INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject Code : **NTN- 501** Course Title : **Nanoscale Materials**

2. Contact Hours : **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs) : Theory : **03** Practicals : **00**

4. Relative Weight : CWS : **15** PRS : **25** MTE : **20** ETE : **40**

5. Credits : **04** 6. Semester : **Autumn** **7.** Pre-requisite **: Nil**

8. Subject Area : **PCC**

9. Objectives: To provide knowledge of various concepts related to nanosized materials, their preparation, properties and applications.

10. **Details of Course**:

S.No.	Contents	Contact Hours
1.	**Classification and Nomenclature of Nanomaterials:** Nanosized metals and alloys, semiconductors, ceramics - a comparison with respective bulk materials; Organic semiconductors, carbon nanotubes; Zero-, one-, two-, and three dimensional nanostructures – quantum dots, quantum wells, quantum rods, quantum wires, quantum rings; bulk nanostructured materials, Nanomachines and Devices.	**6**
2.	**Synthesis by Physical Methods:** Nucleation and growth of Nanosystems; self-assembly; Physical methods – mechanical milling, laser ablation, sputtering and microwave plasma.	**7**
3.	**Synthesis by Chemical Methods:** Chemical reduction and oxidation, hydrothermal, micelles, sol-gel processes, photolysis, radiolysis, and metallo-organic chemical vapor deposition; Designing of advanced integrated nanocomposites, functional nanomaterials and nanostructured thin films.	**7**
4.	**Novel Properties of Nanomaterials and Related Theoretical Background:** Size and shape dependent optical, emission, electronic, transport, photonic, refractive index, dielectric, mechanical, magnetic, non-linear optical properties; Transition metal sols, origin of plasmon band, Mie theory, influence of various factors on the plasmon absorption.	**7**

5.	**Size Effect in Nanomaterials:** Quantum confinement in semiconductors – particle in a box like model for quantum dots; Origin of charge on colloidal sols, zeta potential - DLVO theory; Implications of colloids in making building blocks; Catalytic and photocatalytic properties, Mechanical properties.	**6**
6.	**Characterization of Nanomaterials:** Structural Characterization - XRD, SAXS, SEM, TEM, SPM/AFM; Chemical Characterization – Optical spectroscopy, Electron spectroscopy, Ionic spectrometry; Physical properties – Melting point, Lattice constant, Electrical and magnetic characterization; Mechanical properties – nanoindentaion, nanotribology.	**9**
	Total	**42**

List of Experiments:

1. To investigate the optical properties of certain nanosized semiconducting oxides.
2. To synthesize metal nanostructures and investigate their optical behaviour.
3. To analyze the thickness, optical transmission and reflectivity of thin film of Al.
4. Synthesis and characterization of carbon nanotubes by cracking of gas mixture using tubular furnace.
5. To work out the charge, zeta potential and size distribution of colloidal solution of nanoparticles using dynamic light scattering method.
6. To determine the elemental contents in nanoalloys using different analytical techniques.

11. Suggested Books:

S.No.	Name of Books/Authors/Publishers	Year of Publication/ Reprint
1.	Klabunde, K.J. (Ed.), "Nanoscale Materials in Chemistry", John Wiley & Sons Inc.	**2001**
2.	Nalwa, H.S. (Ed.), "Encyclopedia of Nanoscience and Nanotechnology".	**2004**
3.	Sergeev, G.B. Nanochemistry, Elsevier, B.V.	**2010**
4.	Schmid, G. (Ed.), "Nanoparticles", Wiley-VCH Verlag GmbH & Co. KgaA.	**2004**
5.	Rao, C.N.R., Müller, A. and Cheentham, A.K. (Eds.), "Chemistry of Nanomaterials", Wiley – VCH.	**2005**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN- 502** Course Title: **Biomedical Nanotechnology**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Autumn** 7. Pre-requisite : **Nil**

8. Subject Area: **PCC**

9. Objective: To impart knowledge on biomedical applications of nanotechnology.

10. **Details of Course:**

S.No.	Contents	Contact Hours
1.	Synthesis of nanoparticles by physical, chemical and biological methods; Cell organization and subcellular structure; Cell–nanostructure Interactions; Molecular Biomimetics; Nanostructures for medicinal applications.	**6**
2.	Introduction to genetic engineering and gene therapy; Virus-based nanoparticles for gene therapy; Nanotechnology in nonviral gene delivery.	**4**
3.	Introduction to tissue engineering; Nanotechnology in tissue Engineering; Nanostructured extracellular matrix; Nanomaterials for cell engineering; Nanostructured biomaterials; Nanostructured surface modifications for biomedical implants; Artificial cells; Stem cells in tissue engineering; Nanotechnology for regenerative medicine.	**9**
4.	Nanopharmaceuticals; Biodegradable targeted nano drug delivery system; Diagnostic and therapeutic applications of nanoparticles; Theranostic nanoparticles; Pharmacokinetics of nanocarrier-mediated drug and gene delivery; Nano-enabled components and systems for biodefense.	**7**
5.	Design and applications of nanotechnology in the fields of Oncology, Neurology, Cardiology, Orthopedics, Microbiology, Ophthalmology, Dermatology, Pulmonology and Dentistry.	**9**
6.	Cytotoxicity and genotoxicity; Cell toxicity mechanisms and method of analysis; Toxicity of nanoparticles *in vivo*.	**7**
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors /Books / Publishers	Year of Publication/ Reprint
1.	Malsch, N.H., "Biomedical Nanotechnology", CRC Press.	**2005**
2.	Mirkin, C.A. and Niemeyer, C.M., "Nanobiotechnology II: More Concepts and Applications", Wiley-VCH.	**2007**
3.	Jain, K.K., "The Handbook of Nanomedicine", Humana press.	**2008**
4.	Kumar, C. S. S. R., Hormes, J. and Leuschner C., "Nanofabrication Towards Biomedical Applications: Techniques, Tools, Applications, and Impact", WILEY -VCH Verlag GmbH & Co.	**2005**
5.	Lamprecht, A., "Nanotherapeutics: Drug Delivery Concepts in Nanoscience", Pan Stanford Publishing Pte. Ltd.	**2009**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject Code : **NTN- 503** Course Title : **Numerical Methods and Statistics**

