*		*100 %*	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Krishna SurendraMuvvala, Saint Gobain Research India, India,Krishna.muvvala@saintgobain.com*	1. *Dr.K.Sethupathi. IIT Madras, ksethu@iitm.ac.in*	1. *Dr.M.Navaneethan, SRMIST*
2. *Dr.M.Saravanan, CSIR-NPL, nvijayan@nplindia.org*	2. *Dr.S.Balakumar. University of Madras, Madras, balakumar@iunom.ac.in*	2. *Dr. S.Harish, SRMIST*

Course Code	21NTE321T	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:	*understand the concept of drug delivery*

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

Unit-1 - Introduction	***9 Hour***
Drug delivery systems, Traditional drug delivery, Advantages and disadvantages of various traditional drug delivery systems, Modes of drug delivery, Routes of administration, Novel drug delivery system, Pharmacokinetics, ADME studies, Kinetics of drug delivery, zero order kinetics, First order kinetics, Controlled drug delivery, Mechanism of controlled drug release, Therapeutic index, Drug release profile, Rate controlled drug delivery, Time controlled drug delivery	
Unit-2 - Trageted Delivery	***9 Hour***
Targeted drug delivery system, Site specific drug release, Types of drug targeting, Active targeting, Passive targeting, Barriers for drug targeting, Strategies for site specific drug delivery, Receptors, Ligands, Antibodies based drug delivery, Metabolism based drug delivery, Surface modification of nanoparticles, Bioconjugation of nanoparticles, PEGylation of nanoparticles, reticuloendothelial system, Opsonaization, Renal clearance, Steric repulsion	
Unit-3 - Metal Nanoparticles for Drug Delivery	***9 Hour***
Gold based drug delivery systems, Multifunctional nanoparticles, Multifunctional gold nanoparticles for drug delivery and imaging, Virus based drug delivery system, Polymeric nanoparticles, Classifications of polymers, Polymer micelles, Synthesis of polymeric nanoparticles for drug delivery, Dentrimers, Magnetic nanoparticles for drug delivery, Nanoscaffolds, CNT in drug delivery, Liposomes, Protein drug delivery, Gene delivery, Gene transfection, Methods of gene transfection	
Unit-4 - Drug Delivery to Cancer	***9 Hour***
Cancer therapy, Drug delivery to cancer, Targeted drug delivery to cancer, Enhanced permeability and retention, Cancer markers, Folate receptor, Angiogenesis, Leaky vasculature, Cancer specific targeting, Combinational therapy, Neutron capture therapy, targeting tumor vasculature for imaging, Anticancer drugs, Pharmacodynamics, Photothermal therapy, Cancer imaging, Nanoparticle–Aptamer Conjugates for Cancer Cell Targeting and Detection., Fluorescent Silica Nanoparticles for Tumor Imaging	

Unit-5 - Theranostic Metal Nanoshells	***9 Hour***
Theranostic metal nanoshells, Photothermally-modulated drug delivery using nanoshell, Hydrogels, Nanoporous systems for drug delivery, Molecularly-derived therapeutics, transdermal drug delivery, low-frequency sonophoresis,implants for controlled drug delivery, Responsive release system, Fabrication and Applications of Microneedles, Micropumps, microvalves, Implantable microchips, Quantum Dot Probes, Applications Nano biotechnologies for Single-Molecule Detection, Nanorobots, Drug delivery to Central Nervous systems, Drug delivery across Blood brain barrier	

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

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	25%	-	25%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Mr. K. Chandru, Medical Device Domain, HCL Technologies*	1. *Dr. Asifkhan Shanavas, INST, Mohali, asifkhan@inst.ac.in*	1. *Dr. G. Devanand Venkatasubbu, SRMIST*
2. *Mr. P. Aravind Mukesh, United Breweries, Bengaluru*	2. *Dr.Biman B. Mandal, IIT G, biman.mandal@iitg.ac.in*	2. *Dr. N. Selvamurugan, SRMIST*

Course Code	21NTE322P	Course Name	VACUUM AND THIN FILM TECHNOLOGY	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*understand the thin film*
CLR-2:	*introduce methods of thin film growth, Physical and Chemical*
CLR-3:	*explain various characterization tools to study structural and compositional properties*
CLR-4:	*explain the methods of electrical, optical and thickness measurements*
CLR-5:	*introduce the major application area of thin film technology*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	Program Outcomes (PO) 1	2	3	4	5	6	7	8	9	10	11	12	Program Specific Outcomes		
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply the principles of vacuum technology*	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*gain knowledge on physical and chemical methods of thin film deposition*	2	2	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*understand the importance of structural and compositional characterization of thin films*	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-4:	*acquire knowledge on optical, electrical and thickness measurement methods*	2	-	3	-	-	-	-	-	-	-	-	-	-	2	-
CO-5:	*understanding the utilization of thin film technology in various application areas*	2	-	2	-	-	-	-	-	-	-	-	-	2	-	-

Unit-1 - Introduction ***9 Hour***

Introduction to vacuum technology- What is vacuum?, units, vacuum ranges, flow types, adsorption, desorption, vacuum pumps, rotary, diffusion, turbo molecular, getter ion pumps, design and operation, design of vacuum pumping stations, , vacuum measurement, total pressure measurement equipment, partial pressure measurement equipment / Mass spectrometers, leak detection, Helium leak detection, vacuum-suitable components, Detachable and non- detachable connections, Flange systems and seals,valves, compatible materials, vacuum systems examples

Unit-2 - Introduction to Thin Film Growth ***9 Hour***

Introduction to thin film growth, Kinetic theory of gases, types of thin growth, epitaxial and polycrystalline growth of thin films, Physical vapour deposition method, Thermal evaporation, e-beam evaporation, sputtering principle, DC and RF sputtering, Pulsed laser deposition, Molecular beam epitaxy: Chemical vapor deposition (CVD) method, CVD reaction types, Plasma Enhanced CVD (PECVD), Metallorganic CVD, atomic layer deposition, comparison of PVD and CVD techniques

Unit-3 - Thin Film Characterization ***9 Hour***

Thin film characterization tools: Structural analyses using X-ray and electron diffraction, Surface studies using electron microscopy (SEM, TEM) Atomic force microscopy, Compositional studies using Energy dispersive E-ray emission, X- ray photoelectron spectroscopy XPS, Rutherford Back Scattering spectroscopy (RBS), depth profiling using Secondary Ion Mass Spectroscopy (SIMS).

Unit-4 – Measurements ***9 Hour***

Thickness, electrical and optical properties measurements- In-situ and ex-situ methods, RHEED for epitaxial growth monitoring, Quartz crystal monitoring, contact and non-contact profiler for thickness measurement methods, resistivity, Hall measurements, UV-vis-NIR spectroscopy measurements for determination of reflectance, transmittance, absorbance, optical bandgap determination in semiconducting thin films

Unit-5 - Application ***9 Hour***

Application areas of thin film technology- optical coatings, antireflective coatings, electronic devices, magnetic, diffusion barriers in chemical processes, ceramic and friction reduction in mechanics, transparent conducting oxide film, transparent devices, thin film solar cells

Learning Resources	1. *A User's Guide to vacuum Technology, 3rd edition, by J. F. O'Hanlon, John Wiley, and Sons,2003* 2. *Rointan. F, Bunshah," Hand Book of Deposition technologies for Thin Films and coatings by Science, Technology and Applications", Second Edition, Noyes Publications, 1993.*	3. *Milton Ohring, "Materials Science of Thin films" Published by Academic Press Limited 1991* 4. *Vacuum Physics and Techniques by T. A. Delchar, Chapman, and Hall, 1993* 5. *K. L. Chopra, "Thin Film Phenomena", McGraw Hill, New York, 1969* 6. *L. T. Meissel and R. Glang, "Hand book of thin film technology", McGraw Hill, 1978.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)						Final Examination (0% weightage)	
		Formative CLA-1 Average of unit test (20%)		Project Based Learning CLA-2 (60%)		Report and Viva Voce (20%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	15%	-	15%	-	-
Level 2	Understand	25%	-	-	20%	-	25%	-	-
Level 3	Apply	30%	-	-	25%	-	30%	-	-
Level 4	Analyze	30%	-	-	40%	-	30%	-	-
Level 5	Evaluate	-	-	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-	-	-
	Total	100 %		100 %		100%		-	

Course Designers

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

Course Code	21NTE323T	Course Name	ADDITIVE MANUFACTURING 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	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*introduce the basic principles, advantages and the challenges of additive manufacturing*
CLR-2:	*acquire the knowledge of different additive manufacturing processes*
CLR-3:	*understand the additive manufacturing machines and systems*
CLR-4:	*create insights to pre-processing in additive manufacturing*
CLR-5:	*explain the significance of post-processing in additive manufacturing*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO) 1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	Program Specific Outcomes PSO-1	PSO-2	PSO-3
CO-1:	*define the various processes and materials used in additive manufacturing*	*3*	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*analyze suitable process in additive manufacturing*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	2	-	-
CO-3:	*explain the components and working of various machine tool systems*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	2	-	-
CO-4:	*apply CAD technique and reverse engineering for geometry transformation in additive manufacturing*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*employ the knowledge of additive manufacturing for various applications*	*3*	-	*3*	-	-	-	-	-	-	-	-	-	2	-	-

Unit-1 - Overview ***9 Hour***

Basic principle needs and advantages of additive manufacturing, Procedure of product development in additive manufacturing, Classification of additive manufacturing processes, Materials used in additive manufacturing, Challenges in Additive Manufacturing.

Unit-2 - Z-Corporation 3D-Printing ***9 Hour***

Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modelling (FDM), Laminated Object Manufacturing (LOM), Selective deposition lamination (SDL), Ultrasonic consolidation, Selective laser sintering (SLS), Laser engineered net shaping (LENS), Electron beam free form fabrication (EBFFF), Electron beam melting (EBM), Plasma transferred arc additive manufacturing (PTAAM), Tungsten inert gas additive manufacturing (TIGAM), Metal inert gas additive manufacturing (MIGAM).

Unit-3 - Axes ***9 Hour***

Axes, Linear motion guide ways, Ball screws, Motors, Bearings, Encoders/ Glass scales, Process Chamber, Safety interlocks, Sensors. Introduction to NC/CNC/DNC machine tools, CNC programming and introduction, Hardware Interpolators, Software Interpolators, Recent developments of CNC systems for additive manufacturing.

Unit-4 - 3D-CAD Model ***9 Hour***

Preparation of 3D-CAD model, Reverse engineering, Reconstruction of 3D-CAD model using reverse engineering, Part orientation and support generation, STL Conversion, STL error diagnostics, Slicing and Generation of codes for tool path, Surface preparation of materials.

