CENTRE FOR NANOSCIENCE AND TECHNOLOGY

Madanjeet School of Green Energy Technologies

PONDICHERRY UNIVERSITY

(Accredited with 'A' Grade by NAAC)

PUDUCHERRY - 605 014

M.Sc. - Nanoscience and Technology Programme

Syllabus & Regulations

2019-20 ONWARDS

M.Sc. - NANOSCIENCE AND TECHNOLOGY PROGRAMME

REGULATIONS (2019-20 Onwards)

1 AIM AND OBJECTIVES:

The M.Sc. in Nanoscience and Technology programme is a Multi-disciplinary program open to the students with an undergraduate degree from Physical/Chemical/Biological Sciences. The aim and objective of this program are to make the students understand the behaviour of the Nanomaterials at the Nanoscale, study their properties and also be able to bring out innovative products using this cutting-edge technology.

2. PROGRAMME OUTCOMES:

1. To have expertise in synthesis and processing of nanomaterials as per needs and specifications.
2. To project their skill in computer modelling and simulation, Lithography and Nanofabrication.
3. To demonstrate skills to use imaging equipment to analyze Nanomaterials.
4. To propagate their knowledge to address problems of social relevance such as energy and environment through their specific electives.
5. To show the understanding of the impact of Nanomaterials on the society including environment, health and ecosystem.
6. To able to plan and execute their own innovative ideas in the form of projects.
7. To develop confidence for self-education and ability for life-long learning.

3. DURATION OF THE COURSE: 2 YEARS

4. ELIGIBILITY FOR ADMISSION:

A candidate having a bachelor degree (B.Sc) in Physics/Chemistry/Applied Physics/Applied Chemistry, Industrial Chemistry, Polymer Chemistry or Biotechnology/Bio-Chemistry/Life sciences (botany and zoology) with a minimum of 55% of marks.

5. EXAMINATIONS

Semester examinations will be evaluated as per CBCS Scheme of evaluation of Pondicherry University.

6. The proportion of marks for internal assessment and end-semester examination for each theory and laboratory courses are 40:60 and 60:40 respectively.

7. GUIDELINES FOR AWARDING MARKS FOR IV SEMESTER RESEARCH PROJECT.

The time duration for IV semester Research project is one full semester.
Marks for a project awarded by the Project supervisor: **25 Marks**
Marks for a project mid-term review by 3 Members Committee: **25 Marks**
Marks for project report & Viva-voce exam awarded by the External Examiner: **50 Marks.**

[The mid-term review will be conducted and the assessment shall be made by the *Project supervisor along with a minimum two internal Faculty members of the Centre*. At the end, the project report evaluation & viva – voce exam will be conducted by the External examiner along with the Project Supervisor of the Centre.]

8. **PASSING REQUIREMENTS**

The student should have a minimum of 40% marks in both the Internal and the End Semester Exam and a minimum of 50% marks in aggregate when both the Internal assessment and End Semester Exam marks are added.

9. **INTERNAL ASSESSMENT**

Total internal marks 40; Mark distribution: Minimum of two internal tests to be conducted for 30 marks and for another 10 marks to be given for Assignment and Seminar.

10. INTERNAL ASSESSMENT TEST QUESTION PAPER PATTERN

Time duration: 2 Hours
Maximum Marks: 30

PART A: 5 × 2 = 10 Marks
Answer ALL Questions

Question 01 To Question 05

PART B: 4 × 5 = 20 MARKS
Answer any **FOUR** out of Five Questions

Question 06 To Question 10

11. **END SEMESTER EXAMINATION QUESTION PAPER PATTERN**:

Time duration : 3 Hours
Maximum Marks : 60

PART A: 10 ×2 = 20 Marks
Answer **ALL** Questions
(Two Questions must be asked from each unit)

Question 01 To Question 10

PART B: 5×8 = 40 MARKS Answer **FIVE** out of Seven Questions (Equal weightage must be given to each unit)

Question 11 To Question 17

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M.Sc., Nanoscience and Technology

CURRICULUM (2019-20 Onwards)

SEMESTER – I

Course code	Course Title	Course Type*	L	T	P	C
Hard – Core Course						
NSNT-411	Quantum Mechanics and Electromagnetic theory	H	3	1	0	3
NSNT-412	Thermodynamics and Kinetics for Nanoscience	H	3	1	0	3
NSNT-413	Elements of Materials Science	H	3	1	0	3
NSNT-414	Synthesis and Fabrication of Nano-structured materials	H	3	1	0	3
NSNT-415	Elements of Biology for Nanoscience	H	3	1	0	3
NSNT-416	Characterization Techniques for Nanomaterials	H	3	1	0	3
Practical						
NSNT-410	**Lab-I: Synthesis and Characterization of Nanomaterials**	H	0	2	4	3

Total Credits: 21

SEMESTER - II

Course code	Course Title	Course Type*	L	T	P	C
Hard – Core Course						
NSNT-421	Properties of Nanomaterials	H	3	1	0	3
NSNT-422	Nanoelectronics and Bioelectronics	H	3	1	0	3
NSNT-423	Computational Methods for Modeling and Simulations	H	3	1	0	3
Soft Core Course (Any TWO to be selected)						
NSNT-424	Environmental Nanotechnology	S	3	0	0	3
NSNT-425	Surface Science and Technology	S	3	0	0	3
NSNT-426	Self-Assembly of Nanostructures	S	3	0	0	3
NSNT-427	Bio-Materials and Nanotechnology	S	3	0	0	3
Practical						
NSNT-420	**Lab-II: Computer Modeling and Simulation for Nanomaterials**	H	0	2	4	3

Total Credits: 18

SEMESTER - III

Course code	Course Title	Course Type*	L	T	P	C
Hard – Core Course						
NSNT-531	Nano-Photonics	H	3	1	0	3
NSNT-532	Nanosensors and Devices	H	3	1	0	3
NSNT-533	Polymers and Nanocomposites	H	3	1	0	3
Soft Core Course (Any THREE to be selected)						
NSNT-534	Nanomaterials for Clean Energy Systems	S	3	0	0	3
NSNT-535	Nanomagnetic Materials and Devices	S	3	0	0	3
NSNT-536	Advance Nanobiotechnology	S	3	0	0	3
NSNT-537	Industrial Nanotechnology	S	3	0	0	3
XXX	Core / Soft core courses offered by other Departmants at PG level	S	3	0	0	3
Practical						
NSNT-530	**Lab-III: Fabrication and Characterization of Nanomaterials**	H	0	2	4	3

Total Credits: 21

SEMESTER - IV

Course code	Course Title	Course Type*	L	T	P	C
NSNT - 541	Research Project (Report and Viva- Voce	H	One Full Semester			12
Total Credits (I+II+III+IV Semesters)						72

***H- Hard –core courses; S- Soft –core Courses**
L- Lecture; T- Tutorial; P- Practical; C- No. of Credits

Evaluation:

All theory, practical courses have internal Assessment and External Assessment of **40:60** and Dissertation course are **50:50** respectively.

Semester - I **Credits: 21**

NSNT – 411 Quantum Mechanics and Electromagnetic Theory

Outcome/Knowledge/Skill:

- To Understand basics of Nanoscience and Technology through Quantum Mechanics
- Visualization of Nanotechnology by Quantum mechanics
- Getting fundamentals of electromagnetic theory for the applications in Nanophotonics.

Understanding the concepts of Electromagnetic theory.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT – I **(9 hrs)**

Basics of Quantum Mechanics: Quantum mechanics of a free particle confined to one, two and three dimensional box. Quantum mechanics of a free particle confined to a spherical trap. Electron in a periodic potential, Bloch theorem.

UNIT – II **(9 hrs)**

Approximation methods - Time Independent Perturbation Theory - Non-generate cases – Stark effect in the ground state of Hydrogen atom - Time independent Perturbation Theory for Degenerate case.

UNIT – III **(9 hrs)**

Identical Particles: Systems of Identical particles – Exchange degeneracy – Spin-statistics connection - Constructing symmetric and antisymmetric functions (wave functions of two-, three-, and many-particle systems.

UNIT – IV **(9 hrs)**

Quantum mechanics of Atoms and Molecules: Orbital approximation for multielectron atoms - Pauli's Anti-symmetry principle – Born – Oppenheimer approximation. Theory of H_2 molecule - Molecular orbital theory

UNIT – V **(9 hrs)**

Basics of Electromagnetic Theory: Electrodynamics: Maxwell Equations in Vacuum and Matter-Importance of Maxwell equations. Continuity Equation - Importance. Poynting Theorem-Energy distribution in EM waves. Electromagnetic waves in Vacuum and Matter.

REFERENCE BOOKS:

1. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, Wiley, New York, (2001), ISBN 0-471 48943 3
2. Molecular Quantum Mechanics (3rd Edition), P.W. Atkins and R. S. Friedman, Oxford University Press, (2004), ISBN: 0-19-566751-4
3. Introduction to Electrodynamics, David J. Griffiths, (ISBN: 978-81-203-1601-0), Prentice-Hall, India, (2009)
4. Quantum mechanics, L. I. Schiff, Mc-Graw Hill, New York (1949)
5. Quantum Mechanics, Vol I and Vol II, Claude Cohen-Tannaoudji, Bernard Diu, Franck Laloe, John Wiley & Sons (2005)

6. Quantum mechanics, J. L. Powell and B. Craseman, Addison-Wesley (1964)
7. Classical electromagnetism J. D. Jackson, John Wiley Publications (1999) (ISBN 0-471-30932-X)
8. Electromagnetic fields and waves, Paul Lorrain and Dale Corson, W. H. Freeman & Co, New York, (1988)

NSNT-412: Thermodynamics and Kinetics for Nanoscience

Outcome/Knowledge/Skill:

- Understand fundamental Laws of Thermodynamics, and Chemical Kinetics of reactions.
- Understand the application of statistical thermodynamics concepts for complex reaction and particularly for monodispersed nanoparticle synthesis.
- Get knowledge of phase transformation and crystallization of materials, and skill for nucleation and growth pattern of a nanoparticle.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT-I **(9 hrs)**

Thermodynamics: Thermodynamic laws, Entropy, Micro-and macro-states. Unitary and multi-component systems, Gibbs phase rule, phase diagrams relevant to macro systems and for nanoscale materials formation, Phase transitions. General criterion for equilibrium-Chemical potential and Gibbs free energy.