2. Contact Hours : **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs) : Theory : **03** Practicals : **00**

4. Relative Weight : CWS : **15** PRS : **25** MTE : **20** ETE : **40**

5. Credits : **04** 6. Semester : **Autumn** **7.** Pre-requisite: **Nil**

8. Subject Area : **PCC**

9. Objective: To impart knowledge of various numerical techniques to solve the problems.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	Introduction, roots of a non-linear equation and roots of a polynomial of n^{th} degree [incremental search method, method of successive approximations, Newton's method, bisection method, secant method] and convergence study	**6**
2.	Solution of (non-homogeneous) linear algebraic equations, review of matrix algebra, Gauss elimination method, Cholesky's decomposition method, householder method, Gauss-Siedal iterative method; Solution of non-linear algebraic equations, method of successive approximation, Newton's method, modified Newton – Raphson method, secant method	**8**
3.	Eigen values and Eigen vectors, reduction of generalized Eigen value problem to the standard Eigen value problem, methods for obtaining Eigen values and Eigen vectors	**6**
4.	Time marching schemes for solution of problems in time domain, numerical integration (2 – D) [Newton – Cotes method, Gauss – Legendre method]	**6**
5.	Solution of ordinary and partial differential equations, Euler's method, Runge – Kutta method, finite difference method.	**8**
6.	Sampling distributions, Tests for single mean, Proportion, Difference of means (large and small samples), Tests for single variance and equality of variances, Chi-square test for goodness of fit, Independence of attributes; Completely randomized design, Randomized block design, Latin square design, factorial design	**8**
	Total	**42**

11. Laboratory Practicals:

1. Solution of non-linear equations using MATLAB and related convergence study.
2. Solution of a system of equations using MATLAB and Matrix operations.
3. Curve fitting and polynomial approximation using MATLAB.
4. Consider a initial-value problem for harmonic oscillations. (i) Solve the equation explicitly. (ii) Solve this system with forward Euler method. (iii) Find a condition on the time step to ensure stability. (iv) Plot your solutions as curves. (v) Solve same question with backward Euler method and trapezoidal method.
5. Consider a mixed Neumann-Dirichlet boundary-value problem. Use Matlab to find out the eigenvalues and eigenvectors. Plot the first three eigenvectors. Do they match your theoritical prediction?
6. Numerical differentiation and integration using MATLAB.
7. Numerical approximation of model partial differential equations using MATLAB
8. Design of Experiments in MATLAB
9. ANOVA, Chi-square test for Goodness of fit in MATLAB.
10. Sampling distribution (Discrete and Continuous valiables) in MATLAB

12. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Chapra, S. C. and Canale, R. P., "Numerical Methods for Engineers", Tata McGraw hill	**2003**
2.	Heath, M. T. , "Scientific Computing : An Introductory Survey", McGraw hill	**1997**
3.	Douglas, F. J. and Burden, R.,"Numerical Methods", Cengage Learning, 4th Edition	**2012**
4.	Rajasekaran, S., "Numerical Methods in Science and Engineering: A Practical Approach", S. Chand & Sons	**2003**
5.	Walpole, R.E., Myers, R.H., Myers, S.L., and Ye,K., "Probability and Statistics for Engineers and Scientists", Pearson Education, Asia	**2007**
6.	Yang, W. Y., Cao W., Chung, T.-S., and Morris, J., "Applied Numerical Methods Using MATLAB", Wiley	**2005**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject Code : **NTN- 504** Course Title : **Nanoscale Modeling and Simulation**

