CENTRE FOR NANOSCIENCE AND TECHNOLOGY

Madanjeet School of Green Energy Technologies

PONDICHERRY UNIVERSITY

(Accredited with 'A' Grade by NAAC)

PUDUCHERRY - 605 014

M.Tech. - Nanoscience and Technology Programme

Syllabus & Regulations

2022-23 ONWARDS

M.Tech. - NANOSCIENCE AND TECHNOLOGY PROGRAMME

REGULATIONS (2022-23 Onwards)

1. Duration of the Course: 2 Years

2. Eligibility for Admission:

BE / B.Tech. in Nanoscience and Technology/ Materials Science & Engg./Polymer Science & Engg./ Electrical & Electronics, Electronics & Communication, Instrumentation, Chemical, Mechanical, Metallurgical (or) Bio-Medical Engg.,/ Biotechnology/Environmental Engg.,/Energy Engg., with a minimum of 55% of marks.

(OR)

Masters degree in Physics/ Chemistry / Applied Physics / Applied Chemistry/ Materials Science / Nanoscience and Technology / Biotechnology / Bio-Chemistry with a minimum of 55% of marks.

3. Examinations:

Evaluation of semester examinations is carried out as per the CBCS Scheme of evaluation provided by Pondicherry University.

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

4. Guidelines for awarding marks for IV semester Research project:

The time duration for IV semester Research project is one full semester. Marks for project awarded by the Project supervisor: **25 Marks**
Marks for a project mid-term review by 3 Members Committee: **25 Marks**
Marks for a project report and 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 of 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.]

5 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.

6. Internal assessment:

Total internal marks is 40.

Mark distribution: Minimum of two internal tests are to be conducted for 30 marks. Another 10 marks is assessed through Assignment and Seminar.

7. Question paper pattern for the Internal assessment test

Time duration: 2 Hours

Maximum Marks: 30

PART A: 5 × 2 = 10 Marks

Answer ALL Questions

(From Question # 01 To Question # 05)

PART B: 4 × 5 = 20 MARKS

Answer any **FOUR** out of Five Questions

(From Question # 06 To Question # 10)

8. Question paper pattern for the End Semester Examination:

Time duration: 3 Hours

Maximum Marks : 60

PART A: 10 × 2 = 20 Marks

Answer **ALL** Questions

(Two Questions must be asked from each unit)

(From Question #01 To Question #10)

PART B: 5 × 8 = 40 MARKS

Answer any **FIVE** out of Seven Questions (Equal weightage must be given to each unit)

(From Question # 11 To Question # 17)

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M.Tech. Nanoscience and Technology

CURRICULUM (2019-20 Onwards)

SEMESTER – I

Course code	Course Title	Course Type*	L	T	P	C
Hard – Core Course						
NAST-511	Essentials of Quantum Mechanics and Electromagnetic theory	H	3	1	0	3
NAST-512	Thermodynamics and Kinetics for Nanotechnology	H	3	1	0	3
NAST-513	Elements of Materials Science and Properties of Nanomaterials	H	3	1	0	3
NAST-514	Synthesis and Characterization of Nano-structured materials	H	3	1	0	3
NAST-515	Nanostructure Fabrication and Metrology	H	3	1	0	3
Practical						
NAST-510	**Lab-I: Synthesis and Processing Laboratory**	H	0	2	4	3

Total Credits: 18

SEMESTER – II

Course code	Course Title	Course Type*	L	T	P	C
Hard – Core Course						
NAST-521	Computational methods for Modeling and Simulations	H	3	1	0	3
NAST-522	Polymers and Nanocomposites	H	3	1	0	3
NAST-523	Fundamentals of Biology for Nanotechnology	H	3	1	0	3
Soft Core Course (Any THREE to be selected)						
NAST-524	Surface Engineering for Nanotechnology	S	3	0	0	3
NAST-525	Nanoelectronics and Bioelectronics	S	3	0	0	3
NAST-526	Self- Assembly of Nanostructures	S	3	0	0	3
XXX	Core / Soft core courses offered by other Departments at M.Sc./MTech. level	S	3	0	0	3
Practical						
NAST-520	**Lab-II: Fabrication Laboratory**	H	0	2	4	3

