# ACADEMIC CURRICULA

## Professional Core Courses

### NANOTECHNOLOGY

## Regulations - 2018

## SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Kancheepuram, Tamil Nadu, India

| Course Code | 18NTC101T | Course Name | NANOSCALE CHEMISTRY | 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 | *Nanotechnology* | Data Book / Codes/Standards | *Nil* | | |

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Understand the role of chemistry in nanoparticle synthesis* |
| CLR-2 : | *Improve their ability in understanding the thermodynamic behavior of nanomaterials* |
| CLR-3 : | *Acquire knowledge about size effects and reaction kinetics and phase properties at nanoscale* |
| CLR-4 : | *Enhance knowledge about Symmetry and lattice parameters* |
| CLR-5 : | *Enhance knowledge about the various nanosynthesis techniques* |
| CLR-6 : | *Utilize the knowledge of processing in nanochemistry* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1 | Learning 2 | Learning 3 | PLO 1 | PLO 2 | PLO 3 | PLO 4 | PLO 5 | PLO 6 | PLO 7 | PLO 8 | PLO 9 | PLO 10 | PLO 11 | PLO 12 | PLO 13 | PLO 14 | PLO 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Level of Thinking (Bloom) | Expected Proficiency (%) | Expected Attainment (%) | Engineering Knowledge | Problem Analysis | Design & Development | Analysis, Design, Research | Modern Tool Usage | Society & Culture | Environment & Sustainability | Ethics | Individual & Team Work | Communication | Project Mgt. & Finance | Life Long Learning | PSO - 1 | PSO - 2 | PSO - 3 |
| CLO-1 : | *Identify the difference between bulk and nanoscale thermodynamics* | *2* | *80* | *75* | *M* | *M* | *H* | *H* | *M* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-2 : | *Identify symmetry, point groups and its application in lattice determination* | *2* | *80* | *70* | *H* | *H* | *H* | *H* | *M* | *M* | *M* | *H* | *H* | *H* | *M* | *H* | *M* | *M* | *M* |
| CLO-3 : | *Describe phase diagram and transition in nanoscale* | *2* | *75* | *70* | *H* | *M* | *H* | *M* | *H* | *H* | *H* | *H* | *M* | *M* | *H* | *H* | *H* | *H* | *H* |
| CLO-4 : | *Analyze the physical chemistry of nanomaterials* | *2* | *80* | *75* | *M* | *H* | *M* | *H* | *M* | *H* | *H* | *H* | *M* | *H* | *M* | *M* | *H* | *H* | *H* |
| CLO-5 : | *Analyze the mechanism of different chemical synthesis routes* | *2* | *80* | *70* | *H* | *M* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-6 : | *Analyze the chemistry based processes at nanoscale* | *2* | *80* | *70* | *H* | *M* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Fundamental Properties of nanomaterials* | *Symmetry of molecules* | *Crystalline phase transitions in nanocrystals* | *Supercritical fluids-introduction* | *Introduction on different synthesis route of nanoparticles* |
| | SLO-2 | *Size effects on structure and morphology of free and supported nanoparticles* | *point groups of molecules* | *Phase transitions and grain size dependence* | *Processes involving supercritical fluids* | *Overview on precipitative methods* |
| S-2 | SLO-1 | *Size and confinement effects of nanomaterials* | *Symmetry of nanosystems* | *Phase diagram of Water and Carbondioxide* | *Phase diagram of a pure substance* | *Chemical precipitation and co-precipitation methods to synthesize nanomaterials* |
| | SLO-2 | *Fraction of surface atoms* | *Point groups of nanoclusters* | *Different forms of phase transition* | *Pressure–density diagram for $CO_2$* | *Chemical reduction method to synthesize metallic nanocrystals* |
| S-3 | SLO-1 | *Specific surface energy and surface stress of nanomaterials* | *Miller indices and representation of directions* | *Classification of phase transitions* | *Physicochemical properties: solubility or dissolving power of different fluids* | *Metathesis to prepare nanoparticles* |
| | SLO-2 | *Effect of size on the lattice parameter* | *Bragg's law of diffraction* | *Tools to detect phase transition* | *Variation of viscosity with respect to presure* | *Steps involved in Sol-gel synthesis* |
| S-4 | SLO-1 | *Classification of nano-structured materials* | *XRD analysis of bulk and nanomaterials* | *Wulff anf Wulff-Kirchoff plot for equilibrium geometry* | *Transport properties of supercritical fluids* | *Reaction mechanisms: Hydrolysis and polycondensation* |
| | SLO-2 | *0D, 1D, 2D,3D structures* | *Identification of crystal planes in bulk and nanomaterials* | *Phase transition of Barium Titanate nanoparticles as example* | *Diffusion and Brownian motion* | *Introduction to micelles, reverse micelles and microemulsions* |
| S-5 | SLO-1 | *Introduction to thermodynamics of bulk materials* | *Scherer equation to calculate the grain or crystallite size* | *Influence of the surface or interface on nanocrystals* | *Thermal conductivity or heat transport phenomenon of supercritical fluids* | *Synthesis of nanomaterials using microemulsion route* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | SLO-2 | *Gibb's equation* | *Specific features of nanoscale growth* | *Modification of transition barrier, geometric evolution of the lattice in nanocrystals* | *Purification and extraction of supercritical fluids* | *Prepare inorganic nanomaterials using hydrothermal and solvothermal routes* |
| S-6 | SLO-1 | *Derivation of free energies of nanostructures with different geometry* | *Size control of nanoparticles* | *Influence of the nanocrystal surface or interface on the lattice parameter* | *Synthesis of supercritical fluids* | *Preparation of arrays of oxide nanocrystals using thermolysisroute* |
| | SLO-2 | *Surface energy and work function of nanostructures with different geometry* | *Triggering the phase transition in small particles fabrication* | *Crystallization of metallic glasses* | *Cryochemistry of metals-Introduction* | *Microwave heating assisted synthesis of nanomaterials* |
| S-7 | SLO-1 | *Thermodynamics of nanospheres* | *Application to solid nanoparticles* | *Grain growth and grain growth kinetics* | *Silver and other metals* | *Introduction to sonochemistry* |
| | SLO-2 | *Thermodynamics of nanorods* | *Controlling nucleation in nanomaterial synthesis* | *High pressure phase stabilization and DSC studies of nanomaterials* | *Stabilization of nanoparticles by polymers* | *Sonochemical synthesis of nanometals* |
| S-8 | SLO-1 | *Thermodynamics of nanoclusters* | *Controlling growth in nanomterial synthesis* | *TGA studies of nanomaterials* | *Stabilization of nanoparticles by mesogenes* | *Synthesis of nanosized hydroxides using sonochemical method* |
| | SLO-2 | *Kinetic versus thermodynamic stability* | *Controlling aggregation of nanoparticles* | *Solid solutions* | *Reactions of rare-earth elements activity, selectivity and size effect* | *Core-shell synthesis of semiconductor nanocrystals* |
| S-9 | SLO-1 | *Understanding the thermodynamics at nanoscale* | *Stability of colloidal dispersions* | *Congruence in solid solutions* | *Reactions at superlow temperatures* | *Electrochemical synthesis of nanoparticles* |
| | SLO-2 | *Factors affecting thermodynamics at nanoscale* | *Breaking matter into pieces* | *Phase change and applications of nanosystems* | *Reactions of silver particles of various sizes and shapes* | *Photochemical synthesis of nanoparticles* |

| | | |
|---|---|---|
| Learning Resources | *1. Ben Rogers, Jesse Adams, SumithaPennathur,Nanotechnology – Understanding small systems, 3rd ed., CRC press, 2017* | *2. Nils O Peterson, Foundations for Nanoscience and Nanotechnology, CRC press, 2017* |

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

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

| Course Designers | | |
|---|---|---|
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| *1. Dr. 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. Nagesh Kini, Thermax, Pune, Maharastra, nagesh.kini@gmail.com* | *2. Prof. G. Ranga Rao, Department of Chemistry, IITM Chennai, grrao@iitm.ac.in* | *2. Dr. S. HariniPriya, SRMIST* |

| Course Code | 18NTC102T | Course Name | QUANTUM MECHANICS FOR NANOTECHNOLOGISTS | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 0 | 3 |

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

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Utilize the concept of old and new Quantum Mechanics* |
| CLR-2 : | *Analyze the bound and scattering states* |
| CLR-3 : | *Utilize quantum physics behind applications - Nanodimension* |
| CLR-4 : | *Solve the many body problems using various assumptions* |
| CLR-5 : | *Identify the implications of quantum theory and approximations at nanoscale* |
| CLR-6 : | *Utilize the basis of quantum mechanics and get acquainted with its applications* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1: Level of Thinking (Bloom) | 2: Expected Proficiency (%) | 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | 2: Problem Analysis | 3: Design & Development | 4: Analysis, Design, Research | 5: Modern Tool Usage | 6: Society & Culture | 7: Environment & Sustainability | 8: Ethics | 9: Individual & Team Work | 10: Communication | 11: Project Mgt. & Finance | 12: Life Long Learning | 13: PSO - 1 | 14: PSO - 2 | 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | *Explain the basics of Quantum Mechanics* | 2 | 80 | 75 | M | M | H | M | M | M | M | H | H | H | M | H | H | H | M |
| CLO-2 : | *Apply Quantum Mechanics in low-dimensional systems* | 2 | 80 | 70 | H | M | H | H | M | M | M | H | M | H | M | H | M | M | M |
| CLO-3 : | *Perform approximation methods to solve problems in nanoscale* | 2 | 75 | 70 | M | M | H | M | H | H | H | H | H | H | H | M | H | H | H |
| CLO-4 : | *Gain expertise in processes based on quantum phenomena* | 2 | 80 | 75 | M | H | H | H | M | H | H | H | M | H | M | H | H | H | H |
| CLO-5 : | *Solve problems using quantum mechanics* | 2 | 80 | 70 | H | M | M | M | H | M | M | H | H | H | M | H | H | H | H |
| CLO-6 : | *Analyze the basis of quantum mechanics and get acquainted with its applications* | 2 | 80 | 70 | M | H | M | H | H | M | M | H | H | H | M | H | H | H | H |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Old quantum mechanics, wave particle duality* | *Classical interpretation of scattering state* | *Energy eigen functions and eigen values with precession coordinates* | *Principle of variational method* | *Two particle system's Schrödinger equation* |
| | SLO-2 | *Heisenberg uncertainty principle* | *Quantum interpretation of scattering State* | *Infinite well potential in one dimensions* | *Proof of variational method and implementation* | *Derivation of two particle system's Schrödinger equation* |
| S-2 | SLO-1 | *Generalized Heisenberg uncertainty principle* | *Reflection of particles (wavefunction)* | *Numericals on infinite well potential in one and three dimensions* | *Energy eigen value in case of time independent perturbation theory for non-degenerate energy levels* | *Transformation to center of mass frame from laboratory frame* |
| | SLO-2 | *Ehrenfest theorem* | *Transmission of Particles (wavefunction)* | *Quantum confinement effect in nanoscale* | *Energy eigen value in case of time independent perturbation theory for non-degenerate energy levels (quantitative approach)* | *Exchange operator* |
| S-3 | SLO-1 | *Linear vector space* | *Rectangular potential barrier ($E<V_0$): quantitative* | *Finite Well Potential, Delta potential* | *Eigen function in case of time independent perturbation theory for non-degenerate energy levels* | *Symmetrization of wave function* |
| | SLO-2 | *Hilbert space* | *Rectangular potential barrier ($E>V_0$)* | *Eigen values, Schrödinger equation in spherical coordinates* | *Eigen function in case of time independent perturbation theory for non-degenerate energy levels(quantitative approach)* | *Antisymmetric wave function* |
| S-4 | SLO-1 | *Statistical interpretation, stationary states* | *Transmission probability plot as a function of energy ofparticle* | *Angular equation* | *Energy eigen value in case of Time independent perturbation theory for degenerate energy levels* | *Bosons and Fermions* |
| | SLO-2 | *Orthogonal wave function* | *Numericals in rectangular potential barrier* | *Introduction on radial equation* | *Quantitative approach of energy eigen value in case of Time independent perturbation theory for* | *Exchange forces* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | degenerate energy levels | |
| S-5 | SLO-1 | *Normalization of wave function* | *Tunneling effect* | *Derivation of radial equation* | *Eigen function in case of time dependent perturbation theory for two-level systems* | *Solids, free electron gas* |
| | SLO-2 | *Hermitian operator* | *Relation of tunneling with nanotechnology* | *Infinite spherical well* | *Quantitative approach of eigen Function in case of Time dependent perturbation theory for two-level systems* | *Band structure of solids* |
| S-6 | SLO-1 | *Properties of Hermitian operator* | *Alpha-particle emission* | *Numerical on infinite spherical well* | *Sinusoidal perturbations* | *Quantum scattering theory* |
| | SLO-2 | *Commutation* | *Failure of Classical Mechanics to explain Alpha-particle emission* | *Ground state properties of hydrogen atom* | *Sinusoidal perturbations (quantitative approach)* | *Quantum scattering theory (quantitative approach)* |
| S-7 | SLO-1 | *Energy eigen value equation* | *Derivation on Alpha-particle emission* | *Angular momentum* ($L_x$,$L_y$,$L_z$) | *Incoherent perturbation* | *Differential and total cross sections* |
| | SLO-2 | *Boundary condition of wavefunction* | *Numericals in particle emission* | *Angular momentum* ($L_x$,$L_y$,$L_z$) *in spherical coordinate* | *Role of incoherent perturbation* | *Differential and total cross sections (quantitative approach)* |
| S-8 | SLO-1 | *Schrödinger's time dependent wave equations* | *Resonant tunneling* | *Generalized angular momentum* ($J_x$,$J_y$,$J_z$), *Eigen values* | *Transition rate* | *Green's functions* |
| | SLO-2 | *Schrödinger's time independent wave equations* | *Applications of resonant tunneling* | *Eigen values of momentum operator* | *Transition rate role is perturbation* | *Born approximation* |
| S-9 | SLO-1 | *Schrödinger's representation* | *Negative differential resistance* | *Spin ½, spin for two particle system* | *Adiabatic approximations (elementary concepts)* | *Applications in nanotechnology* |
| | SLO-2 | *Heisenberg representation, interaction picture* | *Negative differential resistance in 2D materials* | *Role of spin in nanospintronics* | *Sudden approximations (elementary concepts)* | *Overall role and implication of quantum phenomena in nanotechnology* |

| | | |
|---|---|---|
| Learning Resources | 1. *G. Aruldhas, Quantum Mechanics, 2nd ed., PHI, 2013*<br>2. *David J. Griffiths, Introduction to Quantum Mechanics, 2nd ed., Pearson, 2009* | 3. *Ajoy Ghatak, S. Lokanathan, Quantum Mechanics, 5th ed., Macmillan, 2009*<br>4. *Bransden B.H., JoachainC.J. Quantum Mechanics, 2nd ed., Pearson, 2007* |