2. Contact Hours : **L: 3** **T: 0** **P: 2**

3. Examination Duration (Hrs) : Theory : **03** Practicals : **00**

4. Relative Weight : CWS : **15** PRS : **25** MTE : **20** ETE : **40** **PRE 0**

5. Credits : **04** 6. Semester : **Spring** **7.** Pre-requisite **:** **Nil**

8. Subject Area : **PCC**

9. Objective: To introduce various approaches used for modeling and simulation of nanomaterials.

10. Details of Course:

S.No.	Contents	Contact Hours
1.	**Introduction:** Definition of a model, modeling in materials science; Simulation vs. modeling; Simulation techniques for nano, micro, meso and continuum scales; Nanoscale and microscale - molecular dynamics and Monte Carlo techniques.	**6**
2.	**Statistical Mechanics:** Microstate, Macrostate, Distribution Laws, Indistinguishable particles, statistical mechanics and thermodynamics laws; Maxwell Botzmann statistics.	**8**
3.	**Monte Caro Simulation:** Principles of equilibrium; Monte Carlo simulation-estimator; Importance of sampling, acceptance ratio, continuous time MC, Ising model and Metropolis algorithm; Simulation of Interfaces; Analysis of MC data; Out of equilibrium simulation; MC simulation in surface science; Implementation of MC algorithms.	**8**
4.	**Molecular Dynamics:** Introduction, Interatomic potentials, Equations of motion, integration, Pair Distribution, constraints and free energy; Time correlation functions and spherical densities; Velocity autocorrelation functions; Time correlation function and relaxation times; Applications in nanomaterials.	**8**
5.	**Molecular Dynamics:** Introduction, Interatomic potentials, Equations of motion, integration, Pair Distribution, constraints and free energy; Time correlation functions and spherical densities; Velocity autocorrelation functions; Time correlation function and relaxation times; Applications in nanomaterials.	**8**
6.	**Overview of Modelling, Simulation and Visualization Software:** LAMMPS, ABMER, Folding@home, GROMACS, NAMD, VMD, XMD, Materials Studio.	**4**
	Total	**42**

11.List of Laboratory Practicals:

1. Simulation of Ising Model using Metropolis algorithms.
2. Simulation of Potts model and its application in studying magnetic properties.
3. Molecular dynamics simulation of thermodynamic and kinetics properties.
4. Sintering of nanoparticles using LAMMPS/XMD
5. Deposition experiment using LAMMPS/XMD.
6. Yield Mechanism of nanostructures using LAMMPS
7. Nano-indentation experiments using LAMMPS
8. Structural properties calculation using LAMMPS.

12. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Newman, M.E.J. and Barkema, G.T., **"**Monte Carlo Methods in Statistical Phyiscs", Oxford University Press.	**1999**
2.	Lee, J. G., "Computational Materials Science – An Introduction", CRC Press.	**2012**
3.	Wolfson, M.M. and Pert, G. J., "An Introduction to Computer Simulation", Oxford Press.	**1999**
4.	Raabe, D., Computational Materials Science: The Simulation of Materials Microstructures and Properties, Wiley-VCH	**2005**
5.	Landau, D.P. and Binder, K., "A Guide to Monte Carlo Simulation in Statistical Physics", Cambridge University Press.	**2005**
6.	Frenkel, D. and Smith, B., "Understanding Molecular Simulation", Academic Press.	**1996**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN- 505** Course Title: **Laboratory methods (Multidisciplinary Experiments)**
2. Contact Hours : **L:0** **T:0** **P:4**
3. Examination Duration (Hours): Theory : **00** Practical : **04**
4. Relative Weight : CWS : 0 PRS : 50 MTE : 0 ETE 0 PRE : 50
5. Credits : **02** 6. Semester : **Spring** 7. Pre-requisite : **Nil**

8. Subject Area: **PCC**

9. Objective: This course is intended to provide the experimental training in multidisciplinary areas of nanotechnology.

10. List of experiments:

1. To study the forming characteristics of nanograined micro/nanostructure by mechanical alloying using high energy planetary ball mill.
2. To study the annealing behavior of nanopowders using microwave furnace under controlled environment.
3. Synthesis of nanocoating by electroless technique and to study the morphology of coatings.
4. Dielectric variation of ferroelectric ceramics PZT and $BaTiO_3$ with temperature and frequency.
5. Magnetic effect on dielectric properties of multiferrites.
6. CV characteristics of diodes to extract doping profile.
7. CV characteristics of MOSFETs to extract surface states.

8. Native agarose – gel electrophoresis for DNA.

9. Quantification of DNA oligonucleotides using UV – spectrophotometer.

11. Suggested Books:

S. No.	Name of Authors / Books / Publisher	Year of Publication/ Reprint
1.	Bhushan, B. (Ed.), Springer Handbook of Nanotechnology, Springer Science international edition.	**2007**
2.	Berg,J.M., Tymoczko, J.L., and Stryer,L., Biochemistry, 6thEd. – Freeman, W.H., and Company, New York.	**2006**
3.	Nalwa,H.S., Ed. Encyclopedia of Nano science and Nanotechnology.	**2004**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN- 601** Course Title: **Structural Analysis of Nanomaterials**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: This course aims at imparting the knowledge on structural aspects of nanomaterials.

10. **Details of Course**

S. No.	Contents	Contact Hours
1	**Introduction:** Phase, Phase rules of Gibbs; Phase diagram: unary, and ternary systems, lever rule; microstructure during cooling, Crystal formation (energy vs. distance between atoms); Structural Magic number rule to show the number of atoms in nanoparticles; X-ray diffraction by the crystalline phase.	4
2	**Quantitative Analysis:** Basic principles; Hanawalt method; Examples of phase analysis single phase and phase mixture; Analysis of unknown phase mixtures; practical difficulties.	4
3	**Quantitative Analysis:** Atom fraction and weight fraction; Factors that control absolute and relative X Ray intensities. **Single Phase:** Chemical analysis by parameter measurement, principle and application of this method. **Multiphase:** Basic principles, Methods like external standard method; Direct comparison method and internal standard method; precautions for precise measurements; Practical difficulties.	4