Total Credits: 21

SEMESTER - III

Course code	Course Title	Course Type*	L	T	P	C
Hard – Core Course						
NAST-631	MEMS/NEMS and Microsystems	H	3	1	0	3
NAST-632	Nanostructured Materials for Clean Energy Systems	H	3	1	0	3
NAST-633	Nano- Photonics and Biophotonics	H	3	1	0	3
Soft Core Course (Any THREE to be selected)						
NAST-634	Nanomagnetic Materials and Devices	S	3	0	0	3
NAST-635	Advance Nanobiotechnology	S	3	0	0	3
NAST-636	Industrial Nanotechnology	S	3	0	0	3
XXX	Core / Soft core courses offered by other Departments at M.Sc./MTech. level	S	3	0	0	3
Practical						
NSNT-630	**Lab-III: Modeling and Simulation Laboratory**	H	0	2	4	3

Total Credits: 21

SEMESTER - IV

Course code	Course Title	Course Type*	L	T	P	C
NAST - 641	Research Project (Report and Viva- Voce)	H	One Full Semester			12
Total Credits Required (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:

(a) All theory courses have Internal and External Assessments at the proportion of **40:60.**
(b) All Laboratory practical courses have Internal and External Assessments at the proportion of **60:40**.
(c) The final semester Project (Dissertation) course has both Internal and External assessments at the proportion of **50:50**.

Syllabus for Courses

Semester - I Credits: 18

NAST- 511: Essentials of Quantum Mechanics and Electromagnetic Theory

Outcome/Knowledge/Skill:

On completion of the course the student will be able 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.
- Will be able to calculate nanoparticles energy states and band gaps based on Quantum theory.
- The content of the course is rich enough so that the student can be competent to be able to grasp the concepts of Physics and Chemistry for Materials applications.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

Unit-I **(9 hrs)**

Introduction to Quantum Mechanics

Limitation of Mechanics at the Nanoscale - Success of Quantum Mechanics – Wave- particle Duality – Quantum mechanics of a free particle confined to 1–D potential barrier – Solution to Infinite Asymmetric Square Well Potential – Zero point energy – Particle in 3-D Potential – General treatment in Cartesian coordinates by Separation of Variables – Rectangular Box potential – The Cubic potential – Concept of Degeneracy related to symmetry – 3-D Problem in spherical Coordinates – Central Potential – General Treatment - Electrons in a periodic potential – Bloch Theorem – Schrodinger equation.

Unit –II **(9 hrs)**

Approximation methods: Essential of approximation methods - Time Independent Perturbation Theory – Non-Degenerate case – First and second order corrections - Non-generate case – Lifting degeneracy from a system.

Identical Particles: Schrodinger equation– Interchange symmetry. Systems of Identical particles (Classical and Quantum View) – Experiment on Indistinguishability– Exchange degeneracy – Symmetrization Postulate – Symmetric and antisymmetric wavefunctions – Comparison of Boson and Fermions - Constructing symmetric and antisymmetric functions (wave functions of two-, three-, and many-particle systems).

Unit - III **(9 hrs)**

Transport in nanostructures

Nanostructures connected to electron reservoirs - Current density and transmission of electron waves - The current density J - Tunneling through a potential barrier – Reflection and transmission coefficients - Tunnelling in field emission guns – Electron wavefunctions in Semiconductor Nanocrystals: Brus relation using a Particle in a Box model.

Unit – IV **(9 hrs)**

Quantum mechanics of Atoms and Molecules

Hamiltonian and Wave functions for Many-particle systems –Multi electron system – The structures of Many-electron atoms - Orbital approximation – Justification - H, He and Li atomic structure – The Pauli's principle – Total wavefunction of two-particle system including spin - Born – Oppenheimer approximation – Potential energy curve for diatomic molecule. Molecular orbital Theory – LCAO - Theory of H_2 molecule – H^+_2 - Bonding and anti-bonding orbitals – Bond Order - Term Symbols.

Unit-V **(9 hrs)**

Review of Electromagnetic Theory

Electrodynamics: Maxwell Equations – Maxwell's correction – Maxwell Equations in Vacuum and Matter - Importance of Maxwell equations. Continuity Equation – Derivation and Importance. Poynting Theorem - Energy distribution in EM waves. Electromagnetic waves in Vacuum and Matter. Reflection and Transmission at Normal and Oblique Incidences - Complex Refractive Index and Dispersion relation.