Unit-5 - Techniques ***9 Hour***

Techniques used in additive manufacturing, Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, Brief information on characterization Applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Learning Resources	1. Chua Chee Kai, Leong Kah Fai, "3D Printing and Additive Manufacturing: Principles & Applications", 4th Edition, World Scientific, 2015 2. Ian Gibson, David W Rosen, Brent Stucker., "Additive Manufacturing Technologies: 3DPrinting, Rapid Prototyping, and Direct Digital Manufacturing", 2nd Edition, Springer, 2015	3. Additive Manufacturing Applications and Innovations Edited By Rupinder Singh, J. Paulo Davim (CRC Press)

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	25%	-	25%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Mr. Aditya Kumar, Marcopolo Products P Ltd, aditya.kumar@marcopolo.co.in	1. Dr. Murugaiyan Amirthalingam, IIT Madras, murugaiyan@iitm.ac.in	1. Dr. Venkata Ravindra A, SRMIST
2. Mr. Venkatesha N, SABIC Research & Technology Pvt. Ltd., Venkatesha.N@sabic.com	2. Dr. Pulak Mohan Pandey, IIT Delhi, pmpandey@mech.iitd.ac.in	2. Dr. Payel Bandyopadhyay, SRMIST

Course Code	21NTE324T	Course Name	PHYSICS OF ELECTRONIC MATERIAL	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the physics of semiconductor electronic materials*
CLR-2:	*understand and analyse the behavior of active and passive devices built from electronic materials*
CLR-3:	*familiarize with different physical properties of electronic materials and devices*
CLR-4:	*understand the physics of magnetism and magnetic materials-based devices*
CLR-5:	*understand the properties of materials that result in specific electrical, optical and magnetic behavior*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*use knowledge of physics to understand the properties of Electronic Materials*	*2*	*3*	-	*2*	-	-	-	-	*2*	-	-	-	-	-	-
CO-2:	*analyze different mechanisms that determine the properties of electronic materials*	*3*	*2*	-	*2*	-	-	-	-	*2*	-	-	-	*2*	-	-
CO-3:	*determine the applications of electronic materials based on their properties*	*2*	*2*	-	*2*	-	-	-	-	*2*	-	-	-	*3*	-	-
CO-4:	*evaluate the material characteristics by applying laws of physics*	*3*	*3*	-	*3*	-	-	-	-	*2*	-	-	-	*3*	-	-
CO-5:	*develop in depth understanding of the physical processes of electronic materials*	*3*	*2*	-	*3*	-	-	-	-	*2*	-	-	-	*3*	-	-

Unit-1 - Introduction	***9 Hour***
Introduction to crystals – Symmetry operations – Point groups and space groups – absence of five-fold symmetry - Basis and Motif – Crystal Unit cell – Types of crystal lattices – Miller indices - Reciprocal lattice – Crystal directions and planes – Cubic lattice in reciprocal space - Distance between two parallel crystal planes - Wigner Seitz Unit cell – Brillouin zone – Diffraction condition - Crystal properties - defects and vacancies	
Unit-2 - Postulates of Quantum Mechanics	***9 Hour***
Postulates of Quantum Mechanics – Formalism – Schrodinger equation – Simple potentials – Particle in infinite well – Particle in finite well - Quantum tunnelling – Transmission coefficient - Classical Drude model – Quantum free electron theory – Particle subjected to periodic potential - Bloch's Theorem – Bloch's waves – Origin of Energy gap – Conductors –Semiconductors and Insulators – Effective mass – E vs k diagram – Intrinsic and Extrinsic semiconductors – Semiconductor doping – Doping methods – Direct and Indirect band gap semiconductors	
Unit-3 - Thermal Properties of Materials	***9 Hour***
Thermal properties of materials – specific heat capacity - thermal expansion - conductivity and thermal stress - Einstein and Debye model of heat capacity - Seebeck effect - thermoelectricity in semiconductors - 2D electronic materials - future perspectives	
Unit-4 - Optical Properties of Material	***9 Hour***
Optical properties of material - refractive index, dispersion, transmittance, reflectance and refractivity - light propagation in a homogeneous medium - absorption - scattering - luminescence - phosphors - fiber optics - LEDs - polarization - LCDs - Band to band absorption - Direct and indirect transitions - Laser operation - spontaneous and stimulated emission - photoluminescence and electroluminescence - electro optic effects - magneto optic effects - MOKE	
Unit-5 - Magnetism	***9 Hour***
Magnetism - Dipole moment - Orbital and spin magnetic moment of an electron - magnetic susceptibility and magnetic permeability - Classification of Magnetic materials - saturation and Curie temperature - exchange interaction - Magnetic domains and domain walls - Superconductivity – Meisner effect – Introduction to BCS Model - Josephson effect - Introduction to magneto resistance - TMR - GMR – TAM	

Learning Resources	1. *S O Kasap, "Principles of Electronic Materials and Devices" – McGraw Hill, Fourth Edition, 2017* 2. *Jørgen Rammer, "Physics of Electronic Materials - Principles and Applications" Cambridge University Press, 2017* 3. *Wei Gao, Zhengwei Li, Nigel Sammes, "An Introduction to Electronic Materials for Engineers" – World Scientific Publishing Co. Pte. Ltd, Second Edition, 2011* 4. *David Jiles, "Introduction to the Electronic Properties of Materials: - Nelson Thornes Ltd, Second Edition, 2001*	5. *David K. Ferry, Jonathan P. Bird "Electronic Materials and Devices" – Academic Press, First Edition, 2011.* 6. *Yuriy M Poplavko, "Electronic Materials: Principles and Applied Science" – Elsevier, First Edition, 2019* 7. *Rolf E. Hummel, "Electronic Properties of Materials: An Introduction for Engineers" – Springer, 1993* 8. *Kittel, C., Introduction to solid state physics Eighth edition, 2021.*

Learning Assessment

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

Course Designers

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

Course Code	21NTE325T	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	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

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

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*acquire knowledge of physics of p-n junction formation and functioning of pn-junction diode*	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*develop in depth understanding on the metal-semiconductor contacts and methods to access their quality*	3	-	-	3	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*differentiate different transistor technologies and know the design and working of MOSFET*	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*familiarize with III-V semiconductor device technologies*	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*analyze optical processes in semiconductor materials for various optoelectronic devices*	2	-	-	3	-	-	-	-	-	-	-	-	-	3	-

Unit-1 - P-N Junction — ***9 Hour***

Physics of the p-n junction formation, Energy band diagram of a p-n junction, Estimation of the electric field, electric potential, and built-in potential, Depletion approximation and estimation of space charge width, Depletion layer capacitance and its estimation, Linearly graded junction in thermal equilibrium, Arbitrary doping profile and understanding the doping profile from 1/C2-V plot, Qualitative description of charge flow in a p-n junction, Ideal current-voltage characteristics of a p-n junction, Derivation of Shockley equation (ideal- diode equation), Generation-recombination process and its effect, Reverse bias breakdown mechanisms in a pn junction, Zener and Avalanche breakdown, Transient behavior of a p-n junction, Concept of Noise in semiconductor devices, Terminal functions of a p-n junction diode, The concept of tunnel diode, p-n junction as rectifier, Zener diode, Varistor, and Varactor

Unit-2 - Metal-Semiconductor Contacts — ***9 Hour***

Metal-semiconductor contacts, Qualitative characteristics of energy band formation, Understand the ideal junction properties, Theoretical considerations in estimating the barrier height, Nonideal effects on the barrier height, Qualitative explanation of image-force-induced lowering of the potential barrier, Current transport processes in metal- semiconductor contacts, Comparison of the Schottky barrier diode and the p-n junction diode, Metal-semiconductor Ohmic contacts, Concept of ideal nonrectifying and tunneling barriers, Tunneling in Ohmic contact structures, The concept of triangular barrier and the Fowler–Nordheim tunneling formula, Methods to experimentally measure the barrier height, Current-voltage and capacitance-voltage measurements, Photoelectric measurements, Figure of merit of ohmic contacts and its determination, the concept of specific contact resistance, Contact resistance of highly doped ohmic contact

Unit-3 - BJT — ***9 Hour***

Fundamentals of BJT operation, Operation modes of a BJT, Structure and working of p-n-p and n-p-n transistors, Band diagram and static characteristics, Factors involved in transistor amplification, BJT fabrication, Non ideal effects in BJT, The physical mechanisms of the current gain limiting factors, The current-limiting factors from the current components in the transistor, Frequency limitations of transistors, The voltage breakdown mechanisms in a bipolar transistor, Heterojunction BJT, Schottky and Photo transistors, Field-effect transistors (FETs), Principle of operation of JFET, Concept of pinch-off and saturation, I-V characteristics of JFET, MOSFET– Principle of working and fabrication, Modes of operation, MOSFET device scaling, Short channel effects in MOSFET, Advanced MOSFET structures, Metal Gate-High-k and Enhanced Channel Mobility Materials and Strained Si FETs, Complementary MOS structure and its formation, CMOS process integration, Dynamic effects in MOS capacitors – The Charge-coupled device, Basic CCD structure and its applications, 3d stacking, CMOS formation with process integration

Unit-4 - Semiconductor Hetero Structures	9 Hour
Isotype and anisotype semiconductor heterostructures - energy band diagrams, Current density equations and physical interpretation, boundary conditions, Periodic and nonperiodic structures - Concept of quantum well, superlattice, and resonant tunnelling structures, Applications of the Schrodinger equation, The importance of III-V semiconductor materials, Concept of high-electron mobility transistors (HEMT), Two-dimensional electron gas, Concept of modulation doping in HEMT, Basic device structure of AlGaAs/GaAs HEMT and I-V characteristics, Output characteristics and channel related phenomenon	
Unit-5 – Photo Generation	**9 Hour**
Photogeneration of carriers in a p-n junction, Types of Photodiodes, Solar radiation and ideal conversion efficiency of a solar cell, Physics of solar cell, Device configuration and technology roadmap, solar cell materials, Solar cell parameters and efficiency calculation, Design principle of photodetector, Types of photodetectors and characteristics, Light-emitting diodes, Basic device structure and the concept of radiative recombination, Materials of choice and technology roadmap, Specifications used in denoting the practical LED bulbs, Physics of laser action, Gain knowledge of stimulated emission and population inversion, Fabrication of p-n junction laser, Emission spectra, Structure and need of heterojunction lasers, Materials for semiconductor lasers and quantum cascade lasers	

Learning Resources	1. S M Sze, Kwok k. Ng, "Physics of semiconductor devices" – John Wiley & Sons, Inc., 2007 2. Ben G. Streetman, Sanjay Kumar Banerjee, "Solid State Electronic Devices", Pearson Education Ltd, 2016	3. E F Schubert, "Physical Foundations of Solid-state Devices" - 2009 4. Donald A. Neamen, "Semiconductor Physics and Devices: Basic" - Principles" – McGraw Hill, Fourth Edition, 2011.