4	**Phase Determination:** Introduction; general principles; Solid solution: Interstitial, Random, Ordered and Defect; determination of the type of solid solutions by XRD; Determination of solvus curves for binary and ternary systems using disappearing phase method and parametric method; Precautions; difficulties.	**3**
5	**The determination of Crystal Structure:** Introduction, Preliminary treatment of data; Indexing patterns of cubic crystals; Indexing patterns of noncubic crystals; Determination of the number of atoms in unit cell; Determination of atom positions.	**3**
6	**Precise Parameter Measurements:** Introduction; Cameras used for measurements; Debys-Scherrer cameras, Back –reflection focusing cameras, Pinhole Diffractometers; Methods of least squares, Cohen' method, calibrations method.	**3**
7	**The structure of Polycrystalline Aggregate:** Introduction; Crystal size; Particle size; Crystal perfection; texture of wire, and rod.	**4**
8	**Orientation of Single Crystals:** Need for orientation identification, methods for determining crystal orientation; Laue method (the back- reflection and the Transmission Laue method); The diffractometer method; Zone , pole and trace, Stereographic projection, Wulff net, Angle between poles and traces, rotation of the poles around axes, Stereographic projection diffraction spots of transmission Laue methods, Greninger chart for the orientation of back- reflection Laue patterns, Leonhardt chart for the orientation of transmission Laue patterns, Diffractometer method of determining orientation, relative orientation of precipitate and matrix.	**4**
9	**Stress Measurement:** Introduction, Applied stress and residual stress, Uniaxial stress, Biaxial stress, Experimental technique using pinhole camera and diffractometer, Applications.	**4**
10	**Order Disorder Transformations:** Introduction Long order; examples like AuCu3 Detection of superlattice lines; Short range order and clustering.	**3**
11	**Structural Studies of Nanomaterials:** Reciprocal Lattice; Edward's Sphare and its application; Principles of emerging nanoscale X-ray techniques such as small angle X-ray scattering and X-ray absorption fine structure (XAFS); Electron and Neutron diffraction techniques and their applications to Nanomaterials.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of the Author(s) / Books/ Publisher	Year of Publication/ Reprint
1.	Cullity, B.D., Stock, S.R. and Stock, S, "Elements of X-Ray diffraction", Prentice Hall, 3rd Edition, New Jersey.	**2001**
2.	Phillips, R., "Crystal defects and Microstructures", Cambridge University Press, Cambridge, U.K.	**2001**
3.	Wang, Z.L., "Characterization of Nanophase Materials", Wiley-VCH, Weinheim, Germany.	**2000**
4.	Graef, M.D., McHenry, M.E., "An Introduction to crystallography, diffraction and symmetry", Cambridge University Press U.K.	**2007**
5.	Allen, S.M., Thomas, E.L., "The structure of Materials" (MIT Series in materials science and engineering), John Wiley & Sons, US.	**1999**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code **NTN- 602** Course Title: **Technology of Nanostructured Fabrications**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: To impart the knowledge on application of thin film technology to fabricate nanoelectronic, optical and magnetic data storage devices.

10. Details of Course

S.No.	Contents	Contact Hours
1.	**Introduction to Nanostructures:** Overview of thin film technology for various nanotechnology applications, Miniaturization of electrical and electronic devices, Moore's law. Epitaxial growth of thin films, Homoepitaxy and heteroepitaxy; lattice misfit and imperfections, thin film superlattice.	**6**
2.	**Production of Nanolayers (PVD & CVD Techniques):** Thermal evaporation, Sputtering, Molecular beam epitaxy (MBE) and Pulsed laser deposition (PLD), Chemical vapour deposition (CVD)	**11**
3.	**Introduction to Various Lithography Techniques:** Introduction & Limitation of Photolithography, X-ray Lithography, Electron Beam Lithography, Nanoimprinting & Soft nanolithography, Dip Pen nanolithography.	**12**
4.	**Applications and Emerging Technologies:** Thin films for micro & nanoelectronics, MEMS, NEMS, Growth and properties of semiconducting nanowires using topdown and bottom up approaches and their applications in electronic devices, mechanical, chemical and biochemical sensing applications. Solar cells, Fuel cells, superconducting and GMR devices, Gas sensors.	**13**
	Total	**42**

11. Suggested books:

S.No	Name of Author (s)/Book/Publisher	Year of Publication/ Reprint
1.	Madou, M., Fundamentals of Microfabrication, CRC Press.	**1997**
2.	Fahrner, W.R., Nanotechnology and Nanoelectronics, Springer.	**2005**
3.	Waits, R.K., Thin film deposition and patterning, American Vacuum Society.	**1998**
4.	Tu, K.N., Mayer, J.W., and Feldman, L.C., Electronic Thin Film Science for Electrical Engineers and Materials Scientists, American Vacuum Society.	**1992**
5.	Poole, C.P., Introduction to Nanotechnology, John Wiley & Sons.	**2003**
6.	Venables, J.A., Introduction to Surface and Thin Film Processes, Academic Press.	**2000**
7.	Vassen, J.1., and Kem, W., Thin Film Procss, Acadmic Press New York.	**1990**
8.	Ohring, M., Materials Science of Thin Films, Academic Press.	**2002**
9.	Callister Jr, D., Materials Science and Engineering: An Introduction 6^{th} Edition. William John Wiley & Sons.	**2003**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code: **NTN- 603** Course Title: **Supramolecular Chemistry of Nanomaterials**
2. Contact Hours : **L:3** **T:1** **P:0**
3. Examination Duration (Hours): Theory : **03** Practical : **00**
4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**
5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: To impart the knowledge on supramolecular Interactions and their importance in natural systems, self-assembly and synthesis nanodevices.