UNIT-II **(9 hrs)**

Statistical Thermodynamics: Partition functions. Thermodynamic functions using appropriate partition functions. Fermi-Dirac and Bose-Einstein statistics and statistical basis of entropy. Heat capacity of solids. Debye and Einstein models.

UNIT-III **(9 hrs)**

Phase Transformations: Fick's laws of diffusion, Solution of Fick's second law and its applications, Atomic model of diffusion, Temperature dependence of diffusion coefficient, Kirkendall effect. Thermodynamic considerations: Free energy of alloy phases and free energy-composition curves for binary systems.

UNIT-IV **(9 hrs)**

Nucleation and Growth: Energy considerations; Heterogeneous nucleation, Growth kinetics, overall transformation rates. Solidification: Nucleation and growth from liquid phase, Stable interface freezing, cellular and dendrite growth, freezing of ingots, nucleation and grain size, Segregation, Directional solidification, Growth of single crystals.

UNIT-V **(9 hrs)**

Precipitation from solid solution: Homogeneous and heterogeneous nucleation of precipitates, The aging curve, Mechanisms of age hardening, Examples from Al-Cu and other alloy systems. Order-disorder transformation: Examples of ordered structures, Long and short-range orders, Detection of super lattices, Influence of ordering on properties.

REFERENCE BOOKS:

1. S. Glasstone, Thermodynamics for chemists, Affiliated East West Press, 1965.
2. B. C. McClelland, Statistical Thermodynamics, Chapman and Hall, 1973.9
3. M. C. Gupta, Statistical Thermodynamics, Wiley Eastern Limited, 1993.
4. V. Raghavan, Solid State Phase Transformations, Prentice-Hall of India Pvt. Ltd. New Delhi, 1987.
5. D.A. Porter and K.E. Easterling, Transformations in metals and alloys, 2nd Edition, CRC Press, 1992.
6. N. D. Smith, Elementary Statistical Thermodynamics, Plenum Press, 1982.
7. J. Rajaram and J. C. Kuriacose, Thermodynamics for Students of Chemistry, Shobanlal Nagin Chand Co, 1986.
8. L. K. Nash, Elements of classical and statistical thermodynamics, Addison-Wesley, 1970
9. G. M. Barrow, Physical Chemistry (V Edition), McGraw Hill international Series, 1988.
10. P. W. Atkins, Physical Chemistry, Sixth edition, Oxford University Press, 1990.

NSNT- 413: Elements of Materials Science

Outcome/Knowledge/Skill:

On completion of the course, the student will be able to

- Understand the basics of crystal structures and crystal defects.
- Get a basic understanding of Nanomaterials and their dimensionality.
- Understand the basics of Symmetry & Group theory.

Understand fundamental concepts of bonding in Nanostructures

(Hard – Core Course)

L	T	P	C	
3	**1**	**0**	**3**	**45L**

UNIT-I **(9 hrs)**

Crystal structures: Crystal geometry: Crystal lattices, space lattices–Basis and crystal structure - Unit cell - Seven crystal systems - Bravais lattices - Crystal directions and crystal planes (Miller indices) - Crystallographic nomenclature- Important parameters in crystal structures**:** No. of atoms per unit cell, coordination number, radius ratio, packing factor - Some special crystal structures - Calculation of lattice constant.

UNIT-II **(9 hrs)**

Defects in Nanomaterials: Point defects: Vacancy defect, Substitutional defect, Interstitial defects, Frenkel defects and Schottky defects - Line defects: Edge dislocation and Screw dislocation - Surface defects: Grain boundary defect, stacking faults and twin boundary - Volume defects - Effect of crystal imperfections - Determination of crystal structure by X-ray diffraction method.

UNIT-III **(9 hrs)**

Classification on Nanomaterials: Classification based on dimensionality – Kinetics in Nanostructured materials**; Bonding in Solids:** Electrostatic interactions/Vander Waals

interaction: Ion pair interactions, solvent effects, Ion-dipole and dipole – dipole interactions, π - interactions - Ionic, covalent and co-ordination/dative bonds, hydrogen bonding, hydrophobic interactions; **Theories of Bonding:** VB theory - VSEPR theory - Hybridization - MO theory - Bonding in some homonuclear diatomic molecules.

UNIT-IV **(9 hrs)**

Symmetry & Group theory: Theories of group – Sub groups – Classes, Group multiplication table, Molecular symmetry and point groups, Symmetry elements and symmetry operations, Matrix representation of symmetry operations, Reducible and irreducible representations, Properties of irreducible representations, Great orthogonality theorem, Character table construction for C_{2v} and C_{3v} point group.

UNIT-V **(9 hrs)**

Bonding in Nanostructures: Graphene – Fullerenes – Carbon nanotubes - Bonding in armchair, zigzag and chiral structures - n-m=3q rule – Inorganic nanotubes, Nanosheets of Dichalcogenides – Reactivity on Nanosurfaces: Functionalization of Carbon nanotubes and Graphene.

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REFERENCE BOOKS

1. Materials Science and Engg., V.Ragavan, Prentice-Hall of India(p) Ltd, New Delhi.
2. The Physics and Chemistry of Solids, S.R.Elliott, John Wiley & Sons, England, 1998.
3. Chemical applications of Group theory, F.A.Cotton, Wiley Eastern Pvt. Ltd., New Delhi, 1978.
4. Nanoscience and Technology, V.S.Muralidharan and A.Sunramania, Ane Books Pvt. Ltd, 2009.
5. Nanostructured Materials and Nanotechnology – II, Eds. Sanjay Mathur and Mrityunjay Singh, Willey, 2008.
6. Carbon Nanotubes Science and Applications, Edited by M.Meyappan, CRC Press, 2005.
7. Group theory and its Chemical applications, P.K.Bhattacharya, Himalaya Publishing House, Mumbai, 1996.
8. Introduction to atomic and molecular structure, Jack Barrett, John Wiley and Sons, London, 1970.
9. Nanostructured Materials, Edited by Carl C. Koch, Noyes Publications, New York, 2002.
10. The Physics and Chemistry of Materials, Joel I.Gersten, F.W.Smith, S.R.Elliott, John Wiley &Sons,New York, 1998.
11. Carbon Nanotubes Science and Applications, Edited byM.Meyappan, CRC Press,2005.
12. Science of Fullerenes and Carbon Nanotubes, M.S.Dresselhaus, G.Dresselhaus, P.C.Eklund, Academic Press, 1996.
13. Theoretical Inorganic Chemistry – M.C. Day and I.Selbin, East –West Press, New Delhi, 1977.
14. Theoretical Inorganic Chemistry – M.C. Day and I.Selbin, East –West Press, New Delh,1977.
15. Crystallography, Walter Borchardt-Ott, Springer, 1995.

NSNT-414: Synthesis and Fabrication of Nanomaterials

Outcome/Knowledge/Skill:

Deals understanding at an advanced level of Physics and Chemistry of Nanotechnological applications and mainly focus on the design and development of efficient innovative nanostructured materials prepared by various methodologies and physicochemical characterization for technological applications and it also acquired an understanding of selected areas of nanoscience and technology for various applications at the frontiers of knowledge, beyond the undergraduate level

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT-I **(9 hrs)**

Chemical methods: Synthesis of nanomaterials by precipitation and co-precipitation methods, Sol-Gel synthesis, Microemulsions synthesis, Hydrothermal and Solvothermal methods. Microwave assisted synthesis, Sonochemical assisted synthesis.

UNIT-II **(9 hrs)**

Metal nanocrystals synthesis by polyol, and borohydrate reduction methods, Photochemical synthesis, Synthesis in supercritical fluids and Electrochemical synthesis, Synthesis of Core-Shell nanostructure, Organic –Inorganic Hybrids, Quantum dots (QDs) Carbon Nanotubes, Graphene nanosheets.

UNIT-III **(9 hrs)**

Physical methods: Fabrication of nanomaterials by DC and RF-sputtering, Molecular beam epitaxy (MBE), Chemical vapor deposition (CVD) method, Template assisted synthesis, Catalyst assisted chemical vapor deposition (CCVD), Spray Pyrolysis.

UNIT-IV **(9 hrs)**

Biological methods: Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles, Mechanism of formation, Viruses as components for nanostructured materials synthesis, Role of plants in nanoparticle synthesis.

UNIT-V **(9 hrs)**

Lithographic Process-Photo Lithography-Electron beam Lithography-X-ray Lithography-Ion beam Lithography. Nanoimprint and Nanosphere Lithography in device fabrication - Soft Lithography, Microcontact Printing-Inkjet and Screen Printing-3D Printing-Stereolithography-Principle and methods of Nanowire Formation-Assembly, Integration-Additive and subtractive techniques of nano fabrication-Anodic Oxidation, Dip pen lithography

REFERENCE BOOKS:

1. Nanochemistry: A Chemical Approach to Nanomaterials – Royal Society of Chemistry, Cambridge UK 2005.
2. Chemistry of Nanomaterials: Synthesis, properties and applications by CNR Rao et.al., Royal Society of Chemistry, Cambridge UK 2006.
3. Active Metals: Preparation, characterization, applications – A. Furstner, Ed., VCH, New York 1996.

4. Characterization of Nanophase materials – Z.L Wang (ed), Wiley-VCH, New York 2000.
5. Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2004.
6. Chris Mack, Fundamental Principle of Optical Lithography, John-Wiley & Sons, Inc., Sussex, 2007.
7. Micro-Nanofabrication Technologies and Applications, Zheng Cui, Springer-Verlag, Beijing, 2005.
8. Nanofabrication Principles, Capabilities and Limits, Zheng Cui, Springer, New York, 2008.
9. Nanostructured Silicon – based powders and composites – Andre P Legrand, Christiane Senemaud, Taylor and Francis, London New York 2003.
10. Processing & properties of structural nanomaterials - Leon L. Shaw (editor)
11. Elements of X-ray Diffraction by Cullity, B. D.,, 4th Edition, Addison Wiley, 1978.
12. Electron Beam Analysis of Materials by Loretto, M. H., Chapman and Hall, 1984.
13. Vacuum Physics and Techniques by T.A. Delcher, Chapman & Hall.