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 nanotechnology, Henrik Brus, (2004) MIC – Department of Micro and Nanotechnology, Technical University of Denmark.
4. Semiconductor Nanocrystals: A Powerful Visual Aid for Introducing the Particle in a Box, Tadd Kippeny, Laura A. Swafford, and Sandra J. Rosenthal, J. Chemical Education, Vol. 79(9), 2002, 1094-1100.
5. Introduction to Electrodynamics, David J. Griffiths, (ISBN: 978-81-203-1601-0), Prentice-Hall, India, (2009).
6. Quantum Mechanics, Vol I and Vol II, Claude Cohen-Tannaoudji, Bernard Diu, Franck Laloe, John Wiley & Sons (2005).
7. Quantum mechanics, J. L. Powell and B. Craseman, Addison-Wesley (1964).
8. Y T Tan et al. 2003 J. Appl. Phys. 94 633.
9. Classical electromagnetism J. D. Jackson, John Wiley Publications (1999) (ISBN 0- 471-30932-X).

NAST-512: Thermodynamics and Kinetics for Nanotechnology

Outcome/Knowledge/Skill:

On Completion of the course the student will be able to

- 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	45 L

UNIT-I **(9 hrs)**

Thermodynamic laws, Entropy, Statistical thermodynamics: 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: Concepts of probability and Maxwell Boltzmann distribution. Different ensembles and 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. Thermodynamic functions of ideal gases, translational, vibrational and rotational contributions at different levels of approximation. Application of statistical thermodynamics concepts to ortho para hydrogen internal rotation - Calculation of equilibrium constants.

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 order, 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.
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. 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. W. Atkins, Physical Chemistry, Sixth edition, Oxford University Press, 1990.

NAST-513: Elements of Materials Science and Properties of Nanomaterials

Outcome/Knowledge/Skill:

On Completion of the course the student will be able to

- Understand the basics of crystal structures and their defects.
- Describe Nanomaterials and their properties based on their dimensionality
- Describe bonding in Nanostructures.
- Describe various physical properties of solids/Nanomaterials

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45 L

UNIT- I **(9 hrs)**

Crystal structures: Crystal geometry: crystal lattices, space lattices, basis and crystal structure, unit cell, lattice parameter of a unit cell - Seven crystal systems - Bravais lattices - Crystal directions and crystal planes (Miller indices) – Important parameters in crystal structures: Number of atoms per unit cell, coordination number, radius ratio, packing factor - Some special crystal structures - Calculation of lattice constant – Symmetry elements and symmetry operations - Point groups - Crystallographic nomenclature - Imperfections/defects in crystalline solids.

UNIT-II **(9 hrs)**

Bonding in Nanostructures: Atomic bonding in solids, Vander Waals interactions/Electrostatic interactions -, Hydrogen bonding - Hydrophobic interactions. Bonding in Graphene – Carbon nanotubes - Bonding in armchair, zigzag and chiral structures - n-m=3q rule, MXene – Inorganic nanotubes: Silica nanotubes, boron nitride nanotubes, Nanotubes of dichalcogenides, and Nanotubes of several metal oxides – Reactivity on Nanosurfaces: Functionalization of CNTs and Graphene.

Size effect of Nanomaterials: Size, shape, density, melting point, wet ability, specific surface area, solid state phase transformation and band gap variation - Quantum confinement, Effect of strain on band gap in epitaxial quantum dots.

UNIT-III **(9 hrs)**

Electronic Properties: Concept of energy band diagram for materials: Conductors, semiconductors and insulators - Classification of semiconductors – PN Junction, Electronic conductivity, band gap tuning/Engineering - band gap determination - Hall effect and its determination. **Optical Properties:** Optical Absorption, and transmission - Photoluminescence, Jablonski diagram, fluorescence and phosphorescence – Electroluminescence.

UNIT-IV **(9 hrs)**

Magnetic properties: Fundamentals of magnetism - Different kinds of magnetisms: dia, para, ferro, ferri and anti-ferromagnetic materials - Magnetic hysteresis – Classification of magnetic materials: hard and soft magnetic materials – Magneto-optic materials and their properties. - Superparamagnetism. **Dielctric Properties:** Effect of particles on dielectric properties, Ferro-electrics, piezo-electric, pyro-electric and muti-ferroics.