10. **Details of Course:**

S. N0.	Contents	Contact Hours
1.	**Introduction to Supramolecular Chemistry:** Inspiration, history and definitions; Molecular forces: Role of non- covalent interactions in supramolecular chemistry, difference with molecular and supramolecular system, kinetics and thermodynamics of supramolecular assemblies.	**5**
2.	**Molecular Structures:** Natural and artificial ionophores and receptors, cyclodextrins, zeolites, cucurbiturils, crown ethers, calixarenes and porphyrins based systems; Synthesis of receptors for cations, anions and neutral molecules; non covalent synthesis of macrocycles; metal containing molecular geometries; Molecular recognition biomaterials and bioinspiration (Protein folding, Assembly and structure, Protien misfolding and disease), biomimetics and nanotechnology.	**15**
3.	**Synthesis and Fabrication:** 'Top –down' vs. 'bottom –up' approaches, self-assembly and core- shell systems; Microspheres: Colors from the Beaker, microporous and mesoporous materials.	**8**
4.	**Applications of Self –assembled Nanomaterials:** Self assembled molecular structure (molecular containers, metalla –cages and capsules), molecular scale machines- mechanical rotors, gears brakes, and molecular switches. Self-assembling blocks copolymers, self-assembly of large building blocks, nanorods, nanotube and nanowire. Nano-imaging and nano-drugs.	**14**
	Total	**42**

11. Suggested Books:

S. No.	Name of the Author(s) / Books/ Publisher	Year of Publication/ Reprint
1.	Pradeep, T., "Nano The Essentials" , Tata Mc Graw Hill, New Delhi.	**2007**
2.	Ozin, G., Arsenault, A., "Nanochemistry A Chemical Approach to Nanomaterials", RSC, London.	**2005**
3.	Wang, Z.L., Zhang, Z., Liu, Y., "Handbook of Nanophase and Nanostructured materials" , Kluwer Academic, New York.	**2002**
4.	Cao, G., "Nanostructures and Nanomaterials, Synthesis, Properties and Application" , Imperial College Press London.	**2004**
5.	Gomez-Romero, P., Sanchez, C., "Functional Hybrid Materials" , Wiley-VCH, weinheim.	**2004**
6.	Balzani, V., Ventdurei, M., Credi, A. , "Molecular Devices and Machines – A journey in to the Nanoworld" , Wiley –VCH Weintheim.	**2003**
7.	Steed, J.W., Atwood, J.L., "Supramolecular Chemistry" , John Wiley & Sons, England.	**2000**
8.	Zang, J.Z., Wang, Z.L., Liu, J., Chen, S.W., Liu, G.Y., "Self –assembled Nanostructures", Kluwer Academic Publisher , New York.	**2002**
9.	Anslyn, V., Dougherty, D.A., "Modern Physical Organic chemistry" , University Science Books , Sausalito, CA.	**2006**
10.	Steed, J.W., Tuner, D.R., Wallace, K.J., "Core Concepts in Supramolecular Chemistry and Nanochemistry" , John Wiley & Sons Ltd., England.	**2007**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN- 604** Course Title: **Physics of Nanomaterials**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: This course is aimed at providing physics related concepts of nanomaterials.

10. **Details of Course:**

S.No.	Content	Contact Hours
1.	**Introduction:** An overview of quantum mechanical concepts related to low – dimensional systems e.g. Wave –particle, deBroglie wavelength, quantum confinement, time- dependent and time independent Schrodinger equation, Particle in box, a free particle.	**5**
2.	**Concepts Related to Electronic Structure:** Three dimensional and direct lattice, packing fraction, reciprocal, Brillouin Zones, Diffraction from 2D structures, Free electron approximation, periodic boundary conditions, allowed k values, Fermi energy, density of electronic states for one, two, and three dimensional electron gas, energy bands, Direct and indirect gap semiconductors, Lattice matching , effective mass, Variation of energy bands with alloy composition and its exploitation for devices.	**12**
3.	**Heterostructures and Electron States:** Heterojunctions, type I and Type II heterostructures , Classification of Quantum confined systems, electrons and holes in Quantum wells, Electronic wavefunctions, energy subbands and density of electronic states in Quantum wells, Quantum wires, and Quantum dots, Superlattices, wavefunctions and Density of State for superlattices, Excitons in Quantum structures and in heterostructures, The unit cell for quantum well, for quantum wire and for quantum dot.	**12**
4.	**Nanoclusters and Nanoparticles:** Introduction, particle shape and the surface, Collective surface area, Porosity, Spherical cluster approximation. Metal nanoclusters: Magic numbers, geometric structures, electronic	**6**

	structure, Bulk to nanotransition, Magnetic clusters; Semiconducting nanoparticles; Rare –gas and Molecular clusters.	
5.	Carbon Nanostructures: Introduction, to Carbon molecules and clusters, Structure of C 60 and its crystal, Small and Large Fullerenes and other Buckyballs, Carbon nanotubes and their electronic structure.	**5**
6.	Bulk Nanostructured Materials: Solid disordered nanostructures, Nanostructured crystals, photonic crystals.	**2**
	Total	**42**

11. **Suggested Books:**

S.No.	**Name of Books / Authors**	**Year of Publication/ Reprint**
1.	Hornyak, G.L., Dutta, J., Tibbals, H.F., Rao, A.K., "Introduction to Nanoscience" , CRC Press.	**2008**
2.	Midtin, V.V., Kochelp, and Strosci, MA., "Quantum Heterostructures: Microelectronics and Optoelectronics", Cambridge University Press.	**1999**
3.	Poole, C.P. Jr. and Owens, F.J., "Introduction to Nanotechnology", Wiley India.	**2006**
4.	Pradeep, T., "Nano: The essentials", Tata Mc Graw Hills.	**2007**
5.	Streetman, B.G., and Banerjee, "Solid State Electronic Devices", prentice Hall of India.	**2001**
6.	Harrison, P., "Quantum Wells, Wires, and Dots: Theoretical and Computational Physics", John Wiley.	**2000**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN-605** Course Title: **Electronic Properties and Measurement Techniques of Nanomaterials**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: To introduce the principles of electronic materials and their properties.