Learning Assessment

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

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

Course Designers

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

| Course Code | 18NTC103L | Course Name | NANOSCALE MATERIALS LABORATORY | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 0 | 0 | 2 | 1 |

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

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Analyze the chemical properties of nanostructured materials based on their size* |
| CLR-2 : | *Utilize microscopes to view the morphology and spectrometers to find the absorbance of the nanomaterial* |
| CLR-3 : | *Demonstrate various synthesis methods for nanomaterials preparation* |
| CLR-4 : | *Utilize the characterization techniques and calculate the size and bandgap* |
| CLR-5 : | *Analyze the optical and magnetic properties of the nanomaterials* |
| CLR-6 : | *Compare the green synthesis and chemical reduction methods* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1 | Learning 2 | Learning 3 | PLO 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Level of Thinking (Bloom) | Expected Proficiency (%) | Expected Attainment (%) | Engineering Knowledge | Problem Analysis | Design & Development | Analysis, Design, Research | Modern Tool Usage | Society & Culture | Environment & Sustainability | Ethics | Individual & Team Work | Communication | Project Mgt. & Finance | Life Long Learning | PSO - 1 | PSO - 2 | PSO - 3 |
| CLO-1 : | *Perform various experimental methods for nanoparticles synthesis* | *2* | *80* | *75* | *M* | *M* | *H* | *H* | *M* | *M* | *M* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *M* |
| CLO-2 : | *Analyze the role of chemistry innanoparticle synthesis* | *2* | *80* | *70* | *M* | *H* | *H* | *H* | *M* | *M* | *M* | *H* | *M* | *H* | *M* | *H* | *M* | *M* | *M* |
| CLO-3 : | *Analyze and interpret data in determining the properties of materials* | *2* | *75* | *70* | *H* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* |
| CLO-4 : | *Describe the behavior of nanomaterials based on its chemistry* | *2* | *80* | *75* | *M* | *M* | *H* | *H* | *M* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *M* |
| CLO-5 : | *Identify the mechanism of different chemical synthesis routes* | *2* | *80* | *70* | *H* | *M* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-6 : | *Perform various characterizations of nanomaterials* | *2* | *80* | *75* | *H* | *H* | *H* | *H* | *H* | *M* | *M* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |

| Duration (hour) | | 6 | 6 | 6 | 6 | 6 |
|---|---|---|---|---|---|---|
| S 1-2 | SLO-1<br>SLO-2 | *Introduction to the basics of laboratory* | *Synthesis of gold nanoparticles by chemical reduction Determination of absorption coefficient using UV-Vis spectrometer* | *Synthesis of photocatalytic solution using co-precipitation method* | *Cryochemical synthesis of metal nanoparticles anddetermination of particle size using UV-Vis spectrometer* | *Synthesis of iron oxide nanoparticles using precipitation method Scherrer formula to determine the crystallite size of nanoparticle using X-ray diffraction technique* |
| S 3-4 | SLO-1<br>SLO-2 | *Synthesis of zinc sulfide quantum dot using co-precipitation method Determination of optical bandgap using UV-Vis spectrometer* | *Synthesis of ferro fluids using chemical precipitation Determination of zeta potential of aqueous dispersion at different pH conditions* | *Synthesis of nanoparticles loaded polymer fibers using electrospinning technique* | *Preparation of nanoparticles using sonochemical method and elemental identification using XRF analysis* | *Determination of pH of unknown solution* |
| S 5-6 | SLO-1<br>SLO-2 | *Synthesis of silica nanospheres using stober's method* | *Synthesis of metal oxide nanoparticles using sol-gel technique* | *Repeat/revision of experiments* | *Fabrication of polymer membrane using phase inversion technique and characterization using scanning electron microscope (SEM) technique* | *Thin film preparation by spin coating technique and to determinethe dislocation density and strain of given sample by XRD method* |

| | | |
|---|---|---|
| Learning Resources | 1. *Nanoscale chemistry laboratory course manual, 2016*<br>2. *Kenneth J. Klabunde, Nanoscale Materials in Chemistry, WileyInterscience publications,2001*<br>3. *Vincenzo Turco Liveri, Controlled Synthesis of Nanoparticles in Microheterogeneous Systems,Springer,2006* | 4. *L.H. Sperling, Introduction to Physical Polymer Science, Wiley Inter science, 2006*<br>5. *http://chemistry.beloit.edu/classes/Chem150/index.html* |

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

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

| Course Designers | | |
|---|---|---|
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| *1. Dr. 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. S. HariniPriya, SRMIST* |

| Course Code | 18NTC104T | Course Name | THERMODYNAMICS AND STATISTICAL MECHANICS | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 0 | 3 |

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

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Utilize the basic principles and laws of thermodynamics* |
| CLR-2 : | *Identify the thermodynamic properties of pure substances and different kinds of equilibrium* |
| CLR-3 : | *Utilize the concept of ensembles and classical statistics* |
| CLR-4 : | *Analyze the concepts of quantum statistics* |
| CLR-5 : | *Analyze the principles of nanothermodynamics* |
| CLR-6 : | *Apply the concepts of Non-equilibrium thermodynamics to Nanoscale systems* |

| | | Learning | | | Program Learning Outcomes (PLO) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Level of Thinking (Bloom) | Expected Proficiency (%) | Expected Attainment (%) | Engineering Knowledge | Problem Analysis | Design & Development | Analysis, Design, Research | Modern Tool Usage | Society & Culture | Environment & Sustainability | Ethics | Individual & Team Work | Communication | Project Mgt. & Finance | Life Long Learning | PSO - 1 | PSO - 2 | PSO - 3 |
| CLO-1 : | *Describe various thermodynamic processes and concepts explained by laws* | *2* | *80* | *75* | *M* | *H* | *H* | *H* | *M* | *M* | *L* | *M* | *M* | *H* | *L* | *H* | *H* | *H* | *H* |
| CLO-2 : | *Analyze the concepts of enthalpy, entropy, chemical potential, fugacity* | *2* | *80* | *70* | *H* | *M* | *H* | *H* | *M* | *M* | *M* | *H* | *M* | *H* | *L* | *M* | *M* | *M* | *M* |
| CLO-3 : | *Describe the postulates of statistical mechanics* | *2* | *75* | *70* | *M* | *M* | *H* | *M* | *H* | *H* | *L* | *M* | *H* | *M* | *M* | *H* | *H* | *H* | *H* |
| CLO-4 : | *Enumerate on Bose-Einstein condensation and Fermi gas* | *2* | *80* | *75* | *M* | *H* | *M* | *H* | *H* | *M* | *M* | *H* | *M* | *H* | *L* | *M* | *H* | *H* | *H* |
| CLO-5 : | *Describe the concept of Hill's nanothermodynamics* | *2* | *80* | *70* | *H* | *H* | *H* | *H* | *M* | *H* | *L* | *M* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-6 : | *Analyze the fluctuations in small systems* | *2* | *80* | *75* | *M* | *H* | *H* | *H* | *M* | *M* | *L* | *M* | *M* | *H* | *L* | *H* | *H* | *H* | *H* |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Properties of a thermodynamic system-concept of system and boundaries* | *Thermodynamic properties of pure substances in solid, liquid, vapor phases* | *Fundamentals of statistical physics-microscopic approach* | *Quantum statistics for identical particles* | *Thermodynamics of small systems and Gibbs equation for nanosystems* |
| | SLO-2 | *Concept of continuum* | *Phase diagrams of a pure substance* | *Concept of phase space* | *Distinguishable and indistinguishable particles* | *Features of Hill's nanothermodynamics* |
| S-2 | SLO-1 | *Thermodynamic equilibrium* | *Gibb's phase rule* | *Concept of gamma space and μ space* | *Grand canonical ensemble* | *Comparison with classical equilibrium thermodynamics* |
| | SLO-2 | *Path and point functions* | *Different kinds of equilibrium* | *Volumes in phase space* | *Determination of Gibbs factor* | *Nanoensemble and its thermodynamic parameters* |
| S-3 | SLO-1 | *Extensive and intensive properties* | *Entropy and energy criteria for equilibrium* | *Difference between microstate and macrostate* | *Photons in an oven* | *Gibbs energy of single-component nanoparticles* |
| | SLO-2 | *Zeroth law of thermodynamics and concept of temperature* | *Ideal gas equation of a state* | *Most probable distribution* | *Principle of detailed balance* | *Fluctuations in small systems* |
| S-4 | SLO-1 | *Energy transfer by heat and work* | *Deviation from ideal gas behavior* | *Equal apriori probability and ergodicity* | *Energy flux* | *Jarzyanki's inequality* |
| | SLO-2 | *Isothermal process* | *VanderWaal's equation of state* | *Ensemble averages* | *Bose gas* | *Classical nucleation thermodynamics* |
| S-5 | SLO-1 | *Adiabatic process* | *Law of corresponding states* | *Derivation of Boltzmann equation S=KlnW* | *Structureless Bose gas* | *Phase diagrams of small systems* |
| | SLO-2 | *Isochoric process* | *Determination of critical constants* | *Thermodynamics of Ensembles* | *Bose Einstein distribution law for bosons* | *Thermodynamics of metastable phase nucleation at the nanoscale* |

| | | | | | | |
|---|---|---|---|---|---|---|
| S-6 | SLO-1 | *Isobaric process* | *Temperature and entropy (T-dS) relations* | *Canonical Ensemble and its thermodynamic parameters* | *Bose-Einstein condensation* | *Nanoscale thermodynamic approach in CVD diamond* |
| | SLO-2 | *First law of thermodynamics* | *Helmholtz Function Gibbs Function* | *Microcanonical Ensemble and its thermodynamic parameters* | *Observation of BECs of cold atoms* | *Nucleation thermodynamics of cubic boron nitride* |
| S-7 | SLO-1 | *Specific Heat at constant Pressure and constant volume* | *General Thermodynamic equations* | *Stirling Approximation* | *Superfluid liquid helium* | *Nonextensivity of nanosystems* |
| | SLO-2 | *Second law of thermodynamics* | *Joule-Thomson coefficient* | *Classification of statistical distributions* | *Fermi gases for electrons* | *Nonintensivity of nanosystems* |
| S-8 | SLO-1 | *Reversibility, irreversibility and Carnot cycle* | *Co-efficient of volume expansion* | *Maxwell-Boltzmann distribution for classical particles* | *Structureless degenerate Fermi gas* | *Principles of non-equilibrium thermodynamics* |
| | SLO-2 | *Reversed Carnot Cycle as a refrigeration cycle* | *Adiabatic and isothermal compressibility* | *Concept of degrees of freedom* | *Fermi Dirac distribution law for fermions* | *Concept of Pseudo equilibrium and benard cells* |
| S-9 | SLO-1 | *Third law of thermodynamics* | *Clapeyron equations* | *Law of equipartition of energy* | *Fermions at low temperatures* | *Out of equilibrium nanosystems* |
| | SLO-2 | *Unattainability of absolute zero* | *Clapeyron-Clausius equations* | *Specific heat capacities of gases* | *Fermi temperature and degenerate pressure* | *Cooling by heating in nonequilibrium nanosystems* |

