M.Tech.

IN

NANOTECHNOLOGY

CURRICULUM AND SYLLABI OF COURSES

(I to IV Semesters)

(Applicable for 2019 Admission onwards)

SCHOOL OF MATERIALS SCIENCE AND ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

CALICUT 673601

KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech. in Nanotechnology

PEO1	To train students from diverse academic backgrounds in engineering, on the fundamental and applied topics in nano science and technology, and make them eligible to contribute through sustained academic and professional activities.
PEO2	To train and mould students to do innovative research in the interdisciplinary areas of experimental and computational nanotechnology.

The Programme Outcomes (POs) of M.Tech. in Nanotechnology

PO1	An ability to independently carry out research /investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	Students should be able to demonstrate a degree of mastery in the area of nanotechnology.
PO4	A sound technical knowledge of basic scientific and engineering principles in the field of Nanotechnology.
PO5	Ability to do innovations in various areas of nano science and technology and contribute to the industries/R&D organizations/Academic profession.
PO6	Ability to perform quality research in both experimental and computational nanotechnology.

CURRICULUM

The total minimum credits for completing the
M.Tech. in Nanotechnology is 60

MINIMUM CREDIT REQUIREMENT FOR THE VARIOUS COURSE CATEGORIES

The structure of M.Tech. in Nanotechnology shall have the following Course categories :

Sl. No.	COURSE CATEGORY	Number of Courses	Credits
1.	Core Courses	6	18
2.	Elective Courses	4	12
3.	Laboratory Courses	2	4
4.	Seminar	2	2
5.	Project Thesis (Part 1and Part 2)	2	24
	TOTAL	16	60

Course Structure

Semester I

Sl. No	Course Code	Course Title	L	T	P	Credits
1	MT6101D	Structure of Nanomaterials	3	0	0	3
2	MT6102D	Thermodynamics for Nano Materials and Systems	3	0	0	3
3	MT6103D	Nanosized Structures	3	0	0	3
4		Elective-I	3	0	0	3
5		Elective-II	3	0	0	3
6	MT6191D	Nanoscience and Technology Lab-I	0	0	3	2
7	MT6192D	Seminar I	0	0	3	1
		Total Credits				18

Semester II

Sl. No.	Course Code	Course Title	L	T	P	Credits
1	MT6111D	Spectroscopic Characterisation of Nanomaterials	3	0	0	3
2	MT6112D	Experimental Techniques in Nanotechnology	3	0	0	3
3	MT6113D	Microscale and Nanoscale Heat Transfer	3	0	0	3
4		Elective III	3	0	0	3
5		Elective IV	3	0	0	3
6	MT6193D	Nanoscience and Technology Lab-II	0	0	3	2
7	MT6194D	Seminar II	0	0	3	1
		Total Credits				18

Semester III

Sl. No.	Course Code	Course Title	L	T	P	Credits
1	MT7198D	Project – Part 1	-	-	-	10
		Total Credits	-	-	-	10

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	Credits
1	MT7199D	Project – Part 2	-	-	-	14
		Total Credits	-	-	-	14

Total Credits = 60

Notes

1. A minimum of 60 credits have to be earned for the award of M. Tech Degree in this Programme.

2. Communicative English and Audit courses are optional. Industrial Training during summer is optional.

The content can be modified according to the requirements of the programme.

MT6101D STRUCTURE OF NANOMATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (10 Lecture hours)
Introduction to nanomaterials: history, scope and applications of nanomaterials, small things making big differences, nanotechnology as nature's technology, clusters and magic numbers, classification of nanomaterials, nanoscale architecture. Recent developments, challenges and future prospects of nanomaterials.

Module 2: (10 Lecture hours)
Physics of nanomaterials: electronic properties of atoms and solids, the isolated atom, bonding between atoms, giant molecular solids, the free electron model and energy bands, band theory, crystallography, anisotropy, periodic potential, confinement, quantization, , exciton, confining the exciton, quantum well, quantum wire and quantum dot.

Module 3: (10 Lecture hours)
Microstructure and defects in nanocrystalline materials: grain size distributions and morphology, grain boundaries, triple junctions and interfaces, dislocations, twins, stacking faults.
Effect of nano dimensions on materials behaviours: elastic properties, melting point, diffusivity, grain growth, solid solubility, magnetic properties, electrical properties, optical properties, thermal properties, mechanical properties.

Module 4: (9 Lecture hours)
Nanocrystalline materials, nanocomposites, bulk metallic glasses, ultrafine grain materials, severe plastic deformation techniques, mechanical alloying, rapid solidification process, surface nano featuring of materials.

References:
1. Murty, B. S., P. Shankar, Baldev Raj, B. B. Rath, and James Murday. Textbook of nanoscience and nanotechnology. Springer Science & Business Media, 2013.
2. Pradeep, T. A textbook of nanoscience and nanotechnology. Tata McGraw-Hill Education, 2012.
3. Prathap, Haridoss., Physics of materials: Essential Concepts of Solid – State Physics, Wiley India Pvt. Ltd., 2016.
4. Yannick Champion , Hans-Jörg Fecht, Nano-Architectured and Nanostructured Materials: Fabrication, Control and Properties, Wiley-VCH,2005.
5. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005.

MT6102D THERMODYNAMICS FOR NANOMATERIALS AND SYSTEMS

Prerequisite: - Nil

L	T	P	C
3	0	0	3

Total Hours: 39

Module 1: (10 Lecture hours)
First Law of Thermodynamics, heat, work, heat capacity, enthalpy and internal energy, Second Law of Thermodynamics – Entropy and Criterion for Equilibrium – Statistical interpretation of entropy – Boltzmann equation.

Module 2: (10 Lecture hours)
Auxiliary Functions – Thermodynamic Relations – Maxwell's Equations – Gibbs - Helmholtz Equation – Examples – Heat capacity, enthalpy, entropy and the third law of Thermodynamics- First, second, and third laws of thermodynamics as applied to nanoscale systems

Module 3: (10 Lecture hours)
Phase equilibrium in a one – component system – Composition and Phase diagrams of binary Systems – Criteria for Phase stability – Thermodynamics and kinetics of phase transformations- Homogeneous nucleation- Heterogeneous nucleation.