10. **Details of Course:**

S.No.	Contents	Contact Hours
1.	**Elementary Material Science Concepts:** Bonding principles and types of solids, crystalline states, Miller Indices, Crystal defects and their significance, amorphous, polycrystalline and single crystalline materials; single crystalline material developing methods and their limitations; solid solutions and two phase solids; phase diagrams of important electrical and electronic materials, nano-grain formation, magic number.	**8**
2.	**Electrical and Thermal Conduction in Solids:** Classical theory; temperature dependence of resistivity; Matthiessen's rule, Nordheim's rule; resistivity of mixtures; Hall effect; thermal conduction; electrical conductivity of semiconductors and ionic crystals, electrical conductivity of nanomaterials.	**6**
3.	**Modern Theory of Solids:** Hydrogen molecule; band theory of solids; semiconductors; density of states in an energy band; Boltzmann statistics; Fermi-Dirac statistics; Quantum theory of metals; Fermi energy significance, thermionic and field emission; selection of nanomaterials.	**6**
4.	**Semiconductors:** Intrinsic and extrinsic semiconductors; temperature dependence of conductivity, recombination and minority carrier injection; optical absorption; peizoresistivity; Schottky junction; direct	**6**

	and indirect semiconducting materials.	
5.	**Dielectric and Magnetic Materials**: Polarization and relative permittivity; electronic polarization, polarization mechanisms, dielectric constant and dielectric loss, dielectric breakdown, capacitor dielectric materials; piezoelectric, pyroelectric and ferroelectric materials and their significant usages; Magnetization of matter; magnetic materials classification – diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism; Ferromagnetism origin and exchange interation, saturation magnetization and Curie temperature, magnetic domains; soft and hard magnetic materials, magnetic recording materials; Superconductivity - Zero resistance, mechanism, Meissner effect, critical current density, applications.	**8**
6.	**Measurement Techniques:** Magnetic measurements: Permeability, saturation magnetization, susceptibility, Hysteresis loop (B-H curve); Vibrating sample magnetometer (VSM); superconducting quantum interference device (SQUID);Electrical measurements: Resistivity, conductivity, inductance, impedance, permittivity; LCR meter; ferroelectric (P-E loop); Dielectric measurements: Transmission line, rectangular waveguide and coaxial cable; scattering parameters (S-parameter); Vector network analyzer (VNA); Piezoelectric measurement; Magneto-electric measurement.	**8**
	Total	**42**

11. **Suggested Books:**

S.No.	**Authors/Name of Books/ Publisher**	**Year of Publication/ Reprint**
1.	Kasap S.O., Principles of Electronic Materials and Devices, 3rd Ed., McGraw-Hill.	**2009**
2.	Hummel R.E., Electronic Properties of Materials, 4th Ed., Springer.	**2011**
3.	White M.A., Physical Properties of Materials, 2nd Ed., CRC Press.	**2011**
4.	Kwok H.L., Electronic Materials, PWS Publications.	**1997**
5.	Streetman B., and Bannerjee S., Solid State Electronic Devices, 6th Ed., Printice Hall.	**2005**
6.	Hench, L.L. and West, J.K., Principle of Electronic Ceramics, 1st Ed., Willey.	**1990**
7.	Cooper W.D. and Helfrick, A.D., Electronic Instrumentation and Measurement Techniques, 3rd Ed., Printice Hall.	**1978**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN-606** Course Title: **Environmental Nanotechnology**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: To impart the knowledge on applications of nanotechnology in the field of Environmental Science and Technology

10. **Details of the Course:**

S. No.	Contents	Contact Hours
1.	Overview of physical, chemical and biological processes concerning the environment; types, transport and transformation processes of contaminants in air, water and soil; effects of contaminants on environment.	**6**
2.	Environmental impacts of nanomaterials - Exposure and risk assessment, Dose-response, mechanisms of toxicity; ecotoxicological impacts of nanomaterials - bioavailability and uptake; assessment of life cycle risk of nanomaterials.	**6**
3.	Nanoparticle transport, aggregation and deposition – physicochemical interaction, aggregation, deposition, nanoparticle behavior in heterogenous systems, airborne nanoparticles,	**5**
4.	Reactive oxygen species (ROS) generation – semiconductor nanoparticles and ROS generation, metal sulphide surface chemistry and free radical generation, fullerene photochemistry and ROS generation potential.	**5**
5.	Environmental applications of nanomaterials – Mechanism for remediation of aqueous contaminants, photocatalyst; membranes incorporating nanomaterials, transport processes in membrane technology; nanomaterial based adsorbents for water and wastewater treatment – adsorption at metal oxide surfaces, hybrid adsorbents; case studies.	**10**