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. D.K. Aswal, 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. S. Balakumar, University of Madras, balakumar@iunom.acs.in	2. Dr. E. Senthil Kumar, SRMIST

Course Code	21NTE326T	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	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*illustrate the extraction of molecular symmetry using group theory*
CLR-2:	*understand light matter interaction*
CLR-3:	*understand rotational and vibrational transition and their spectroscopy*
CLR-4:	*understand electronic transition in atoms and molecules and their spectroscopy*
CLR-5:	*concept of electron and nuclear spin*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*classify the symmetry of molecules using group theory*	3	3	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*identify the selection rules for spectroscopic transitions within atoms and molecules*	3	2	-	-		-	-	-	-	-	-	-	3	-	-
CO-3:	*analyse spectroscopic data obtained from Microwave, Raman and IR spectroscopy*	3	-	-	3	-	-	-	-	-	-	-	-	-	2	-
CO-4:	*interpret electronic transitions and the photoelectron spectra of molecules*	3	2	-	-		-	-	-	-	-	-	-	-	-	3
CO-5:	*predict the relative intensities and selection rules in NMR and ESR spectra*	3	3	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 - Group Theory ***9 Hour***

Introduction to group theory- Properties of a group-Subgroup and Class-Symmetry point groups- Symmetry elements, operations and point groups - Molecules and point groups - Representations Reducible and Irreducible representations-Great Orthogonality Theorem and its consequences, Character tables-Wavefunctions as bases for irreducible representation- Schonflies notation-Point Group Determination-Symmetries of molecular orbitals - Symmetries of normal modes of molecules -Applications of Symmetry - Prediction of Dipole Moment and Optical Activity- Selection rules-Application of Group Theory to Quantum Mechanics- Degenerate Eigen Functions

Unit-2 - Interaction of Radiation with Matter ***9 Hour***

Interaction of radiation with matter- Regions of the electromagnetic radiation- origin of spectrum-Spectroscopic transition between two stationary states-Transition probability and Selection Rules- Absorption and emission of a photon-Einstein A and B co-efficients-Line shape functions-Spectral broadening mechanisms -Fourier Transform-spectral resolution-Intensity of spectral lines–Born Oppenheimer Approximation - rotational, vibrational and electronic energy levels

Unit-3 - Microwave Spectroscopy ***9 Hour***

Microwave spectroscopy-Classification of molecule– Rigid rotor model– Effect of isotopic substitution on the transition frequency- Non-rigid rotor– Stark effect - Nuclear and electron spin interaction-IR spectroscopy-Harmonic Oscillator and Vibrational energies of diatomic molecules - Force Constant and Bond strength - Anharmonicity - Morse potential energy diagram -P.Q.R. Branches - Vibration of polyatomic molecules - Factor affecting the band position & intensities-Raman Effect - Classical Theory - Quantum Theory - Pure Rotational, Vibrational and Rotational- Vibrational Raman Spectra - Mutual Exclusion Principle

Unit-4 - Electronic Spectroscopy ***9 Hour***

Electronic spectroscopy-Principal quantum number and energy levels, spin-orbit coupling, singlet and triplet states-Energy of electronic transitions - Electronic states of diatomic molecules - Franck-Condon Principle -Vibrational fine structure and Herzberg-Teller vibronic coupling - UV - absorption – decay of an electronically excited state, photophysical processes, Jablonsky diagram Fluorescence- Phosphorescence -excited state lifetime and quantum yield-Photoelectron spectroscopy– Basic Principles - Photoelectric Effect - Ionization Process - Koopman's Theorm - Photoelectron spectra of simple molecules - ESCA - Chemical Information from ESCA - Auger electron transitions

Unit-5 - Atoms in Magnetic Fields	**9 Hour**
Atoms in magnetic fields- The normal Zeeman effect -Spin-orbit coupling in alkali atoms -The anomalous Zeeman effect -Russel-Saunders coupling and jj-coupling in many-electron atoms -Microstates and eigenstates -NMRspectroscopy -Nuclear Spin - NMR active nuclei - Spinning Nuclei-Magnetic moments-Larmor Precision - Theory of NMR - Nuclear Resonance– Nuclear Saturation and Relaxation Process– Instrumentation– Shielding of magnetic nuclei– Spin –Spin interactions-Electron Spin Spectroscopy -Types of substances with unpaired electrons (ESR active species) -Basic Principle of ESR spectrum -g-value and factors affecting g- value –Determination of value of g - Hyperfine splitting constant -Zero Field splitting-Applications of ESR Spectrum	

Learning Resources	1. *Peter Atkins, Julio de Paula Atkins, "Physical Chemistry", W. H. Freeman and Company,New York, 2010* 2. *Thomas Engel, Quantum Chemistry & Spectroscopy, Pearson 2013* 3. *Collin Banwell, Mc Cash, "Fundamentals of Molecular Spectroscopy", McGraw Hill publishing, 2001* 4. *G.Aruldhas, "Molecular structure and spectroscopy" ,Prentice Hall, 2001* 5. *P.S.Sindhu, "Fundamentals of molecular spectroscopy" New age international publishers,2006*	6. *J. M. Hollas, Modern spectroscopy, Wiley, New York, 2004* 7. *Donald A. McQuarrie and John D. Simon, Physical Chemistry - A Molecular Approach,University science books,1997* 8. *Alan Vincent, Molecular Symmetry and Group Theory (Second Edition), John Wiley &Sons, LTD, 2010 9.Online source: Molecular Spectroscopy https://www.youtube.com/watch?v=RBPtLn3M8TI http://mpbou.edu.in/slm/mscche1p4.pdf*

Learning Assessment

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

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr.D.K.Aswal, 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.Senthil Kumar, SRMIST*

Course Code	21NTE327T	Course Name	NANO CATALYSTS	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:	*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*

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

Unit-1 - Introduction to Catalysis	***9 Hour***
Introduction to catalysis – classifications - heterogeneous catalysis - Reaction on the solid surfaces - Active sites- Activation energy - Adsorption isotherms - Physisorption and chemisorptions - Brunauer-Emmett-Teller (BET) theory- Total surface area- Pore volume and pore size distribution - Hg porosimetry method - N2 adsorption-desorption method - Reaction mechanism - Kinetics of the heterogeneous catalytic reactions - Activation energy (Arrhenius equation, Eyring equation) - Terminology in catalysis, TO(Turnover),TON(Turnover number), TOF(Turnover frequency) - Sequences involved in a catalysed Reaction - Asymmetric synthesis using a catalyst	
Unit-2 - Adsorption and Desorption Processes	***9 Hour***
Adsorption and Desorption Processes - Adsorption Rate - Desorption Rate - Catalytic activity (bulk and nanoscale) - Catalytic activity determinationfor metal/metal oxidenanostructures - Langmuir-Hinshelwood mechanism for nanocatalyst - Mass transport - Diffusion controlled process - Adsorption equilibrium on uniform - surfaces-Langmuir isotherms single-site (non-dissociative) adsorption - Dual-site (dissociative) adsorption - Derivation of the Langmuir isotherm - Adsorption equilibrium on non-uniform surfaces-Langmuir isotherms- The Freundlich isotherm - The Temkin Isotherm - Activated adsorption - Catalytic efficiency - Application of metal nanoparticles in - organic reactions - Environmental remediation	
Unit-3 - Kinetics and Photocatalytic Activity	***9 Hour***
Kinetics and photocatalytic activity - Introduction to photocatalyst - Basics of electrochemistry – Photochemistry - Electronic structure and photoabsorption - Jablonskii diagram - Structure of photocatalysts - Solar spectrum - Fundamental understanding of semiconductor interfaces - Principles and relevance to - photoelectrochemical mechanism - Photocatalysis mechanism - Properties of good photocatalysts - Advantages of photocatalysts - Types of photocatalysts - Homogeneous and heterogeneous photocatalyst - Carbonaceous photocatalysts. - Plasmonic photocatalysts. - Application of photocatalyst	

Unit-4 - Catalyst in Nanoscale	9 Hour
Catalyst in Nanoscale - Noble metals nanocatalyst (Ru, Rh, Pd, Pt, etc) - Polymer stabilized Rh and Ru nanoparticles - Oxide supports for nano-catalysts; carbon supports for nano-catalysts - Gold nanoparticle-based catalyst - Gold vs. Palladium catalysts for the aerobic oxidation of alcohols - Oxide based catalyst - Metal free catalyst (CNT, Graphene based - Transition metal dichalcogenides based catalyst - Microporous materials: Zeolites-Zeotypes Catalyst) - Overall steps in zeolite crystallization - Zeolite synthesis via.- dry gel route - Zeolite Y- determination of surface acidity - Shape-selectivity - Synthesis of Mesoporous Silica MCM-41 - Mesoporous Carbon - Sulfated Zirconia - Ag/SiO_2 composite nanocatalysts	
Unit-5 - Applications	**9 Hour**
Applications of Nano-Catalyst - Toxic Gases conversion using nanocatalyst: NOx - CO oxidation using nanocatalyst - Hydrogenation of compounds with C≡C bonds, hydrogenation of aromatic compounds – Greenhouse gases: CO_2 conversion - Dissociative mechanism: oxygen reduction reaction using nanocatalyst - Associative mechanism: oxygen reduction reaction using nanocatalyst - Hydrogen Production using oxide and dichalcogenides based catalyst - Energy processing: Processes involved in crude oil refinery - Gasoline production – Cracking - Fuel cell - Biomass gasification – Biodiesel - Photocatalyst for self-cleaning - Purification of water and air - Environmental remediation - Future possibilities	

Learning Resources	1. M. Albert Vannice, Kinetics of Catalytic Reactions, Springer, 2008. 2. Nick Serponeand 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 (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	40%	-	40%	-	40%	-
Level 4	Analyze	20%	-	20%	-	20%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. P. Sudhakara, CLRI – CSIR, Jalandhar, sudhakarp@clri.res.in	1. Dr.G. Arthanareeswaran, NIT Trichy, arthanareeg@gmail.com	1. Dr. N. Angeline Little Flower. SRMIST
2. Dr. Sudhakar selvakumar, CSIR-Central Electrochemical ResearchInstitute, ssudhakar79@gmail.com	2. Dr. A. Kannan, IIT Madras, kannan@iitm.ac.in	2. Dr. M.Alagiri, SRMIST

Course Code	21NTE421T	Course Name	SURFACE ENGINEERING	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*outline the fundamentals and failure micro mechanism occurrence in science engineering processes*
CLR-2:	*illustration and overview on the co-relations about the micro mechanism failures for optimizing the surface engineered microstructures*
CLR-3:	*introducing about the various phenomena for identifying the appropriate Engineering approach towards device development*
CLR-4:	*explaining advanced surface engineering processes*
CLR-5:	*introduction on various state-of-the-art Surface Characterization techniques for thin bi- and multi-layers*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*gaining knowledge about the fundamentals and failure micro mechanisms occurrence in surface engineering process*	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-2:	*earning knowledge with enhanced understanding to become capable to co-relate the micro mechanism failures for optimizing the surface engineered microstructures*	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-3:	*gaining knowledge for identifying the appropriate Engineering approach towards developing devices for innovative applications*	3	-	2	-	-	-	-	-	-	-	-	-	-	2	-
CO-4:	*acquiring knowledge and sound understanding for advanced surface engineering processes*	3	-	2	-	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*utilizing knowledge for state-of-the-art Surface Characterization techniques for thin bi- and multi-layers*	3	-	2	-	-	-	-	-	-	-	-	-	-	-	3

Unit-1 - Importance	***9 Hour***
Importance and scope of surface engineering, conventional surface engineering practices like pickling, grinding, and buffing; Surface degradation, Wear and corrosion, Surface dependent properties and failures, Surface and surface energy: Structure and types of interfaces, surface energy and related equations, Types of wear: Abrasive wear, Adhesive wear, Surface fatigue, Fretting wear, Erosive wear, Corrosion and oxidation wear	
Unit-2 - Surface Roughness	***9 Hour***
Role and estimate of surface roughness in Surface engineering, Surface engineering by material addition: liquid bath - hot dipping, Electrodeposition; Surface modification of steel and ferrous components: Pack carburizing; Surface modification of ferrous and non-ferrous components: Aluminizing, calorizing, diffusional coatings; Surface modification using liquid/molten bath: Cyaniding, liquid carburizing; Surface modification using gaseous medium: Nitriding carbonitriding	
Unit-3 - Surface Engineering by Energetic Beams	***9 Hour***
Surface engineering by energetic beams: scope and principles; Laser assisted microstructural modification - surface melting, hardening, shocking; Laser assisted compositional modification - surface alloying of steel and non- ferrous metals and alloys, surface cladding, and composite surfacing; Electron beam assisted modification and joining; Ion beam assisted microstructure and compositional modification; Flame spray; Plasma coating; High-velocityoxy-fuel (HVOF), Cold spray	
Unit-4 - Thermal Evaporation	***9 Hour***
Thermal Evaporation, Electron beam (e-beam) evaporation, Molecular beam Epitaxy (MBE), DC sputter deposition, RF sputter deposition; Ion Beam deposition; Hybrid PVD coating processes; Plasma-enhanced chemical vapor deposition (PECVD), Atomic layer Deposition (ALD; Plasma and ion beam assisted surface modification; Ion implantation and Ion beam mixing.	