NSNT-415: Elements of Biology for Nanoscience

Outcome/Knowledge/Skill:

On Completion of the course the student will be able to

- Understand basic cell structure and cell cycles.
- Understand the metabolic pathways to anabolism and catabolism of carbohydrate, protein and lipids.

Get basic understanding of a living system and its energetics.

(Hard – Core Course)

L	T	P	C	
3	**1**	**0**	**3**	**45L**

UNIT – I **(9 hrs)**

Carbohydrates: Sugars - dissacharides, trioses, tetroses, pentoses, hexoses – stereoisomers - aminosugars, phosphosugars, sugar derivatives, deoxysugars - Oligossacharides-polyssacharides-homo and hetero polyssacharides, amylose, amylopectin, dextrans, limit dextran – starch - glycogen- synthesis and degradation-glycolysis, TCA cycle, glycosyl moieties, cell wall polyssacharides – cellulose, chitin.

UNIT- II **(9 hrs)**

Proteins: Amino acids, - essential and non essential - dipeptides, oligipeptides, polypeptides-monomers,dimers, oligomers - fibrous proteins and globulins - primary, secondary, tertiary, quarternary structures- disulfides, hydrogen bonds, schiff's base-amino and carboxy termini - alpha helix and beta pleats – triple helix - Ramachandran plots.

UNIT- III **(9 hrs)**

Nucleic acids: Nitrogen bases-purines, pyrimidines, nucleosides and nucleotides – oligonucleotides - base paring – DNA, RNA - tRnNA, mRNA, rRNA, antisense RNA – linear and circular forms, single and double stranded– hypo and hyperchromicity - DNA varieties – A, B, and Z – Okazaki fragments

UNIT- IV **(9 hrs)**

Lipids: Fats, Oils, Waxes - Fatty acids – types, saturated, unsaturated, essential, short and long chain – triglycerides, lipids and cholesterol - fatty acid / triglyceride / cholesterol synthesis and degradation – alpha, beta and omega oxidation of fatty acids.

UNIT- V **(9 hrs)**

Biocatalysis & Structural biology: Enzymes – active site, reaction rates, site specificity, sequence specificity, cofactor dependency, pH, temperature and ionic strength dependency – synthetic enzymes -enzyme classification - types of inhibition – enzyme immobilization - Industrial enzymes.

REFERENCE BOOKS:

1. Harper's Biochemistry, 28th edition, Robert K Murray; Daryl K Garner; Peter A Mayes; Victor W Rodwell. Lange Medical Books/ McGraw Hill, New York.
2. Lehninger Principles of Biochemistry, 5th edition, David L Nelson; Michael M Cox. W.H.Freeman Publishers, New York.
3. Biochemistry, 3rd edition, Donald Voet and Judith Voet. John Wiley Publishers.
4. Cell & Molecular Biology, 8th edition, E.D.P.De Robertis. Lippincott publishers.
5. Molecular biology of the cell, 6th edition, Alberts. Garland Publishing.
6. Essentials of Molecular biology, David Freifelder, Jones & Bartlett Publishers.
7. Genes, 9th edition, Lewin Benjamin. CBS Publishers and Distributors.
8. Molecular Cell Biology, Harvey Lodish; David Baltimore; Arnold Berk. WH Freeman and Co.

NSNT-416: Characterization Techniques for Nanomaterials

Outcome/Knowledge/Skill:

Knowledge:

The properties of Materials emanate from structure, chemistry and dimension. Hence, materials including that of Nanomaterials needs to be characterized with respect to physical dimension, crystal structure, phase formation and chemistry. Hence, a strong background is required with respect to fundamental principle, instrumentation and interpretation of various characterization tools. Hence, Characterization techniques for Nanomaterials becomes important and it provides an overview of various techniques.

Skills:

The students get acquainted with characterization techniques which is essential for understanding material properties.• Exposure to various tools may impart better insight to understand the real life evaluation of materials

(Hard – Core Course)

L	T	P	C	
3	**1**	**0**	**3**	**45L**

UNIT – I **(9 hrs)**

Diffraction and Scattering Techniques: X-ray diffraction – principle of operation – structural, size and strain determination – Grazing Incidence XRD (GIXRD) –Small angle X-ray scattering

(SAXS) – Mie theory of scattering – Dynamic Light Scattering (DLS) - X-ray photoelectron spectroscopy (XPS).

UNIT-II **(9 hrs)**

Spectroscopic Methods: Principle, instrumentation, operation, sampling and instrumentation of UV – Visible, Photoluminescence (PL), Fourier Transform Infrared (FT-IR), Raman and Surface Enhanced Raman (SERS), electron spin resonance (ESR) and nuclear magnetic resonance (NMR) Spectroscopy.

UNIT-III **(9 hrs)**

Microscopic techniques: Electron microscopy – instrumentation, sample requirements and application – Types of vacuum pumps and gauges – scanning electron microscope (SEM) – environmental SEM – contrast mechanism – types of electron and detection – transmission electron microscope (TEM) – selected area diffraction – Energy dispersive X-ray analysis (EDAX) – chemical quantification Scanning probe techniques – Principle of Atomic force microscope (AFM) and scanning tunneling microscope (STM) – Modes of operation and limitation

UNIT –IV **(9 hrs)**

Thermal Analysis Methods: Principle of Instrumentation and Applications - Thermogravimetric/Differential Thermal Analyzer (TG/DTA) – Differential scanning calorimetry (DSC) – Importance of thermal analysis for Nanostructures.

UNIT-V **(9 hrs)**

Mechanical Testings: Tensile/Microtensile testing - **Nanoindentation:** Nanoindentation principles, elastic and plastic Deformation-Mechanical properties of materials in small Dimensions-Models for interpretation of nanoindentation load displacement curves-Nanoindentation data analysis Methods-Hardness testing of thin films and coatings.

REFERENCE BOOKS:

1. Allessandra L. Da Roz, M. Ferreira, F. L. Leite, O. N. Oliviera, Nanocharacterization Techniques, 2017, Elsevier, Cambridge, USA, ISBN: 978-0-323-49788-7
2. S. Myhra, J. C. Riviere, Characterization of Nanostructures, 2013, CRC Press, Boca Raton, USA, ISBN: 978-1-4398-5415-0.14
3. Douglas A Skoog, F James Holler, Stanley R Crouch, Principles of Instrumental analysis, Seventh Edition, 2018, CENGAGE Learning, Boston, USA, ISBN: 978-1-305-57721-3.
4. David B Williams, C Barry Carter, Transmission Electron Microscopy, 2009, Plenum Publishing Corporation, New York, USA, ISBN: 978-0-387-76500-6.
5. Sergey Edward Lyshevski, Cristian I Contescu, Karol Putyera, Dekker Encyclopedia of Nanoscience and Nanotechnology, Second Edition, 2004, Marcel Dekker Inc., ISBN: 0-8247-5055-1
6. S. Zhang, Raman Spectroscopy and Its Application in Nanostructures, Second Edition, 2012, Wiley, Chichester, ISBN: 978-0-470-68610-2
7. Z. Wang, W. Zhou, Scanning Microscopy for Nanotechnology: Techniques and Applications, 2010, Springer, New York, ISBN: 9781441922090.
8. Y. Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, 2008, John Wiley & Sons (Asia) Pte Ltd., Singapore, ISBN:978-0-470-82298-2.
9. Ray F. Egerton, Physical Principles of Electron Microscopy, 2005, Springer, ISBN: 978-0387-25800-0.

NSNT-410: Lab-I: Synthesis and Characterization of Nanomaterials

Outcome/Knowledge/Skill:

Received training in research skills and methodology for novel chemical, physical and biological synthesis and processing approaches of nanomaterials.

(Hard – Core Course)

L	T	P	C	
0	**2**	**4**	**3**	**45L**

1. Synthesis of metal oxide nanoparticles by solution combustion and sol-gel methods,
2. Synthesis of metal oxide nanowores/rods by hydrothermal method
3. Synthesis of metal oxide nanosheets by sono-chemical method.
4. Synthesis of multi-ferrite nano-particles by chemical co-precipitation method.
5. Synthesis of silver nanoparticles, and its spectral analysis.
6. Preparation of nano-composites, nanoporous materials and core –shell nanoparticles.
7. Preparation of quantum dots such as cadmium selenides and its optical studies.
8. Preparation of cadmium sulphide nanoclusters and its spectral studies.

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Semester - II **Credits: 18**

NSNT-421: Properties of Nanomaterials

Outcome/Knowledge/Skill:

On completion of the course, the student will be able to

- Understand the size effect of nanomaterials.

Understand the various physical properties of Nanomaterials.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT-I **(9 hrs)**

Size effect of nanomaterials: Size, shape, density, melting point, wet ability, specific surface area, solid state phase transformation and band gap variation. **Diffusion properties:** Diffusion mechanism - Applications of diffusion -.Effect of diffusion on strength and flow of materials; Methods of enhancing or retarding diffusion - Grain boundary sliding and grain boundary migration.

UNIT-II **(9 hrs)**

Electronic Properties: Classification of materials based on band structures - Brillouin zone – Effect of temperature on conductors – Intrinsic and extrinsic semiconductors - Hall effect and its determination. **Optical Properties:** Photo conductivity - Optical absorption and transmission – Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence – Band gap engineering – Optical properties of semiconductor nanoparticles.

UNIT-III **(9 hrs)**

Magnetic properties: Brief review on dia, para, ferro, ferri and anti-ferromagnetic materials – Superparamagnetism and its limits – Important properties in relation to nano-magnetism –Size induced magnetism on Au and Ag nanoparticles. **Dielectric Properties:** Dielectric materials - Effect of particle size on dielectric properties, ferroelectrics piezoelectrics and pyroelectrics.

UNIT-IV **(9 hrs)**

Mechanical Properties: Stress-strain behavior, tensile strength, toughness, micro-hardness, wear resistance and corrosion resistance behaviour of nanomaterals. Microstructure dislocation interactions at low and high temperatures.

UNIT-V (9 hrs) Thermal properties: Heat capacity, thermal conductivity and thermal expansion of nanomaterials – Thermal stresses. **Environmental degradation:** Corrosion and oxidation of nanomaterials and their prevention.