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

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

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

| Course Designers | | |
|---|---|---|
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| *1. Dr. D.K. Aswal, National Physical Laboratory, New Delhi, dkaswal@nplindia.org* | *1. Prof. V. Subramaniam, IITM, Chennai, manianvs@iitm.ac.in* | *1. Dr. Annie Sujatha, SRMIST* |
| *2. Dr. Vinay Kumar Gupta, National Physical Laboratory, New Delhi, guptavinay@nplindia.org* | *2. Dr. R.Gnanamoorthy,IITM,Chennai, gmoorthy@iitm.ac.in* | *2. Dr. BibhuRanjanSarangi, SRMIST* |

| Course Code | 18NTC105T | Course Name | BIOLOGICAL PRINCIPLES FOR NANOSCALE SCIENCE | 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 | Nanotechnology | Data Book / Codes/Standards | Nil | | |

| Course Learning Rationale (CLR): | The purpose of learning this course is to: |
|---|---|
| CLR-1 : | Know about various biological molecules |
| CLR-2 : | Understand the structure and functions of various biological membranes and transportation across membrane |
| CLR-3 : | Know about various molecular biology principles |
| CLR-4 : | Acquire insight into bioenergetic cycles |
| CLR-5 : | Gain knowledge about various gene transfer technologies |
| CLR-6 : | Understand the basic biological principles and mechanisms |

| Course Learning Outcomes (CLO): | At the end of this course, learners will be able to: | Learning 1: Level of Thinking (Bloom) | 2: Expected Proficiency (%) | 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | 2: Problem Analysis | 3: Design & Development | 4: Analysis, Design, Research | 5: Modern Tool Usage | 6: Society & Culture | 7: Environment & Sustainability | 8: Ethics | 9: Individual & Team Work | 10: Communication | 11: Project Mgt. & Finance | 12: Life Long Learning | 13: PSO - 1 | 14: PSO - 2 | 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | Describe importance of biological molecules | 2 | 80 | 75 | H | H | H | H | H | M | H | H | H | H | M | H | H | H | M |
| CLO-2 : | Analyze the various biological membranes and transportation process across membrane. | 2 | 80 | 70 | H | M | H | H | M | M | M | H | M | H | M | H | M | M | M |
| CLO-3 : | Describe the obtained knowledge on molecular biology | 2 | 75 | 70 | H | M | M | H | H | H | H | H | H | H | M | M | H | H | H |
| CLO-4 : | Analyze the techniques of Bio energetics | 2 | 80 | 75 | H | H | H | H | H | H | H | H | M | H | H | H | H | H | H |
| CLO-5 : | Apply measuring the concept of gene transfer technology | 2 | 80 | 70 | H | H | H | H | H | H | H | H | H | H | H | H | H | H | M |
| CLO-6 : | Describe various biological principles and mechanisms | 2 | 80 | 75 | H | H | H | H | H | M | H | H | H | H | M | H | H | H | M |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | Carbohydrates: classification | Models of membrane | DNA replication | Principles of bioenergetics | Introduction of foreign genes into animal cells |
| | SLO-2 | Configurations and conformations | Membrane structure | Enzymology of DNA replication | Biological Oxidation reduction reactions | Transgenic technology |
| S-2 | SLO-1 | Sugar derivatives – structural polysaccharides | Erythrocytes | Transcription | Carbohydrate metabolism | Transgene transfer techniques |
| | SLO-2 | Storage polysaccharides | Erythrocytes membrane | Types of RNA molecules | Glycolysis | DNA Microinjection |
| S-3 | SLO-1 | Amino acids: general properties | Plant cell | RNA splicing | Glucogenesis | Embryonic stem cell mediated gene transfer |
| | SLO-2 | Peptide bonds | Cell membrane | Splicing mechanism | Gluconeogenesis | Retrovirus mediated gene transfer |
| S-4 | SLO-1 | Essential amino acids | Bacterial cell | Translation | Glycogenolysis | Plant tissue culture |
| | SLO-2 | Non-essential amino acids | Bacterial cell wall | Genetic code | Pentose-phosphate pathway | Totipotency |
| S-5 | SLO-1 | Lipids: classification | Membrane lipids | Codon-Anticodon | Coordinated regulation of glycolysis and gluconeogenesis | Transgenic plants |
| | SLO-2 | Fatty acids | Structure and function | Codon-Anticodon interaction | Citric acid cycle | Agrobacterium mediated gene transfer |
| S-6 | SLO-1 | Biological significance of lipids | Membrane proteins | Ribosomes | Reactions of the citric acid cycle | Ti plasmid |
| | SLO-2 | Functions of lipids | Membrane carbohydrates | Protein synthesis | Glyoxylate cycle | Vectors |
| S-7 | SLO-1 | Nucleic acid | Thermodynamics of transport | Posttranslational Modification of Proteins | Electron transport chain | Animal cell culture |
| | SLO-2 | Chemical structure and base composition | Kinetics of transport | Difference between protein synthesis in | Oxidative phosphorylation | Basic tissue culture techniques |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | eukaryotic and prokaryotic cells | | |
| S-8 | SLO-1 | *Double helical structures* | *Mechanism of transport* | *Protein structures* | *Electron-Transfer Reactions in mitochondria* | *Concepts of transgenic animal technology* |
| | SLO-2 | *Supercoiled DNA* | *Active and passive transport* | *Primary, secondary, tertiary and quaternary structures of protein* | *Proton pumping* | *Strategies for the production of transgenic animals and their importance* |
| S-9 | SLO-1 | *Vitamins, water and fat soluble vitamins* | *ATP-driven active transport* | *Gene regulation* | *ATP molecule* | *Gene therapy* |
| | SLO-2 | *Deficiency and diseases* | *Ion gradient driven active transport* | *Concept of operon* | *ATP synthesis mechanism* | *Clinical significance* |

| | | |
|---|---|---|
| Learning Resources | 1. *David L Nelson, Michael M. Cox, Lehninger Principles of Biochemistry, 7th ed., WH Freeman & Co, 2012*<br>2. *Donald Voet, Judith G. Voet, Biochemistry, Wiley, 2003*<br>3. *David Freifelder, Molecular Biology, 2nd ed., Narosa, 2004* | 4. *George M Malacinski, Freifelders Essentials of Molecular Biology, 4th ed., Jones & Bartlett, 2015*<br>5. *S.B. Primrose and R.M. Twyman, Principles of Gene Manipulation and Genomics, 7th ed., Wiley, 2006* |

Learning Assessment

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

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

Course Designers

| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
|---|---|---|
| 1. Mr. K. Chandru, Trivitron Healthcare Pvt. Ltd. Chennai, chandru.k@trivitron.com | 1. Prof. K. Chandraraj, IITM, Chennai, kcraj@iitm.ac.in | 1. Dr. G. Devanand Venkatasubbu, SRMIST |
| 2. Dr. Achuth Padmanaban, Baylor College of Medicine, USA, achuthz@gmail.com | 2. Dr. P. Balasubramanian, NIT Rourkela, biobala@nitrkl.ac.in | 2. Mrs. J. Jositta Sherine, SRMIST |

| Course Code | 18NTC106T | Course Name | DESIGN AND SYNTHESIS OF NANOMATERIALS | 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 | *Nanotechnology* | Data Book / Codes/Standards | *Nil* | | |

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Gain insight into fundamental principles involved in the growth of nanomaterials* |
| CLR-2 : | *Familiarize with zero dimensional materials and their synthesis techniques* |
| CLR-3 : | *Know the concept of one dimensional materials and fabrication procedures* |
| CLR-4 : | *Understand the fundamentals of thin films growth* |
| CLR-5 : | *Acquire knowledge on special nanomaterials and their fabrication methods* |
| CLR-6 : | *Evaluate the potential of various growth approaches in designing nanomaterials* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1: Level of Thinking (Bloom) | Learning 2: Expected Proficiency (%) | Learning 3: Expected Attainment (%) | 1 Engineering Knowledge | 2 Problem Analysis | 3 Design & Development | 4 Analysis, Design, Research | 5 Modern Tool Usage | 6 Society & Culture | 7 Environment & Sustainability | 8 Ethics | 9 Individual & Team Work | 10 Communication | 11 Project Mgt. & Finance | 12 Life Long Learning | 13 PSO - 1 | 14 PSO - 2 | 15 PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | *Describe the fundamental concepts involved in nanoparticle synthesis* | 2 | 80 | 75 | M | H | H | M | M | M | M | H | M | H | L | H | H | H | M |
| CLO-2 : | *Identify various synthesis techniques involved in synthesis of quantum dots and nanoparticles* | 2 | 80 | 70 | H | M | H | H | M | M | M | H | H | H | M | H | M | M | M |
| CLO-3 : | *Distinguish nanowires, nanorods and nanotubes from bulk materials and 1D nanostructures* | 2 | 75 | 70 | M | H | H | M | H | H | H | M | M | H | L | M | H | H | H |
| CLO-4 : | *Apply the knowledge of thin films growth using PVD and CVD techniques* | 2 | 80 | 75 | H | M | H | H | M | H | M | H | M | M | M | H | H | H | H |
| CLO-5 : | *Describe the concept of self-assembly, biosynthesis and green synthesis of nanomaterials* | 2 | 80 | 70 | M | H | H | M | H | M | H | H | M | H | L | H | H | H | H |
| CLO-6 : | *Design experiments on the growth of nanomaterials* | 2 | 80 | 75 | M | H | H | M | M | M | M | H | M | H | L | H | H | H | M |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Introduction to nanomaterials* | *Classification of nanoparticle synthesis techniques* | *1-Dimensional nanostructures: introduction* | *Fundamentals of thin film growth* | *Self assembly* |
| | SLO-2 | *Nanomaterials classification based on dimension* | *Top down and bottom up approach of nanoparticles synthesis* | *Various examples of 1D nanostructures* | *Fundamentals of thinfilm growth (Quantitative approach)* | *Self-assembled monolayers* |
| S-2 | SLO-1 | *Surface energy* | *Nanoparticle synthesis by mechanical alloying* | *Spontaneous growth of 1D nanostructures* | *Physical vapor deposition* | *Monolayers of organosilicon* |
| | SLO-2 | *Surface energies of different surfaces of FCC structure* | *Nanoparticle synthesis by mechanical milling* | *Evaporation (dissolution) condensation growth* | *Evaporation* | *Monolayers of alkanethiols and sulfides* |
| S-3 | SLO-1 | *Chemical potential as a function of surface curvature* | *Vapor-phase synthesis of nanoparticles* | *Fundamentals of evaporation (dissolution) condensation growth* | *Molecular beam epitaxy (MBE) - principle* | *Langmuir-Blodgett (LB) technique* |
| | SLO-2 | *Gibbs-Thompson relation* | *Inert gas condensation of nanoparticles* | *quantitative approach* | *Epitaxial growth of thin films using MBE* | *Monolayer thin film formation using LB technique* |
| S-4 | SLO-1 | *Concept of Ostwald ripening* | *Plasma-based synthesis of nanoparticles* | *Fundamental aspects of (vapour-liquid-solid) VLS growth* | *Sputtering and Sputtering targets* | *Graphene preparation methods* |
| | SLO-2 | *Role of Ostwald ripening in nanoparticle synthesis* | *Spark plasma method for nanoparticles synthesis* | *Fundamental aspects of SLS growth* | *DC and RF sputtering* | *Mechanical exfoliation* |
| S-5 | SLO-1 | *Fundamentals of homogeneous nucleation* | *Flame-based synthesis of particles* | *Au-Si phase diagram* | *Chemical vapor deposition (CVD)* | *Liquid phase exfoliation* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | SLO-2 | *Critical radius and critical energy* | *Combustion synthesis of nanoparticles* | *VLS growth of various nanowires* | *Basic chemical reactions in CVD* | *Role of intercalation in graphene exfoliation* |
| S-6 | SLO-1 | *Effect of temperature on critical size and critical free energy* | *Spray pyrolysis based synthesis of nanoparticles* | *Control of the size of the nanowires* | *Reaction kinetics in CVD* | *Large area synthesis of graphene* |
| | SLO-2 | *Process of nucleation and subsequent growth* | *Nanoparticle nucleation and growth in spray pyrolysis* | *Catalyst size dependent nanowires growth* | *Transport phenomena* | *CVD synthesis of graphene* |
| S-7 | SLO-1 | *Growth controlled by diffusion* | *Solution processing of nanoparticles* | *Various precursor sand catalysts used for nanowires growth* | *Atomic layer deposition (ALD)* | *Biological synthesis of nanoparticles* |
| | SLO-2 | *Growth controlled by diffusion (quantitative approach)* | *Sol-gel processing* | *SLS growth of various nanowires* | *Self-limiting growth using ALD* | *Nanoparticles synthesis using viruses* |
| S-8 | SLO-1 | *Growth controlled by surface process* | *Kinetically confined synthesis of nanoparticles* | *Stress induced recrystallization growth* | *Electrochemical deposition* | *Nanoparticles synthesis using bacteria* |
| | SLO-2 | *Growth controlled by surface process (quantitative approach)* | *Nanoparticle synthesis using micelles* | *Template based synthesis of NWs,* | *Electrochemical deposition – Nernst equation and film growth* | *Role of bacteria in nanoparticle synthesis* |
| S-9 | SLO-1 | *Fundamentals of heterogeneous nucleation* | *Nanoparticle synthesis using microemulsion* | *Template filling* | *Sol-Gel Films - spin coating* | *Green chemistry of nanoparticles* |
| | SLO-2 | *Fundamentals of heterogeneous nucleation (Quantitative approach)* | *Aerosol synthesis of nanoparticles* | *Nanofibres producion using Electrospinning* | *Dip coating, Electrophoretic deposition* | *Nanoparticles synthesis using plant extract* |

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

Learning Assessment

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

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

Course Designers

| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
|---|---|---|
| *1. Dr. M. Krishna Surendra, Saint-Gobain Research, Chennai, krishna.muvvala@saint-gobain.com* | *1. Prof. S. Balakumar, University of Madras, balakumar@unom.ac.in* | *1. Dr. E. Senthil Kumar, SRMIST* |
| *2. Dr. M. Sathish, CSIR-CECRI, Karaikudi, msathish@cecri.res.in* | 2. Prof. S. Ramaprabhu, *IIT Madras, ramp@iitm.ac.in* | *2. Dr. S. Chandramohan, SRMIST* |

| Course Code | 18NTC107J | Course Name | ADVANCED CHARACTERIZATION OF NANOMATERIALS | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 2 | 4 |