Unit-5 - Measurement	9 Hour
Thickness measurement: Ellipsometry; porosity & adhesion of surface coatings; Measurement of residual stress & stability; Surface microscopy & topography via. scanning probe microscopy (SPM: AFM, STM and MFM); Reflection High Energy Electron Diffraction (RHEED), Low Energy Electron Diffraction LEED, X-ray Photoelectron Spectroscopy (XPS), X-ray Diffraction (XRD), Scanning electron microscopy (SEM); Energy Dispersive X-ray analysis (EDX), Focused ion Beam (FIB)	

Learning Resources	1. Peter Martin, " Introduction to Surface Engineering and Functionally Engineered Materials", John Willey.2011 2. Devis, J.R.," Surface Engineering for Corrosion & Wear Resistance", Maney Publicsing.2001 3. Mircea K. Bologa, "Surface Engineering and Applied Electrochemistry", Springer. Journal	4. K.G. Budinski, Surface Engineering for Wear Resistances, Prentice Hall, Englewood Cliffs, 1988. 5. Yip-Wah Chung, Practical Guide to Surface Science and Spectroscopy (AP) ,2001 6. Kelly, Groves and Kidd, Crystallography and Crystal Defects (John Wiley)2010

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Muhammad Shahid Anwar, CSIR - Institute of Minerals and MaterialsTechnology, Bhubaneswar, shahid@immt.res.in	1. Dr. S. Amirthapandian, Surface Science, Materials Science, IGCAR,pandian@igcar.gov.in	1. Dr.Jitendra Kumar Tripathi, SRMIST
2. Dr. Ashutosh Rath, CSIR - Institute of Minerals and Materials Technology, Bhubaneswar, ashutosh@immt.res.in	2. Dr. K. Ganesan, Materials Physics Division, IGCAR, kganesan@igcar.gov.in	2. Dr. S. Chandra mohan, SRMIST

Course Code	21NTE422T	Course Name	MICROELECTRONICS AND VLSI	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire knowledge on basic electronic components and physical effects at semiconductor junctions*
CLR-2:	*learn construction of MOSFETs and its operation*
CLR-3:	*understand operation of various types of amplifiers*
CLR-4:	*realize IC and its passive components*
CLR-5:	*understand usage and management of power in IC*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*apply basic semiconductor physics for the working of semiconductor devices, Boolean algebra, operation of logic gates*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	*3*	-	-
CO-2:	*analyze models of MOSFET and CMOS*	*2*	-	-	*2*	-	-	-	-	-	-	-	-	-	-	-
CO-3:	*apply CMOS designing and circuits*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*visualize importance of interconnects and its usage*	*3*	-	-	*2*	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*evaluate power management and supply in IC*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	-

Unit-1 - Introduction ***9 Hour***

Introduction to electronic materials and classification, Origin of energy band gap, Density of states, Fermi energy level, Types of semiconductors, Doping in semiconductors, Formation of p-n junction, Electrostatics of p-n junction transport and operation, Diode as circuit element, Large signal and small signal operation of diode, Applications of diodes: limiting circuits-voltage doubler-shifters and switches, Current-voltage characteristics and operation of bipolar junction transistors, Ebers-Moll representation of transistor for circuit element, AC operation of transistor, Large and small signal model, Amplifiers, Transistor connections in various modes, Number systems: Binary and octal numbering-Hexadecimal numbering-Conversions between number systems, Boolean algebra, Logic gates: Truth tables for AND, OR, NOT, NAND, NOR gates

Unit-2 - MOFET, N- and P-MOSFET ***9 Hour***

Introduction to MOFET, N- and P-MOSFET, DC operation of MOSFET, Derivation of I-V characteristics, Modelling of MOSFET, Small signal model, AC operation of MOSFET, Enhancement and depletion modes, Threshold voltage, Introduction to Complementary Metal Oxide Semiconductor (CMOS), CMOS inverter and its operation

Unit-3 - MOSFET ***9 Hour***

MOSFET amplifiers, Realization of current sources, Differential amplifier: general considerations-MOS differential pair-cascode diff. amp, Cascode stages and current mirrors, Operational amplifier: as an black box-Op-Amp based circuits-non-linear functions and non-idealities, Frequency response of MOSFET: concepts-high frequency models-low and high frequency response, process integration

Unit-4 - ICs ***9 Hour***

Introduction to Integrated circuits (ICs), Monolithic integration, Active and passive devices, Passive devices: resistor-capacitor-inductor, Interconnects, Interconnect Parameters: Capacitance-Resistance-Inductance, Electrical wire model: ideal wire-lumped model-lumped RC model, Transmission line response, Types of terminations, VLSI, introduction to packaging

Unit-5 - Power Management	*9 Hour*
Power Management in IC, MOSFET Structures and comparison, Power analysis, Scaling effects, Leakage power dissipation, Challenge of power management in IC: Multi-Vth Technology- Performance Boosters-Layout-Dependent Proximity Effects-Impacts on Circuit Design, Principles in Power Management Module: Load Regulation- Transient Voltage Variations- Conduction Loss and Switching Loss- Power Conversion Efficiency	

Learning Resources	1. *Behzad Razavi. Microelectronics, 2nd Ed, John Wiley & Sons, 2015* 2. *Jan M Rabaey; Anantha P Chandrakasan; Borivoje Nikolic. Digital integrated circuits: a design perspective, Pearson Education, 2003*	3. *Ke-Horng Chen. Power management techniques for integrated circuit design, Wiley, 2016*

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Vinay Kumar Gupta, NPL, guptavinay@nplindia.org*	1. *Prof. K. Sethupathi, IITM Chennai, ksethu@iitm.ac.in*	1. *Dr. Abhay A. Sagade, SRMIST*
2. *Dr. Pramod Rajanna, HHV Bangalore, pramod@hhv.ac.in*	2. *Dr. Aditya Sadhanala, IISc Bangalore, sadhanala@iisc.ac.in*	2. *Dr. P. Malar, SRMIST*

Course Code	21NTE424T	Course Name	SENSORS AND TRANSDUCERS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

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

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*analyse calibration techniques and signal types of sensors*	3	-	-	2	-	-	-	-	-	-	-	-	3	-	-
CO-2:	*expertise in various types of Sensors & Transducers and their working principles*	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-3:	*evaluate performance characteristics of different sensors and transducers*	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*predict exactly the expected performance of various sensors*	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*develop advance techniques in sensor technology and devise smart sensors for real time applications*	3	-	2	-	-	-	-	-	-	-	-	-	-	-	-

Unit-1 - Measurements	***9 Hour***
Measurements-basic method of Measurement, errors, classification of errors, error analysis, statistical methods, sensors/transducers-introduction, principles of sensors/transducers, classification of sensors/transducers, static characteristics of sensors/transducers, cccuracy-precision-resolution-minimum detectable signal, threshold-sensitivity-selectivity and specificity-non-linearity, hysteresis-output impedance-isolation and grounding,dynamic characteristics, zero order and first order sensors, second order sensors, electrical characterization, mechanical and thermal characterization, optical characterization-chemical/biological characterization	
Unit-2 - Mechanical and Electromechanical Sensors	***9 Hour***
Mechanical and electromechanical sensors, resistive potentiometer, strain gauge, Inductive sensors, sensitivity and linearity of sensor, ferromagnetic plunger type transducers, electromagnetic transducer, magneto strictive transducer, capacitive sensors, parallel plate capacitive sensor, serrated plate capacitive sensor, variable thickness dielectric capacitive sensor, stretched diaphragm variable capacitance transducer, electrostatic transduce, piezoelectric elements, piezoelectric materials, deformation modes and multimorphs, lead zirconate titanate (PZT) family, force/stress sensors using quartz resonators	
Unit-3 - Thermal Sensors	***9 Hour***
Thermal sensors- gas thermometric sensors, thermal expansion type thermometric sensors, acoustic temperature sensor, dielectric constant and refractive index of thermosensors, helium low temperature thermometer- nuclear thermometer, magnetic thermometer, resistance change type thermometric sensors, metal resistance thermometric sensors, thermistors, thermo emf sensors, materials for thermo emf sensors, E (emf)-T(temperature) relations, thermosensors using semiconductor devices, thermal radiation sensors, detectors, pyroelectric thermal sensor, quartz crystal thermoelectric sensors, heat flux sensors, accelerometer	

Unit-4 - Magnetic Sensors	*9 Hour*
Magnetic sensors-introduction, principles behind, yoke coil sensors, coaxial type sensors-force and displacement sensors, magneto resistive sensors- anisotropic magneto resistive sensing, semiconductor magnetoresistors,active semiconductor magnetic sensors, Hall effect sensor-sensor geometry and fabrication, variable inductance sensors, Eddy current sensors, radiation sensors-introduction-basic characteristics, types of photoresistors/photodetectors, photoemissive cell and photomultiplier, photoconductive cell-LDR, photocurrent, photo resistors and photo FETs and other devices, fibre optic sensors, temperature sensors-microbend sensors	
Unit-5 – Electro Analytical Sensors	*9 Hour*
Electroanalytical sensors-introduction, electrochemical cell, sensor electrodes-molecular selective electrodes, chemFET, recent trends in sensor technologies, film sensors- thick and thin film sensors, semiconductor ICtechnology, micro electro mechanical system (MEMS)- micromachining, some application examples, nanosensors, Onboard automobile sensors-flow rate sensors-pressure sensors, temperature sensors-oxygen sensors, torque and position sensors, home appliance sensors, aerospace sensors-fluid velocity sensors, sensing direction of air flow- monitoring strain, force, thrust and acceleration, medical diagnostic sensors sensors for environmental monitoring	

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

Learning Assessment

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

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Maximilian Fleischer, Siemens, Germany, maximilian.fleischer@siemens.com*	1. *Dr. Somnath Chanda Roy, IIT Madras, somnath@iitm.ac.in*	1. *Dr. S. Yuvaraj, SRMIST*
2. *Dr. Shyam Sunder Tiwari, Sensor's technology Private Limited, India,sst@sensorstechnology.com*	2. *Dr. Karuna Kar Nanda, IISc, nanda@iisc.ac.in*	2. *Dr. A. Karthigeyan, SRMIST*