Module 4: (9 Lecture hours)
Physical phenomena of small systems - nano-crystals, macromolecules, thermodynamics and physical properties of long chain molecules and molecular structures

References:

1. David V. Ragone, Thermodynamics of Materials, Volume I, J. W. Wiley 1995.
2. Thermodynamics in Materials Science, By Robert T. De Hoff, McGraw-Hill, 1993.
3. Stoichiometry and Thermodynamic Computations in Metallurgical Processes, Y.K. Rao, Cambridge University Press, 1985.
4. Robert K, Ian H, Mark G, Nanoscale Science and Technology, John Wiley & sons Ltd.,2005.
5. Daniel V. Schroeder: An Introduction to Thermal Physics, Addison-Wesley, 2000.

MT6103D NANOSIZED STRUCTURES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (9 Lecture hours)
Design principles and implementation of nano-engineered materials in the development of nanotechnology applications, importance of nanomaterials, properties and applications, surface science for nanomaterials, surface energy, stabilization mechanisms, electrostatic - Nernst Equation, electric double layer, Debye-Huckel Screening strength. Interaction between nanoparticles - DLVO Theory, steric stabilization and electrosteric stabilization, nucleation and growth of nuclei, critical radius, homogenous and heterogeneous nucleation.

Module 2: (10 Lecture hours)
Bottom-up approaches for nanostructure fabrication:- Factors controlling the bottom up approaches. Metal nanocrystals by reduction, Solvothermal, Photochemical, Template based and Electrochemical synthesis, Nanocrystals of semiconductors and oxides by arrested precipitation, sonochemical routes, Hybrid methods, Post-synthetic size-selective processing, sol- gel, micelles and microemulsions, top down approaches for nanostructure fabrication.

Module 3: (10 Lecture hours)
One dimensional nanostructures, evaporation condensation growth, fundamentals of evaporation condensation growth. Vapor –Liquid-Solid (VLS) growth, electrospinning, Two dimensional nanostructures, thin films, single and multilayered material structure, molecular beam epitaxy, chemical vapour deposition, atomic layer deposition, molecular self-assembly phenomena, Langmuir-Blodgett films and self-assembled monolayers, emerging hybrid materials, nanoporous materials.

Module 4: (10 Lecture hours)
Nanomaterials for advanced technology- advanced topics in molecular materials and architectures, Photonic crystals, molecular electronics and nanoelectronics, Single electron transistors, Nanoparticle-biomaterial hybrid systems for bioelectronic devices, DNA Nanotechnology, nanostructures in biodiagnostics, tissue engineering and drug delivery.

References:
1. G. Cao and Y.Wang, *Nanostructures and Nanomaterials*, 2nd Ed., Imperial College Press, 2004.
2. R. Kelsall , I.Hamley and M. Geoghegan, *Nanoscale Science and Technology*, Wiley, 2005.
3. K. J Klabunde, R. M. Richards, *Nanoscale Materials in Chemistry*, 2nd Ed., Wiley, 2009.
4. T. Pradeep, *A text book of Nano Science and Technology*, Tata McGraw-Hill Education, 2012.
5. G. Schmidt, *Nanoparticles: from Theory to applications*, Wiley-VCH, 2004.

MT6191D NANOSCIENCE AND TECHNOLOGY LAB-I

Pre-requisites: Nil
Lab

L	T	P	C
0	0	3	2

Total hours: 39

Selected experiments/problems from the following:

1. Preparation of nanofluids.
2. Measurement of stability of nanofluids.
3. Measurement of onset of natural convection in nanofluids.
4. Performance evaluation of nano fuel additives.
5. Tribological studies of nano lubricants.
6. Thermal conductivity measurement of nanofluids.
7. Study of burn-out phenomena in nanofluids.
8. Performance study on heat exchangers with nanofluids.
9. Quenching studies in nanofluids.
10. Determination of viscosity of nanofluids.
11. Evaporation studies of nanofluids.
12. Gas absorption studies in nanofluids.
13. Optical properties of nanofluids.
14. Performance study of nanofluids for solar thermal applications.

References:

1. Nanofluids: Science and Technology, Sarit K. Das, Stephen U. Choi, Wenhua Yu, T. Pradeep, Wiley, 2007.
2. Heat Transfer Enhancement with Nanofluids, Vincenzo Bianco, Oronzio Manca, Sergio Nardini, Kambiz Vafai, CRC Press, 2017.
3. Thermal Energy Storage Using Phase Change Materials: Fundamentals and Applications, Amy S. Fleischer, Springer, 2015.
4. Applications of Nanofluid for Heat Transfer Enhancement , Mohsen Sheikholeslami and Davood Domairry Ganji, Elsevier, 2017.
5. Nanofluids: Synthesis, Properties and Applications, S M Sohel Murshed, Carlos Nieto de Castro, Nova Science Publishers, 2014.

MT6192D SEMINAR I

Pre-requisites: Nil

L	T	P	C
0	0	3	1

Total hours: 39

Seminar

Each student shall prepare a paper on any topic of interest in the field of specialization – Nanotechnology. He/she shall get the paper approved by the Programme Coordinator/ Faculty in-charge and present it in the class in the presence of Faculty in-charge of seminar class. Every student shall participate in the seminar. Grade will be awarded on the basis of the student's paper, presentation and his/her participation in the seminar.

MT6111D SPECTROSCOPIC CHARACTERISATION OF NANOMATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module1: (11 Lecture hours)
Surface analytical techniques, Surface sensitivity, Basics of spectroscopy, Infrared spectroscopy (IR), Functional groups, Attenuated total internal reflection IR, Diffuse reflectance and specular reflectance, *Surface enhanced infrared absorption* spectroscopy , Raman Spectroscopy, resonance Raman, surface enhanced Raman and surface enhanced resonance Raman spectroscopy, Tip enhanced Raman spectroscopy, Confocal Raman microscopy, Analysis of nanomaterials using IR, Raman spectroscopy.

Module2: (11 Lecture hours)
UV-Visible absorption spectroscopy, Principle and application in nanomaterials, Metal nanoparticles and semiconductor nanoparticles, Diffuse reflectance, Calculation of band gaps from diffuse reflectance spectroscopy, Fluorescence spectroscopy, Photoluminescence of nanomaterials, Photoelectron spectroscopy, Ultraviolet photoelectron spectroscopy and X-ray photoelectron spectroscopy, Principle and analysis of spectra, X-ray Fluorescence, Auger electron spectroscopy, Electron energy loss spectroscopy.