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

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Utilize the concepts of SEM, TEM, SPM, XPS, AES and SIMS to characterize nanomaterials* |
| CLR-2 : | *Utilize materials characterization techniques at the morphological, structural and chemical level* |
| CLR-3 : | *Analyze different types of nanostructures* |
| CLR-4 : | *Asses the performance of broad range of advanced characterization techniques used in nanotechnology* |
| CLR-5 : | *Apply the advanced techniques for solving problems in materials science and engineering* |
| CLR-6 : | *Demonstrate skills in the use of advanced experimental techniques* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1: Level of Thinking (Bloom) | Learning 2: Expected Proficiency (%) | Learning 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | PLO 2: Problem Analysis | PLO 3: Design & Development | PLO 4: Analysis, Design, Research | PLO 5: Modern Tool Usage | PLO 6: Society & Culture | PLO 7: Environment & Sustainability | PLO 8: Ethics | PLO 9: Individual & Team Work | PLO 10: Communication | PLO 11: Project Mgt. & Finance | PLO 12: Life Long Learning | PLO 13: PSO - 1 | PLO 14: PSO - 2 | PLO 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | *Explain the principles of optical, electron and scanning probe microscopies and photoelectron, Auger electron spectroscopic and secondary ion mass spectrometric techniques.* | 1 | 80 | 75 | H | M | H | H | H | H | H | H | M | H | L | H | H | H | H |
| CLO-2 : | *Describe the construction and operation of different characterization techniques.* | 1 | 80 | 70 | H | M | H | H | M | M | M | H | M | H | L | H | M | M | M |
| CLO-3 : | *Perform experiments using SEM, TEM, SPM, XPS, AES, SIMS and optical microscopies.* | 2 | 75 | 70 | H | H | H | H | H | H | H | H | M | H | L | H | H | H | H |
| CLO-4 : | *Apply suitable techniques for characterizing nanomaterials and devices.* | 2 | 80 | 75 | H | H | H | H | H | H | H | H | M | H | M | H | H | H | H |
| CLO-5 : | *Analyze the morphology, structure, elemental composition and chemical state of the given /synthesized nanomaterials using advanced techniques,* | 2 | 80 | 80 | H | H | H | H | H | H | H | H | M | H | L | H | H | H | H |
| CLO-6 : | *Apply skills acquired for advanced experimental characterization* | 2 | 80 | 80 | H | H | H | H | H | M | H | H | H | H | M | H | H | H | H |

| Duration (hour) | | 15 | 15 | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Image formation, numerical aperture resolution, effective magnification* | *Scanning electron microscopy; electron optics; imaging with electrons* | *TEM imaging system* | *Scanning probe microscopy* | *Basic principles: X-ray photoelectron spectroscopy(XPS)* |
| | SLO-2 | *Brightness and contrast, depth of field, aberrations* | *Magnetic and electrostatic lenses* | *Instrumentation of TEM* | *Scanning probe microscopy: Instrumentation* | *Auger electron spectroscopy(AES)* |
| S-2 | SLO-1 | *Instrumentation: illumination system, objective lens and eyepiece* | *Signal detection* | *Electron sources* | *Scanning tunneling microscopy, tunneling current* | *Instrumentation: XPS* |
| | SLO-2 | *Steps for optimum resolution, steps to improve depth of field* | *Detector* | *Specimen stage and specimen preparation* | *Probe tips and working environments* | *Instrumentation: AES* |
| S-3 | SLO-1 | *Imaging modes bright-field and dark-field imaging* | *Probe size and current* | *Kinematics of scattering by nucleus* | *Atomic force microscopy* | *Photoelectron spectra* |
| | SLO-2 | *Kohler illumination* | *Electron–specimen interactions* | *Electron – electron scattering* | *Cantilevers and deflection measurements* | *Auger electron spectra* |
| S 4-5 | SLO-1 SLO-2 | *Lab 1:Introduction to the basics of laboratory* | *Lab 4: Morphological study of nanostructured material using SEM* | *Lab 7: Imaging and analysis using transmission electron microscope* | *Lab 10: Tunneling measurements using scanning tunneling microscope (STM)* | *Lab 13: Interpretation of XPS spectra* |
| S-6 | SLO-1 | *Phase-contrast microscopy* | *Topographic contrast* | *Image modes: Mass–density contrast* | *Contact AFM* | *Qualitative analysis* |
| | SLO-2 | *The behavior of waves from phase objects in brightfield microscopy* | *Compositional contrast* | *Diffraction contrast, phase contrast* | *Non-contact AFM* | *Peak identification, chemical shifts, composition imaging* |

| | | | | | | |
|---|---|---|---|---|---|---|
| S-7 | SLO-1 | Properties of polarized light | Working distance and aperture size | Selected-area diffraction (SAD) and characteristics | Dynamic contact AFM | Quantitative analysis: peaks and sensitivity factors |
| | SLO-2 | Polarized-light microscopy | Acceleration voltage and probe current | Single-crystal diffraction, polycrystalline diffraction | Taping AFM | Composition depth profiling |
| S-8 | SLO-1 | Differential interference contrast microscopy and modulation contrast microscopy: DIC optical system | Astigmatism | Dark field images | Force modulation | Secondary ion mass spectrometry (SIMS): Basic principles |
| | SLO-2 | Modulation contrast microscopy | Specimen preparation | Phase control | Manipulation of atoms | Secondary ion generation |
| S 9-10 | SLO-1<br>SLO-2 | Lab 2: Optical microscope based investigation of microfabricated structures | Lab 5: SE and BSE imaging with SEM | Lab 8: Selected area electron diffraction using TEM (SAED) | Lab 11: Nanoparticle size determination using atomic force microscopy (AFM) | Lab 14: Peak identification of in AES spectra, analysis of the AES depth profile |
| S-11 | SLO-1 | Physical basis of fluorescence | Elemental imaging using EDS | High resolution images | Advanced SPM techniques | Dynamic and static SIMS |
| | SLO-2 | Fluorescence microscopy | Applications of elemental imaging | Interpretation of high resolution images | Kelvin probe force microscopy | SIMS -instrumentation |
| S-12 | SLO-1 | Confocal laser scanning microscopy: the optical principle of confocal imaging | Field emission SEM | Ultrahigh resolution TEM | Scanning capacitance microscopy | Sample handling |
| | SLO-2 | Techniques for improving imaging of nanoscale materials | Environmental SEM | Dynamic TEM | Scanning thermal microscopy | Spectrum interpretation |
| S-13 | SLO-1 | Diffraction limit | Time resolved microscopy | z-contrast imaging | Magnetic force microscopy | Element identification |
| | SLO-2 | Breaking the diffraction limit | Time resolved microscopy:Applications | Coherent and incoherent imaging | Piezoelectric force microscopy | SIMS depth profiling |
| S 14-15 | SLO-1<br>SLO-2 | Lab 3: Bioimaging using fluorescence microscopy | Lab 6: EDS for chemical identification | Lab 9: Repeat/Revision of the experiments | Lab 12: Surface morphology by STM and roughness determination by AFM | Lab 15: Analysis of SIMS profile spectra |

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

Learning Assessment

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

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

| Course Designers | | |
|---|---|---|
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| 1. Dr. N. Vijayan, CSIR-NPL, nvijayan@nplindia.org | 1. Prof. S. Balakumar, University of Madras, balakumar@unom.ac.in | 1. Dr. C. M. Navaneethan, SRMIST |
| 2. Mr.K.R. Navaneethakrishnan, GLR Laboratories Pvt Ltd | 2. Dr. N. Vijayan, CSIR-NPL, nvijayan@nplindia.org | 2. Dr. A. Karthigeyan,SRMIST |

| Course Code | 18NTC108T | Course Name | MODELING AND COMPUTATIONAL TOOLS | Course Category | C | *Professional Core* | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 0 | 3 |

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

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Know the basics of MATLAB and C++* |
| CLR-2 : | *Acquire detailed knowledge of Density Functional Theory* |
| CLR-3 : | *Utilize and gain knowledge of Molecular Dynamics* |
| CLR-4 : | *Solve in detail the Monte Carlo Method and problems* |
| CLR-5 : | *Understand the basics of modeling and computational tools* |
| CLR-6 : | *Know the materials modeling and to determine the desired properties* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1: Level of Thinking (Bloom) | Learning 2: Expected Proficiency (%) | Learning 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | PLO 2: Problem Analysis | PLO 3: Design & Development | PLO 4: Analysis, Design, Research | PLO 5: Modern Tool Usage | PLO 6: Society & Culture | PLO 7: Environment & Sustainability | PLO 8: Ethics | PLO 9: Individual & Team Work | PLO 10: Communication | PLO 11: Project Mgt. & Finance | PLO 12: Life Long Learning | PLO 13: PSO - 1 | PLO 14: PSO - 2 | PLO 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | *Execute and solve problems with the basics of computational tools* | 2 | 80 | 75 | M | M | H | H | H | M | M | H | H | H | M | H | H | H | H |
| CLO-2 : | *Utilize the principles of DFT* | 2 | 80 | 70 | H | M | H | M | M | M | M | H | M | M | M | H | M | M | M |
| CLO-3 : | *Apply the knowledge of molecular dynamics to solve problems* | 2 | 75 | 70 | M | M | H | H | H | H | H | M | M | H | M | H | H | H | H |
| CLO-4 : | *Solve and perform modeling with Monte Carlo method* | 2 | 80 | 75 | H | H | M | H | H | M | H | H | H | M | H | M | H | H | H |
| CLO-5 : | *Execute the computational codes and tools* | 2 | 80 | 70 | M | M | H | H | H | H | M | H | H | H | M | H | H | H | H |
| CLO-6 : | *Predict the physical properties from modeling and simulation* | 2 | 80 | 70 | M | H | H | H | H | M | M | M | H | H | M | H | H | H | H |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Introduction to MATLAB-Arrays and Matrices-Matrix operation* | *Introduction to MATLAB* | *Schrodinger equation* | *Classical molecular dynamics* | *Monte-Carlo method: Introductory examples* |
| | SLO-2 | *Eigen value problem* | *Arrays* | *Schrodinger equation for Many Body problem* | *Discussions on Classical molecular dynamics* | *Brief history* |
| S-2 | SLO-1 | *Solution of simultaneous equation* | *Matrices-Matrix operation* | *Born-Oppenheimer approximation* | *Tight bindingmolecular dynamics* | *Fundamental key concepts* |
| | SLO-2 | *Arithmetic operations* | *Inverse of a Matrix* | *Introduction to DFT* | *Discussions on Tight bindingmolecular dynamics* | *Transformation methods* |
| S-3 | SLO-1 | *Logical operations* | *Eigen value problem* | *Hohenberg-Kohn Theorem 1* | *The basics of molecular dynamics (MD) algorithm* | *Rejection sampling* |
| | SLO-2 | *If-else clause* | *Problems on Eigen value problem* | *Discussions on Hohenberg-Kohn theorem 1* | *Discussions with examples on MD algorithim* | *Discussions of Rejection sampling* |
| S-4 | SLO-1 | *Loop control structure and statements* | *Arithmetic operations* | *Hohenberg-Kohn Theorem 2* | *Verlet algorithms* | *Importance sampling* |
| | SLO-2 | *Break statement, Switch statement* | *Logical operations* | *Discussions on Hohenberg-Kohn theorem 2* | *Discussions Verlet algorithms* | *Discussions on Importance sampling* |
| S-5 | SLO-1 | *Self-consistent method* | *Loop control structure and statements* | *Kohn-Sham Equation* | *Predictor - Corrector algorithm* | *Integration by importance sampling-theory* |
| | SLO-2 | *Functions-data visualization in 2D and 3D* | *Break statement* | *Discussion on Kohn-Sham Equation* | *Discussions on - Corrector algorithm* | *Integration by importance sampling-example* |

| | | | | | | |
|---|---|---|---|---|---|---|
| S-6 | SLO-1 | Introduction to C++ | Switch statement | Exchange-correlation functions LDA (Basic Concept) | MD in different ensembles | Metropolis algorithm |
| | SLO-2 | Algorithms | If and else if statements | LDA (explanation of the equation) | Discussions MD in different ensembles | Discussions on Metropolis algorithm |
| S-7 | SLO-1 | Structured-programing | Functions-data visualization in 2D | Exchange-correlation functions GGA (Basic Concept) | Examples of MD simulation | Introduction to Kinetic Monte Carlo (KMC) |
| | SLO-2 | I/O statements | Examples on data visualization in 2D | GGA (explanation of the equation) | Discussions on qualitative results | Qualitative discussions and basic concept |
| S-8 | SLO-1 | Controlstatements | Functions-data visualization in 3D | Basis set | Temperature variation effects in MD | Introduction to Quantum Monte Carlo (QMC) |
| | SLO-2 | Looping (loop statement) | Examples on data visualization in 3D | Types of basis set (basic level) | Examples on Temperature variation effects in MD | Qualitative discussions and basic concept |
| S-9 | SLO-1 | Matrix: Basic matrix operations | Basic concept of Computer clusters, Master Node, Working Node | Flow chart of DFT scfprocedure | Limitations of MD | Merits and demerits of KMC and QMC |
| | SLO-2 | Basic idea of parallel programing | Bewolf and Shared memory clusters in introductory level | Discussions on Flow chart | Case study examples | Case study examples |

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

Learning Assessment

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

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

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

| Course Code | 18NTC109T | Course Name | SOLID STATE ENGINEERING | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 0 | 3 |

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

| Course Learning Rationale (CLR): | The purpose of learning this course is to: |
|---|---|
| CLR-1 : | Acquire knowledge on various chemical bonding in solids |
| CLR-2 : | Understand theory of crystal diffraction, vibrations and heat capacity |
| CLR-3 : | Describe the concept of free electron Fermi gas and transport properties |
| CLR-4 : | Classify semiconductors, metals and insulators via band theory |
| CLR-5 : | Gain knowledge on excitons, plasmons, polarons and polaritons |
| CLR-6 : | Understand the principles of Raman and optical spectroscopy |