REFERENCE BOOKS:

1. Fundamental Properties of Nanostructured Materials, Ed. D. Fiorani (World Scientific, Singapore, 1994.
2. Nanoscience and Technology, V.S.Muralidharan and A.Sunramania, Ane Books Pvt. Ltd, 2009.
3. Properties of Materials, Robert E.Newnham,Oxford University Press, 2005.
4. Materials Science and Engg., V.Ragavan, Prentice-Hall of India(p) Ltd, New Delhi.

5. Fundamental Properties of Nanostructured Materials, Ed. D. Fiorani (World Scientific, Singapore, 1994.
6. The Physics and Chemistry of Materials, Joel I.Gersten, F.W.Smith, S.R.Elliott, John Wiley &Sons,New York, 1998.
7. The Physics and Chemistry of Solids, S.R.Elliott, John Wiley & Sons, England, 1998.
8. Principles of Corrosion Engineering & Corrosion Control, Zaki Ahmad, Butterworth Heinemann, 2006.
9. Corrosion Engineering, M.G.Fontana, N.D.Greena, Mc Graw Hill, New York, 1978.

NSNT-422: Nanoelectronics and Bioelectronics

Outcome/Knowledge/Skill:

On successful completion of this course, the students will able to

- Understand the basic of nanoelectronics and bioelectronics.
- Acquire knowledge on principle and operation of various electronics and biomedical devices, like FET, LED, MOSFET, etc.

Acquire knowledge on utilization of various nanostructures for fabrications of nanoelectronic devices and biomedical devices

(Hard – Core Course)

L	T	P	C	
3	**1**	**0**	**3**	**45L**

UNIT-I **(9 hrs)**

Semiconductor LEDs and Lasers: LED, white light LEDs, GaN and other visible LEDs, GaAs/ GaAlAs quantum well lasers, quantum wire lasers, quantum dot lasers, vertical cavity surface emitting lasers, quantum cascade lasers, other semiconductor lasers.

UNIT-II **(9 hrs)**

Nanoscale MOSFETs: Challenges in miniaturization, quantum effects, thin oxides, tunnelling and sub-threshold currents, power density, hot electron effects, fundamental limits of MOS operations, MODFET (Modulation Doped FET), GaN based HEMT (High Electron Mobility Field Effect Transistors).

UNIT-III **(9 hrs)**

Molecular Nanoelectronics: Electronic and optoelectronic properties of molecular materials, Electrodes & contacts, molecular electronic devices, organic material based diode, organic LEDs, organic FETs, carbon nanotube and grapheme based FETs.

UNIT-IV **(9 hrs)**

Nanoelectronics and Quantum Devices: Fundamentals of Semiconductor physics, Quantum confinement theory, Electronic transport in 1, 2 and 3 dimensions, energy sub-bands, Effective mass, Single electron tunnelling phenomena, Coulomb blockade, Coulomb staircase, Bloch oscillations.

UNIT-V **(9 hrs)**

Nanobioelectronics: Nanoelectronic Biosensors, Materials for biosensor applications, Nanowire Biosensors, Carbon Nanotube Biosensors, Graphene Biosensors, DNA based biosensors, protein based biosensors, quantum dot based bio imaging, Cell Interfaces and Electrophysiological Recording.

REFERENCE BOOKS

1. Nanoscale Transistors- Device Physics, Modeling and Simulation, M. Lundstrom and J. Guo, Springer, 2005, ISBN- 978-0-387-28003-5, 978-0-387-28002-8, 978-1-4419-3915-9.
2. Nanoelectronics- principles and devices, M. Dragoman and D. Dragoman, Artech House publishers, 2005, ISBN: 9781596933682.
3. Fundamentals of modern VLSI devices, Y. Taur and T. H. Ning, Cambridge University Press, 1998, ISBN: 0521559596, 9780521559591
4. Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices, K. Goser, P. Glosekotter and J. Dienstuhl, Springer, 2005, ISBN 978-3-662-05421-5.
5. Handbook of Thin Film Materials, volume 5, edited by H.S Nalwa American Scientific Publishers, 2002, ISBN: 9780125129084, 9780080533247.
6. Encyclopedia of Nanoscience and Nanotechnology, Edited by H.S. Nalwa, American Scientific Publishers, 2007, ISBN: 1-58883-001-2 , ISBN: 1-58883-159-0
7. Nanoelectronics and Information Technology, W. Rainer, Wiley, 2003, ISBN: 978-3-527-40927-3
8. Nanosystems, K.E. Drexler, Wiley, 1992, ISBN:0-471-57518-6
9. Science of Fullerenes and Carbon Nanotubes, M.S. Dresselhaus and G. Dresselhaus, Academic press, 1996, ISBN: 9780080540771.

NSNT-423: Computational Methods for Modeling & Simulations

Outcome/Knowledge/Skill:

On completion of the course the student will be able to

- Understand the scientific problems represented in mathematical forms such as differential equations and integral equations.
- Get introduction to Numerical methods in order to solve scientific problems.
- Get a good introduction and application how to simulate nanotechnological materials systems with the aid of computation and simulation.

Will be Competent with Strong topics such as Monte Carlo simulations using Random numbers and finite difference and finite element methods are learnt to have an advanced computational technique.

(Hard – Core Course)

L	T	P	C	
3	**1**	**0**	**3**	**45L**

UNIT – I **(9 hrs)**

Analytical methods: Ordinary differential equations – Types - General solutions - Laplace transform –Application to functions and differential equations. Partial differential equations: Introduction - Separation of variables

UNIT – II **(9 hrs)**

Numerical Methods: Numerical Differentiation - Numerical solution of a system of ordinary differential equations: Runge Kutta method and adaptive step size control - predictor and corrector method.

UNIT – III **(9 hrs)**

Numerical integration: Newton-Cotes integration formulae – Derivation of Trapezoidal and Simpson's integration formulae from Taylor Series – Problems – Monte Carlo Integration.

UNIT – IV **(9 hrs)**

Numerical Linear Algebra: Matrices - Solution of linear algebraic equations – Standard methods - Singular value decomposition, Eigenvalue problems - Computing Eigenvalues and Eigenvectors. Iterative methods for linear systems.

UNIT – V **(9 hrs)**

Computer Programming: Fortran Programming - Fortran based programming for numerical differentiation, Integration – Programs to solve linear systems.

REFERENCE BOOKS:

1. Advanced Engineering Mathematics, Michael D. Greenberg, Pearson Education Asia, (2002) ISBN: 81-7808-799-5
2. Computational methods in Physics and Engineering, 2nd Edition, Samuel S.M. Wong, ISBN: 9810230176, World Scientific-Singapore (2003)
3. Numerical Methods in Fortran, John McCormic and Mario G. Salvodori, Prentice Hall Inc, N.J. USA.
4. Scientific Computing: An Introduction with Parallel Computing, G. Golub and J.M. Ortega, Academic Press, (1993).Scientific Computing: An Introductory Survey, Michael T. Heath, McGraw-Hill, New York, (2002).
5. Numerical Recipes in Fortran / F-90 / C, W.H. Press et. al., Cambridge Univ. Press (1996)
6. A First Course in Computational Physics, P.L. DeVries, John Wiley (1994).
7. Computational physics- Problem solving with computers, Rubin H. Landau, Manuel J. Paez, John Wiley & sons (1997).
8. Guide to Neural Computing Applications, L. Tarassenko, Arnold Publishers, (1998).
9. Genetic Algorithms in Search, Optimization, and Machine Learning, D. E. Goldberg, Addison Wesley, Reading, Massachusetts, (1989).

NSNT-424: Environmental Nanotechnology

Outcome/Knowledge/Skill:

This will provide knowledge on the effect of nanomaterials on various environmental factors. This deals with the environment remediation through nanotechnology, nanotoxicology and different methods to analyze the effect of nanotechnology on the environment.

(Soft – Core Course)

L	T	P	C	
3	0	0	3	45L

UNIT I **(9 hrs)**

Introduction

Environmental impact of nanomaterials – Exposure and risk assessment – Mechanism of toxicity, Toxicological impacts of Nanomaterials – Ecotoxicological impact of Nanomaterials.

UNIT II **(9 hrs)**

Environmental Nano-Remediation Technology

Physical, Chemical and Biological methods – Nanofiltration for treatment of wastes – Removal of Organics, Inorganics and Pathogens – Nanotechnology for water purification –Treatment of industrial waste water using Nanomaterials – Environmental benefits of Nanomaterials.

UNIT III **(9 hrs)**

Nanomaterial remediation

Nanomembranes – Nanofibers - Nanoclays - Nano-adsorbents - Zeolites - Nanocatalysts - Photocatalysis - Carbon nanofibers.

UNIT IV **(9 hrs)**

Toxicological impacts of nanomaterials

Ecological impacts of Nanomaterials – Sustainability and Global conditions – Material and solid waste management – Energy Management – Chemical waste Management and Green Chemistry, Climate change and air emission Management, Drinking water and Waste water management.

UNIT V **(9 hrs)**

Analytical methodologies

Impact of Nanomaterials in Environment –Atomic Absorption Spectroscopy – Inductively coupled plasma spectroscopy – Chromatography – Thermal methods – Hyphenated techniques.

REFERENCES

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, 2008.18
3. Lead J., and Smith, E. ―Environmental and Human health Imapcts of Nanotechnology‖ John Wiley & Sons. 2009

4. Skoog, D.A., and Holler, F.J and Crouch S.R. ―Instrumental Analysis‖ Cleanage
5. Learning India Private Limited, New Delhi. 2007
6. Masters, G.M. and Ela, W.P. ―Introduction to Environmental Engineering and Science‖ Prentice Hall. 2007
7. Environmental applications of nanomaterials – Synthesis, Sorbents and Sensors, edited by Glen E Fryxell and Guozhong Cao, worldscibooks, UK
8. Environmental nanotechnology, Mark Weisner, JeoYuesBolteru, 2007, McGraw Hill.
9. The Chemistry of Nanomaterials, Synthesis, Properties and applications. Edited by7 C.N.R. Rao. Muller, A.K.Cheetham Copyright 8 2004 WILEY-VCH Verlag GmbH&Co.KGaA, Weinheim
10. Handbook of Nanotechnology, Edi-Bharat Bhushan, Springer, 2004.