Module3: (6 Lecture hours)
Mass spectrometry techniques -Basics and application in nanomaterials, Tandem Mass, Matrix Assisted Laser Desorption/Ionisation, Secondary ion mass spectrometry, Electron spray ionization, Analysis of clusters using mass spectrometry.

Module4: (11 Lecture hours)
An overview of electrochemistry, Electrochemistry in materials science, Principles of electrochemistry, Dynamic electrochemistry: Processes at electrodes, Electrochemical instrumentation and techniques, Cyclic voltammetry, Differential pulse voltammetry, Square wave voltammetry, Impedance spectroscopy, Electrochemical quartz crystal microbalance, Electro chemiluminescence, spectroelectrochemistry, Optical probing of electrode-solution interfaces.

References:

1. J. O'Connor, B. Sexton, R. Smart, Surface Analysis Methods in Materials Science, Springer, 2003.
2. Helmut Gunzler and Alex Williams, Handbook of Analytical Techniques, Wiley-VCH, 2002.
3. C. Banwell and E. Mccash, Fundamentals of molecular spectroscopy, Mc Graw Hill, 1994.
4. G. Hodes, Electrochemistry of Nanomaterials, Wiley-VCH, 2001.
5. D.P. Woodruff, Modern Techniques of Surface Science, Cambridge University Press, 2016.

MT6112D EXPERIMENTAL TECHNIQUES IN NANOTECHNOLOGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (9 Lecture hours)
Design of Experiments - Best guess approach-One factor- at - time approach- Factorial approach-Elementary ideas of blocking, randomization, replication – Errors – Uncertainty analysis. Material characterization techniques –BET surface area analysis - Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Thermo Gravimetric Analysis (TGA) - Dynamic mechanical analysis (DMA)-Temperature programme reduction.

Module 2: (10 Lecture hours)
Intrusive and non-intrusive temperature measurement techniques, Infrared thermography, Thermo reflectance thermography, Liquid crystal thermography. Interferometry, Moir’e interferometry- Electronic speckle pattern interferometry- Deformations in nanostructures Measurement of properties of Nanofluids -thermal conductivity - steady state and transient methods- viscosity- Broke field viscometer. Stability of nano fluids- Particle size distribution - Zeta potential - Dynamic light scattering system-Acoustic-Attenuation spectroscopy, Photo acoustic spectroscopy, Surface energy analysis.

Module 3: (10 Lecture hours)
Characterization techniques in nanotechnology – Electron Microscopy - instrumentation and application, Sample preparation techniques - contrast mechanisms - Scanning electron microscopy, Transmission electron microscopy and HRTEM, SAED, EELS, Electron back scattering (EBSD) - X-ray micro analysis (EDS, WDS).

Module 4: (10 Lecture hours)
Scanning probe microscopy, tapping mode, contact mode, MFM, EFM, I-AFM, DC-AFM, PFM, FMM, LFM, SCM, SThM, SKM, F-d spectroscopy, Nanoindentation, Nanoscratching, Scanning tunneling microscopy, Scanning near field microscopy (SNOM), XRD.

References:

1. Robert K, Ian H, Mark G, Nanoscale Science and Technology, john Wiley & sons Ltd.,2005.
2. Weilie Zhou and Zhong Lin Wang, Scanning Microscopy for Nanotechnology, Springer 2006.
3. David B. Williams, C. Barry Carter, Transmission Electron Microscopy, Springer 2009.
4. Nan Yaho and Zhong, Hand book of Microscopy for Nanotechnology, Kluwer Academic press, Boston, 2005.
5. K.S Birdi, Scanning Probe Microscopy, CRC Press, 2003.
6. C B Sobhan, G P Peterson, Microscale and Nanoscale Heat Transfer-Fundamentals and Engineering Applications, Taylor and Francis/CRC, 2008.
7. Ernest O Doeblin., "Measurement Systems: Application and Design", McGraw Hill (Int. Edition) 1990.
8. MIcheal E Brown, Introduction to Thermal Analysis, Techniques and applications, Kluwer Academic Publishers 2001.

MT6113D MICROSCALE AND NANOSCALE HEAT TRANSFER

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1 (8 Lecture hours)
Introduction to microscale heat transfer - Observations on deviations from conventional theory – experimental and theoretical findings – Overview of studies and comparison of results – Introductory ideas about single phase, multiphase and gas flow in small channels – Contradictory observations and view points in microchannel heat transfer- Applications of microscale heat transfer – basic ideas on micro heat exchangers and microscale heat sinks – applications in electronics cooling, biotechnology and MEMS.

Module 2: (10 Lecture hours)
Conduction in integrated circuits and their constituent films – current trends and future challenges – Microscale thermometry techniques – electrical and optical methods – thermorefectance thermometry – Thermal properties of amorphous dielectric films – Thermal characterization and heat transport in dielectric films – Heat conduction in crystalline silicon films – Phonon dispersion - heat conduction in semi-conductors at high temperatures – phonon transport equations – hot phonon effects.

Module 3: (11 Lecture hours)
Fundamentals of convective heat transfer in microtubes and channels – Thermodynamic concepts, general laws and particular laws - Governing equations and size effects. Single phase forced convection in microchannels – Flow structure – entrance length – experimental observations on flow and heat transfer characteristics – Theoretical investigations – Forced convection in mixtures - Gas flow in microchannels. Boiling and two- phase flow heat transfer in small channels – Boiling curve and critical heat flux - flow patterns – Bubble dynamics and thermodynamic aspects – Mathematical modeling and measurement of microscale convective boiling; Applications of microchannel heat transfer – microchannel heat sinks – micro heat pipes and micro heat spreaders – integration of microchannel heat sinks and heat spreaders to silicon structures – experimental and theoretical investigations.