6.	Analytical methodologies for studying impact of nanomaterials in environment – atomic absorption spectrometry, inductively coupled plasma spectrometry, chromatography, thermal methods, hyphenated techniques	**10**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Authors/Book/ Publisher etc.**	**Year of Publication/ Reprint**
1.	Wiesner, M.R., and Bottero, J.Y. (Ed.) "Environmental Nanotechnology: Applications and Impacts of Nanomaterials" McGraw-Hill, New York.	**2007**
2.	Diallo, M., Duncan, J., Savage, N., Street, A., and Sustich, R. (Eds). "Nanotechnology Applications for Clean Water" William Andrew.	**2008**
3.	Lead J., and Smith, E. "Environmental and Human Health Impacts of Nanotechnology" John Wiley & Sons.	**2009**
4.	Skoog, D.A., Holler, F.J., and Crouch S.R. "Instrumental Analysis" Clenage Learning India Private Limited, New Delhi.	**2007**
5.	Masters, G.M. and Ela, W.P. "Introduction to Environmental Engineering and Science" Prentice Hall.	**2007**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN-607** Course Title: **Transport Phenomenon in Nanomaterials**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: This course aims at imparting the knowledge on fluid flow, heat and mass transfer with specific emphasis on nanomaterials.

10. **Details of Course:**

S.No.	Contents	Contact Hours
1.	**Introduction:** Principle of momentum, mass and energy balance; Dimensional analysis and its applications; Generalized interface models for transport phenomena- unusual scale effects in composite nanomaterial.	**5**
2.	**Fluid Flow:** Laminar and Turbulent Fluid Flow; Viscosity; Mass balance-continuity equation for steady state, incompressible fluid; Momentum balance- equation of motion; Laminar flow through pipes; Over all mass and momentum balance; Flow meters; Flow through packed and fluidized beds; Motion of gas bubbles in liquids, Theory of transport phenomena on nanomaterials, Process parameters including the application in nanotechnology.	**8**
3.	**Heat Conduction:** Fourier's law of heat conduction; Conductivity; Heat conduction equation in rectangular, cylindrical and spherical coordinates; Steady state one dimensional and multidimensional heat conduction; Unsteady state heat conduction.	**5**
4.	**Heat Convection**: Forced convection; Natural convection; Overall thermal energy balance and concept of heat transfer coefficient.	**5**
5.	**Heat Transfer by Radiation**: Thermal radiations and related properties of materials like two dimensional nanomaterials (thin films); Emissivity and absorptivity of substances; Heat exchange between two infinitely long and wide parallel plates; Heat exchange between surfaces of finite area.	**5**
6.	**Mass Transfer:** Modes of mass transfer viz. diffusion and convection; Diffusion- Fick's laws of diffusion; Diffusion in gasses, liquids and solid;	**7**

	Convective mass transfer- natural and forced convection; Application in nanomaterials.	
7.	**Applications of Nanofluids:** Nanomaterials and their application in enhancement of thermal conductivity and heat convection; Nanofluids for heat transfer applications.	**7**
	Total	**42**

11. Suggested Books:

S.No.	Name of Author (s) / Book/ Publisher	Year of Publication / Reprint
1.	Bird, R. B. , Stewart, W.E. and Lightfoot, E.N., "Transport Phenomena", Revised 2nd Edition, John Wiley & Sons, Inc.	**2007**
2.	Geankoplis, C.J., "Transport Processes & Separation Processes Principles",4th Edition, PHI Learning Pvt. Ltd., New Delhi.	**2012**
3.	Incroperia, F.P., Dewitt, D.P., Bergman, T.L. and Lavine, A.S., "Principles of Heat and Mass Transfer";7th Edition, John Wiley & Sons, Inc.	**2013**
4	Nag, P.K., "Heat and Mass Transfer", 3rd Edition, Mc Graw Hill Education(India) Pvt. Ltd.	**2011**
5.	Thirumaleshwar, M., "Fundamentals of Heat and Mass Transfer" Pearson Education in South Asia.	**2012**
6.	Rathore, M.M., "Engineering Heat and Mass Transfer" 2nd Edition, University Science Press, New Delhi.	**2006**
7.	Arora, D., "A Course of Heat Mass Transfer" Dhanpat Rai Publishing Company (P) Limited.	**2005**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN-608** Course Title: **Surface Engineering of Nanomaterials**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Both** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: To impart knowledge on surface engineering of nanomaterials and their applications.

10. Details of Course:

S. No.	Particulars	Contact Hours
1.	**Fundamentals:** Introduction to tribology, surface degradation, wear and corrosion, types of wear, adhesive, abrasive, oxidative, corrosive, erosive and fretting wear, classification of nano coatings, definition, scope and general principles, application of surface engineering towards nanomaterials.	**6**
2.	**Conventional surface engineering:** Surface engineering by material removal, material addition, surface modification using liquid/molten bath, thermal and chemical treatments, gaseous medium etc.	**6**
3.	**Advanced surface engineering practices:** Surface engineering by energy beams, laser assisted microstructural and compositional modification, electron and laser beam, ion beam, plasma beam etc.	**9**
4.	**Advanced coating practices:** Cold spray, sputter deposition, ion implantation, sol-gel technique, electrolysis and electroless techniques, HVOF, PVD, PECVD, CVD, ALD etc.	**9**
5.	**Characterization of surfaces and coatings:** Porosity and adhesion of surface coatings, Measurement of coating thickness, wear track and debris analysis, surface microscopy and topography by scanning probe microscopy, spectroscopy analysis, XRD, AFM etc.	**6**
6.	**Functional coatings and Applications:** Brush, Screen printing, Spray, powder, Dip-coating, ED, Fluidized Bed, Electrostatic spray gun, photovoltaics, bio-and chemical sensors, semiconductors, polymers and composites, electronic, optical and magnetic devices, modeling.	**6**
	Total	**42**