NSNT-425: Surface Science and Technology

Outcome/Knowledge/Skill:

Knowledge:

Surfaces are vital to many knowledge domains as it modulate the properties of few atoms. Ranging from colloids, coating and films, nanostructures the primary beneficial property arise from the arrangement of atoms over the surface. It provides an overview on the various aspects of surface interactions with liquid-solid-gas environment. It provides a selective understanding on the surface phenomenon, thereby providing another dimension in the understanding.

Skills:

- Ability to generate colloids and stabilization, functional coatings
- Surface characterization tools and interpretation of the results from the evaluation

(Soft – Core Course)

L	T	P	C	
3	**0**	**0**	**3**	**45L**

UNIT-I **(9 hrs)**

Surfaces and Characterization: Surface and Interface – Importance of surface at nanoscale – TLK model – Field Ion Microscopy (FIM) and Low Energy Electron Diffraction (LEED) – X-ray photoelectron spectroscopy (XPS) – Surface Defects and determination – Thermodynamics of surfaces – surface free energy–Surface tension/energy and wetting – Young-Laplace equation – contact angle – Experimental evaluation of surface tension – minimization of surface tension

UNIT – II **(9 hrs)**

Colloids: Introduction to colloids material – preparation & characterization of colloidal particles – Electrical properties of surfaces – determination of zeta potential- structure of the electrical double layer - Interactions between particles: repulsive and attractive forces, DLVO theory – stability of colloids – Surfactants – theory and types – Shape, size and structure of surfactants – Micelle, Emulsions, Microemulsions & Gels – Applications

UNIT- III **(9 hrs)**

Catalysis: Need for a catalyst – Classification and properties of catalyst – homogeneous and heterogeneous catalysis –internal and external surfaces – Adsorption of gases at surfaces, chemisorption, physisorption, isotherms – surface area determination – Catalytic reaction

mechanisms and kinetics on solid surface – activation energy – Electronic structure of catalyst – factors influencing catalytic activity at nanoscale –Applications –Photocatalyst

UNIT – IV **(9 hrs)**

Electrochemical aspects of Corrosion: Corrosion and its importance – Electrochemical and thermodynamic principles – Nernst equation and electrode potential of metals, standard electrodes and reference electrodes, E.M.F. and galvanic
series – Exchange current density, different forms of polarization – Tafel equation – theories of passivity – Various types of corrosion – Corrosion prevention, design improvement, cathodic and anodic protection, metallic and non-metallic coatings – corrosion inhibitors

UNIT- V **(9 hrs)**

Surface modification/protection by coatings: Self-cleaning, anti-fouling/microbial, bioinspired, anti-fingerprint, abrasion & wear resistant, thermal barrier, UV resistant, anti-reflection, corrosion protection, conductive, superhydrphobic nanocoatings

TEXT BOOKS:

1. A.W. Adamson and A.P.Gast, Physical Chemistry of surfaces, 1997, Wiley, New York, ISBN: 978-0-471-14873-9.
2. P.C Hiemen and R.Rajgopalam, Principle of colloid and surface Chemistry, Third Edition, 1997, Marcel Dekker Inc., New York, ISBN:978-0-8247-9397-5
3. K. W. Kolasinski, Surface science – Foundation of catalysis and nanoscience, Third Edition, 2012, Wiley, Chichester, ISBN-978-0-470-66556-5.
4. M.G. Fontana, Corrosion Engineering, Third Edition, 2005, Tata McGraw-Hill Publishing Company Limited, New Delhi, ISBN: 0-07-021463-8.
5. Steven Abbott, Nigel Holmes, Nanocoatings: Principles and practice, 2013, DEStech Publication Inc., Pennsylvania, ISBN: 978-1-60595-090-7
6. Gabor A. Somorjai, Yimin Li, Introduction to Surface Chemistry and Catalysis, Second Edition, 2010, Wiley, New Jersey, ISBN: 978-0-470-508237-7.
7. M. J. Rosen, J. T. Kunjappau, Surfactant and Interfacial phenomena, Fourth Edition. 2012, John Wiley & Sons Inc, New Jersey, ISBN-978-0-470-54194-4.
8. T. Cosgrove, Colloid Science Principles, methods, Second Edition, 2010, Wiley, Wiltshire, 9781444320190
9. Self-Cleaning Coatings – Structure, Fabrication and Application, 2017, Royal Society of Chemistry, Cambridge, ISBN-978-0-78262-286-4.
10. M. Aliofkhazraei, Anti-abrasive Nanocoatings – Current and Future Applications, 2015, Woodhead Publishing, Cambridge, ISBN: 978-0-85709-211-3.
11. Lech Pawlowski, The Science and Engineering of Thermal Spray Coatings, Second Edition, 2008, John Wiley & Sons Inc., Sussex, ISBN: 978-0-471-49049-4

NSNT-426: Self-Assembly of Nanostructures

Outcome/Knowledge/Skill:

- Extend their knowledge of design of innovative nanostructured materials based on basic chemistry, physics, biology and self assembly concepts applied to nanoelectronics, nanophotovoltaic and energy materials
- Self-assembly of nanomaterials and their nanohybrids for technological applications

(Soft – Core Course)

L	T	P	C	
3	0	0	3	45L

UNIT-I **(9 hrs)**

Self-assembly and Self-organization of nanostructured materials, growth mechanism, Chemical, physical and biological self-assembly, Assembling and patterning of particles, Self-organization of different Nano-morphologies (Quantum Dots, Nanorods, Nanowires and Nanotubes.

UNIT-II **(9 hrs)**

Bottom-up approach, Self-assembly of single electron transistors (SET), Photovoltaic related devices, Langmuir Blodgett films (LB): principle of formation of monolayer formation, compression of monolayer-fabrication of LB films, applications.

UNIT-III **(9 hrs)**

Self Assembled Monolayer (SAM), guided self-assembly, nanolithography, surface topography,surface wetting, Electrostatic force, Nano-manipulators,grippers, design and geometry.

UNIT-IV **(9 hrs)**

Self Assembly by micro contact printing, creating the stamp, substrate, creating self-assembled monolayers, industrial applications. Macroscopic expressions of natural existing nanostructured materials,hierarchical ordering in natural nanoscale materials

UNIT-V **(9 hrs)**

Bio-Inspired approach for complex superstructures in biology, Self-Assembly in the biological systems,Superhydrophobicity, Self-cleaning property, Multi scale ordering and functional mechanism, Biological Nanoscale Materials:proteins, carbohydrates, lipids, nucleic acid and shell as a Composite Materials.

REFERENCE BOOKS:

1. Self-Organized Nanoscale Materials: Nanostructure Science and Technology by Motonari Adachi and David J. Lockwood, 2006 Springer Science, Business Media, Inc. NY, USA
2. Self-Assembled Nanostructures: Jin Z. Zhang, Zhong-lin Wang, Jun Liu, Shaowei Chen, and Gang-yu Liu, 2003 Kluwer Academic/Plenum Publishers, NY, USA
3. Nanoparticles: Theory to Applications by Günter Schmid, 2010 WILEY-VCH Verlag GmbH & Co. KGaA, Boschstr. 12, 69469 Weinheim.
4. Hand Book of Nanotechnology, by Bharat Bhushan, 2007, Springer Science + Business Media, Inc, NY, USA.
5. Prospects in Nanotechnology: Toward Molecular Manufacturing, Markus Krummenacker and James Lewis (Editors), Wiley 1995.

NSNT-427: Bio-Materials and Nanotechnology

Outcome/Knowledge/Skill:

- Gain a basic knowledge on the scientific disciplines involved in the development of biomaterials for a wide range of biomedical applications.
- A comprehensive knowledge will be acquired on the different type of biomaterials namely the variation in metals, ceramics and polymers in terms of their chemical and physical aspects.

(Soft – Core Course)

L	T	P	C	
3	0	0	3	45L

UNIT I **(9 hrs)**

Class of Materials Used in Medicine: Introduction, Properties of Materials, Type of Materials in Medicine – Metals, Polymers, Hydrogels, Ceramics, Glasses and Glass Ceramics, Composites, Thin films, Grafts and Coatings.

UNIT II **(9 hrs)**

Biological Interactions with Materials: Introduction, Biocompatibility, Toxicity, Cytotoxicity, Hypersensitivity, Carcinogenicity, Interaction of Materials with Soft Tissues, Inflammation, Granulation Tissue Formation, Foreign Body Reaction, Fibrosis, Modification of Blood-Biomaterial Interactions, Interaction with Blood by Heparin, Interactions with Proteins.

UNIT III **(9 hrs)**

Biomaterials Testing: *In Vitro* Assessment of Tissue Compatibility, *In Vivo* Assessment of Tissue Compatibility, Testing of Blood—Materials interactions, Animal Models.

UNIT IV **(9 hrs)**

Degradation of Materials in Biological Environment: Chemical and Biochemical Degradation of Polymers, Degradative Effects of the Biological Environment on Metals and Ceramics, Mechanical Breakdown in the Biological Environment

UNIT V **(9 hrs)**

Application of Materials in Medicine: Treatments and Strategies, Cardiovascular Applications, Dental Implants, Ophthalmologic Applications, Ophthalmologic Applications, Orthopedic Applications, Drug Delivery Systems, Sutures, Burn dressings, Biomedical Sensors and Biosensors.

REFERENCE BOOKS:

1. Biomaterials Science, An Introduction to Materials in Medicine, Edited by Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, Academic Press, A
2. division of Harcourt Brace & Company, 525 B Street, Suite 1900, San Diego, California 92101 -4495, USA.
3. The Chemistry of Medical and Dental Materials, John W. Nicholson, RSC materials monographs, Published by The Royal Society of Chemistry, Thomas Graham House, Science Park, Milton Road, Cambridge CB4 OWF, UK. ISBN 0-85404-572-4.