Module 4: (10 Lecture hours)
Fundamentals of heat transport at the nanoscale – characteristic lengths and heat transfer regimes – Nanoscale heat transfer phenomena – Conduction, radiation and convection in the nanoscale – Applications of nanoscale heat transfer in microelectronics, energy, nanomaterial synthesis, nano fabrication – Nanowires and carbon nanotubes – Analytical methods – Boltzmann equation approach - Molecular dynamics simulation – Challenges and Future applications

References:
1. C B Sobhan, G P Peterson, Microscale and Nanoscale Heat Transfer-Fundamentals and Engineering Applications, Taylor and Francis/CRC, 2008.
2. Ju, Y.S., and Goodson, K. , Microscale Heat Conduction in Integrated Circuits and their Constituent Films, Kluwer Academic Publishers, Boston, 1999.
3. Chen, G., Nanoscale Energy Transport and Conversion, Oxford University Press, 2005.
4. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2005.

MT6193D NANOSCIENCE AND TECHNOLOGY LAB-II

Pre-requisites: Nil
Lab

L	T	P	C
0	0	3	2

Total hours: 39

Selected experiments/problems from the following:

1. Synthesis of cerium zirconium oxide nanoparticle by co-precipitation method.
2. Synthesis of ceria nano fibres by Solvo thermal method.
3. Electrochemical deposition of palladium over graphite electrode coated with CNT.
4. Synthesis of silica nanoparticles using Stober method.
5. Development of a silica sol gel coating on a mica sheet.
6. Synthesis of Iron oxide nanoparticles using co-precipitation method.
7. Synthesis of molybdenum disulfide nanoparticles.
8. Synthesis of titania nano fibers by hydrothermal method.
9. Synthesis of gold nano particles using chemical reduction method.
10. Fabrication and wettability characterization of nanostructured soft polymer surfaces.
11. Temperature measurement using interferometry.

References:

1. Pradeep, T. A textbook of nanoscience and nanotechnology. Tata McGraw-Hill Education, 2003.
2. Chandran PR, Naseer M, Udupa N, Sandhyarani N. Size controlled synthesis of biocompatible gold nanoparticles and their activity in the oxidation of NADH. Nanotechnology. 2011 Dec 8;23(1):015602.
3. Ibrahim IA, Zikry AA, Sharaf MA. Preparation of spherical silica nanoparticles: Stober silica. J. Am. Sci. 2010;6(11):985-9.
4. Chen X, Mao SS. Titanium dioxide nanomaterials: synthesis, properties, modifications, and applications. Chemical reviews. 2007 Jul 11;107(7):2891-959.

MT7198D PROJECT – PART 1

Pre-requisites: Nil

L	T	P	C
-	-	-	10

The project work starts in the third semester and extends to the end of the fourth semester. The student will be encouraged to fix the area of work and conduct the literature review during the second semester itself. The topic shall be research and development oriented. The project can be carried out at the institute or in an industry/research organization. Students desirous of carrying out project in industry or other organization have to fulfill the requirements as specified in the “Ordinances and Regulations for M. Tech. under the section - Project Work in Industry or Other Organization.”

At the end of the third semester, the students’ thesis work shall be assessed by a committee and graded as specified in the “Ordinances and Regulations for M. Tech.”. If the work has been graded as unsatisfactory, in the third semester the committee may recommend a suitable period by which the project will have to be extended beyond the fourth semester.

MT7199D PROJECT – PART 2

Pre-requisites: Nil

L	T	P	C
-	-	-	14

At the end of the fourth semester, the student shall present his/her thesis work before an evaluation committee, which will evaluate the work and decide whether the student may be allowed to submit the thesis or whether he/she needs to carry out additional work. The final viva-voce examination will be conducted as per the "Ordinances and Regulations for M. Tech.".

LIST OF ELECTIVES

Sl. No	Code	Title of Course
1	MT6121D	Mechanics of Finite Size Elements
2	MT6122D	Nano Materials for Energy and Environment
3	MT6123D	Nanofluids
4	MT6124D	Computational Nanotechnology
5	MT6125D	Carbon Nanomaterials
6	MT6126D	Combustion and Nanoparticle Fuel-Additives
7	MT6127D	Polymer Technology
8	MT6128D	Chemistry of Materials
9	MT6129D	Nano Fabrication
10	MT6130D	Elements of X-Ray Diffraction
11	MT6131D	Surface Science with Nanomaterials
12	MT6132D	Micro Electro Mechanical Systems and applications

*** Any other subject offered in the Institute with the approval from the Programme Coordinator**

MT6121D MECHANICS OF FINITE-SIZE ELEMENTS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (11 Lecture hours)
Mathematical preliminaries - scalar, vector and tensor quantities, deformation and strain tensor, strain-displacement relations, stress tensor, equilibrium equations, constitutive relations for elastic and elasto-plastic material behaviour, formulation and applications.

Module 2 : (10 Lecture hours)
Fundamentals, dislocation modeling, singular stress states, distributed cracks and voids, micropolar elasticity. Mesoscale applications - heterogeneous media and homogenization.

Module 3: (9 Lecture hours)
Introduction, concepts from classical and statistical mechanics, virial stress tensor, introduction to computational methods, mechanics of nanoscale systems and assemblies, applications of nanomechanics.

Module 4: (9 Lecture hours)
Introduction to fracture mechanics, dislocation mediated deformation mechanisms, fracture and deformation of nanoscale solids, creep and fatigue of nanoscale structures.

References:

1. Sadd, Martin H., Elasticity – Theory, Applications and Numerics, Academic Press, 2006.
2. Liu, Wing Kam, Karpov, E.G., and Park, H.S., Nanomechanics and Materials, John Wiley & Sons, 2006.
3. Cleland, A.N, Foundations of Nanomechanics, Springer Verlag, 2005.
4. Robert, K., Ian, H., Mark, G., Nanoscale Science and Technology, John Wiley & Sons, 2005.

MT6122D NANOMATERIALS FOR ENERGY AND ENVIRONMENT

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module1: (10 Lecture hours)
Energy and Environment, sustainable energy production based on renewable energy sources, Sustainability: Agriculture, Water, Energy, Materials and clean environment, Nanomaterials used in energy and environmental applications and their properties**,** Solar energy, solar cells, dye sensitized solar cell, organic solar cells, Hydrogen energy, hydrogen production by water splitting, hydrogen storage.