| Course Learning Outcomes (CLO): | At the end of this course, learners will be able to: | Learning 1: Level of Thinking (Bloom) | Learning 2: Expected Proficiency (%) | Learning 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | PLO 2: Problem Analysis | PLO 3: Design & Development | PLO 4: Analysis, Design, Research | PLO 5: Modern Tool Usage | PLO 6: Society & Culture | PLO 7: Environment & Sustainability | PLO 8: Ethics | PLO 9: Individual & Team Work | PLO 10: Communication | PLO 11: Project Mgt. & Finance | PLO 12: Life Long Learning | PLO 13: PSO - 1 | PLO 14: PSO - 2 | PLO 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | Apply the principles of chemical bonding to understand elastic properties of solids | 2 | 80 | 75 | H | M | H | H | H | M | M | H | H | H | M | H | H | H | H |
| CLO-2 : | Analyze crystalline materials and their thermal properties using the concept of phonons | 2 | 80 | 70 | H | M | M | H | M | M | M | H | M | H | M | H | M | M | M |
| CLO-3 : | Utilize the Fermi-Dirac distribution function for electrical transport properties of solids | 2 | 75 | 70 | H | M | H | H | H | H | H | M | H | H | H | H | H | H | H |
| CLO-4 : | Calculate carrier concentration and mobility of metals and intrinsic and extrinsic semiconductors | 2 | 80 | 75 | M | H | H | M | H | H | H | H | H | H | M | H | H | H | H |
| CLO-5 : | Apply the concept of quasi-particles to understand the optical properties of solids | 2 | 80 | 70 | H | M | H | H | H | M | M | H | M | H | M | H | H | H | H |
| CLO-6 : | Utilize the spectroscopic concepts to analyze the properties of materials | 2 | 80 | 75 | H | M | M | H | H | M | M | H | H | H | M | H | H | M | H |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | Interatomic forces: Understanding of crystal binding | Crystal diffraction | Free electron gas | Nearly free electron model | Electronic interband transitions |
| | SLO-2 | Bonding in solids | Bragg's law | Energy levels of free electron gas in one dimension | Nearly free electron model (Quantitative approach) | Direct and indirect transitions |
| S-2 | SLO-1 | Van der Waals interaction | Reciprocal lattice vectors and Brillouin Zones (BZ) | Fermi- Dirac distribution | Origin and magnitude of the energy gap | Concept of excitons |
| | SLO-2 | Quantitative approach of London interaction | BZ of square lattice and oblique lattice | Effect of temperature on the Fermi – Dirac distribution function | Bloch function | Energy level diagram of excitons |
| S-3 | SLO-1 | Equilibrium lattice constants | Vibration of crystals with monoatomic basis | Free electron gas in three dimensions (Quantitative approach) | Classification of solids using band gap | Frenkelexcitons |
| | SLO-2 | Cohesive energy | Dispersion relation | Fermi energy, density of states | Metals, semiconductors and insulators | Frenkelexcitons in alkali halides and molecular crystals |
| S-4 | SLO-1 | Nature of bonding in ionic crystals | Group velocity | Heat capacity of the free electron gas | Direct and indirect band gap semiconductors | Mott-Wannierexcitons |
| | SLO-2 | Madelung constant | Quantization of elastic waves (concept of phonon) | Heat capacity of the free electron gas (Quantitative approach) | Relation between bandgap energy, photon and phonon energy | Modified Rydberg's equation |
| S-5 | SLO-1 | Madelung energy | Phonon heat capacity-Planck's distribution | Electrical conductivity | Concept of holes in semiconductors | Quantitative approach for Raman effect |

| | | | | | | |
|---|---|---|---|---|---|---|
| | SLO-2 | *Evaluation of Madelung constant* | *Normal modes* | *Ohm's law* | *Effective mass* | *Application: Raman effect in solids* |
| S-6 | SLO-1 | *Covalent bonding* | *Phonon -density of states (modes) in one dimensions* | *Electrical resistivity* | *Intrinsic carrier concentration* | *Concept of plasmons in metals* |
| | SLO-2 | *Metallic and hydrogen bonding* | *Phonon- density of states (modes) in three dimensions* | *Matthiessen's rule* | *Intrinsic carrier concentration – quantitative approach* | *Plasma frequency* |
| S-7 | SLO-1 | *Hooke's law in solids* | *Debye model for density of states (modes)* | *Motion of electron in magnetic field* | *Impurity conductivity: doping* | *Concept of polarons* |
| | SLO-2 | *Elastic strain components (Quantitative treatment)* | *Cutoff frequency in Debye solids* | *Cyclotron frequency* | *Donor and acceptor states* | *Concept of polaritons* |
| S-8 | SLO-1 | *Dilation in solids* | *Debye – $T^3$ law* | *Hall effect: quantitative approach* | *Zener tunneling, Zener breakdown and Zener diodes* | *Defects in solids – lattice vacancies* |
| | SLO-2 | *Elastic stress components* | *Debye – $T^3$ law (Quantitative approach)* | *Hall coefficient* | *Avalanche bvreakdown and Avalanche diodes* | *Schottky and Frenkel defects* |
| S-9 | SLO-1 | *Elastic compliance components* | *Einstein model for density of states* | *Thermal conductivity of metals: Wiedemann-Franz law* | *Super lattices and quantum wells* | *Color centers: F centers* |
| | SLO-2 | *Elastic stiffness components* | *Einstein model for density of states – quantitative approach* | *Lorentz number* | *Multi Quantun well light emitting diodes (MQW-LEDs)* | *Other centers in alkali halides* |

| | | |
|---|---|---|
| Learning Resources | 1. *C. Kittel, Introduction to Solid State Physics, 8th ed., Wiley, 2015*<br>2. *Fundamentals of Solid State Engineering, ManijehRazeghi, Kluwer Academic Publishers, 2002* | 3. *Solid State Electronic Devices, Ben. G. Streetman amd Sanjay Banerjee, 7thEdison, Pearson, 2006* |

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

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

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

# ACADEMIC CURRICULA

## Professional Core Courses

## NANOTECHNOLOGY

## Regulations - 2018

## SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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

Kattankulathur, Kancheepuram, Tamil Nadu, India

| Course Code | 18NTC201T | Course Name | NANOPHOTONICS | 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 | *Nanotechnology* | Data Book / Codes/Standards | | *Nil* | |

| Course Learning Rationale (CLR): | The purpose of learning this course is to: |
|---|---|
| CLR-1 : | *Understand the fundamentals of light interaction with nanoscale materials* |
| CLR-2 : | *Learn the basic concepts of quantum confined materials* |
| CLR-3 : | *Understand the principles of photonic crystals* |
| CLR-4 : | *Enrich their knowledge on plasmonics and near field optics* |
| CLR-5 : | *Familiarize themselves with nanophotonic fabrication* |
| CLR-6 : | *Understand the various aspects of nanobiophotonics* |

| Course Learning Outcomes (CLO): | At the end of this course, learners will be able to: | Learning 1: Level of Thinking (Bloom) | 2: Expected Proficiency (%) | 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | 2: Problem Analysis | 3: Design & Development | 4: Analysis, Design, Research | 5: Modern Tool Usage | 6: Society & Culture | 7: Environment & Sustainability | 8: Ethics | 9: Individual & Team Work | 10: Communication | 11: Project Mgt. & Finance | 12: Life Long Learning | 13: PSO - 1 | 14: PSO - 2 | 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | *Apply the principles of Quantum confinement effects to understand Nanoscale interaction dynamics* | 2 | 80 | 75 | H | M | H | H | H | M | M | H | H | H | M | H | H | H | H |
| CLO-2 : | *Utilize the photonic crystals in various applications* | 2 | 80 | 70 | H | M | M | H | M | M | M | H | M | H | M | H | M | M | M |
| CLO-3 : | *Explore the principles of plasmonics to study Near field scanning optical microscopy* | 2 | 75 | 70 | H | M | H | H | H | H | H | M | H | H | H | H | H | H | H |
| CLO-4 : | *Utilize the Near field scanning optical microscopy in data storage applications* | 2 | 80 | 75 | M | H | H | M | H | H | H | H | H | H | M | H | H | H | H |
| CLO-5 : | *Apply fundamental principles of Near field optical chemical vapor deposition technique for fabrication of nanophotonic materials* | 2 | 80 | 70 | H | M | H | H | H | M | M | H | M | H | M | H | H | H | H |
| CLO-6 : | *Utilize the Fluorescence contrast mechanism concepts to analyze the properties of organic materials* | 2 | 80 | 75 | H | M | M | H | H | M | M | H | H | H | M | H | H | M | H |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Photons and electrons* | *Quantum confined materials* | *Plasmonics* | *Nanophotonic Fabrication* | *Biophotonics* |
| | SLO-2 | *Similarities and differences* | *Inorganic quantum confined structures* | *Internal reflection* | *Adiabatic nanofabrication* | *Nanobiophotonics* |
| S-2 | SLO-1 | *Free space propagation* | *Manifestation of quantum confinement* | *Evanescent waves* | *Non adiabatic nanofabrications* | *The cell and scale* |
| | SLO-2 | *Confinement of photons and electrons* | *Quantum confined Stark effect* | *Plasmons and surface plasmon resonance* | *Conditions for non-adiabatic nanofabrications* | *The cell and constituents* |
| S-3 | SLO-1 | *Propagation through a classically forbidden zone - Electrons* | *Dielectric confinement effect* | *Attenuated total reflection* | *Near field optical Chemical Vapour Deposition NFO CVD - Philosophy* | *Origin of contrast mechanisms* |
| | SLO-2 | *Propagation through a classically forbidden zone - Photons* | *Super lattices* | *Grating SPR coupling* | *Near field optical Chemical Vapour Deposition – Design and technique* | *Optical contrast mechanisms* |
| S-4 | SLO-1 | *Tunneling Localization under a periodic potential - Electrons* | *Core-shell quantum dots* | *Optical waveguide SPR coupling* | *Near field photolithography - Philosophy* | *Classical contrast mechanisms* |
| | SLO-2 | *Tunneling Localization under a periodic potential - Photons* | *Quantum wells* | *SPR dependencies and materials* | *Near field photolithography design and technique* | *Bright field and dark field contrast* |
| S-5 | SLO-1 | *Band gap and cooperative effects of photons* | *Quantum confined structures as lasing media* | *Plasmonics and nanoparticles* | *Self-assembling method* | *Phase contrast* |
| | SLO-2 | *Band gap and cooperative effects of electrons* | *Organic quantum confined structures* | *Near-Field Optics* | *Self-assembling method via optical near field interactions* | *Inter ferrometric contrast* |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-6 | SLO-1 | *Nanoscale optical interactions* | *Photonic crystals* | *Aperture less near field optics* | *Regulating the size of Nanoparticles* | *Fluorescence contrast mechanism* |
| | SLO-2 | *Axial and lateral nanoscopic localization* | *Important features of photonic crystals* | *Near field scanning optical microscopy (NSOM or SNOM) - Principle* | *Size dependent resonance* | *Confocal Microscopy* |
| S-7 | SLO-1 | *Nanoscale confinement of photonic interactions* | *Applications of Photonic crystals* | *Near field scanning optical microscopy design and technique* | *Controlling size of Nanoparticles* | *Nonlinear microscopy based on second harmonic generation* |
| | SLO-2 | *Nanoscale confinement of electronic interactions* | *Dielectric mirrors* | *SNOM Applications* | *Alignment of Size controlled Nanoparticles* | *Coherent anti-stokes Raman scattering (CARS)* |
| S-8 | SLO-1 | *Quantum confinement effects* | *Interference filters* | *SNOM based visualization of waveguide structures* | *Controlling position of Nanoparticles* | *Reduction of the observation volume* |
| | SLO-2 | *Nanoscale interaction dynamics* | *Photonic crystal laser, Photonic crystal sensing* | *SNOM based energy transport* | *Alignment of position controlled Nanoparticles* | *Far field method - 4Pi microscopy* |
| S-9 | SLO-1 | *Nanoscale electronic energy transfer* | *Photonic crystal fibers (PCFs)* | *SNOM based optical data storage* | *Separation of Nanoparticles* | *Microscopy on a mirror* |
| | SLO-2 | *Cooperative emissions* | *Introduction to Metamaterials* | *SNOM based optical data recovery* | *Alignment of Separated and controlled Nanoparticles* | *Stimulated emission depletion (STED)* |

| | | |
|---|---|---|
| Learning Resources | 1. *M.Ohtsu,K.Kobayashi,T.Kawazoe and T.Yatsui, Principals of Nanophotonics (Optics and Optoelectronics),CRC press,2003*<br>2. *H.Masuhara,SKawata and F Tokunga, NanoBiophotoics, Elsevier Science, 2007* | 3. *BEA Saleh and AC Teich, Fundamentals of Photonics, John Wiley and Sons,1993*<br>4. *Y. V. G.S. Murthy and C. Vijayan, Essentials of Nonlinear Optics, Wiley, 1st edition, 2014* |

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

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

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

| Course Code | 18NTC202J | Course Name | NANOBIOTECHNOLOGY | 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 | *Nanotechnology* | Data Book / Codes/Standards | *Nil* | | |

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Understand the interaction of nanomaterials with biological systems* |
| CLR-2 : | *Know about the properties of biomaterials* |
| CLR-3 : | *Learn various applications of nanotechnology in biology* |
| CLR-4 : | *Apply the nanoscience concepts in biotechnology* |
| CLR-5 : | *Utilize various biological techniques to understand nano bio interactions* |
| CLR-6 : | *Demonstrate skills in nanobiotechnology experimental techniques* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1: Level of Thinking (Bloom) | 2: Expected Proficiency (%) | 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | 2: Problem Analysis | 3: Design & Development | 4: Analysis, Design, Research | 5: Modern Tool Usage | 6: Society & Culture | 7: Environment & Sustainability | 8: Ethics | 9: Individual & Team Work | 10: Communication | 11: Project Mgt. & Finance | 12: Life Long Learning | 13: PSO - 1 | 14: PSO - 2 | 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | *Choose appropriate biomaterial for biological application* | *1* | *80* | *75* | *H* | *M* | *H* | *H* | *H* | *H* | *H* | *H* | *M* | *H* | *L* | *H* | *H* | *H* | *H* |
| CLO-2 : | *Explain the concept of biocompatibility* | *1* | *80* | *70* | *H* | *M* | *H* | *H* | *M* | *M* | *M* | *H* | *M* | *H* | *M* | *H* | *M* | *M* | *M* |
| CLO-3 : | *Perform experiments like Electrophoresis, Protein estimation and Drug loading* | *2* | *75* | *70* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *M* | *H* | *L* | *H* | *H* | *H* | *H* |
| CLO-4 : | *Describe about various biological molecules.* | *2* | *80* | *75* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *M* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-5 : | *Analyze the interaction of nanomaterials with biomolecules* | *2* | *80* | *80* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *M* | *H* | *L* | *H* | *H* | *H* | *H* |
| CLO-6 : | *Demonstrate skills required for application of nanotechnology in biology* | *2* | *80* | *80* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *M* | *H* | *M* | *H* | *H* | *H* | *H* |