4. Nanoscale Technology in Biological Systems, Edited by Ralph S. Greco, Fritz B. Prinz, R. Lane Smith, CRC PRESS, Boca Raton London New York Washington, D.C. Copyright © 2005 by Taylor & Francis
5. Biological Nanostructures and Applications of Nanostructures in Biology. Electrical, Mechanical, and Optical Properties. Edited by Michael A. Stroscio and Mitra Dutta, 2004, kluwer academic publishers, new york, boston, dordrecht, london, moscow, eBook ISBN: 0-306-48628-8, Print ISBN: 0-306-48627-X 30.
6. Biomedical Nanostructures. Edited by Kenneth E. Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair, wiley-interscience a john wiley & sons, inc., publication, 2008.
7. Dendrimer based Nanomedicine, Edited by Istvan J. Majoros, James R. Baker, 2008, Pan Stanford Publishing Pte. Ltd.
8. Nanoparticulate Drug Delivery Systems, Edited by Deepak Thassu, Michel Deleers, Yashwant Pathak, 2007, Informa Healthcare USA, Inc., 270 Madison Avenue, New York, NY 10016, ISBN-13: 978-0-8493-9073-9.

NSNT-420:

Lab-III: Computer Modeling and Simulation for Nanomaterials

Outcome/Knowledge/Skill:

On successful completion of this computer lab course, the students will able to

- Acquire knowledge on various scientific modelling and simulation techniques.
- Understand various syntax and command code for wide used modelling and simulation softwares.

Acquire knowledge to theoretically simulate the physical and chemical properties of various nanomaterials based on available data.

(Hard – Core Course)

L	T	P	C	
0	**2**	**4**	**3**	**45L**

1. **Modeling and Simulation programs using MATLAB & Simulink or similar program for solving problems of Nanoscience and Nanotechnology.**

- Matrix algebra (addition, subtraction & multiplication) using MATLAB.
- Solving a set of simultaneous equations by Gauss elimination method using MATLAB
- Solving a set of simultaneous equations by Gauss Jordan Method using MATLAB.
- Solving the equation by Runge-Kutta method using MATLAB.
- Finding the roots of the equation by Newton-Raphson method using MATLAB.
- Generate sine wave and plotting a graph using MATLAB
- Fitting a curve using MATLAB.
- To evaluate and plot the Eigen value & Eigen function of a particle in a one dimensional box.
- To find the size dependent band gap of a material using MATLAB.
- Image processing using MATLAB software.

2. **Fortran Programming for solving problems of Nanoscience and Nanotechnology.**

- Introduction to FORTRAN software.
- Matrix algebra (addition, subtraction & multiplication) using FORTRAN software.
- Solving Quadratic equation using FORTRAN.
- Solve the linear differential equation using Runge-Kutta 4th order method using FORTRAN software.

3. **Theoretical calculations using Material Studio or Similar programs.**
   - Introduction to Material Studio.
   - Construction of single layer graphene functionalized with Ti and find gas adsorption using material studio.
   - Calculation of single point energy of benzene using Material Studio software.

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Semester - III **Credits: 21**

NSNT-531: Nano-photonics

Outcome/Knowledge/Skill:

On completion of the course the student will be able to

- Understand the basics of Nanophotonics and Biophotonics based on Electromagnetic theory.
- Concepts of Photonics band gap will be understood.
- Learn the techniques on fabrication of 1, 2 and 3 D photonics crystals.

Concepts of quantum dots and their application in nanotechnology for bioimaging is studied.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT I **(9 hrs)**

Introduction to photonics: Electromagnetic properties of nanostructures – Wavelength and Dispersion laws – Density of states – Maxwell and Helmholtz equations - Photonic band-structure and photonic band gap

UNIT II **(9 hrs)**

Photonic Crystals Understanding Photonic crystals – 1D, 2D and 3D - Photonic crystals by self-assembly - Photonic Crystals by Microfabrication - Photonic Crystals with Tunable Properties – Bragg's law.

UNIT III **(9 hrs)**

Semiconductor nanocrystals (quantum dots) From atom to crystal - Particle-in-a-box theory of electron–hole states - Quantum chemical theory - Absorption spectra, electron–hole pair states and many-body effects – Luminescence – Applications: Quantum dot lasers

UNIT IV **(9 hrs)**

Photobiology Interaction of light with cells and Tissues: Light absorption– Light induced processes in cells and tissues – Nature of Optical interactions – Measurement of optical properties of a tissue – Light-induced Processes in Tissues – Autofluorescence, photochemical processes, thermal effects, photoablation, plasma induced ablation and photodisruption.

UNIT – V **(9 hrs)**

Nanotechnology for biophotonics: Surface plasomon resonance - Metallic nanoparticles Biosensing – Up-converting nanophores - Pebble nanosensors for Invitro Bioanalysis - Nanoclinics for optical diagnostics and Targeted therapy.

REFERENCE BOOKS:

1. Introduction to Nanophotonics, Sergey V. Gaponenko, Cambridge University Press, New York, ISBN-13 978-0-521-76375-2 (2010)
2. Photonic Crystals (2nd edition), John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, Robert D. Meade, Princeton University Press, ISBN: 978-0-691-12456-8 (2008)
3. Introduction to Biophotonics, Paras N. Prasad, (John Wiley and Sons, New Jersey), ISBN: 0-471-28770-9 (2003)

4. Photonic Crystals:Towards Nanoscale Photonic Devices, J.-M. Lourtioz • H. Benisty •
5. V. Berger, J.-M. Gerard • D. Maystre • A. Tchelnokov, ISBN-13 978-3-540-24431-8, Springer-Verlag Berlin Heidelberg (2005)
6. Principles of Nanophotonics, MotoichiOhtsu, et al. ISBN : 13: 978-1-58488-972-4, by Taylor & Francis Group, LLC (2008)
7. Advances In Biophotonics, (Eds.) Brian C. WilsonValery V. Tuchin andStoyanTanev, IOS Press, ISBN 1-58603-540-1, (2005)
8. Biophotonics, Optical Science and Engineering for the 21st Century, (Ed.) Xun Shen And Roeland Van Wijk, ISBN-10: 0-387-24995-8; ISBN-13: 978-0387-24995-7; eISBN: 0-387-24996-6
9. Nano Biophotonics: Science and Technology, (Eds) Hiroshi Masuhara, Satoshi Kawata and Fumio Tokunaga, ISBN-13: 978-0-444-52878-0; ISBN-10: 0-444-52878-4, Elsevier (2007)

NSNT-532: Nano sensors and Devices

Outcome/Knowledge/Skill:

Knowledge:

Sensors and nanomaterials-based devices are important areas where various products are emerging to usher the development. This is of great significance to the students of nanotechnology as technological improvement of product supports the growth of nanotechnology. This course on Nanosensors and Devices provides an understanding on the important aspects of sensor, its properties, various types and testing.

Skills:

Students get to understand the basics of sensor technology and fabrication. It provides an overview of various sensors and technologies which are in the frontiers of application.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT-I **(9 hrs)**

Sensors: Sensors – properties of sensor – Static and Dynamic Characteristics – Micro and nano-sensors Sensors – Surface Interactions - Surface Materials and Surface Modification, Fundamentals of sensors, biosensor, micro fluids, Molecular interaction and detection principle – Sensor Behaviour

UNIT-II **(9 hrs)**

Materials and Fabrication: Sensor and Actuator– materials – Overview of fabrication technology – MEMS based Devices –Methods of packaging at zero level, dye level and first level – assembly and testing

Unit-III **(9 hrs)**

Mechanical, electrical and magnetic sensors: Piezoelectric, Piezoresistive, Electrostrictive, triboelectric and magnetostrictive properties, nanogenerators, nanopiezotronics, application in sensors and actuator devices Resistance, current and voltage sensors, electrical power sensors, magnetism sensors - Mechanical sensors - pressure sensors, gas and liquid flow sensors,

position sensors - Resonant mechanical sensors, accelerometers – Applications in automobiles, aerospace and defense

Unit-IV (9 hrs)

Thermal, Optical and Gas Sensors: Thermal energy sensors - temperature and heat sensors- Electromagnetic sensor – Optical and radiation sensors- Criteria for the choice of gas sensing materials – materials, properties, measurement of gas sensing property, sensitivity –Sensors for various gases – Gas sensors based on semiconductor devices sensor.

Unit-V (9 hrs)

Chemical and Biosensors: Chemical sensor – pH sensor – electrochemical sensor – Protein and DNA based biosensors –Detection by optical, electrochemical and fibre optic techniques – microfluidics – Lab on a chip – Cellular biosensing – Nanoscale biosensors – Biosensors for drug discovery

REFERENCE BOOKS:

1. Vinod Kumar Khanna, Nanosensors Physical, Chemical and Biological, 2012, CRC Press, Boca Raton, ISBN: 978-1-4398-2713-0.
2. Z. Zhou, Z. L. Wang and L. Lin, Microsystems and Nanotechnology, 2012, Springer, Beijing, ISBN: 978-7-302-24307-6.
3. Richard C. Dorf, Sensor, Nanoscience, Biomedical Engineering and Instruments, 1st Edition, 2006, CRC Press, Boca Raton, ISBN: 978-1-4200-0316-1.
4. S. Soloman, Sensors Handbook, Second Edition, 2010, McGraw-Hill, New York, ISBN: 9780071605700.
5. Florinel-Gabriel Banica, Chemical Sensors and Biosensors – Fundamentals and Application, 2012, Wiley, ISBN: 978-0-470-71066-1
6. W. Gopel, J. Hesse, J. N. Zemel, Sesnors A Comprehensive Survey, Volume: 1 to 8, 1991, VCH, Weinheim, ISBN: 9783527620173
7. G.K. Knoff, A.S. Bassi, Smart Biosensor Technology, 2019, CRC Press, Boca Raton, ISBN: 9781498774482
8. Brian R Eggins, Chemical Sensors and Biosensors, 2004, John-Wiley & Sons, Ltd., Sussex, ISBN: 0 471 89913 5
9. Challa Kumar, Nanomaterials for Biosensors, 2007, Wiley – VCH, Weinheim, ISBN: 978-3-527-31388-4
10. J. Cooper and C. Tass, Biosensors,2004, Oxford University Press, Oxford, ISBN: 9780199638451.

NSNT-533: Polymers and Nanocomposites

Outcome/Knowledge/Skill:

On completion of the course, the student will be able to

- Understand the basic concepts of polymers, their nomenclature and molecular weight determinations.
- Understand various polymerization techniques and polymerization mechanisms.
- Get familiarize with the basic concepts of conducting polymers and their applications in various advanced technologies.
- Understand various speciality polymers and their potential applications.