Module2: (12 Lecture hours)
Alternative energy technologies, Electrochemical energy conversion and storage systems, Fuel cells, Types of fuel cells, thermodynamics of fuel cells, electrocatalysts for anode reactions, catalysts for oxygen reduction reactions, Batteries, Li-ion battery, Na-ion battery, General properties of electrochemical capacitors, Supercapacitor, Electrical double layer capacitor, pseudocapacitor, Li-ion based hybrid supercapacitors, Applications of electrochemical capacitors.

Module3: (10 Lecture hours)
Green nanotechnology and its principles, Nanomaterials for environmental Remediation, Photocatalysis, Water purification using nanomaterials, desalination of water, Solid waste removal, Porous materials to store clear energy gases, Metal organic frame works(MOFs), Storage of carbon dioxide, methane and hydrogen in MOFs.

Module4: (7 Lecture hours)
Potential impacts of nanomaterials on organisms and ecosystems, Nanotoxicology**,** Introduction to nanomaterial toxicity, environmental and health impacts, Biomagnification, Nanoparticles exposure assessment, toxicity of inhaled nanomaterials, Basics of toxicity studies, Cytotoxicity induced by nanomaterials, ethical, legal, and societal implications of nanotechnology.

References:

1. Jingbio louise Liu, Sajid Bashir, Advanced Nanomaterials and their applications in Renewable energy, Elsevier, 2015.
2. Tetsuo Soga, Nanostructured Materials for Solar Energy Conversion, Elsevier , 2006.
3. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kluwer Academic Publishers, Dordrecht, Netherlands, 2004.
4. J. Larmine and A. Dicks, Fuel Cell System Explained, John Wiley, New York , 2000.
5. Francois B´eguin and El˙zbieta Frackowiak, Supercapacitors, Wiley-VCH, 2013.
6. Challa S.S.R. Kumar, Nanomaterials: toxicity, health and environmental issues, Wiley-VCH, 2006.

MT6123D NANOFLUIDS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (9 Lecture hours)
Nanofluids- Synthesis of nano fluids- two step methods- single step method- stability – factors affecting stability- surfactants- Electrical double layer- stabilization methods – steric stabilization - electrostatic stabilization -Zeta potential – Methods of stability measurement - Dynamic light scattering system – Acoustic Attenuation spectroscopy- Properties of nano fluids- thermal conductivity –viscosity – specific heat – wetting characteristics.

Module 2: (11 Lecture hours)
Enhancement of heat transfer by passive methods and active methods - Forced convective heat transfer in nanofluids: horizontal and vertical loops – Free convective heat transfer in nanofluids – Flow stability in thermosyphon loops – surface modified channels – Non-intrusive flow measurements in nanofluids – Nanofluid flow and heat transfer enhancement using electric and magnetic field - boiling and condensation enhancement using modified surfaces and acoustic waves; Nano encapsulated phase change material- Evaporation of nanofluids – boiling – condensation; Nanofluids for solar energy retrieval: Solar thermal collectors: Optical properties of nanofluids – extinction coefficient – solar stills – solar cookers.

Module 3: (11 Lecture hours)
Lubricants – Types of lubricants – properties- Nano lubricant additives –solid lubricant additives – lamellar structure – synthesis and characterization - MoS_2/WS_2/graphene nanoparticles- Synthesis methods- Hydraulic assisted exfoliation – Friction and wear measurements
Application of nanofluids in refrigeration and air conditioning - Magnetic nano particles - Rheological fluids - Ferro fluids.
Gas absorption: CO_2 absorption in nanofluids – Direct contact method – Bubble type absorption – Packed bed absorption

Module 4: (8 Lecture hours)
Fuels – properties - Nano fuel additives – catalytic nano particles – synthesis and characterization - cerium – cerium based mixed oxide nanoparticles –– oxygen storage capacity – Temperature programme reduction –stability – surfactants – diesel engine exhaust emissions – HC, CO, NO_x, CO_2, smoke - Diesel particulate filter -DPF regeneration.

References:

1. Nanofluids: Science and Technology, Sarit K. Das, Stephen U. Choi, Wenhua Yu, T. Pradeep, Wiley, 2007.
2. Heat Transfer Enhancement with Nanofluids, Vincenzo Bianco, Oronzio Manca, Sergio Nardini, Kambiz Vafai, CRC Press, 2017.
3. Thermal Energy Storage Using Phase Change Materials: Fundamentals and Applications, Amy S. Fleischer, Springer, 2015.
4. Applications of Nanofluid for Heat Transfer Enhancement , Mohsen Sheikholeslami and Davood Domairry Ganji, Elsevier, 2017.
5. Nanofluids: Synthesis, Properties and Applications, S M Sohel Murshed, Carlos Nieto de Castro, Nova Science Publishers, 2014.

MT6124D COMPUTATIONAL NANOTECHNOLOGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (10 Lecture hours)
Introduction- Computational simulation, need for discrete computation. Classical Mechanics: Mechanics of Particles, D' Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

Module 2: (9 Lecture hours)
Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, partition function for identical particles, Maxwell distribution of molecular speeds.

Module 3: (10 Lecture hours)
Atomistic Simulation Techniques:
Molecular Dynamics (MD): Introduction, inter-atomic potential function, Lennard-Jones potential, MD simulation – equilibration and property evaluation, various types of potential functions, computational aspects, introduction to advanced topics. Monte Carlo (MC) Method: Introduction, Metropolis algorithm, advanced algorithms for Monte Carlo simulations, comparison with Molecular Dynamics.

Module 4: (10 Lecture hours)
Mesoscopic Simulation Techniques:
Lattice Boltzmann Method (LBM): Boltzmann equation, derivation of the hydrodynamic equation from Boltzmann equation, Lattice Boltzmann equation and LBM, applications of LBM. Dissipative Particle Dynamics (DPD): Fundamentals of DPD simulations, time step size and noise, repulsion parameter, approximate expressions for transport coefficients. Introduction to Multiscale methods and applications.

References:

1. Bird, G.A., Molecular Gas Dynamics and the Direct Simulation of Gas Flows, Oxford Science Publications, 1994
2. Goldstein, H., Poole, C., and Safko, J., Classical Mechanics, 3rd Edn., Pearson Education, 2006.
3. Bowley, R., and Sanches, M., Introductory Statistical Mechanics, 2nd Edn., Oxford Science Publications, 2007.
4. Ercolessi, F., A Molecular Dynamics Primer, Notes of Spring College in Computational Physics, ICTP, Trieste, June 1997.