| Duration (hour) | | 15 | 15 | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Biomaterials* | *Structure of membranes* | *Nanodiagnosis* | *Drug delivery systems* | *Biosensor* |
| | SLO-2 | *Surface and bulk properties of bio materials* | *Lipid bilayer* | *Detection of tumors* | *Traditional drug delivery* | *Nanobiosensors design* |
| S-2 | SLO-1 | *Nanoceramics* | *Traffic across membranes* | *Detection of plaque* | *Controlled drug delivery* | *optical biosensors based on nanoplasmonics* |
| | SLO-2 | *Polymeric nanoparticles* | *Endocytosis* | *Genetic defects* | *Nanoparticle based drug delivery* | *Nanoimmuno sensors* |
| S-3 | SLO-1 | *Hydroxyapatite: Structures, Chemical composition* | *Exocytosis* | *Nano medical devices.* | *Targeted drug delivery to cancer* | *Immuno Fluorescent Biomarker Imaging* |
| | SLO-2 | *Applications of hydroxyapatite* | *Receptor mediated transport* | *In vivo imaging* | *Types of drug targeting* | *Iron Oxide Nanoparticles in Magnetic Resonance Imaging* |
| S 4-5 | SLO-1 SLO-2 | *Lab 1:Introduction to Nanobiotechnology laboratory* | *Lab 4: Analysis of antimicrobial activity of nanoparticles* | *Lab 7: Hemocompatability analysis of nanoparticles* | *Lab 10: Fabrication of nanoparticles incorporated scaffolds for tissue engineering* | *Lab 13: Determination of controlled drug release from controlled drug delivery system* |
| S-6 | SLO-1 | *Surface modification of biomaterials* | *Active transport* | *Nanotechnology in gene therapy* | *Surface Modified Nanoparticles* | *Nanotechnology in food processing* |
| | SLO-2 | *Surface immobilized biomolecules* | *Passive transport* | *Stem cells* | *Peptide/DNA Coupled Nanoparticles for drug delivery and targeting* | *Food preservation* |
| S-7 | SLO-1 | *Interaction of biomaterials with cells* | *Membrane transporters* | *Polymerase chain reaction* | *Lipid Nanoparticles For Drug Delivery and targeting* | *Nanomaterials for food packing* |

| Duration (hour) | | 15 | 15 | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| | SLO-2 | *Immune response to biomaterials* | *Membrane proteins and Pumps* | *Enzyme-linked immunosorbent assay(ELISA)* | *Inorganic Nanoparticles For Drug Delivery* | *Delivery of nutraceuticals* |
| S-8 | SLO-1 | *Biocompatibility* | *Antibodies* | *DNA profiling* | *Metal/Metal Oxide Nanoparticles for antibacterial/anti-fungal/anti-viral activity* | *Delivery of functional foods* |
| | SLO-2 | *In vitro analysis* | *Monoclonal antibodies* | *Nanoprobes* | *Hyperthermia treatment* | *Nanosensors for food Pathogen Detection* |
| S 9-10 | SLO-1 SLO-2 | *Lab 2: Preparation of media, slants and plates for bacterial growth* | *Lab 5: Isolation of Genomic DNA* | *Lab 8: Amplification of DNA by PCR* | *Lab 11: Quantitation estimation of biomolecules* | *Lab 14: Fluorescent imaging of nano-bio interaction* |
| S-11 | SLO-1 | *In vivo analysis* | *Nanoimmuno assay* | *Blotting techniques* | *Dental implants* | *Nanotechnology in agriculture* |
| | SLO-2 | *Tissue compatibility* | *Blood-Biomaterial Interactions* | *Western Blotting* | *Regenerative medicine* | *Nanoformulation For The Control Of Plant Disease* |
| S-12 | SLO-1 | *Biomolecular motors* | *Interactions with Proteins* | *Surface plasmon Resonance* | *Tissue engineering* | *Nanomaterials for PEST control in PLANTS* |
| | SLO-2 | *Linear motors* | *Cell Adhesion* | *Surface enhanced Raman scattering* | *Nanoparticles and polymeric nanofibers in tissue engineering* | *Nanotechnology and Agricultural Sustainable Development* |
| S-13 | SLO-1 | *Rotary motors* | *Biocompatibility* | *Analysis of biomolecular structure by AFM* | *Scaffold design and fabrication* | *Toxicity of nanomaterials* |
| | SLO-2 | *Actin and myocin* | *Safety Testing of Biomaterials* | *Analysis of biomolecular structure by molecular pulling force spectroscopy* | *Controlled release strategies in tissue engineering* | *Environmental risks of nanomaterials* |
| S 14-15 | SLO-1 SLO-2 | *Lab 3: Growth of Bacteria by pour plate, spread plate and streak plate techniques* | *Lab 6: DNA fragmentation analysis by Agarose gel electrophoresis* | *Lab 9: Repeat/Revision of the experiments* | *Lab 12: Estimation of drug loading percentage* | *Lab 15: Protein separation by SDS PAGE analysis* |

| | | |
|---|---|---|
| Learning Resources | 1. *Niemeyer, C.M. and Mirkin, C.A., Nanobiotechnology: Concepts, Applications and Perspectives, Wiley-VCH, 2004.*<br>2. *Madhuri Sharon, Maheshwar Sharon, Sunil Pandey and Goldie Oza, Bio-Nanotechnology_ Concepts and applications. Ane Books Pvt Ltd, 1 edition 2012.* | 3. *Goodsell, D.S., Bionanotechnology, John Wiley and Sons, Inc., 2004.* |

Learning Assessment

| | Bloom's Level of Thinking | Continuous Learning Assessment (50% weightage) | | | | | | | | Final Examination (50% weightage) | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CLA – 1 (10%) | | CLA – 2 (15%) | | CLA – 3 (15%) | | CLA – 4 (10%)# | | | |
| | | Theory | Practice | Theory | Practice | Theory | Practice | Theory | Practice | Theory | Practice |
| Level 1 | Remember / Understand | *20%* | *20%* | *15%* | *15%* | *15%* | *15%* | *15%* | *15%* | *15%* | *15%* |
| Level 2 | Apply / Analyze | *20%* | *20%* | *20%* | *20%* | *20%* | *20%* | *20%* | *20%* | *20%* | *20%* |
| Level 3 | Evaluate / Create | *10%* | *10%* | *15%* | *15%* | *15%* | *15%* | *15%* | *15%* | *15%* | *15%* |
| | Total | 100 % | | 100 % | | 100 % | | 100 % | | 1000% | |

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

| Course Designers | | |
|---|---|---|
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| *1. Mr. K. Chandru Trivitron Healthcare Pvt. Ltd. Chennai, chandru.k@trivitron.com* | *1. Dr. Mukesh Doble, IIT M, mukeshd@iitm·ac* | *1. Dr. G. Devanand Venkatasubbu, SRMIST* |
| *2. Dr. Asifkhan Shanavas, INST Mohali, asifkhan@inst.ac.in* | *2. Dr. T. Prakash, UOM, thanigaiprakash@gmail.com* | *2.Dr. N. Selvamurugan,, SRMIST* |

| Course Code | 18NTC203T | Course Name | NANOTOXICOLOGY | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 0 | 3 |

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

| Course Learning Rationale (CLR): | The purpose of learning this course is to: |
|---|---|
| CLR-1 : | Understand the concept of toxicity |
| CLR-2 : | Acquire knowledge on physical properties of nanostructured materials on toxicity |
| CLR-3 : | Learn about nanoparticle interaction with cells |
| CLR-4 : | Know about various methods of toxicity assessment |
| CLR-5 : | Learn various in vivo toxicity methods |
| CLR-6 : | Gain knowledge about the toxic nanomaterials and their properties |

| Course Learning Outcomes (CLO): | At the end of this course, learners will be able to: | Learning 1: Level of Thinking (Bloom) | 2: Expected Proficiency (%) | 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | 2: Problem Analysis | 3: Design & Development | 4: Analysis, Design, Research | 5: Modern Tool Usage | 6: Society & Culture | 7: Environment & Sustainability | 8: Ethics | 9: Individual & Team Work | 10: Communication | 11: Project Mgt. & Finance | 12: Life Long Learning | 13: PSO - 1 | 14: PSO - 2 | 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | Aware about toxicity caused by nanomaterials | 1 | 80 | 75 | H | M | H | H | H | H | H | H | M | H | M | H | H | H | H |
| CLO-2 : | Relate the physical properties of nanostructured materials to its toxicity | 1 | 80 | 70 | H | M | H | H | M | M | M | H | M | H | M | H | M | M | M |
| CLO-3 : | Analyze the various symptoms caused due to toxicity of nanoparticles | 2 | 75 | 70 | H | H | H | H | H | H | H | H | M | H | M | H | H | H | H |
| CLO-4 : | Apply the various methods of toxicity assessment | 2 | 80 | 75 | M | H | H | M | H | H | H | H | M | H | M | H | H | H | H |
| CLO-5 : | Analyze the in vivo toxicity data | 2 | 80 | 80 | M | H | H | M | H | M | H | H | M | H | M | M | H | H | H |
| CLO-6 : | Demonstrate skills required for application of nanotechnology in toxicity studies | 2 | 80 | 80 | M | H | H | M | H | M | H | H | M | H | M | M | H | H | H |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Introduction to toxicity* | *Nanoparticles vs. micron-size particle* | *Interaction of nanoparticles with lipid bilayers* | *Methods for toxicity assessment* | *In vivo Analysis* |
| | SLO-2 | *Size-specific behavior of nanomaterials* | *Nanoparticle toxicity* | *Cell-level studies* | *LADMET hypothesis* | *species and strains of animals used in toxicity studies* |
| S-2 | SLO-1 | *Challenges in Nanotoxicology* | *Comparison to larger counterparts* | *Nanoparticle-induced membrane permeability* | *Effects of Nanoparticle on the Cardiovascular System* | *Dosing profile for animal models* |
| | SLO-2 | *Entry Routes into the Human Body* | *Requirement for appropriate model* | *Internalization of cation nanoparticles into cells* | *Thrombosis* | *Studies on toxicology* |
| S-3 | SLO-1 | *Importance of size and shape of Nano particle* | *Exposure assessment* | *Placental Barrier* | *Cardiac ischemia* | *Histopathology studies* |
| | SLO-2 | *Physicochemical properties of nanomaterials* | *Types of exposure pathways* | *Biological barrier model evaluation of nanoparticle transfer* | *Fibrinolysis* | *metabolism in mouse and rat* |
| S-4 | SLO-1 | *Mediators of nano toxicity* | *Significance of Exposure assessment* | *Transport across placental barrier* | *Coagulation* | *Predicting Penetration of nanomaterials* |
| | SLO-2 | *physicochemical properties of Nanomaterials related to toxicity* | *Occurrence of exposure pathways* | *Assessment of placental Transfer* | *Endothelial Dysfunction* | *Fate of Nanoparticles in the Body* |
| S-5 | SLO-1 | *Characterization of administered nanomaterials* | *Nature of exposures* | *Biological mechanism of nanoparticle disposition* | *Effect of Nanoparticles on Nervous system* | *Toxicity Mechanisms* |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| | SLO-2 | *Toxicity studies* | *Documentation of toxicity* | *Outline of gene* | *Effect of Nanoparticles on Genotoxicity* | *Mechanisms for Radical Species Production* |
| S-6 | SLO-1 | *Nanomaterial characterization after administration* | *Bio-distribution of nanoparticles* | *Cellular interactions* | *Effect of Nanoparticles on carcinogenicity* | *Genotoxicity Mechanisms* |
| | SLO-2 | *Source and types of Nanoparticles-* | *Localization of particles in tissues* | *Nano Biointeractions* | *Mechanism of carcinogenecity* | *Detection of Genotoxicity* |
| S-7 | SLO-1 | *Particles due to airpollution* | *Nanoparticles in the environment* | *Toxicity based on route of entry* | *Toxicity caused to Organ by Nanoparticles* | *Characterization of Genotoxicity* |
| | SLO-2 | *Biotoxicity of metal oxide Nanoparticles* | *Nanoparticles in mammalian system* | *Nature of toxicity* | *Effect of nanoparticles on Respiratory system* | *Inflammation analysis* |
| S-8 | SLO-1 | *Carbon nanotubes in practice* | *Health threats due to Nanoparticles* | *Toxicodynamics* | *Dermal toxicity analysis* | *Biocompatibility studies* |
| | SLO-2 | *Postproduction processing of carbon nanotubes* | *Nanoparticle translocation in mammalian system* | *Dose vs Toxicity Relationships* | *Hepato toxicity analysis* | *Laws and Regulations Governing Animal Care and Use in Research* |
| S-9 | SLO-1 | *Toxicity of Carbon nano tubes* | *Direct vascular effects in mammalian system* | *Toxicokinetics* | *Nephrotoxicity studies* | *Factors Affecting Exposure to Nanomaterials* |
| | SLO-2 | *Body Distribution;Nanoparticles and Cellular Uptake* | *Role of Nanoparticles in Mediating the Adverse Pulmonary Effects* | *Absorption, distribution, metabolism excretion studies (ADME)* | *Assessment of oxidative stress and antioxidant status* | *Elements of a Risk Management Program* |

| | | |
|---|---|---|
| Learning Resources | 1. *Niemeyer, C.M. and Mirkin, C.A., "Nanobiotechnology: Concepts, Applications and Yuliang Zhao, Hari Singh Nalwa, "Nanotoxicology: interactions of nanomaterials with biological systems", American Scientific Publishers, 2007.*<br>2. *Lynn Goldman, Christine Coussens, "Implications of nanotechnology for environmental health research", National Academic Press, Washington, 2007.* | 3. *Approaches to safe nanotechnology: Managing the health and safety concerns associated with Engineered Nanomaterials", DHHS (NIOSH) publishers, 2009* |

Learning Assessment

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

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

Course Designers

| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
|---|---|---|
| *1. Mr. K. Chandru Trivitron Healthcare Pvt. Ltd. Chennai, chandru.k@trivitron.com* | *1. Dr. Asifkhan Shanavas, INST Mohali, asifkhan@inst.ac.in* | *1. Dr. G. Devanand Venkatasubbu, SRMIST* |
| *2. Dr. Achuth Padmanaban, Baylor College of Medicine, USA, achuthz@gmail.com* | *2. Dr. Dayanand Reddy, CRIS Chennai, dayanand01@gmail.com* | *2. Dr. Selvamurugan, SRMIST* |

| Course Code | 18NTC204J | Course Name | NANOELECTRONICS | 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 | *Nanotechnology* | Data Book / Codes/Standards | | *Nil* | |