UNIT-V **(9 hrs)**

Mechanical behavior: Stress-strain behavior of metallic, ceramic and polymeric materials, Modulus of elasticity, yield strength, tensile strength, toughness, elongation, plastic deformation, visco-elasticity, micro-hardness, impact strength, creep, fatigue, ductile and brittle fracture, wear and friction of Nanomaterials; Effect of diffusion on strength and flow of materials, Methods of enhancing (or) retarding diffusion - **Thermal properties:** Heat capacity of solids, thermal conductivity and thermal expansion of solids – Thermal stresses; **Environmental degradation:** Corrosion and oxidation of materials and their prevention.

TEXT BOOKS

1. M.S.Vijaya,G.Rangarajan, Materials Science, Tata McGraw-Hill publishing company Ltd., New Dehli.
2. V.Ragavan, Materials Science and Engg., Prentice-Hall of India(p) Ltd, New Delhi.
3. The Physics and Chemistry of Solids, S.R.Elliott, John Wiley & Sons, England, 1998.
4. Theoretical Inorganic Chemistry – M.C. Day and I.Selbin, East –West Press, New Delhi, 1977.
5. Fundamental Properties of Nanostructured Materials, Ed. D. Fiorani (World Scientific, Singapore, 1994.

6. Nanostructured Materials and Nanotechnology – II, Eds. Sanjay Mathur and Mrityunjay Singh, Willey, 2008.
7. Understanding Solids: The Science of Materials, Tilley, Richard J. D. John Wiley & Sons,2004
8. Nanostructured Materials, Edited by Carl C. Koch, Noyes Publications, New York, 2002.

REFERENCE BOOKS

1. The Physics and Chemistry of Materials, Joel I.Gersten, F.W.Smith, S.R.Elliott, John Wiley & Sons, New York, 1998.
2. Properties of Materials, Robert E.Newnham,Oxford University Press, 2005.
3. Crystallography, Walter Borchardt-Ott, Springer, 1995.
4. Carbon Nanotubes Science and Applications, Edited by M.Meyappan, CRC Press, 2005.
5. Science of Fullerenes and Carbon Nanotubes, M.S.Dresselhaus, G.Dresselhaus, P.C.Eklund, Academic Press, 1996.

NAST-514: Synthesis and Characterization of Nanostructured Materials

Outcome/Knowledge/Skill:

Deals understanding at an advanced level of Physics and Chemistry for 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 that can facilitate widespread commercialization and it also acquired an understanding of selected areas of nanoscience and technology for various applications at the frontiers areas, beyond the undergraduate level

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45 L

UNIT-I **(9 hrs)**

Soft Chemical processes

Synthesis of Nanomaterials by Soft Chemical Methods: Chemical precipitation and co- precipitation: Metal nanocrystals synthesis by polyol, and borohydrate reduction methods, Sol- Gel synthesis; Microemulsions synthesis, normal and reverse micelles formation, Hydrothermal, Solvothermal.

UNIT-II **(9 hrs)**

Chemical processes

Synthesis methods of dimensionally modulated Inorganic nanostructured materials Thermolysis routes, Microwave assisted synthesis; Sonochemical assisted synthesis, Core-Shell nanostructure, Organic – Inorganic Hybrids, Quantum dot (QDs) synthesis. Carbon Nanotubes, (SWCNT, MWCNT), Graphene nanosheets. Porous materials, Photochemical synthesis, Synthesis in supercritical fluids and Electrochemical synthesis

UNIT-III **(9 hrs)**

Physical processes

Fabrication of Nanomaterials by Physical Methods: Inert gas condensation, Arc discharge, RF- plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy (MBE), Chemical vapour deposition (CVD) method. Template assisted synthesis, Catalyst assisted chemical vapour deposition (CCVD).

UNIT-IV **(9 hrs)**

Biological Methods of Synthesis

Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the nanostructured materials; synthesis process and application, Role of plants in nanoparticle synthesis.