Course Code	21NTE425T	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	*Physics and Nanotechnology*	Data Book / Codes / Standards	*Nil*		

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
CLR-1:	*understand the theory of fluidics in a micro scale*	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CLR-2:	*gain knowledge in micro fluidics equations*															
CLR-3:	*understand the concept behind viscous flow in micro scale*															
CLR-4:	*acquire the knowledge in Micro fluidic devices and manufacturing*															
CLR-5:	*gain knowledge scaling materials for manufacturing*															
Course Outcomes (CO):	***At the end of this course, learners will be able to:***															
CO-1:	*apply the concept of fluidics in micro and nanoscale*	3	2	-	-	-	-	-	-	-	-	-	-	3	3	-
CO-2:	*analyze the flow and viscosity of the fluidics*	3	2	-	-	-	-	-	-	-	-	-	-	3	2	-
CO-3:	*analyze the viscous flow of micro/nano fluidic devices*	3	2	-	-	-	-	-	-	-	-	-	-	3	-	3
CO-4:	*utilize the knowledge gained for designing micro/nano fluidic devices*	2	3	-	-	-	-	-	-	-	-	-	-	3	-	2
CO-5:	*apply the various fluidic equations to design micro/nano fluidic devices*	3	2	-	-	-	-	-	-	-	-	-	-	3	2	-

Unit-1 - Fundamentals of Kinetic Theory ***9 Hour***

Introduction: Fundamentals of molecular models, Micro and nanofluids – An Introduction, Basic concepts in microfluidics & Nanoscale fluidics, Binary collisions, Distribution functions, Laws of fluid flows determination of transport properties, Classification of fluid flow, Wall slip effects, Accommodation coefficients, Kinematics of Microscale Liquid Flow, Derivation of Kinematics of Microscale Liquid Flow, Pressure driven gas micro- flows,Micro flows with wall slip effects, Navier- Stokes equation, Equation's properties, Mechanism of micro flows under compression, Compressibility and its effects, Knudsen number

Unit-2 - Kinetic Theory of Micro and Macroscopic Properties ***9 Hour***

Molecular models of micro and macroscopic properties, Governing equations, Applications- Preparatory concepts, Boltzmann equation, Maxwellian distribution functions, Continuum approximation, Limitations and drawbacks, Flow and heat transfer analysis of microscale, Couette flows, Liquid flow along surface, Effect of body forces in liquid flow, Concept of Heat transfer in micro-Poiseuille flows, Expression for Poiseuille flows,Theory of Two-dimensional Navier- Stokes equation, Two-dimensional Navier- Stokes equation in terms of Reynolds Equation, Navier- Stokes equation for Steady and compressible flow, Steady and incompressible flow Navier-Stokes equation

Unit-3 - Introduction to Microscale Viscous Flow ***9 Hour***

Structure of flow in a pipe or channel, One-dimensional temperature distributions in channel flow, Temperature distributions in channel flow (Quantitative approach), Velocity in slip flow of gases, Velocity in slip flow of liquids, the temperature distribution in fully developed tube flow, Nusselt number, Derivation - thin film under gravity, Properties of thin film equation, Mass transfer in thin films, A thin liquid film falling under gravity, Surface tension driven flow And its limitations, The stochastic nature of diffusion, Brownian motion, Simple model for blood flow, Non-Newtonian properties of blood

Unit-4 - Elements of Electrochemistry and the Electrical Double Layer ***9 Hour***

Introduction, The structure of water and ionic species, Fabrication of A Simple Microfluidic Chip, Advantages of microfluidic devices, Chemical potential, Chemical potential (Quantitative approach), Scaling of materials, Silicon materials for the manufacture, Electrochemical potential, Acids, bases, and electrolytes, Fluidic structures, Manufacturing a fluidic structure, Qualitative description of the electrical double layer, Qualitative description of the electrical double layer - triple layer model, Surface modifications, Different techniques involved in Surface modifications, Electrical conductivity in an electrolyte solution, Electrophoretic effect

Unit-5 - Introduction to Electro Chemistry	***9 Hour***
Electrical double layer, Electro-chemical potential, Chemical potential-acid and base, Electrolyte & electrical conductivity, Semi-permeable membrane, Micro and nano fluidics devices, Applications in different fields, Fabrication and design of microfluid device, Testing of microfluid device, DNA transport, Development of artificial kidney, Electrochemical sensing, Electrochemical Micro/Nao fluidic devices, Receptor and Transducer based classification of biosensors, Types of Biotransducers, Nanopores and nanopore membrane for biochemical sensing, Single Molecule sensing devices	

Learning Resources	1. *TerrenceConlisk,"Essential of Micro and nanofluidics: with applications to biological and chemical sciences", Cambridge University Press,2012* 2. *Joshua Edel, "Nanofluidics", RCS publishing,2009*	3. *HenrikBruus, "Theoretical Microfluidics", Oxford Master Series inPhysics,2007* 4. *PatricTabeling, "Introduction to Microfluids", Oxford U. Press,2005*

Learning Assessment

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

Course Designers

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

Course Code	21NTE520T	Course Name	MEMS AND NEMS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

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

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

Unit-1 - MEMS and NEMS Systems — ***9 Hour***

Micro and nano-electromechanical systems (MEMS and NEMS), Importance of MEMS in daily life,MEMS - Scaling Laws, Conventional electromechanical systems,Mathematical Modeling,Important steps for analysis and design of engineering steps,Microsensors and microactuators, Principle of sensing and actuation, capacitive sensors, pressure sensors,NEMS-Scaling Effect: Intrinsic losses: Phonon/phonon interaction, Electrical resistivity, depletion, the deactivation of dopants, Quantum confinement effect, Electron/phonon interactions, two-level, and surface effects, Extrinsic losses: Fluid interactions, Dissipation of mechanical energy in the
support, Near field effect in a nanostructure: Casimir force, Casimir force between two silicon slabs, Impact of the Casimir force in a nano-accelerometer, Optomechanical nano-oscillators, Quantum optomechanics

Unit-2 - Nano Machining — ***9 Hour***

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

Unit-3 - Sensing and Actuation — ***9 Hour***

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

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

Learning Resources		
	1. Mahalik N P, "MEMS", Tata McGraw-Hill Education, 2008. 2. Laurent Duraffourg and Julien Arcamone, "Nanoelectromechanical systems", 3. John Wiley & Sons, Inc., 2015.	4. Sergey Edward Lyshevski, "Micro-Electro-Mechanical and Nano-Electromechanical Systems, Fundamental of Nano-and Micro-Engineering", CRC Press, 2005 5. MEMS and NEMS Systems, Devices, and Structures, By Sergey Edward Lyshevski,2002 CRC Press

Learning Assessment

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

Course Designers

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

Course Code	21NTE521T	Course Name	2-D LAYERED MATERIALS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understanding the electronic properties of 2D materials, especially Graphene*
CLR-2:	*acquire knowledge on different synthesis methods*
CLR-3:	*describe the various properties of 2D-layered structure*
CLR-4:	*classify the 2D layered Nanomaterials*
CLR-5:	*illustrate the application of layered Nanomaterials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	PSO-1	PSO-2	PSO-3
		Program Outcomes (PO)												**Program Specific Outcomes**		
CO-1:	*interpret the atomic and electronic structure to understand the physical and chemical properties of graphene*	*3*	-	*2*	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*identify the procedure to synthesize layered materials and the concept of Raman spectra over synthesized materials*	-	-	*3*	*2*	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*Utilize the spectroscopic concepts to analyze the properties of layered materials*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-4:	*apply the concept and the uses of semiconducting and metal dichalcogenides based materials*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	-	2	-
CO-5:	*relate the application of layered materials in various fields*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 - Introduction of 2D Layered Nanomaterials ***9 Hour***

Introduction of different types of 2D materials beyond graphene. Dimension of carbon allotrope, electronic band structure, Force between the layer-Vander Waals- covalent bond,Crystal plane of 2D graphene,Manipulation of quantum degree of freedom, Fermi level graphene- role of doping and defect, 2D Metal Carbides, 2D material classification, 2D transition metal dichalcogenidesphos-phorene -Black phosphors- Mexene.

Unit-2 - Preparation Techniques ***9 Hour***

Introduction of scotch-tape method- graphene preparation, Thermal growth of graphene- Epitaxial growth of graphene, Chemical vapor deposition (CVD), plasma enhanced CVD, combustion method, Recent advanced in free standing films-Vacuum Filtration Method, Direct Evaporation Method-CVD, mechanical exfoliation- preparation of graphene using liquid phase- exfoliation, sonication exfoliation- Intercalation exfoliation, Liquidexfoliation. Principles of Raman spectroscopy- Limitations, Raman spectrum of graphene, D band G band Raman spectra.

Unit-3 - Characterization of 2D Materials ***9 Hour***

Introduction to X-ray photoemissionspectroscopy–limitation, Introduction to X-ray-diffraction-limitation, Introduction to Optical absorption spectroscopy–limitation,Introduction and limitations of Scanning Tunnelling Microscopy, Introduction and limitations to BET analysis, Introduction and limitations to VSM analysis, ferroelectricity-Anisotropy-magnetic and catalytic properties, types interaction metal-graphene interaction, Metal – non-metal supported graphene and properties.

Unit-4 - 2D Materials and Properties ***9 Hour***

Graphene and its properties, 2D materials-phase transformation, Penta-graphene and its properties, h-BN structure, synthesis, Application of h-BN and properties SiC structure, synthesis and properties Si structure, synthesis and properties g-C3N4, black phosphorus structure, synthesis and properties Application of g-C3N4, black phosphorus. Two-dimensional metal oxide materials, Properties of oxide materials and Sustainable energy application-solar absorber, Introduction and types of transition metal dichalcogenides, 2D materials-phase transformation, Ti3C2 based 2 D Nanomaterials, V2C based 2 D Nanomaterials V2C, Introduction of Si2BN and its application, Introduction of MoS2 and its applications.

Unit-5 - 2D Materials and Applications	9 Hour
Introduction to SPR sensor, SPR sensing mechanism and types of sensors SPR sensor and its principles, uses smart energochromic sunscreen devices. 2D materials based thermoelectric, Application of membrane, Uses of 2D materials in hydrogen storage, Optoelectronic devices, Super capacitor, TMD –Photodetector, Piezoelectricity of 2D materials, Types of nanogenerator, 2D materials nanogenerator applications	

Learning Resources	1. Houssa, Michel, Athanasios Dimoulas, and Alessandro Molle, "2D Materials for Nano- electronics"- CRC Press, 2016. 2. Banks, Craig E., and Dale AC Brownson, eds. "2D Materials: Characterization, Pro-duction and Applications"- CRC Press, 2018. 3. Inamuddin, RajenderBoddula, Mohdimran Layered 2D Materials and Their Allied Ap-plications Willey-2020	4. Tiwari, Ashutosh, and Mikael Syväjärvi, eds. "Advanced 2D Materials" -John Wiley & Sons,2016 5. Dragoman, Mircea, and DanielaDragoman,"2DNanoelectronics: PhysicsandDevicesof Atomically Thin Materials"- Springer, 2017. 6. Spyridon Zafeiratos 2D Nanomaterials for Energy application- Springer,2020 7. Graphene and Other 2 D materials based thin films Federico Cesano, Domenica Scarano-Coat- ings, 2019.