MT6125D CARBON NANOMATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (11 Lecture hours)
Different carbon based nanostructures, Historical developments: Fullerenes, Graphene, Carbon nanotubes and its derivatives, Common synthesis technique for carbon nanostructures: arc evaporation, laser ablation and chemical vapor deposition, purification by dry and wet method, Techniques for alignment of CNTs: horizontal alignment and vertical alignment, organization on surfaces: organized assembly, field and flow directed growth,surface directed growth(epitaxy),patterned growth on surfaces, Single and multi walled Carbon Nanotubes-Chemical Reactivity and Related Structures

Module 2: (11 Lecture hours)
Mechanical Properties Graphene and carbon nanotubes , thermal stability of carbon nanotubes , ballistic heat transport, phonon transport ,thermal conductance, length effect on thermal conductivity ,influence of defects on thermal conductivity , diffusive heat transport in SWNTs, Heat transport in MWNTS, Metrology for CNT, electron microscopy, HRTEM, electron diffraction, SPM, Spectroscopy, Photoluminescence, Introduction to optical response of Carbon Nanotubes, Excitonic effects, Optical spectra of SWNTs ,pressure, temperature and strain effects, Overview of Resonance Raman Spectroscopy, Photoluminescence spectroscopy of nanotubes, photoluminescence imaging ,Introduction to ultrafast sepectroscopy of carbon nanotubes , Rayleigh scattering spectroscopy , near field optical microscopy for carbon nanotube study and characterization. electrochemistry of carbon nanotubes.

Module 3: (9 Lecture hours)
Magnetic phenomena in carbon nanotubes, band structure, magnetization , magneto transport , magneto optics, Introduction to Carbon nanotube optolectronics, Overview of CNT electronics, Photoconductivity ,Nanotube photodetectors , CNT photoconductor, Photovoltage in CNT diodes, photovoltage imaging, Electroluminescence, Electrical transport in Carbon Nanotubes ,Quantum transport, Quantum dots.

Module 4: (8 Lecture hours)
Challenges: CNT- separation of semiconductor and metallic CNT, defect free CNT, contacts(thermal and electrical); Graphene band gap, large area defect free transfer. Doping in graphene and carbon nanotubes, methods, characterization and applications. Applications of Carbon Nanotubes, Electronics, energy, mechanical, sensors, field emission and lighting, biological, Environmental and health effects of carbon nanotubes. Other 2D structures: Chalcogenides and Boron nitride.

References:

1. Jorio, A., Dresselhaus, G., and Dresselhaus, M.S. (Eds.), “Carbon Nanotubes – Advanced Topics in the Synthesis, Structure, Properties and Applications,” Springer Verlag, New York, 2008.
2. Michael J. O'Connell, Carbon Nanotubes: Properties and Applications, CRC; 1 edition, 2006.
3. Jorio, A.; Dresselhaus, M. S.; Saito, R. & Dresselhaus, G. Raman spectroscopy in graphene related systems Wiley, 2011.
4. Krueger,A. Carbon materials and nanotechnology Carbon Materials and Nanotechnology, Wiley-VCH, 2010.

MT6126D COMBUSTION AND NANOPARTICLE FUEL-ADDITIVES

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (9 Lecture hours)
Review of basic thermodynamics and gaseous mixtures, Combustion Thermodynamics, Stoichiometry, First and Second Laws of Thermodynamics applied to combustion, Composition products in equilibrium.

Module 2: (10 Lecture hours)
Fundamentals of combustion kinetics, General characteristics of combustion flame, detonation, deflagration, Factors affecting flame velocity and thickness, Quenching, Flammability, Flame stabilization, Laminar premixed flames, diffusion flames, Turbulent premixed flames.

Module 3: (10 Lecture hours)
Combustion in I.C. engines, A/F ratio requirements, Ignition temperature- Ignition delay, Normal combustion in SI engines, Knocking, Effect of variable on knocking tendency, Octane number, Normal combustion in CI Engines- Theories of detonation - Cetane number

Module 4: (10 Lecture hours)
Fuels for I.C. Engines, Properties of fuels, Measurement methods, Fuel additives, Nano catalysts, synthesis and characterization of Ceria based oxide nanoparticles, Oxygen storage capacity, Nano fluids, Diesel engine emissions, Effect of nano particles on fuel properties and emissions, Emission control devices.

References:

1. Stephen R Turns, An Introduction to Combustion, McGraw- Hill International Edition, 2000.
2. Kuo, K. K., Principles of Combustion, John Willey & Sons, 1986.
3. Mukunda, H. S., Understanding Combustion, Macmillan India Ltd., 1992.
4. Smith, M. L. and Stinson, K. W., Fuels and Combustion, McGraw-Hill, 1952.
5. Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill, 1989.
6. Fristrom. R. M. and Westenberg, A. A., "Flame Structure", McGraw – Hill Book Co. New York, 1965.
7. Maleev, M. L., Internal Combustion Engines, Second edition, McGraw-Hill, 1989.
8. Mathur, M. L. and Sharma, R. P., Internal Combustion Engines, Dhanpath Rai & Sons, 2005.
9. G. R. Pryling, "Combustion Engineering", Revised Edn., Combustion Engg. Inc., New York 1967.
10. C. Eckbreth, "Laser Diagnostics for Combustion Temperature and Species", Cambridge, Abacus Press, 1988.
11. Sajith V. and Shijo Thomas, “Internal Combustion Engines”, Oxford University Press, 2017.

MT6127D POLYMER TECHNOLOGY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (10 Lecture hours)
Introduction to Polymers, Basic concepts, characteristic features, texture of polymers, molecular forces and chemical bonding, secondary bond forces, tacticity in polymers, stereo isomerism in polymers, basic determinants of polymer properties, polymer chain flexibility, factors affecting chain flexibility, glass transition temperature and crystalline melting points, variation and structure, molecular interpretation of glassy state of polymers.