UNIT-V **(9 hrs)**

Nanostructured materials Characterization Techniques

X-ray diffraction (XRD), SEM, EDAX, TEM, Elemental mapping, FTIR, UV-Visible spectrophotometer, Nanomechanical Characterization using Nanoindentation, Differential Scanning Calorimeter (DSC), Differential Thermal Analyzer (DTA), Thermo gravimetric Analysis (TGA), TEM, X-ray Photoelectron Spectroscopy (XPS), ICP-AES chemical analysis, Electrochemical Characterization measurements and particle size analyzer.

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TEXT 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. Nanostructured Silicon – based powders and composites – Andre P Legrand, Christiane Senemaud, Taylor and Francis, London New York 2003.
7. Processing & properties of structural naonmaterials - Leon L. Shaw (editor)
8. Elements of X-ray Diffraction by Cullity, B. D.,, 4th Edition, Addison Wiley, 1978.
9. Electron Beam Analysis of Materials by Loretto, M. H., Chapman and Hall, 1984.
10. Vacuum Physics and Techniques by T.A. Delcher, Chapman & Hall.

NAST-515: Nanostructure Fabrication and Metrology

Outcome/Knowledge/Skill:

Knowledge:

- Fabrication and Metrology (science of measurement) becomes important engineering aspect with respect to industry.
- It provides a source for lithography as well as non-lithogrpahy technology and test the materials with respect to dimension, chemistry etc.

Skill:

- Lithography as well as non-lithography taught at the M.Tech level results in the easy way to handle the fabrication tools.
- The students get acquainted with testing protocol – important for device technology.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45 L

UNIT-I

Principles of Photo Lithography **(10 hrs)**

Overview of lithographic process-Classification – Optical principles, Fresnel and Fraunhofer diffraction – Exposure methods –contact, proximity and projection printing – Mask Fabrication– Photoresist – positive and negative – properties of photoresist–Dill parameter –Projection system – Steppers and scanners – Cleanroom design and facilities.

UNIT-II **(8 hrs)**

Advances in Optical Lithography and Pattern transfer

Limitations of Optical Lithography – Lasers for Lithography – Deep and extreme UV lithography – Near field optical microscopy – Interference optical lithography – Maskless optical lithography– Resolution Enhancement Techniques–Vacuum techniques – Oxidation – Diffusion- Metallization - Doping techniques – ion implantation

UNIT-III **(9 hrs)**

Electron (E) - Beam Lithography: Electron Optics – Process, E beam sources, Raster and Vector scan – Proximity/Projection printing - SCALPEL – Direct writing – Interaction of electron with substrate – Electron Beam resist – E beam applications.

Xray Lithography: Principle, X-ray sources, system and components – resists, mask preparation, resolution enhancement.

Ion Beam Lithography: Focused Ion Beam – Process, Ion Source, Ion Column – Masked Ion Beam Lithography and Ion Projection Lithography.

UNIT-IV **(9 hrs)**

Nonlithographic patterning

Template based fabrication –Nanostencil, Nanoimprint and Nanosphere Lithography in device

fabrication– Soft Lithography, Microcontact Printing – Inkjet andScreen Printing – 3D printing - Stereolithography - Principle and methods of Nanowire Formation - Assembly, Integration - Additive and subtractive techniques of nano fabrication – Anodic Oxidation, Dip Pen Lithography

UNIT-V **(9 hrs)**

Metrology

Critical dimension (CD) – optical line width, defects, thickness and reflectance tools – ellipsometry – reflectometry – scatterometry – photoacoustic metrology –Electrical measurement-Dopant Concentration measurement techniques- surface defects - confocal microscopy,CD- SEM, TEM–AFM 3D surface mapping.