11. Suggested Books:

S. No.	Name of Author (s) / Book/ Publisher	Year of Publication / Reprint
1.	Morton, P.H., "Surface Engineering & Heat Treatment", I.I.T, Brooke field.	**1991**
2.	"ASM Metals Handbook: Surface Cleaning, Finishing & Coating", Tenth Edition, Vol.5, Ohio, Metals Park, USA.	**2000**
3.	Satas, D. and Tracton, A.A., "Coating technology handbook", Mercel Dekker, New York.	**2001**
4	Davis, J.R., (Ed.)., "Surface Engineering for Corrosion and Wear Resistance", ASM International, Materials Park, Ohio.	**2001**
6.	Fontana, M.G., "Corrosion Engineering", 3rd Edition, M. C. Graw Hill, New York.	**2005**
7.	Winston Revie, R., (Ed.), "Uhlig's Corrosion Handbook", 3rd Edition, John Wiley & Sons. New York. USA.	**2011**
8.	Bieleman, J., "Additives for coating", Wiley-VCH Verlag, Germany.	**2008**
9.	Peter M. Martin, "Introduction to Surface Engineering and Functionally Engineered Materials", Wiley.	**2011**
10	Pal, K., (Ed.), "Recent Advances in Elastomeric Nanocomposites", Springer, Berlin	**2011**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT. /CENTRE : **Centre of Excellence: Nanotechnology**

1. Subject code : **NTN- 609** Course Title: **Nanobiotechnology**

2. Contact Hours : **L:3** **T:1** **P:0**

3. Examination Duration (Hours): Theory : **03** Practical : **00**

4. Relative Weight : CWS : **25** PRS : **00** MTE : **25** ETE : **50**

5. Credits : **04** 6. Semester : **Spring** 7. Pre-requisite : **Nil**

8. Subject Area: **PEC**

9. Objective: This course is intended to impart the knowledge of nanoscale biological molecules, their methods of analysis, integration to macromolecules, and providing an understanding of various nanobiological applications.

10. **Details of Course:**

S. No.	Contents	Contact Hours
1.	**Overview of Nanobiotechnology:** Historical perspective of integration of biology, chemistry and material science opportunities and promises of nanobiotechnology.	**2**
2.	**Biological Molecules and their Analysis:** Complexity and size of biological molecules – DNA, RNA proteins and carbohydrates; Techniques: Biological analysis electrophoretic and chromatographic analysis – basic principles and applications.	**6**
3.	**Single Molecule Approaches in Biotechnology:** Fluorescence – spectroscopy-Fluorescent probes for analysis of proteins and nucleic acids. Labeling of proteins and nucleic acids by acids by various fluorescent dyes. Molecular beacons and applications.	**4**
4.	**Microbiology and Nanotechnology:** Bacteria viruses: Prokaryotic complexity and size distribution; Bacterial cell-to –cell communication, quorum sensing, chemotaxis; Microbial production of inorganic nanoparticles; Gold nanoparticles for imaging and therapy.	**8**
5.	**Miniaturized Devices-Nanotechnology and medical devices:** Overview of smart devices for medical field; miniaturized devices for drug delivery;	**6**

	advantages of miniaturized devices; lab on chip concept; epipen; intelligent pill; wobbling gels.	
6.	**Nanomaterials used in Biotechnology:** Nanoparticles; carbon nanotubes; fullerenes; nanofibres; quantum dots and buckyballs interface with biological macromolecules; Biological perspectives of Nanomaterials: Impact of Nanomaterials in biological process; tolerance by immune systems and toxicity; Nucleic acid Engineering: Modifications of DNA for nanotechnological applications; Nanostructure assembly using DNA.	**7**
7.	**Applications of Nanobiotechnology:** Nano – Biosensing –Biosensors and nanobiosensors – basic Design type of nano –biosensors. DNA aptamers for nano- biosensing and drug discovery; Nano–medicine – Impact of nanotechnology in health medicine – overview .Promising applications of nanomedicine- recent concepts – implantable devices, dendrimers – polymers for drug delivery , targeted drug delivery for cancer and other diseases.	**6**
8.	**Chemical Biology and system biology:** Small molecules as antibiotics – mode of action, chemical genetics, nanotechnology and high throughput screening for drug discovery.	**3**
	Total	**42**

11. Suggested Books:

S. No.	Name of Books / Authors	Year of Publication / Reprint
1.	Berg, J.M., Tymoczko, J.L., and Stryer, L., "Biochemistry", 6thEd**. -** W. H. Freeman and Company, NewYork.	**2006**
2.	Goodsell, D.S., "Bionanotechnology: Lessons from Nature", Wiley Press.	**2004**
3.	Niemeyer, C.M. and Mirkin, C.A., (Editor). "Nanotechnology: Concepts, Applications and perspectives" , Wiley Press.	**2004**
4.	Weish, C., "Antibiotics: Action, Origins, and resistance" , ASM Press	**2003**
5.	Arya, D.P., "Aminoglycoside Antibiotics: From Chemical biology to Drug Discovery" Wiley Press.	**2007**
6.	Labhasehwar, V., and Leslie-Pelecky, D.L., (editor), "Biomedical Applications of Nanotechnology" , Wiley Press.	**2007**
7.	Klussman, S., "The Aptamer Handbook : Functional Oligonucleotides and their Applications" , Wiley VCH Press.	**2006**
8.	Paulter Adans, R.L., Knwler, L., and Leader, D.P., "The Biochemistry of the Nucleic Acids" Springer verlag GmbH.	**2007**