Learning Assessment

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

Course Designers

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

Course Code	21NTE522T	Course Name	FUNCTIONAL MATERIALS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the concepts of different types of materials*
CLR-2:	*create insights to the concepts of magneto-caloric effect, colossal magneto resistance and spintronics materials*
CLR-3:	*introduces multiferroic materials and applications in electrocaloric devices and ferroelectric random-access memory*
CLR-4:	*provide the knowledge on functional superconducting materials*
CLR-5:	*comprehend the concepts of optical properties in materials, Introduces non-linear optical and photonic band-gap materials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*identify the magnetic, ferroelectric, superconducting and optical materials*	3	-	2	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*identify the MCE materials in Magnetic Refrigeration, and CMR materials*	-	-	3	2	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*analyse the various types of multiferroic Materials for applications in electrocaloric and FeRAM devices*	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-4:	*apply the background of superconducting phenomena in materials to the development of high Tc and other emergingsuperconducting materials*	2	-	-	3	-	-	-	-	-	-	-	-	-	2	-
CO-5:	*utilize the Knowledge on optical properties of materials to explore Non-linear and Photonic Band-gap Materials*	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 - Introduction on Materials — ***9 Hour***

Introduction on Materials, Crystalline and Amorphous Materials, Discussion on Non-magnetic and Magnetic materials, Dia-, Para, Antiferro, Ferri-, Ferro-, Superparamagnetism, Ferroelectric, and Multiferroic Materials, Superconductor, Types of Superconductors, Optical Materials, and Definition of functional materials, introduction to meta-materials.

Unit-2 - Functional Magnetic Materials — ***9 Hour***

Functional Magnetic Materials: Magnetocaloric Effect, Fundamentals of magnetic cooling and heating, Magnetic Transition and Magneto caloric effect, Relative cooling power, Magnetocaloric Materials, Challenges in MCE materials in Magnetic Refrigeration, Magnetic Nanoparticles, Spintronics Materials, Nanoparticles for High Density Magnetic recording, colossal magneto resistance (CMR) Materials, Magnetic Random-Access Memory (MRAM)

Unit-3 - Multiferroic Materials — ***9 Hour***

Multiferroic Materials: Origin of Ferroelectricity, Mutual Exclusive Reason for Multiferroicity, Types of Multiferroic Materials, Observation of Multiferroic Properties, Examples of Multiferroic Materials: Perovskite type, Composites of Perovskites, Bismuth-based Perovskites, Applications: Electrocaloric Devices, Ferroelectric Random-Access Memory (FeRAM), Dynamic Random-Access Memory (DRAM)

Unit-4 - Superconducting Materials — ***9 Hour***

Functional Superconducting Materials: Background of superconducting Materials, Niobium Titanium (NbTi), A 15 Superconductors and Niobium-tin (Nb3Sn), Chevrel-Phase Superconductors, High-Tc Superconductors, MgB2, Borocarbides, and Iron Arsenide Superconductors

Unit-5 - Optical Materials	*9 Hour*
Functional Optical Materials: Introduction to optical Materials, Origin of different types optical materials, Optical Parameters, Optical properties of metal, insulator and nanomaterials, Non-linear Optical Materials, Examples of non-linear optical process, Glasses as non-linear optical materials, Photonic Band-gap materials	

Learning Resources		
	1. *S. Banerjee, and A.K. Tyagi, Functional Materials: Preparation, Processing and Applications, Publisher-Elsevier (2011).* 2. *Hasse Fredriksson and Ulla Ãkerlind, Physics of Functional Materials, Publisher-Wiley-Black- well (2008).* 3. *N. Spaldin, Magnetic Materials: Fundamentals and Applications, (CUP, 2012, 2nd Ed).*	4. *Junling Wang, Multiferroic Materials: Properties, Techniques, and Applications: Publisher- CRC Press (2016).* 5. *Kelly S. Potter and Joseph Habib Simmons, Optical Materials, Publisher-Elsevier – 2nd Edition (2021).* 6. *C. Kittel, Introduction to Solid State Physics, 8th Ed., J. Wiley and Sons, 2005.*

Learning Assessment

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

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. Krishna Surendra Muvvala Saint-Gobain Glass Pvt.Ltd.*	1. *Prof. Prahallad Padhan, IIT Madras, Chennai, Email: padhan@iitm.ac.in*	1. *Dr. Bhaskar Chandra Behera, SRMIST*
2. *Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in*	2. *Prof. S. Balakumar, University of Madras, balakumar@iunom.acs.in*	2. *Dr. Trilochan Sahoo, SRMIST*

Course Code	21NTE523T	Course Name	MATERIALS UNDER EXTREME TEMPERATURE	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*acquire the concepts of High Temperature Materials*
CLR-2:	*gain the knowledge about mechanical properties of materials*
CLR-3:	*understand the various fracture and diffusion mechanism*
CLR-4:	*gain the knowledge on the process of oxidation and corrosion*
CLR-5:	*describe the various mechanisms involved in High -Temperature materials*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO) 1: Engineering Knowledge	2: Problem Analysis	3: Design/development of solutions	4: Conduct investigations of complex problems	5: Modern Tool Usage	6: The engineer and society	7: Environment & Sustainability	8: Ethics	9: Individual & Team Work	10: Communication	11: Project Mgt. & Finance	12: Life Long Learning	Program Specific Outcomes PSO-1	PSO-2	PSO-3
CO-1:	*express the properties and functions of High-Temperature materials*	*2*	-	-	*3*	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*express the mechanical properties of materials*	*3*	*2*	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*evaluate the fracture in different materials*	-	*2*	-	*3*	-	-	-	-	-	-	-	-	2	-	-
CO-4:	*analyze the oxidation and corrosion property*	*3*	-	*1*	-	-	-	-	-	-	-	-	-	-	2	-
CO-5:	*apply the High-Temperature in different materials for engineering applications by knowing its mechanisms*	*2*	*3*	-	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1 - Components at Elevated Temperatures	***9 Hour***
Factors influencing functional life of components at elevated temperatures, Requirements of High Temperature Materials, High-Temperature Materials, Chemistry and Thermodynamics, High Temperature Materials Processing, Characterization of High-Temperature Materials	
Unit-2 - Creep Curve	***9 Hour***
Definition of creep curve, various stages of creep, Metallurgical factors influencing various stages, Effect of stress, temperature and strain rate, Design of transient creep, time hardening, strain hardening, Expressions for rupture life for creep, ductile and brittle materials - Monkman - Grant relationship	
Unit-3 - Fracture	***9 Hour***
Various types of fracture, Brittle to ductile from low temperature to high temperature, Cleavage, ductile fracture due to microvoid coalescence, Diffusion controlled void growth, Fracture maps for different alloys and oxides	
Unit-4 - Oxidation Etc	***9 Hour***
Oxidation, Pilling-Bedworth ratio,Kinetic laws of oxidation, Defect structure and control of oxidation by alloy additions, sulphation, Hot gas corrosion deposit, modified hot gas corrosion, effect of alloying elements on hot corrosion	
Unit-5 - High-Temperature Materials and Mechanisms	***9 Hour***
High-Temperature Materials and Mechanisms: Applications and Challenges - Iron base, nickel base and cobalt base superalloys, composition control, solid solution strengthening, precipitation hardening by gamma prime - grain boundary strengthening, TCP phase, embrittlement - solidifi cation of single crystals, Intermetallic Materials, High-Temperature Ceramics, Glasses and Glass Ceramics, coatings and composites	

Learning Resources	1. *Raj R, 'Flow and Fracture at Elevated Temperatures', American Society for Metals, 1985* 2. *Materials for High Temperature Engineering Applications, Geoffrey W. Meetham, Marcel* 3. *H. Van de voorde, Springer, 2000*	4. *Materials Under Extreme Conditions, A.K. Tyagi and S. Banerjee, Elsevier, 2017* 5. *High Temperature Materials and Mechanisms, Yoseph Bar-Cohen, CRC press, 1st edition, 2017*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	20%	-	25%	-
Level 3	Apply	30%	-	25%	-	30%	-
Level 4	Analyze	30%	-	25%	-	30%	-
Level 5	Evaluate	-	-	10%	-	-	-
Level 6	Create	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. N. V. Chandra Shekar, IGCAR, Kalpakkam, chandru@igcar.gov.in*	1. *Dr. Balan Palanivel, Pondicherry Engineering College, Pondicherry, bpvel@pec.edu*	1. *Dr. V. Kathirvel, SRMIST*
2. *Dr. V. Pandiyarasan, Indian Institute of Information Technology, Design, and Manufacturing (IIITDM) Kancheepuram, pandiyarasan@iiitdm.ac.in*	2. *Dr. G. Kalpana, Anna University, Chennai, g_kalpa@yahoo.com,*	2. *Dr. Kiran, SRMIST*

Course Code	21NTE524T	Course Name	MICRO AND NANO PROCESSING OF MATERIALS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the basic machining processes*
CLR-2:	*understand the conventional processes*
CLR-3:	*gain knowledge about non-conventional processes*
CLR-4:	*learn Micro and nano finishing processes*
CLR-5:	*learn micro joining processes*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*acquire the basics of various machining processe*	*3*	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2:	*gain knowledge on conventional process of micro and nano machining*	*3*	-	-	*3*	*2*	-	-	-	-	-	-	-	*3*	-	-
CO-3:	*obtain the knowledge on non-conventional processes using lasers*	*3*	-	-	*3*	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*acquire knowledge on micro and nano finishing processesn*	*3*	-	-	*3*	*2*	-	-	-	-	-	-	-	-	-	-
CO-5:	*gain knowledge on micro joining processing using various welding techniques*	*3*	-	*3*	*3*	*2*	-	-	-	-	-	-	-	-	*2*	-

Unit-1 - Diamond Technology	***9 Hour***
Diamond technology, Preparation of substrate, Modified HFCVD process, Nucleation and diamond growth, Deposition on complex substrates, Diamond micromachining.	
Unit-2 - Micro-Procesing	***9 Hour***
Introduction, Micro-turning, Micro-drilling, Micro-milling, Product quality in micromachining Micro-grinding and Ultra-precision Processes, Micro and nanogrinding, Nanogrinding tools.	
Unit-3 – Laser Fabrication	***9 Hour***
Introduction, Fundamentals of lasers, Laser microfabrication, Laser nanofabrication.Evaluation of Subsurface Damage in Nano and Micromachining,Destructive evaluation technologies, Non-destructive evaluation technologies	
Unit-4 - Finishing	***9 Hour***
Need for Nano finishing, Magnetic abrasive Finishing, Magnetorheological Finish, Elastic Emission Finishing, Magnetic Float Polishing, Ion Beam finishing.	
Unit-5 - Welding	***9 Hour***
Challenges, Micro Resistance welding, Ultrasonic welding, Micro TIG, Applications.	