Understand preparation, properties and applications of polymer and metal matrix nanocomposites.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT-I **(9 hrs)**

Basic Aspects: Classification - Some basic definitions - Addition and condensation polymerizations, and copolymerization - Mechanism of free radical, cationic and anionic polymerizations – Nomenclature - Tacticity – Glass transition and melting temperatures - Crystallinity in polymers. **Polymerization Techniques:** Bulk, Solution, Suspension and Emulsion polymerizations - Polymerization using metal catalysts and surfactants.

UNIT-II **(9 hrs)**

Molecular weight of polymers: Number average, weight average and viscosity average molecular weights of polymers - Determination of molecular weight of polymers by GPC and viscometry methods. **Thermal analysis of polymers:** Thermal analysis using DSC, TGA, DTA and DMA - **Specialty Polymers:** Synthesis, properties and functional applications of polyamides, polyimides, Silicone polymers, Epoxy polymers, Polyurethane, Bio-degradable polymers.

UNIT-III **(9 hrs)**

Conducting Polymers

Structural characteristics and doping concept - Charge carriers and conducting mechanism – Intrinsic and extrinsic conducting polymers - Synthesis of conducting polymers – Applications of conducting polymers in corrosion protection, sensors, electronic and electrochemical energy devices.

UNIT-IV **(9 hrs)**

Polymer Nanocomposites

Polymer/ Metal oxide nanocomposites, Polymer/CNTs and Polymer/Nanoclay based composites and their properties and functional applications.

UNIT-V **(9 hrs)**

Other Kinds of Nanocomposites: Metal matrix nanocomposites, Glass - metal nanocomposites, Core-shell structured nanocomposites, Super hard nanocomposites, Self-cleaning nanocomposites.

REFERENCE BOOKS:

1. Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, Singapore, 1994.
2. Gowariker and Viswanathan, Polymer Science, Wiley Eastern, 1986.
3. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley, 2010.
4. Nanocomposites - Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun, Wiley-VCH, 2004.
5. George Odian, Principles of Polymerization, John Wiley & Sons, 1933
6. Conducting polymers with micro or nano meter structure, Meixiang Wan, Springer, 2008.
7. Polymer-Clay Nanocomposites, T.J. Pinnayain, G.W.Beall, Wiley, New York, 2001.
8. Composite Materials, Deborah D.L.Chung, Springer, 2002.
9. Alfred Ruiden, Elements of Polymer Science and Engineering, Elsevier Science, 1998.

NSNT-534: Nanomaterials for Clean Energy Systems

Outcome/Knowledge/Skill:

- Fundamental understanding of the structure-composition-performance relationships of materials energy materials. Fabrication and evaluation of prototype clean energy conversion & storage devices (DSSC and Perovskite based solar cells, lithium batteries, supercapacitors, and fuel cells)
- Fabrication and evaluation of prototype clean energy conversion & storage devices

(Soft – Core Course)

L	T	P	C	
3	0	0	3	45L

UNIT-I **(9 hrs)**

Fundamental Concepts in Clean Energy Systems, electrochemical cell, Faraday's laws, Electrode Potentials, Thermodynamics of electrochemical cells, Polarization losses in electrochemical cells, Electrode process and kinetics, Electrical double layer, Photoelectrochemical cell, thermoelectric effect.

UNIT-II **(9 hrs)**

Nanomaterials for Photovoltaic Solar Energy Conversion Systems, principles of photovoltaic energy conversion (PV), Types of photovoltaics Cells, Physics of photovoltaic cells, Organic photovoltaic cell cells, thin film Dye Sensitized Solar Cells, Quantum dot (QD) Sensitized Solar Cells (QD-SSC), Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Current status and future trends.

UNIT-III **(9 hrs)**

Nanomaterials for Clean Energy Conversion (Fuel cells) Systems, Issues and Challenges of functional Nanostructured Materials for electrochemical Energy, Conversion Systems, Fuel Cells, Principles and nanomaterials design for; Proton exchange membrane fuel cells (PEMFC); Direct methanol fuel cells (DMFC); Solid-oxide fuel cells (SOFC), Current status and future trends.

UNIT-IV **(9 hrs)**

Nanomaterials for Advanced Clean Energy Storage (Batteries) Systems, Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium ion Batteries), Cathode and anode materials, Nanostructured Carbon based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.

UNIT-V **(9 hrs)**

Nanomaterials for Energy Storage (Supercapacitor) Systems, Capacitor, Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon based materials, Redox capacitor Nano Oxides, Conducting polymers based materials, Current status and future trends.

REFERENCE BOOKS:

1. Electrochemical methods: Fundamentals and Applications, Allen J.Bard and Larry R. Faulkner, 2nd Edition John Wiley & Sons. Inc (2004)
2. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw-Hill, New York (1995)
3. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, KulwerAcdemic Publishers, Dordrecht, Netherlands (2004).
4. J. Larmine and A. Dicks, Fuel Cell System Explained, John Wiley, New York (2000).
5. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).
6. M. S. Whittingham, A. J. Jacobson, Intercalation Chemistry, Academic Press, New York (1982).
7. M. Wakihara, O. Yamamoto, (Eds.) Lithium Ion Batteries: Fundamentals and Performance, Wiley –VCH ,Weinheim (1998).
8. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun.

NSNT-535: Nanomagnetic Materials and Devices

Outcome/Knowledge/Skill:

On successful completion of this course, the students will able to

- Understand the basics of magnetism and magnetic properties
- Acquire knowledge on principle and operation of various magnetic devices.

Acquire knowledge on utilization of various nanostructures for fabrications of advanced magnetic devices, like GMR, TMR, BMR devices.

(Soft – Core Course)

L	T	P	C	
3	0	0	3	45L

UNIT-I **(9 hrs)**

Magnetism of the solid state: Fundamentals of magnetism, magnetic flux, magnetization, susceptibility and permeability, Domains and the magnetization process, magnetic energies (magnetostatic energy, magnetocrystalline energy, magnetostrictive energy), diamagnetism, diamagnetic susceptibility, Paramagnetism,paramagnetic
susceptibility, Pauliparamagnetism, Ferromagnetism, ferrimagnetism, antiferromagnetism.

UNIT-II **(9 hrs)**

Spin electronics and Giant magnetoresistance: Introduction to spintronics, Hall effect and quantum hall effect, magnetoresistance, GMR, AMR, spin dependent scattering of electrons, mechanism of GMR, co-operative phenomena and magnetization reversal, comparison of GMR and AMR, CPP GMR and CIP GMR.

UNIT-III **(9 hrs)**

Tunnel magnetoresistance and other types of magnetoresistance: Introduction to tunnel magneto resistance, ferromagnetic tunnel junctions, phenomenological theory of TMR, MR ratio and spin polarization, factors influencing TMR, MR ratio for Fe/MgO/ Fe system.Ballistic magneto resistance, Anisotropicmaneto resistance,Colossal magnetoresistance.

UNIT-IV **(9 hrs)**

Magnetic nanostructures and Applications: Magnetism of nanoparticles, nanoclusters and nanowires. Hard and soft magnetic materials and their applications. Magnetic data storage.Magneto-optic reading and recording. Magnetic sensors. Ferro fluids. Spin glass - magnetic properties and electronic structure.

UNIT-V **(9 hrs)**

Nanobiomagnetism: Materials for biomagnetism.Magnetic targeting, separation and detection.Magnetic tweezers, drug and gene delivery, chemo therapy, MRI, hyperthermia, application of various nanomagnetic materials in biotechnology, superparamagnetism and iron oxide.

TEXT BOOKS:

1. Magnetic Microscopy of Nanostructures, Hans P.O., and Hopster H, Springer (2004), ISBN: 978-3-540-26641-9, 978-3-540-40186-5
2. Magnetic Materials: Fundamentals and Device Applications, Nicola A.S., Cambridge University Press (2003), ISBN: 9780511781599
3. Introduction to magnetic materials, Cullity and Graham, John Wiley & Sons Inc., 2009, ISBN: ISBN: 978-0-471-47741-9
4. Introduction to magnetism and magnetic materials, D. Jiles, Chapman and Hall pub., 1991, ISBN: 9781482238877.
5. Fundamentals of Magnetism, Mathias Getzlaff, Springer, 2008, ISBN 978-3-540-31152-2.
6. Fundamentals of Nanomagnetis, Bland J.A.C., and B. Heinrich.B., Springer (2004), ISBN 978-3-540-27163-5.
7. Modern magnetic materials, Robert C. O'Handley, John Wiley & Sons Inc., 2000, ISBN: 978-0-471-15566-9.
8. Spin Electronics, M. Ziese and M.Thornton (Eds.), Springer, 2001, ISBN 978-3-540-45258-4
9. Advanced Magnetic Nanostructures, Sellmyer and Skomski (Eds.), Springer, 2006, ISBN 978-0-387-23316-1

NSNT-536: Advanced Nanobiotechnology

Outcome/Knowledge/Skill:

- The research oriented concepts of implant design and standards.
- Toxicity of Nanomaterials, and evaluation of biocompatibility of nanomaterials
- Fundamentals of tissue engineering, drug delivery and immunology

(Soft – Core Course)

L	T	P	C	
3	**0**	**0**	**3**	**45L**

UNIT-I **(9 hrs)**

Implant Design and Standards: Sterilization of Implants and Devices, Implant and Device Failure, Implant Retrieval and Evaluation, Regulation of Medical Products Using Biomaterials, Ethical Issues in Biomaterials Development, Legal Aspects of Biomaterials

UNIT –II **(9 hrs)**

Nanotoxicology: Introduction, Toxicity of nanoparticles, Types of Nanoparticles causing Toxicity, Target organ toxicity, Exposure, Uptake, and Barriers, Experimental Models in Nanotoxicology - In vitro Models, In Vivo Models.

UNIT –III **(9 hrs)**

Immunology: Innate and adaptive immunity, Types of adaptive immunity, Properties of adaptive immune responses, Cells of the immune system, Tissues of the immune system, Overview of immune responses to microbes, Summary. Experimental systems: *In vitro* and *In vivo* Models

UNIT –IV **(9 hrs)**

Tissue engineering: Introduction, Stem cells, Morphogenesis, Generation of tissue in the embryo, Tissue homeostasis, Cellular signaling.Cell source, Cell culture: harvest, selection, expansion, and differentiation, Cell nutrition, Cryobiology, Scaffold design and fabrication, Controlled release strategies in tissue engineering.