Module 2: (10 Lecture hours)
Compounding and processing of polymers, Additives for compounding plastics, additives for compounding of rubbers, two roll mill, banbury mixer, pigments, processing aids, processing methods for the manufacture of products, blending and mastication, masterbatching, mixing and compounding, calendaring, extrusion and moulding. Different elastomer curing systems-efficient, semi efficient, conventional and sulphurless curemechanism of vulcanization, sulphur vulcanization, non sulphur vulcanizing systems for olefin rubbers, batch vulcanization-autoclave, gas curing, oven curing, water curing, cold curing, continuous vulcanisation-high performance steam, hot air tunnel, molten salt bath, fluidized bed, continuous drum cure, microwave curing.

Module 3: (10 Lecture hours)
Testing of Rubbers. Importance of standards and standards organizations, processability and performance, testing of plastics and rubbers, material characterization tests such as hardness, tensile stress/strain, compression stress/strain, shear stress/strain, flexuaral stress/strain, tear tests, rebound resilience, friction, creep, fatique, melt flow index, capillary rheometer test, viscosity test, gel permeation chromatography, thermal analysis such as TGA, TMA, and DSC.

Module 4: (9 Lecture hours)
Introduction to polymer melt rheology, viscosity, types of fluid flow, time dependent fluids, time independent fluids, viscoelastic fluids, complex rheological fluids, Newtonian fluids, non-Newtonian fluids, Bingham plastics, psuedo plastics, rheopectic and thixotropic behaviour, rheological measurements-the capillary rheometer, cone and plate viscometer, melt flow index apparatus, elastic effects in polymer melt flow-die swell, elastic turbulance, melt fracture, sharkskin.

References:

1. Fred W. Billimeyer, Jr, Text Book of Polymer Science, third edition, Wiley Interscience Publication, 1994.
2. Joel R. Fried,m Polymer Science and Technology, Prentice- Hall, Inc. Englewood Cliffs, N. J., USA, 2000.
3. Hand book of Elastomers: New Developments and Technology (Eds. A. K. Bhowmic and H.
C. Stephense), Marcel- Dekker Inc., New York, 1995.
4. D. R. Paul and S. Newman, Polymer Blends, Academic Press, New York, 1978.
5. M. J. Folkes, Short Fibre Reinforced Thermoplastics, John Wiley, New York, 1982.
6. Jacob Kline, Handbook of Biomedical Engineering, Academic press, NY, 1988.
7. Joseph D. bronzino, The Biomedical engineering Handbook, CRC press, London, 2003.

MT6128D CHEMISTRY OF MATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (**9 Lecture hours**)
Structure of materials, crystal structures, introduction to lattices, bonding in solids, diffraction and reciprocal lattice, order and disorder in solids, electrical, optical and magnetic properties, unique bonding in nanoparticles and powders, novel properties of nanomaterials, classification of nanomaterials, interparticle interactions, superlattices.

Module 2: (**10 Lecture hours**)
Classes of materials, Semiconductors, metals and alloys, ceramics, polymers, dielectric and ferroelectric materials, magnetic materials, optical materials, super conductors, high Tc Materials, Perovskites, micro and mesoporous materials, nanoporous materials, aerogels, host-guest systems based on nanoporous crystals.

Module 3: (**10 Lecture hours**)
Physical chemistry of surfaces, interfaces, thin films, preparation, characterization and application, Langmuir-Blodgett films: growth techniques, self assembled monolayers, nanocrystalline phases, preparation, nanocomposites, fullerenes, carbon nanotubes, grapheme, carbon dots, effect of synthesis on the structure and properties of various materials.

Module 4: (10 Lecture hours)
Supramolecular chemistry, rotaxanes as ligands for molecular machines and metal-organic frameworks, synthetic nanotubes from calixarenes, moular gels-nanostructured soft materials, periodic nanostructures based on metal-organic frameworks (MOFs).

References:

1. Nanoscale materials in chemistry, 2nd ed, Ed. by K. J. Klabunde, Richards, Ryan. John-Wiley and sons, 2009.
2. Solid state chemistry , A.R. West, Wiley, 1999.
3. Nanostructures and nanomaterials, G. Gao, Imperial college press, 2006.
4. Organic nanostructures, Ed. by Jerry L.Attwood, Jonathan W. Steed, Wiley-VCH, 2008.
5. Handbook of porous solids, Ed. by F. Schuth, Kenneth, S.W. Sing, Jens Weitkamp , Wiley interscience, 2002.
6. Host-guest-systems based on nanoporous crystals, Ed. F. Laeri, Ferdi Schuth, Ulrich Simon, Michael Wark, Wiley interscience, 2003.

MT6129D NANOFABRICATION

Pre-requisites: Nil

L	T	P	C
2	0	1	3

Total hours: 39

Module 1: (10 Lecture hours)
Fabrication of Nanomaterials by Physical method: Nanofabrication by bottom up and top down approach, Inert gas condensation, ARC Discharge, RF Plasma. Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical and Physical vapor deposition method, Electro deposition, Nanogrinding, LPCVD.

Module 2: (10 Lecture hours)
Nanofabrication by photons and charged beams, Optical Lithography, Photoresist, Deep UV, Extreme UV and X ray Lithography, optical E-beam lithography mask making. Mask less optical lithography, contact proximity and projection lithography, Different etching techniques, reactive Ion Etching. ICPRIE, Thermal oxidation of silicon. Focused ion beam, Dual Beam and electron beam for nanolithography, Limitations of Lithography.

Module 3: (10 Lecture hours)
Nanofabrication by scanning probe, Nanoscratching and oxidation, soft lithography, nanoimprint lithography, Immersion lithography, Deep pen lithography.

Module 4: (10 Lecture hours)
Nanofabrication by replication, Nanofabrication by self assembly and scanning tunneling techniques, nanopatterning, Nanomanipulation. MEMS fabrication , Lab on Chip.

References:

1. Kazuaki Suzuki. Bruce W Smith. “Microlithography : science and technology” ,CRC press 2007.
2. Mark J Jackson,” Microfabrication and nanomanufacturing”, CRC press Taylor & Francis Group, Poblished in 2006.
3. John A. Rogers, Hong H Lee,”Unconventional nanopatterning techniques and applications”, Published by John Wiley & Sons, Inc., Hoboken, New jersey 2009.
4. Syed Rizvi, “ Handbook of Photomask Manufacturing Technology “ CRC Press Taylor & Francis Group, Poblished in 2005.