Learning Resources		
	1. J. Paulo Davim, Mark J. JacksonNano and Micromachining,John Wiley & Sons, 2013 *2. V.K.Jain, Micro-manufacturing Processes, CRC Press, 2012.*	*3. Yi Qin, Micro-manufacturing Engineering and Technology, William Andrew, 2015* *4. Kapil Gupta, Micro and Precision Manufacturing, Springer, 2017*

Learning Assessment							
	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	20%	-	25%	-
Level 3	Apply	30%	-	25%	-	30%	-
Level 4	Analyze	30%	-	25%	-	30%	-
Level 5	Evaluate	-	-	10%	-	-	-
Level 6	Create	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Dr. Avik Chatterjee, Chief Scientist,Centre for Advanced Manufacturing and Metrology Group Advanced Design and Analysis Group- CSIR-CMERI	1. Dr. M. S. Shunmugam, Professor, Department of Mechanical Engineering, IIT Madras	1. Dr. C. Gopalakrishnan, SRMIST
2. Dr. Soumen Mandal, Senior Scientist, Central Mechanical Engineering Research Institute, Durgapur, WB	2. Dr. Jose Mathew, Professor,Department of Mechanical Engineering, NIT Calicut	2. Dr. Geethapriyan, SRMIST

Course Code	21NTE525T	Course Name	SMART ENGINEERING MATERIALS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*understand the physics of piezoelectricity*
CLR-2:	*familiarize with the concept of magnetostatic and spintronics*
CLR-3:	*acquire the knowledge of different types of shape memory*
CLR-4:	*understand the theory of metamaterials*
CLR-5:	*acquire knowledge on the materials and working of nano-gels*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	1 Engineering Knowledge	2 Problem Analysis	3 Design/development of solutions	4 Conduct investigations of complex problems	5 Modern Tool Usage	6 The engineer and society	7 Environment & Sustainability	8 Ethics	9 Individual & Team Work	10 Communication	11 Project Mgt. & Finance	12 Life Long Learning	PSO-1	PSO-2	PSO-3
		Program Outcomes (PO)												**Program Specific Outcomes**		
CO-1:	*acquire knowledge of physics of Piezoelectric Materials and Pieoresistivity Sensors*	3	-	-	2	-	-	-	-	-	-	-	-	4	-	-
CO-2:	*develop in depth understanding on the Nanomagnetic Behavior and Role of Electron Spin in Magnetoresistive*	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-
CO-3:	*apply Shape Memory for Manufacturing of Shape Memory Smart Materials*	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-4:	*employ the knowledge of additive manufacturing for various applications*	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-
CO-5:	*implement the concepts of Nanogel in real time applications*	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-

Unit-1 - Piezoelectric Materials ***9 Hour***

Piezoelectric Materials, Principles of Piezoelectricity, Desired Properties of Piezoelectric Materials, Elastic Properties of Crystals, The Strained Body, Thermodynamics of Mechanical Deformation, Piezoelectric Ceramic Actuators, Energy harvesters and Sensors, Piezoresistivity Effect, Piezoresistive Strain/Stress Sensor configuration, Piezoresistive Strain Sensor, Physical Causes of Piezoresistivity, Merit of Pieoresistivity Sensors vs. Capacitive Sensors, Pieoresistivity Components

Unit-2 - Magnetostrictive Effects ***9 Hour***

Various Magnetostrictive Effects, Origin of Nanomagnetic Behavior, Magnetic Domains, Exchange Interaction, Magnetostatic Energy, Domain wall, Terfenol-D Availability, Properties of Terfenol-D, Gaint Magnetostrictive Materials (GMSs), Ordinary Magnetoresistance (OMR), Giant Magnetoresistive (GMR), Spintronics and GMR Effect, Spin Dependent Transport, Spin Dependent Resistivity, Applications of GMR, Role of Electron Spin in GMR, GMR in Granular Structures, GMRs as Smart Sensors, Hard Disk Drives

Unit-3 - Shape Memory Effect ***9 Hour***

Shape Memory Effect (SME), Shape Memory Alloys (SMAs), Properties of SMAs, Thermodynamics of martensitic transformation, Stress-Strain-Temperature dependence of SMAs, SME Variations, One-way SME (OWSME), Two-way SME (TWSME), Constitutive Equations for SMAs, Tanaka Model, The Liang and Roger Model, The Brinson Model, Cardiovascular Superelastic Stents, Medical Applications, Magnetic Shape Memory Smart Materials (MSMA), MSMA Actuators. Typical MSMA materials, MSM Mechanism, Manufacturing of MAMAs

Unit-4 - Mechanochromic Materials ***9 Hour***

Mechanochromic Materials, Example of Mechanochromic Materials, Mechanochromic devices Based on Marine Biological Systems, Mechanical Metamaterials, Mechanical Metamaterials with Negative Parameters, Background of Metamaterials, Classification of Metamaterials, Reconfigurable and Tunable Metadevices, Electromagnetic Metamaterials, Elastic Metamaterials, Acoustic Metamaterials, Structural Metamaterials, Nonlinear Metamaterials, Super lens

Unit-5 - Polymer-Based Micro/Nano Gels	**9 Hour**
Polymer-based Micro/Nano Gels, Synthesis of Micro/Nano Gels, Transformation from Hydrogels to Nanogels for Imaging, Characterization of Nano Gels, Polymeric Building Blocks for Designing Nanogels, Nanocomposite Hydrogels, Polymer Nanofiller Composites, Biomedical Applications, Self-healing Materials, Self-healing Cementitious and Concrete Materials, Self-healing Polymers and Elastomers, Ionic Self-healing Polymers	

Learning Resources	1. *Jan Tichý, Jirí Erhart, Erwin Kittinger, Jana Prívratská, Fundamentals of Piezoelectric Sensorics, Mechanical, Dielectric, and Thermodynamical Properties of Piezoelectric Materials, Publisher:Springer Berlin Heidelberg, 2010* 2. *Alberto P. Guimarães, Principles of Nanomagnetism, Springer International Publishing, 2017* 3. *K Yamauchi, I Ohkata, K. Tsuchiya, S Miyazaki, Shape Memory and Superelastic Alloys Applications and Technologies, Elsevier Science, 1st ed., 2011*	4. *Leonardo Lecce and Antonio Concilio, Shape Memory Alloy Engineering for Aerospace, Structural and Biomedical Applications, Elsevier Science, 2014* 5. *Xingcun Colin Tong, Functional Metamaterials and Metadevices, Springer International Publishing, 2017* 6. *Arti Vashist, Ajeet K Kaushik, Sharif Ahmad, Madhavan Nair, Nanogels for Biomedical Applications (Smart Materials Series) 1st Ed.,Royal Society of Chemistry, 2017*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA) Formative CLA-1 Average of unit test (50%)		Continuous Learning Assessment (CLA) Life-Long Learning CLA-2 (10%)		Summative Final Examination (40% weightage)	
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	20%	-	25%	-
Level 3	Apply	30%	-	25%	-	30%	-
Level 4	Analyze	30%	-	25%	-	30%	-
Level 5	Evaluate	-	-	10%	-	-	-
Level 6	Create	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. *Dr. D.K. Aswal, National Physical Laboratory, dkaswal@nplindia.org*	1. *Prof. M.S. Ramachandra Rao, IITM Chennai, msrrao@iitm.ac.in*	1. *Dr. Debabrata Sarkar, SRMIST*
2. *Dr. S. Sudhakar, CSIR-CECRI, sudhakar@cecri.res.in*	2. *Prof. S. Balakumar, University of Madras, balakumar@iunom.acs.in*	2. *Dr. Ravikirana, SRMIST*

Course Code	21NTE526P	Course Name	NANO FABRICATION	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							2	1	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*introduce what is lithography and types of lithography tools*
CLR-2:	*explain the need for etching in lithography process and its types*
CLR-3:	*explain replication tools*
CLR-4:	*introduce various application areas where nanofabrication tools are utilized*
CLR-5:	*introduce what is lithography and types of lithography tools*

		Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*understand the difference between bottom up and top down nanofacrication and various tools required*	3	2	-	-	-	-	-	-	-	-	-	-	3	-	-
CO-2:	*gain knowledge on lithography types and process*	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-3:	*understand the need for etching processes during lithography fabrication process*	3	2	-	-	-	-	-	-	-	-	-	-	-	3	-
CO-4:	*acquire knowledge on different types of replication processes in nanofabrication*	3	-	-	-	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*understand the utilization of lithography process in difference application areas*	3	-	2	-	-	-	-	-	-	-	-	-	-	2	-

Unit-1- Fabrication	***9 Hour***
Concept of Top Down and Bottom-Up Fabrication approach, Self-assembly, Bio-mediated assembly, template assisted synthesis, epitaxial growth, growth mechanism and kinetics, Substrates, cleaning, Advanced cleaning techniques, native films growth, chemical vapor deposition, atomic layer deposition, physical vapor deposition, metallization.	
Unit-2 - Photoresists	***9 Hour***
Photoresists, Resist process, Optical lithography, Mask making, UV imprint lithography, Electron beam lithography (EBL), Xray lithography, focused ion beam (FIB) lithography	
Unit-3 - Etching	***9 Hour***
Wet etching: basics and techniques, dry etching: mechanism, chemistry, Plasma etching, Chemical Mechanical Polishing	
Unit-4 - Replication	***9 Hour***
Replication tools, PDMS casting, hot embossing, micro injection molding, nano imprint lithography, introduction to inspection	
Unit-5 - Applications	***9 Hour***
Nanofabrication in semiconductor industry: Metal Oxide Semiconductor (MOS) transistor, Complementary Metal Oxide Semiconductor (CMOS) transistor, Nanofluidic devices: basics, Nano electro mechanical devices: basics	

Learning Resources		
	1. Hans H. Gatzen, Volker Saile, Jürg Leuthold, "Micro and Nano Fabrication", Springer 2015 *2. Stefan Landis, "Lithography and nanolithography", Published by Wiley - ISTE, 2010* *3. Nano Lithography, Stefan Landis (Editor), Wiley, 2011* *4. Nanofabrication: Techniques and Principles, Stepanova, Maria, Dew, Steven (Eds.), Springer, 2012*	*5. Fundamentals of Nanoscale Film Analysis edited by Terry L Alford, Leonard C. Feldman and James W. Mayer (Springer 2007)* *6. Nanofabrication: Nanolithography technique and their applications edited by Jose Maria De Teresa (IOP 2020)*

Learning Assessment									
	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)						Final Examination (0% weightage)	
		Formative CLA-1 Average of unit test (20%)		Project Based Learning CLA-2 (60%)		Report and Viva Voce (20%)			
		Theory	Practice	Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	-	15%	-	15%	-	-
Level 2	Understand	25%	-	-	20%	-	25%	-	-
Level 3	Apply	30%	-	-	25%	-	30%	-	-
Level 4	Analyze	30%	-	-	40%	-	30%	-	-
Level 5	Evaluate	-	-	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-	-	-
	Total	100 %		100 %		100%			

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	1. Prof. S. Balakumar, Madras University, balakumar@unom.ac.in	1. Dr. P. Malar, SRMIST
2. Dr.S.V.Pandurangaiah, Raith India Pvt Ltd, pandurangaiah.sv@simcogroup.in	2. Dr. K. Suresh Babu, Central University, sureshbabu.nst@pondiuni.edu.in	2. Dr. Abhay A Sagade, SRMIST

Course Code	21NTE527T	Course Name	BIOCOMPOSITES	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	***The purpose of learning this course is to:***
CLR-1:	*learn the different classes of biomaterials used in medicine*
CLR-2:	*understanding of the concept of biocompatibility and the methods for biomaterials testing, nteractions between biomaterials, proteins and cells*
CLR-3:	*learn about various types of bioceramics*
CLR-4:	*acquire knowledge on various types of polymers for bio application*
CLR-5:	*acquire knowledge about implants*

Course Outcomes (CO):	***At the end of this course, learners will be able to:***	Program Outcomes (PO)												Program Specific Outcomes		
		1	2	3	4	5	6	7	8	9	10	11	12			
		Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1:	*understand common use biomaterials as metals, ceramics and polymers and its chemical structure, properties and morphology*	3	-	1	-	-	-	-	-	-	-	-	-	2	-	-
CO-2:	*describe interactions between biomaterials, proteins and cells*	3	2	-	-	-	-	-	-	-	-	-	-	-	2	-
CO-3:	*choose the correct ceramic for medical application*	3	-	2	-	-	-	-	-	-	-	-	-	2	-	-
CO-4:	*explain methods to modify surfaces of biomaterials and choose material for desired biological response*	3	-	2	-	-	-	-	-	-	-	-	-	2	-	-
CO-5:	*understand the various materials for implant application*	3	2	-	-	-	-	-	-	-	-	-	-	2	-	-

Unit-1 – Biomaterials ***9 Hour***

Definition of biomaterials, requirements & classification of biomaterials, Comparison of properties of some common biomaterials. Effects of physiological fluid on the properties of biomaterials. Biological responses (extra and intra-vascular system). Surface properties of materials, physical properties of materials, mechanical properties. Polymers, silicone biomaterials, medical fibres and biotextiles – Smart polymers – bioresorbable and bioerodiblematerials – natural materials, metals and ceramics – physicochemical surface modification.