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Acquire knowledge on quantum confinement and low-dimensional nanostructures for use in nanoelectronics* |
| CLR-2 : | *Understand the key aspects of electron tunneling and its application in the operation of nanodevices.* |
| CLR-3 : | *Understand the functioning of tunnel junctions in single electron devices* |
| CLR-4 : | *Understand the concept of molecular electronics for realization of device miniaturization* |
| CLR-5 : | *Acquire knowledge on the fabrication, characterization and modeling of nanodevices* |
| CLR-6 : | *Acquire knowledge on designing and fabrication process which is Essential for simulation of nanoelectronic devices.* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning | | | Program Learning Outcomes (PLO) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | | Level of Thinking (Bloom) | Expected Proficiency (%) | Expected Attainment (%) | Engineering Knowledge | Problem Analysis | Design & Development | Analysis, Design, Research | Modern Tool Usage | Society & Culture | Environment & Sustainability | Ethics | Individual & Team Work | Communication | Project Mgt. & Finance | Life Long Learning | PSO - 1 | PSO - 2 | PSO - 3 |
| CLO-1 : | *Acquaint with the fundamentals of nanoelectronics* | *1* | *80* | *75* | *H* | *H* | *M* | *M* | *M* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-2 : | *Utilize their knowledge on the electron tunneling phenomena in semiconductor nanodevices* | *1* | *80* | *70* | *H* | *H* | *M* | *M* | *M* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-3 : | *Apply the knowledge on the operation and application perspectives of various tunnel devices* | *2* | *75* | *70* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *M* | *H* | *M* | *H* | *H* | *H* | *H* |
| CLO-4 : | *Analyze the concept of molecular electronics* | *2* | *80* | *75* | *M* | *H* | *M* | *M* | *H* | *H* | *H* | *H* | *M* | *H* | *L* | *H* | *M* | *M* | *M* |
| CLO-5 : | *Apply their knowledge on the fabrication and modeling of nanodevices* | *2* | *80* | *80* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *H* | *L* | *H* | *H* | *H* | *H* |
| CLO-6 : | *Demonstrate skills required for using advanced experimental techniques* | *2* | *80* | *75* | *H* | *M* | *M* | *H* | *M* | *M* | *M* | *H* | *H* | *H* | *M* | *H* | *H* | *M* | *H* |

| Duration (hour) | | 15 | 15 | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Introduction to nanoelectronics* | *Tunnel effect and tunneling elements* | *Classical and semi-classical transport* | *Introduction to molecular electronics* | *Introduction to computational methods* |
| | SLO-2 | *Review of basic quantum physics* | *Nanoelectronics in tunneling devices* | *Ballistic transport in nanostructures* | *Atomic-scale junctions: an overview* | *Necessity of computational methods* |
| S-2 | SLO-1 | *Moore's law and its consequences* | *Tunneling of electrons through a potential barrier* | *Coulomb blockade - an overview* | *Schrodinger equation* | *Molecular wire* |
| | SLO-2 | *Silicon electronics - limitations* | *Electron tunneling–key points* | *Single electron tunneling and Coulomb blockade* | *Self-consistent field* | *Molecular wire conductance* |
| S-3 | SLO-1 | *International technology roadmap characteristics (ITRC)* | *Potential energy profiles for material interfaces* | *Coulomb blockade in a quantum dot circuit* | *Molecular functionalities* | *Theoretical aspects on molecular conductance* |
| | SLO-2 | *ITRC and Nanoscale importance* | *Metal-semiconductor and metal-insulator junctions* | *Coulomb blockade in a nano-capacitor* | *Metal-molecule interfaces* | *Computational aspects on molecular conductance* |
| S 4-5 | SLO-1 SLO-2 | *Lab 1: Determination of electron concentration versus temperature using MATLAB* | *Lab 4: Four probe resistivity measurement* | *Lab 7: PSpice simulation of FET and its I-V characteristics* | *Lab 10: PSpice simulation of MOSFETs using a simple DC circuit and a CMOS inverter with DC sweep analysis* | *Lab 13: Simulation of diode using TCAD and its characterization* |
| S-6 | SLO-1 | *Need for new concepts in electronics* | *Metal-insulator-metal junctions* | *Ballistic transport and the Landauerformula* | *Molecular band Structure* | *Various modeling techniques* |
| | SLO-2 | *Challenges in micro to Nano conversion* | *Metal work function and electron affinity* | *Quantized Conductance* | *Level broadening* | *Monte Carlo method* |
| S-7 | SLO-1 | *Dimensionality in materials* | *Tunneling applications* | *Working principle of Single Electron Transistor (SET)* | *Atomistic view of electrical resistance* | *Ab initio simulations* |

| Duration (hour) | | 15 | 15 | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| | SLO-2 | *Density of states of materials at nanoscale* | *Field electron emission* | *A single-electron pump and turnstile* | *Conductance of atomic-scale contacts* | *Ab initio simulations: examples and problems* |
| S-8 | SLO-1 | *Effect of band gap of material at different dimensions* | *Double barrier tunneling* | *Quantum dot* | *Coherent transport through molecular junctions* | *Multiscale modeling* |
| | SLO-2 | *Length scales of charge scattering* | *Resonant tunneling diodes* | *Quantum-dot cellular automata* | *Non-coherent transport in molecular electronics devices* | *Modeling of nanodevices and applications* |
| S 9-10 | SLO-1 SLO-2 | *Lab 2: Determination of electron (µn) and hole (µp) mobilities versus doping concentration in semiconductor using MATLAB* | *Lab 5: PSpice simulation of diode and its I-V characteristics with smoke analysis* | *Lab 8: Hall effect of semiconductors* | *Lab 11: PSpice simulation of Zener Diode model and its I-V characteristics* | *Lab 14: Designing of 2D MOSFET using TCAD* |
| S-11 | SLO-1 | *Special dimensionality case of carbon* | *Tunneling in MOS Transistors* | *Electron transport in quantum dots* | *Molecular diodes* | *TCAD* |
| | SLO-2 | *Introduction to 0D, 1D, 2D and 3D carbon forms* | *unnel transistor* | *Electron transport in quantum wires* | *Conducting mechanism of single-molecule junctions* | *TCAD: examples and problems* |
| S-12 | SLO-1 | *Nanocomputing* | *Hot electron effects in MOSFETs* | *Introduction to spintronics* | *Single-molecule transistors* | *NEH DFT* |
| | SLO-2 | *Device simulation software at nanoscale* | *Gate-oxide tunneling* | *Giant magneto resistance* | *Elastic and inelastic co-tunneling* | *NEH DFT: examples and problems* |
| S-13 | SLO-1 | *Future Prospects of Nanoelectronic Devices* | *Principles of scanning tunneling microscopy (STM)* | *Tunnel magneto resistance* | *Molecular devices and logic switches* | *Materials studio* |
| | SLO-2 | *Progress in Nanoelectronic Architectures* | *Applications of STM in nanotechnology* | *Spintronic devices and applications* | *Interface engineering issues* | *Future of nanoscale modeling* |
| S 14-15 | SLO-1 SLO-2 | *Lab 3: Determination of Fermi function for different temperature using MATLAB* | *Lab 6: PSpice simulation of BJT and its I-V characteristics* | *Lab 9: Repeat/Revision of the experiments* | *Lab 12: PSpice simulation of a Phototransistor* | *Lab 15: Repeat/Revision of the experiments* |

Learning Resources


1. *G. W. Hanson, Fundamentals of Nanoelectronics, Pearson Education; 1 edition (2009)*
2. *V. V. Mitin, V. A. Kochelap, M. A. Stroscio, Introduction to Nanoelectronics, Cambridge University Press; 1 edition (2007)*
3. *E. Scheer and J. C. Cuevas, Molecular Electronics: An Introduction to Theory and Experiment, World Scientific Pub Co Inc; 1 edition (2010)*
4. *K. I. Ramachandran, Computational Chemistry and Molecular Modeling, Springer, 2008*
5. *Nanoelectronics simulation laboratory course manual, 2016*
6. *Sarhan. M. Musa, Computational Nanotechnology: Modeling and Applications with MATLAB", CRC Press, 2011*
7. *John O. Attia, Electronics and Circuit Analysis using Matlab, CRC Press, 2001*
8. *Mitchell A. Thornton, PSpice for Circuit Theory and Electronic Devices,Morgan& Claypool Publishers series*
9. *Simon Li and Yue Fu, 3D TCAD Simulation for Semiconductor Processes,Devices and Optoelectronics, Springer,2012*


Learning Assessment

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

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

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

| Course Code | 18NTC205J | Course Name | MICRO AND NANOFABRICATION | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 2 | 4 |

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

| Course Learning Rationale (CLR): | The purpose of learning this course is to: |
|---|---|
| CLR-1 : | *Overview the techniques and processes to organize nanoscale materials in device form* |
| CLR-2 : | *Understand methodology of lithography and etching to pattern materials* |
| CLR-3 : | *Acquire knowledge of different deposition techniques and ion implantation* |
| CLR-4 : | *Get acquainted with CMOS fabrication rules* |
| CLR-5 : | *Introduce next generation printed electronics technology* |
| CLR-6 : | *Make aware of VLSI technology* |

| Course Learning Outcomes (CLO): | At the end of this course, learners will be able to: | Learning 1: Level of Thinking (Bloom) | 2: Expected Proficiency (%) | 3: Expected Attainment (%) | PLO 1: Engineering Knowledge | 2: Problem Analysis | 3: Design & Development | 4: Analysis, Design, Research | 5: Modern Tool Usage | 6: Society & Culture | 7: Environment & Sustainability | 8: Ethics | 9: Individual & Team Work | 10: Communication | 11: Project Mgt. & Finance | 12: Life Long Learning | 13: PSO - 1 | 14: PSO - 2 | 15: PSO - 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLO-1 : | *Realizing the technology of Si wafer manufacturing* | 2 | 80 | 75 | H | M | H | H | H | M | M | H | H | H | M | H | H | H | H |
| CLO-2 : | *Pattern diverse materials using lithography techniques to enhance the device density on chip* | 2 | 80 | 70 | H | M | M | H | M | M | M | H | M | H | M | H | M | M | M |
| CLO-3 : | *Applying basic diffusion processes importance in semiconductor technology* | 2 | 75 | 70 | H | M | H | H | H | H | H | M | H | H | H | H | H | H | H |
| CLO-4 : | *Fabricate small-scale devices and chip level device space management* | 2 | 80 | 75 | M | H | H | M | H | H | H | H | H | H | M | H | H | H | H |
| CLO-5 : | *Envision low cost production of electronic devices using printed technology* | 2 | 80 | 70 | H | M | H | H | H | M | M | H | M | H | M | H | H | H | H |
| CLO-6 : | *Imagining importance of nanoscale devices* | 2 | 80 | 75 | H | M | M | H | H | M | M | H | H | H | M | H | H | M | H |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Importance of micro and nanofabrication techniques in IC: front and back plane* | *Need and basics of lithography* | *Classification of material deposition techniques* | *History of complementary metal-oxide-semiconductor (CMOS)* | *Overview of printing processes* |
| | SLO-2 | *Over view of crystal and lattices* | *Optical lithography* | *Overview of physical and chemical deposition technique* | *Requirements of device isolation* | *Advantages of printing* |
| S-2 | SLO-1 | *Classification of grades of silicon* | *Optical lithography controls and mask making* | *Physical vapour deposition* | *Types of isolation* | *Requirements of printing* |
| | SLO-2 | *Production of electronic grade silicon* | *Working concept and controls of e-beam lithography* | *Resistive heating evaporation* | *Local Oxidation of Silicon (LOCOS) and shallow trench isolation (STI) processes for local isolation* | *Printing tools* |
| S-3 | SLO-1 | *Czochralski growth technique* | *Resolution of electron beam lithography* | *Electron beam heating evaporation* | *Concept of self-alignment* | *Types of fluids for ink* |
| | SLO-2 | *float zone growth technique* | *X-ray lithography* | *Pulsed laser evaporation* | *MOS fabrication with self-alignment* | *Properties of fluids in printing processes* |
| S-4,5 | SLO-1<br>SLO-2 | *Lab 1:Introduction to the basics of laboratory* | *Lab 4: To perform patterning by photolithography process* | *Lab 7: To deposit Al thin film on the oxidized silicon surface by thermal evaporation* | *Lab 10:To form local anodic oxidation pattern by scanning probe microscopy* | *Lab 13:To perform contact angle measurement of solvents used in printing process* |
| S-6 | SLO-1 | *Silicon wafer shaping* | *Stamp based lithography* | *Basics of sputtering* | *Requirement of planarization* | *Working principle of flexographic printing (FP)* |

| Duration (hour) | | 9 | 9 | 9 | 9 | 9 |
|---|---|---|---|---|---|---|
| | SLO-2 | Wafer manufacturing steps and inspection | Nanoimprint lithography and applications | DC and magnetron sources for sputtering | Local and global planarization using chemical-mechanical polishing | Advantages and disadvantages of FP |
| S-7 | SLO-1 | Overview of types of epitaxy | Etching of silicon | Introduction to atomic layer deposition | Importance of MOS devices | Working principle of gravure printing (GP) |
| | SLO-2 | Definition-epitaxy | Wet etching mechanism and disadvantages | Working principle of atomic layer deposition | Concept of well formation with p and n doping | Advantages and disadvantages of GP |
| S-8 | SLO-1 | Comparison of vapour phase epitaxy (VPE), liquid phase epitaxy (LPE) and molecular beam epitaxy (MBE) | Types of dry etching | Concepts of diffusion | Working principle of integrated CMOS inverter | Working principle of screen printing (SP) |
| | SLO-2 | Working of MBE process | Ways of plasma generation for etching processes, Sputter etching | Using Fick's diffusion in semiconductor doping | Fabrication process of CMOS inverter | Advantages and disadvantages of SP |
| S-9,10 | SLO-1<br>SLO-2 | Lab 2: To perform wafer cleaning processes followed for VLSI applications | Lab 5: To perform wet chemical etching of silicon dioxide | Lab 8: To deposit Al thin film on the oxidized silicon surface by e-beam evaporation | Lab 11: To design MOS capacitor design layout using 'layout editor' | Lab 14: To measure gauge factor of flexible strain gauge |
| S-11 | SLO-1 | General epitaxy growth mechanism | Capacitively coupled plasma | Process of ion implantation | Usage of isolation and biasing of inverter | Working principle of inkjet printing (IP) |
| | SLO-2 | Epitaxy growth kinetics and examples | Inductively coupled plasma | Ion implantation tool | 'Latch up' concept for inverter | Advantages and disadvantages of IP |
| S-12 | SLO-1 | Understanding silicon oxide properties | Classification of plasma using its density | Fundamentals of ion energy loss and stopping | Design rules for CMOS | Examples of printed devices |
| | SLO-2 | Thermal oxidation furnace | High density plasma | Damage due to implantation | MOSIS specifics for inverter | Comparison of printed devices with lithographically fabricated devices |
| S-13 | SLO-1 | Silicon oxide growth kinetics | Reactive ion etching | Ion distribution, junction control | Introduction to silicon-on-insulator (SOI) | Concept of hybrid printed electronics |
| | SLO-2 | Thin oxide growth and process of oxidizing polysilicon | Deep reactive ion etching and bosh process | Carrier recovery using annealing process | On chip fabrication processes of passive components | Future of printed low-cost electronics |
| S-14,15 | SLO-1<br>SLO-2 | Lab 3: To oxidize silicon under $O_2$ ambient using temperature controlled furnace | Lab 6: To perform wet chemical etching of metal films | Lab 9: To perform ion beam implantation process and defect analysis using SRIM software | Lab 12: To fabricate MOS capacitor and study its I-V characteristics | Lab 15: Repeating of experiments |