MT6130D ELMENTS OF X-RAY DIFFRACTION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (7 Lecture hours)
Introduction- Electromagnetic radiation, continuous spectrum, characteristic spectrum, absorption, filters, Production of x-rays, Absorption of X-rays, Detection of x-rays. Diffraction - Bragg law, X-ray spectroscopy, Diffraction directions, Diffraction methods. Diffraction under nonideal conditions. Scattering by an electrons, Scattering by an atom,

Module 2: (10 Lecture hours)
Lattices and crystal structures, Types of solid and order, Point lattices and unit cells, Crystal systems and Bravais lattices, Crystal structures, atoms per lattice points, Miller indices, Diffraction from crystalline materials. Scattering by a unit cell, Structure-factor calculations, Multiplicity factor, Lorentz factor, Absorption factor, Temperature factor. Intensities of powder pattern lines, Measurement of x-ray intensity.Structure factor

Module 3: (12 Lecture hours)
Geometry of an X- Ray diffractometer, Components of an X-Ray diffractometer, X-Ray sources, Optics, detectors, X-ray safety, Crystal structure data, ICDD, JCPDS etc., Crystal structure determination Cubic, Hexogonal strucutures, Methods for indexing of XRD peaks, peak shift, residual stress

Module 4: (10 Lecture hours)
Precise Parameter Measurements- Debye-Scherrer cameras, Method of least squares, Cohen's method, Calibration method, Phase diagram determination- General principles, Solid solutions, Determination of solvus curves- disappearing-phase method and parametric method, Ternary systems. Order – Disorder Transformations, Long-range order, Detection of superlattice lines, Short-range order and clustering.

References:

1. B.D.Cullity and S.R.Stock, "Elements of X-Ray Diffraction" Third edition, Prentice Hall, 2001.
2. Aaron.D. Krwitz, “Introduction to Diffraction in Material Science and Engineeing”, Wiley-Interscience, 2001.
3. C. Suryanarayana and M.Grant Norton, “X-Ray Diffraction - A Practical Approach”, Springer, 1998.
4. K. Ramakanth Hebbar, “Basics of X-Ray Diffraction and its Applications”, I.K.International Publishing House, 2011.
5. Yoshio Waseda, Eiichiro Matsubara and Kozo Shinoda, “X-Ray Diffraction Crystallography: Introduction, Examples and Solved Problems” Springer, 2011.

MT6131D SURFACE SCIENCE WITH NANOMATERIALS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (9 Lecture hours)
The nature of surfaces and interfaces, Surface free energy, Molecular nature of Interfacial regions, surface activity and Surfactant structures, Classification of physical forces, van der Waals forces, Interaction between surfaces and particles, Electrostatic forces and electrical double layer, Surface force measurements, Colloid structure, mechanism of colloid formation, Sources of colloidal stability, Steric and Enthalpic stabilization, Coagulation kinetics, The complete interaction curve.

Module 2:(9 Lecture hours)
Surfactants and self assembly, Micelles and critical micelle concentration, Adsorption in colloid and surface science, Adsorption theories, Adsorption from solution, Characterization methods of colloids-Kinetic properties and rheology, Optical properties, Scattering spectroscopy and Microscopy.

Module 3: (10 Lecture hours)
Capillarity-physical origin and measurement techniques, Introduction to wetting, Cassie and Wenzel models, Experimental studies of wetting phenomena, capillary length and shape of a liquid meniscus, Hysteresis and elasticity of triple lines, wetting in porous substrates, wetting at soft surfaces, Dewetting , smart surfaces.

Module 4: (11 Lecture hours)
Capillary driven transport and assembly, Chemical-gradient driven transport, Temperature-gradient driven transport, Capillary flows in an evaporating drop-Coffee ring effect, Reactive wetting, Electrokinetic transport phenomena, Electro-osmosis, Electrophoresis: Electrophoresis in solution, Electrophoresis of non-interacting solutes in gels.

References:

1. Morton, Rosoff. Nanosurface chemistry, Marcel Dekker Inc., 2002.
2. Georgios M. Kontogeorgis, Soren Kiil. Introduction to applied colloid and surface chemistry, Wiley, 2016.
3. Arthur W. Adamson, Alice P. Gast. Physical chemistry of surfaces, John-Wiley &Sons, 1997.
4. de-Gennes, P-G; Brochard-Wyart, F; Quéré, D. Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls and Waves, Springer, 2004.
5. H. Watarai, N. Teramae, T. Sawada. Interfacial nanochemistry, Springer, 2003.
6. Mayers, Drew. Surfaces, Interfaces and Colloids-Principles and applications, 2nd edition, Wiley- VCH 1999.

MT6132D MICRO ELECTRO MECHANICAL SYSTEMS AND APPLICATIONS

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total hours: 39

Module 1: (11 Lecture hours)
Overview of micro electro mechanical devices and technologies. Introduction to architecture design, process flow, fabrication, packaging and testing. MEMS Fabrication,Deposition, lithography, and etching, Surface micromachining, Bulk micromachining, bonding technologies, LIGA technology and related fabrication methods

Module 2: (10 Lecture hours)
MEMS device concepts (micro sensors/actuators), Use of capacitive, inductive, optical, piezoresistive, piezoelectric methods for sensing. MEMS Applications, Accelerometers and gyroscope,Pressure sensors, Micro optics, Microsystems Packaging.

Module 3: (9 Lecture hours)
Introduction to existing and next-generation metrology tools for MEMS and NEMS inspection and qualification. Theoretical principles of metrology and experimental work on characterization of prototype MEMS and NEMS devices.

Module 4: (9 Lecture hours)
Cross-disciplinary application of MEMS and NEMS to the biological sciences. Interaction of living cells/tissues with nanofabricated structures, microfluidics for the movement and control of solutions - the development of I/O architectures for efficient readout of bioreactions.

References

1. Mohamed Gad – el – Hak (ed.), The MEMS Handbook, Second Edition, CRC Press, 2005.
2. James J. Allen , Micro Electro Mechanical System Design, CRC, 2005.
3. K. Subramanian , Micro Electro Mechanical Systems: A Design Approach, Springer, 2008.