Unit-2 - Bio Compatibility ***9 Hour***

Biocompatibility concepts: Introduction to biocompatibility – cell material interaction – types of materials – toxic, inert, bioactive – long term effects of materials within the body – cell response. Biocompatibility & Toxicologicalscreening of biomaterials: Definition of biocompatibility, blood compatibility and tissue compatibility. Toxicity tests: acute and chronic toxicity studies (in situimplantation, tissue culture, haemolysis, thrombogenic potential test, systemic toxicity, intracutaneous irritation test), sensitization, carcinogenicity, mutagenicity and special tests.

Unit-3 - Ceramics and Bio-Ceramics ***9 Hour***

Ceramic implant materials: Definition of bio ceramics. Common types of bio ceramics: Aluminum oxides, Glass ceramics, Carbons. Bio resorbable and bioactive ceramics. Importance of wear resistance and low fracture toughness. Host tissue reactions: importance of interfacial tissue reaction (e.g., ceramic/bone tissue reaction). Composite implant materials: Mechanics of improvement of properties by incorporating different elements. Composite theory of fiber reinforcement (short and long fibers, fibers pull out). Polymers filled with osteogenic fillers (e.g. hydroxyapatite). Host tissue reactions.

Unit-4 - Polymer Implant Materials ***9 Hour***

Polymeric implant materials: Polyolefin's, polyamides, acrylic polymers, fluorocarbon polymers, silicon rubbers, acetyls. (Classification according to thermo sets, thermoplastics and elastomers). Viscoelastic behavior: creep- recovery, stress-relaxation, strain rate sensitivity. Importance of molecular structure, hydrophilic and hydrophobic surface properties, migration of additives (processing aids), aging and environmental stress cracking. Physiochemical characteristics of biopolymers. Biodegradable polymers for medical purposes, Biopolymers in controlled release systems. Synthetic polymeric membranes and their biological applications.

Unit-5 - Metallic Implant Material	**9 Hour**
Metallic implant materials: Stainless steel, Co-based alloys, Ti and Ti-based alloys. Importance of stress-corrosion cracking. Host tissue reaction with bio metal, corrosion behavior and the importance of passive films for tissue adhesion. Hard tissue replacement implant: Orthopedic implants, Dental implants. Soft tissue replacement implants: Percutaneous and skin implants, Vascular implants, Heart valve implants-Tailor made composite in medium.	

Learning Resources	1. *Biomaterials Science: An Introduction to Materials in Medicine, By Buddy D. Ratner, ET. Al. Academic Press, San Diego, 1996.* 2. *Sujata V. Bhat, Biomaterials, Narosa Publishing House, 2002.*	3. *J B Park, Biomaterials – Science and Engineering, Plenum Press, 1984.* 4. *Buddy D Ratner, Allan S Hoffman, "Biomaterials Science – An introduction to materials in Medicine",* 5. *Elsevier academic press, (2004).*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	15%	-	15%	-	15%	-
Level 2	Understand	25%	-	20%	-	25%	-
Level 3	Apply	30%	-	25%	-	30%	-
Level 4	Analyze	30%	-	25%	-	30%	-
Level 5	Evaluate	-	-	10%	-	-	-
Level 6	Create	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	**Experts from Higher Technical Institutions**	**Internal Experts**
1. Mr. K. Chandru, Medical Device Domain, HCL Technologies	1. Dr. Asifkhan Shanavas, INST, Mohali, asifkhan@inst.ac.in	1. Dr. G. Devanand Venkatasubbu, SRMIST
2. Mr. P. Aravind Mukesh, United Breweries, Bengaluru	2. Dr.Biman B. Mandal, IIT G, biman.mandal@iitg.ac.in	2. Dr. N. Selvamurugan, SRMIST

Course Code	21NTE528T	Course Name	ATOMISTIC MODELING	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

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

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

Unit-1 - Classical Many,Body System ***9Hour***

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

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

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

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

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

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

Introduction, key concepts, Starting structure , energy cutoff, State space sampling, Classical momentum, Metropolis algorithm, Examples with a problem, Monte Carlo simulation analysis, Limitations of Monte Carlo simulations, Introducing ensemble sin MC, Kinetic Monte Carlo, Key concepts: starting structure in MD, Key concepts: starting structure in KMC, Convergence criteria, Scaling with lattice parameters, Understanding the electronic structure, Electrical conductivity, Excited electron states, Application of MC method as Case Study: Temperature effect, Determination of Tc

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

Learning Resources		
Learning Resources	1. *Jörg-Rüdiger Hill,Lalitha Subramanian and Amitesh Maiti, Molecular modeling techniques in material sciences, Taylor & Francis/CRC Press: Boca Raton,2005* 2. *Andrew R.Leach, Molecular modelling: principles and application, Pearson Education, In- dia, 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 (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-1 Average of unit test (50%)		Life-Long Learning CLA-2 (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	*Remember*	15%	-	15%	-	15%	-
Level 2	*Understand*	25%	-	20%	-	25%	-
Level 3	*Apply*	30%	-	25%	-	30%	-
Level 4	*Analyze*	30%	-	25%	-	30%	-
Level 5	*Evaluate*	-	-	10%	-	-	-
Level 6	*Create*	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

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

Course Code	21NTE529T	Course Name	DEFECTS IN MATERIALS	Course Category	E	PROFESSIONAL ELECTIVE	L	T	P	C
							3	0	0	3

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

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1:	*utilize XRF material characterization techniques to analyse defects in materials*
CLR-2:	*introduce strain and deformation in materials*
CLR-3:	*introduce dislocations and boundaries defects*
CLR-4:	*explain the crystallographic features of materials*
CLR-5:	*introduce magnetic defects*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*
CO-1:	*acquire knowledge on different types of defects in materials through XRF techniques*
CO-2:	*gain knowledge on strain and deformation in materials*
CO-3:	*gain knowledge on dislocations and boundaries defects*
CO-4:	*acquire knowledge on crystallographic features of materials*
CO-5:	*gain knowledge on magnetic defects*

	Program Outcomes (PO)												Program Specific Outcomes		
	1	2	3	4	5	6	7	8	9	10	11	12			
	Engineering Knowledge	Problem Analysis	Design/development of solutions	Conduct investigations of complex problems	Modern Tool Usage	The engineer and society	Environment & Sustainability	Ethics	Individual & Team Work	Communication	Project Mgt. & Finance	Life Long Learning	PSO-1	PSO-2	PSO-3
CO-1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CO-2	2	-	-	3	2	-	-	-	-	-	-	-	3	-	-
CO-3	2	-	-	3	-	-	-	-	-	-	-	-	-	-	-
CO-4	2	-	-	3	2	-	-	-	-	-	-	-	-	-	-
CO-5	2	-	-	3	2	-	-	-	-	-	-	-	-	2	-

Unit-1 - Defects in Crystalline Solids ***9 Hour***

Point and Electronic defects in crystalline solids, effect on electronic properties (doped Si and Ge), optical properties (F center and Ruby), Thermoelectric properties (Seebeek Coefficient); Point defect notations, Charges on defect. Balanced population on point defect: Schottky and Frenkel Defects, Determination of mineral concentration using XRF spectrometer for metal oxide / sulfide nanoparticles synthesized by chemical precipitation method

Unit-2 - Strain ***9 Hour***

Strain: Introduction, Infinitesimal strain, Homogeneous Strain; Stress; Elasticity of Crystals Translation Glide, Glide elements, independent slip systems, Large strain, texture Twinning, description of deformation twinning, Examples of twin structures, twinning elements, morphology of twinning elements.

Unit-3 - Dislocation ***9 Hour***

Dislocation; Edge, Screw & Mixed dislocations, Unit & partial dislocations, Multiplication of Dislocations, Interaction of Dislocations & Point Defects, Dislocations in Nonmetallic Crystals, Internal Boundaries, Low-Angle Grain Boundaries, Twin Boundaries, Antiphase Boundaries

Unit-4 - Martensitic Transformation ***9 Hour***

Martensitic transformation, General crystallographic features, Examples Co, Zr, In-Th, Steels; Transformations in non-metals, Crystallographic aspect of Nucleation and growth. Structure of Surface and Surface free energy, Structure and energy of Grain boundaries.

Unit-5 - Magnetic Defects ***9 Hour***

Magnetic defects, magnetic defects in semiconductor, magnetic defects in Ferrites, Charge and spin state of Cobaltites and Manganites, Extended Magnetic Defects Optical Defects, Absorption and scattering, Pigments,minerals and Gemstones. Colours and Impurity. Photoluminescence, Energy Degradation and Down-conversion, Up-conversion

Learning Resources	1. *R. J. D. Tilley, Defects in solids, (Wiley, 2011)* 2. *Kelly, Groves and Kidd, Crystallography and Crystal Defects (John Wiley,2000)*	3. *D. Hull and D. J. Bacon, Introduction to Dislocations, 5th Edition, Pergamon Press, 2011*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
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Level 2	*Understand*	25%	-	20%	-	25%	-
Level 3	*Apply*	30%	-	25%	-	30%	-
Level 4	*Analyze*	30%	-	25%	-	30%	-
Level 5	*Evaluate*	-	-	10%	-	-	-
Level 6	*Create*	-	-	5%	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. *Dr. Venkataramana Bonu, NAL, Bangalore*	1. *Dr. Herojit Loushambam, NIT Manipur*	1. *Dr. S. Anbumozhi Angayarkanni, SRMIST*
2. *Dr. Manan, IGCAR, manan@igcar.gov.in*	2. *Dr. Sudhashu Sekar Pati, NIT Jamshedpur, sspati.chem@nitjsr.ac.in*	2. *Dr. Rudra Banerjee SRMIST*

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