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

Learning Assessment

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

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

| Course Designers | | |
|---|---|---|
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| 1. Dr. Hemant Dixit, GlobalFoundaries,USA, aplahemant@gmail.com | 1. Dr. A. Subrahmanyam, IIT Madras, manu@iitm.ac.in | 1. Dr. Abhay Sagade, SRMIST |
| 2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com | 2. Dr. N. N. Murthy, IIT Tirupati, nnmurty@iittp.ac.in | 2. Dr. P. Malar, SRMIST |

| Course Code | 18NTC301J | Course Name | POLYMER AND NANOCOMPOSITES | Course Category | C | Professional Core Course | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 3 | 0 | 2 | 4 |

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

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Acquire knowledge 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* |
| CLR-6 : | *Understand the significance of nanosize on polymer and composites* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1: Level of Thinking (Bloom) | Learning 2: Expected Proficiency (%) | Learning 3: Expected Attainment (%) |
|---|---|---|---|---|
| CLO-1 : | *Apply the chemical concepts to understand the configuration and conformation of polymers* | *1* | *80* | *75* |
| CLO-2 : | *Analyze the mechanical behavior of polymers by studying its properties* | *1* | *80* | *70* |
| CLO-3 : | *Utilize the basic principles about polymerization to synthesize polymers using monomers* | *2* | *75* | *70* |
| CLO-4 : | *Apply the knowledge about fibers and matrix materials in making nanocomposites* | *2* | *80* | *75* |
| CLO-5 : | *Analyze the types of matrix and reinforcements available for the preparation of nanocomposites* | *2* | *80* | *80* |
| CLO-6 : | *Utilize the knowledge about polymers towards environmental and biomedical applications* | *2* | *80* | *80* |

Program Learning Outcomes (PLO)

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

| Duration (hour) | | 15 | 15 | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Importance of polymers: basic concepts* | *Conducting polymers* | *Introduction and additives of composites* | *Metal – Polymer Nanocomposites* | *Metal Matrix Nanocomposites* |
| | SLO-2 | *Classification of polymers on the basis of microstructures & macrostructures* | *Discovery* | *Characteristics of composites* | *Physical and chemical properties of Nanosized metal particles* | *Introduction to metal matrix composites* |
| S-2 | SLO-1 | *polymer classifications based on-occurrence, types, process and applications* | *Structural characteristics* | *Classification- particulate, fibrous* | *Metal containing polymers: cryochemical synthesis, structure and physio-chemical properties* | *Reinforcement and matrix materials* |
| | SLO-2 | *Chain structure, configuration and conformation* | *Intrinsic and extrinsic conduction in polymers* | *Laminated and hybrid composites* | *Nanostructured polymer nanoreactors for metal particle formation* | *Mechanism of reinforcement* |
| S-3 | SLO-1 | *Homo and heteropolymers - copolymers* | *Charge carriers and conducting mechanism* | *Additives for Composites* | *Metal-polymer nanocomposite synthesis, Ex-situ, In-situ* | *Long fiber, short fiber and particulate* |
| | SLO-2 | *Chemistry of polymerization* | *Chemical and electrochemical methods of synthesis of conducting polymers* | *Catalysts* | *Optically anisotropic metal polymer nanocomposites* | *Interlayer in metal matrix composites* |
| S 4-5 | SLO-1 SLO-2 | *Lab 1:Introduction to the basics of Polymer science* | *Lab 4: Preparation of poly vinyl alcohol nanofibers by electro spinning technique* | *Lab 7: Fabrication of polymer thin film composites using phase inversion techniques* | *Lab 10: Preparation of ceramic based nanocomposites* | *Lab 13: Synthesis of particulate reinforced composites* |
| Coupling Agents | SLO-1 | *Molecular solution, Melt and elastomer* | *Synthesis method of polyaniline* | *Accelerators* | *Polymer- Clay Nanocomposites* | *Characterization and relevance to material properties* |

| Duration (hour) | | 15 | 15 | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| | SLO-2 | *Crystalline nature of polymers* | *Polypyrrole* | | *Synthesis of Nylon 6-clay hybrid (NCH) composites and characterization* | *Ceramic Matrix Nanocomposites* |
| S-7 | SLO-1 | *Factors affecting crystallization phenomenon* | *Characterization using UV-Visible and FTIR spectrometer* | *Fillers* | *Crystal structure of NCH and properties of NCH* | *Fibrous monolithic ceramic, fiber reinforced ceramic composites* |
| | SLO-2 | *Glass transition temperature (Tg)* | *Morphological study using SEM and TEM* | *Toughening Agents* | *Polypropylene layered silicate Nanocomposites* | *Whisker reinforced ceramic matrix composite* |
| S-8 | SLO-1 | *Melting temperature(Tm)* | *Applications of conducting polymers in corrosion protection* | *Reinforcement Materials* | *Epoxy Nanocomposite* | *Particulate reinforced, graded and layered ceramic composite* |
| | SLO-2 | *Factors affecting Tg and Tm* | *Sensors* | *Fibre Reinforcements* | *Layered silicate Nanocomposites* | *Nanophase ceramic composites* |
| S 9-10 | SLO-1 SLO-2 | *Lab 2: Polymerization of Urea-formaldehyde resin* | *Lab 5: Characterization of the fibers prepared using SEM and wettability test* | *Lab 8: Preparation of metal-polymer nanocomposites* | *Lab 11: Morphological characterization of prepared composites using SEM* | *Lab 14: Synthesis of hydrogel using cellulose acetate polymer* |
| S-11 | SLO-1 | *Importance of Tg* | *Conducting adhesives* | *Woven and Non-Woven Fabrics* | *Structure, properties and characterization* | *Metal reinforced ceramic matrix nanocomposites* |
| | SLO-2 | *Molecular weight distribution* | *Electro conducting polymers* | *Carbon , Aramid Fibre and Boron Fibres* | *Poly(ethyl acrylate)/bentonite nanocomposites* | *Refractory and special ceramic composites* |
| S-12 | SLO-1 | *Degree of polymerization* | *Polymer batteries and electrets* | *Natural Fibres – Cellulose* | *Poly(butylene terephthlate) based Nanocomposites* | *Non-oxide ceramic composites* |
| | SLO-2 | *Reaction kinetics of polymerization* | *Polymers with piezoelectric property* | *Testing of Composites* | *Polymer/calcium carbonate Nanocomposites* | *Machinable Nanocomposite ceramics-Silicon nitride and silicon carbide based ceramics* |
| S-13 | SLO-1 | *Dielectric constant* | *Pyroelectric and ferroelectric property* | *Tensile, Impact strength, Compression and Flexural Strength* | *Functional applications of polymer-clay Nanocomposites* | *Functionally graded ceramics- clay Nanocomposites* |
| | SLO-2 | *Polarization; Dissipation factor* | *Photo conducting polymers.* | *Applications of composites* | *Biodegradable polymer categories, properties and drawback* | *Applications of ceramic matric Nanocomposites* |
| S 14-15 | SLO-1 SLO-2 | *Lab 3: Interfacial Polymerization of polyamide from Diamine and Diacid Chloride.* | *Lab 6: Fabrication of polymer membrane using phase inversion techniques* | *Lab 9: Repeat/Revision of the experiments* | *Lab 12: Synthesis of Nylon-6 polymer* | *Lab 15: Study of glass transition, melting and crystallization temperature of given materials* |

| | | |
|---|---|---|
| Learning Resources | 1. *Gowariker V.R., Viswanathan N.V., Sreedhar J., Polymer Science, New age International publications, 2005*<br>2. *Luigi Nicolais, Gianfranco Carotenuto,Metal–polymerNanocomposites,Wiley-Interscience,2005*<br>3. *BorZ.Jang, Advanced Polymer composites, ASM International, USA, 1994.* | 4. *Alfred rudin , The elements of polymer science and engineering, 2nd edition, Academic press publication, 1999*<br>5. *Low I. M., Ceramic matrix composites: Microstructure, properties and applications, Woodhead Publishing Limited, 2006* |

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

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

| Course Designers | | |
| --- | --- | --- |
| Experts from Industry | Experts from Higher Technical Institutions | Internal Experts |
| 1. *Dr. 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 | 18NTC350T | Course Name | COMPREHENSION | Course Category | C | Professional Core | L | T | P | C |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | 0 | 1 | 0 | 1 |

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

| Course Learning Rationale (CLR): | *The purpose of learning this course is to:* |
|---|---|
| CLR-1 : | *Acquire skills to develop knowledge in nanotechnology principles* |
| CLR-2 : | *Acquire skills to understand quantum mechanical concepts of free electron and band theory of solids* |
| CLR-3 : | *Acquire skills in size effects and reaction kinetics at nanoscale* |
| CLR-4 : | *Acquire skills in various imaging techniques related to the field of nanotechnology* |
| CLR-5 : | *Acquire skills in chemistry of biological molecules* |
| CLR-6 : | *Acquire skills in knowing the electronic property of materials in mesoscopic level* |

| Course Learning Outcomes (CLO): | *At the end of this course, learners will be able to:* | Learning 1 | 2 | 3 | Program Learning Outcomes (PLO) 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Level of Thinking (Bloom) | Expected Proficiency (%) | Expected Attainment (%) | Engineering Knowledge | Problem Analysis | Design & Development | Analysis, Design, | Modern Tool Usage | Society & Culture | Environment & | Ethics | Individual & Team Work | Communication | Project Mgt. & Finance | Life Long Learning | PSO - 1 | PSO - 2 | PSO - 3 |
| CLO-1 : | *Practice and gain confidence and competence to solve problems in statistical mechanics & thermodynamics* | *3* | *85* | *80* | *H* | *H* | *H* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *M* | *L* | *M* |
| CLO-2 : | *Practice and gain confidence and competence to solve many body problems using various quantum phenomenon & assumptions* | *3* | *85* | *80* | *H* | *H* | *M* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *M* | *M* | *M* |
| CLO-3 : | *Practice and gain confidence and competence to solve problems in biophysical principles and dynamics involved in biological systems* | *3* | *85* | *80* | *H* | *H* | *M* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *M* | *L* | *M* |
| CLO-4 : | *Practice and gain confidence and competence to solve problems & simulation process involved in nanoelectronics devices* | *3* | *85* | *80* | *H* | *H* | *M* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *M* | *M* | *M* |
| CLO-5 : | *Practice and gain confidence and competence to solve problems using spectroscopic techniques* | *3* | *85* | *80* | *H* | *H* | *H* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *M* | *L* | *M* |
| CLO-6 : | *Solve problems in the broad domain of Naotechnology and competitive examinations in Nanoscience & NT* | *3* | *85* | *80* | *H* | *H* | *M* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *L* | *M* | *M* | *M* |

| Duration (hour) | | 3 | 3 | 3 | 3 | 3 |
|---|---|---|---|---|---|---|
| S-1 | SLO-1 | *Tutorial on Solid State Physics* | *Tutorial on Synthesis Methods of Nanomaterials* | *Tutorial on Nanomagnetism* | *Tutorial on Nanocomposite Materials* | *Tutorial on Nanotoxicology* |
| | SLO-2 | *Problem Solving* | *Problem Solving* | *Problem Solving* | *Problem Solving* | *Problem Solving* |
| S-2 | SLO-1 | *Tutorial on Thermodynamics & Statistical Mechanics* | *Tutorial on Nanophotonics* | *Tutorial on Nanoelectronics* | *Tutorial on Nanobiotechnology* | *Tutorial on Environmental Nanoscience* |
| | SLO-2 | *Problem Solving* | *Problem Solving* | *Problem Solving* | *Problem Solving* | *Problem Solving* |
| S-3 | SLO-1 | *Tutorial on Biological Principles* | *Tutorial on Micro and Nanofabrication* | *Tutorial on Polymer Technology* | *Tutorial on Quantum Mechanics* | *Tutorial on Industrial Nanotechnology* |
| | SLO-2 | *Problem Solving* | *Problem Solving* | *Problem Solving* | *Problem Solving* | *Problem Solving* |

| Learning Resources | 1. *Sulabha K. Kulkarni, Nanotechnology: Principles and Practices, 3rd Edition, Springer, 2015* |
|---|---|

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

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

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