UNIT –V **(9 hrs)**

Drug Delivery Systems: Fundamentals of Drug Nanoparticles: Production, Size, Surface area, Suspension and Settling, Magnetic and Optical Properties, Biological Transport. Manufacturing of Nanoparticles: Ball-Milling, High-Pressure Homogenization, Spray-Drying Production in Nonaqueous Liquids, Hot-Melted Matrices, Pelletization Techniques, Direct Compress.

REFERENCE BOOKS:

1. Blomaterials Science, An Introduction to Materials in Medicine, Edited by Buddy D. Ratner, Allan S. Hoffman, Frederick J. Schoen, Jack E. Lemons, Academic Press, A division of Harcourt Brace & Company, 525 B Street, Suite 1900, San Diego, California 92101 -4495, USA.
2. The Chemistry of Medical and Dental Materials, John W. Nicholson, RSC materials monographs, Published by The Royal Society of Chemistry, Thomas Graham House, Science Park, Milton Road, Cambridge CB4 OWF, UK. ISBN 0-85404-572-4.

3. Tissue Engineering, Clemens van Blitterswijk, Peter Thomsen, Anders Lindahl, Jeffrey Hubbell, David Williams, RanieriCancedda, Joost de Bruijn, JérômeSohier, Academic Press, Elsevier, 84 Theobald's Road, London WC1X 8RR, UK, Corporate Drive, Suite 400, Burlington, MA 01803, USA, 525 B Street, Suite 1900, San Diego, CA 92101 -4495, USA, 2008 ISBN: 978-0-12-370869-4.
4. Nanoparticulates Drug Carriers, Edited by vladimir p torchilin, 2006, Imperial College Press, 57 Shelton Street, Covent Garden, London WC2H 9HE, ISBN 1 - 86094-630-5
5. Basic Immunology: Functions and Disorders of the Immune System, fifth edition, Abul K. Abbas, Andrew H. Lichtman, Shiv Pillai, Illustrations by David L. Baker, MA Alexandra Baker, MS, CMI DNA Illustrations, Inc.3251 Riverport Lane St. Louis, Missouri 63043, Elsevier, ISBN: 978-0-323-39082-8
6. Nanoparticle Technology for Drug Delivery. Edited by Ram B. Gupta, Uday B. Kompella, 2006, Taylor & Francis Group, 270 Madison Avenue, New York, NY 10016.
7. Biological Nanostructures and Applications of Nanostructures in Biology. Electrical, Mechanical, and Optical Properties. Edited by Michael A. Stroscio and Mitra Dutta, 2004, kluwer academic publishers, new york, boston, dordrecht, london, moscow, eBook ISBN: 0-306-48628-8, Print ISBN: 0-306-48627-X 30
8. BIOMEDICAL NANOSTRUCTURES. Edited by Kenneth E. Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair, wiley-interscience a john wiley & sons, inc., publication, 2008.
9. Dendrimer based Nanomedicine, Edited by Istvan J. Majoros, James R. Baker, 2008, Pan Stanford Publishing Pte. Ltd.
10. Nanoparticulate Drug Delivery Systems, Edited by Deepak Thassu, Michel Deleers, Yashwant Pathak, 2007, Informa Healthcare USA, Inc., 270 Madison Avenue, New York, NY 10016, ISBN-13: 978-0-8493-9073-9
11. Essential Immunology, lvan M. Roitt, Peter J. Delves Blackwell Science, Inc., 350 Main Street, Malden, Massachusetts 02148-5018, USA ISBN 0-632-05902-8.
12. Nanofabrication towards Biomedical Applications, Techniques, Tools, Applications, and Impact. C. S. S. R. Kumar, J. Hormes, C. Leuschner, 2005, WILEY -VCH Verlag GmbH & Co. KGaA, Weinheim, ISBN-13 978-3-527-31115-6.
13. Nanoscale Technology in Biological Systems, Edited by Ralph S. Greco, Fritz B. Prinz, R. Lane Smith, CRC PRESS, Boca Raton London New York Washington, D.C. Copyright © 2005 by Taylor & Francis

NSNT-537: Industrial Nanotechnology

Outcome/Knowledge/Skill:

On completion of this course, the student will be able to

- Understand the advantages of Nanotechnology-based applications in various industries.
- Understand the future technological advantages and the increasing role of Nanotechnology in each industry.

(Soft – Core Course)

L	T	P	C	
3	0	0	3	45L

UNIT-I **(9 hrs)**

Nanotechnology in Electrical and Electronics Industry

Advantages of nano electrical and electronic devices -Electronic circuit chips - Nanosensors and Actuators, Optical switches - Diodes and Nano-wire transistors -Data memory-Lighting and Displays - Filters (IR blocking) - Quantum optical devices- Energy storage devices - Photovoltaic cells -Lead-free solder - EMI shielding.

UNIT-II **(9 hrs)**

Nanotechnology in Electrochemical Industry

Electrocatalysis, Electrolytic production of metal nanopowders, Secondary recovery of metals: Importance and approaches with respect to lead, silver and gold. - Electochemical deposition of Nanostructured metals and metal nanocomposites - Electrospinning for the production of 1-D Nano-metal oxides - Electrochemical exfoliation for Graphene production - Electro-painting - Electrochemical preparation of conducting polymers.

UNIT-III **(9 hrs)**

Nanotechnology in Textile Industry

Nanofibre production: Electrospinning - Controlling morphologies of nanofibers - Nano-filled polypropylene fibers; Nanotechnology for coating and structuring of textiles; **Bionics:** Swim-suits with shark-skin effect,Soil repellence, Lotus effect - Nano finishing in textiles - UV resistant, anti-bacterial, hydrophilic, self-cleaning, flame retardant finishes; **Modern textiles:** Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof clothes.

UNIT-IV **(9 hrs)**

Nanotechnology in Agriculture

Nanotechnology in Agriculture - Precision farming, Smart delivery system - Nanofertilizers-Nanourea and mixed fertilizers - Nanofertigation - Nanopesticides, Nano-seed Science.

UNIT-V **(9 hrs)**

Nanotechnology in Food Industry: -Nanopackaging for enhanced shelf life - Smart/Intelligent packaging - Food processing and Food safety and bio-security - Food analysis and contaminant detection.

Cosmetics Industry: Formulation of Gels, Shampoos, Hair-conditioners (Micellar self-assembly and its manipulation) - Sun-screen dispersions for UV protection using titanium oxide -Colour cosmetics.

REFERENCE BOOK

1. P. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead publication, London, 2006.

2. Jennifer Kuzma and Peter VerHage, Nanotechnology in Agriculture and Food Production, Woodrow Wilson International Center, (2006).

3. Lynn J. Frewer, WillehmNorde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, (2011).

4. P. J. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead Publishing Limited, Cambridge, (2007).

5. Q. Chaudry, L.Castle and R. Watkins Nanotechnologies in Food, RSC Publications, 2010.
6. Y-W. Mai, Polymer Nano composites, Woodhead publishing, (2006).

7. Udo H. Brinker, Jean-Luc Mieusset (Eds.), Molecular Encapsulation: Organic Reactions in Constrained Systems,Wiley Publishers (2010).

8. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun.

9. E.Raub and K.Muller, Fundamentals of Metal deposition, Elsevier Publishing Co, New York, 1967.

10. K.I.Popov, S.S.Djokic and B.N.Grgur, Fundamentals of Electrometallurgy, Kluwer Academic Publishing, 2002.

11. M.R.Rifi and F.H.Covitz, Industrial Electrochemistry, Marcel Deckker. Inc., New York, 1974.

12. W.N.Chang, Nanofibers Fabrication, Performance and Applications, Nova Science Publishers Inc., (2009).

NSNT-530: Lab-II: Fabrication and Characterization of Nanomaterials

Outcome/Knowledge/Skill:

On successful completion of this lab course, the students will able to

- Acquire knowledge on principle and operation of various fabrication devices.
- Acquire knowledge on fabrication of various nanostructures using various techniques like, e-beam, sputtering, electrospum, spin coating, dip-coating, and etc.

(Hard – Core Course)

L	T	P	C	
0	2	4	3	45L

1. Clean Room: Familiarizing with essential terms, tools and practices.
2. Fabrication of thin films by Sputtering, Electron beam and Spray pyrolysis methods.
3. Fabrication of TiO_2 nanofibers on ITO glass substrate by Electro-spinning technique.
4. Synthesis of CNTs by CVD method.
5. Nanocrystalline thin film by spin coating.
6. Fabrication of CdS thin film by chemical bath deposition (CBD) technique.
7. Fabrication of ZnO film by doctor blade method for DSSCs application.
8. Chemical bath deposition by dip coating.

9. Electrodeposition of polyaniline on ITO substrate.
10. Electroless deposition of Ag or Au on ITO or Si substrate
11. Band gap determination by diffuse reflectance spectrocopy method.
12. Dip-pen lithography using AFM with molecular inks.
13. Nano-patterning by AFM lithography.
14. Nanosphere lithography using silica nanospheres
15. Surface topography of a sputtered Au using AFM / STM.
16. Electrical resistivity measurement by Four probe method.
17. Polymer membrane electrolyte preparation and its porosity, electrolyte uptake and ionic conductivity measurements.
18. Determination of thermal expansion of nano-ceramic material by dilatometer.
19. Film thickness measurement by ellipsometer.

Semester - IV Credits: 09

NSNT-541: Research Project (Report and Viva-Voce)

Outcome/Knowledge/Skill:

- Supports advance research capabilities undertaking a major, individual, related project
- Develope communication skills, both written and oral, to specialized in Nanoscience and Technology for society.

(Hard – Core Course)

L	T	P	C	
0	**0**	**0**	**3**	**45L**

Students are required to carry out a research project for **one full semester** related to Nanoscience and Nanotechnology and submit a project report. Each student is assigned with a supervisor among the faculty members of the CNST of Pondicherry University. Arrangement could also be made to pursue research studies at institutions other than the CNST of PU. In such circumstance, the student is assigned with two supervisors: an internal supervisor/advisor from the CNST of PU and an external supervisor from the institutions where the research project is carried out.

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