REFERENCE BOOKS

1. Chris Mack, Fundamental Principle of Optical Lithography, John-Wiley & Sons, Inc., Sussex, 2007, ISBN: 978-0-470-01893-4.
2. Zheng Cui, Micro-Nanofabrication Technologies and Applications, Springer-Verlag, Beijing, 2005, ISBN: 9783540289227.
3. U. Okoroanyanwu, Chemistry and Lithography, SPIE Press, Washington, 2011, ISBN: 9781118030028.
4. Michael Quirk, Julian Serda, Semiconductor Manufacturing Technology, Prentice-Hall Inc., New Jersey, 2001, ISBN: 9780130815200
5. Horst Czichos, Tetsuya Saito, Leslie Smith, SpringerHandbook of Materials Measurement Methods, Springer, New York, 2006, ISBN: 978-3-540-20785-6
6. Garry P. Wiederrecht, Handbook of Nanofabrication, First Edition, Elsevier, Amsterdam,
7. 2010, ISBN: 9780123751768.
8. Zheng Cui, Nanofabrication Principles, Capabilities and Limits, Springer, New York, 2008, ISBN:978-0-387-75576-2.
9. Ampere A Tseng, Nanofabrication Fundamentals and Applications, World Scientific, Singpore, 2008, ISBN:987-981-270-076-6.
10. Mark James Jackson, Microfabrication and Nanomanufacturing, Taylor & Francis, Boca Raton, 2005, ISBN:978-1-4200-2827-0.
11. Harry J. Levinson, Principles of Optical Lithography, SPIE Press, Third Edition, Washington, 2010, ISBN:9780819456601.
12. Ray F. Egerton, Physical Principles of Electron Microscopy – An Introduction to TEM, SEM and AFM, Springer, New York, 2005, ISBN:978-0387-25800-0.
13. John A. Rogers and Hong H. Lee, Unconventional nanopatterning technique and applications, John Wiley & Sons, Inc., New York, 2009, ISBN:978-0-470-009957-5.

NAST-510 : Synthesis and Processing Laboratory

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	
3	1	0	3	45 L

- Synthesis of $LiCoO_2$ by a simple solution combustion method
- Synthesis of calcium hydroxyapatite through aqueous precipitation technique.
- Bioglass synthesis through sol-gel method.
- Synthesis of semiconducting metal oxides by sono-chemical and microwave assisted methods.
- Preparation of Graphene by Chemical and electrochemical exfoliation method.
- Preparation of metal oxide nanorodes by hydrothermal method.
- Bio-synthesis of metal nanoparticles.
- Synthesis of multi-ferrite nanoparticles by dilute co-precipitation method.
- Preparation of Nanoporous material and Core –shell nanoparticles.
- Synthesis of gold and silver nanoparticles and its spectral analysis.
- Preparation of metal chalcogenide nanocrystals/quantum dots and its spectral studies.
- Preparation of carbon dots and its optical studies.
- Preparation of CdS, ZnS, ZnO and TiO_2 semiconducting nanoparticles and its spectral studies.
- Microwave-Assisted Hydrothermal Synthesis of Nanostructured Materials

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Semester - II **Credits: 21**

NAST – 521 Computational methods for Modeling and 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.
- Made in simple way so that of all branches including biology can understand and do simulations.
- Good mathematical and computational skill will be developed. Will be able to computations for making crystals and carbon nanotubes.
- 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 – Introduction – Types – First and Second order DE - General solutions – Laplace transform – Linearity and Shifting properties - Application to common functions and differential equations – Separation of variables to ODE - Partial differential equations: Introduction - Separation of variables – First order and second order PDE – Solution to Wave equation, Laplace equation, Schrodinger equation and Diffusion equation.

UNIT – II **(9 hrs)**

Numerical Methods

Numerical Algorithms and Programming – Programming Language Fortran – Basics of Fortran – Arrays and Loops - Sub-Programs - Computer programs in Fortran for Numerical methods. **Numerical Differentiation** – Three, and Four point formulae from Taylor series – Problems - Numerical solution of a system of ordinary differential equations: Runge Kutta method - Adaptive step size control. **Numerical integration**: Newton- Cotes integration formulae – Rectangular, Trapezoidal rule, and Simpson's 1/3 rules – Simple and Composite rules - Simpson's 3/8 and 4/3 rules - Gauss quadrature method – Problems using 2- and 3-point Gauss quadrature formulas.

UNIT – III **(9 hrs)**

Numerical Linear Algebra: Matrices – Orthogonal and symmetric matrices - Solution of linear algebraic equations – Standard methods – Gauss Elimination method – Gauss-Jordan Elimination

method - Iterative methods for linear systems – Jacobi method – Gauss-Seidel method – Convergence - Eigenvalue problems - Computing Eigenvalues and Eigenvectors.

UNIT – IV **(9 hrs)**

Random numbers and Monte Carlo methods: Definition and Types of Random Numbers – Random number Generators (RNG) for True and Pseudo Random Numbers – - Properties of RNG - Uniformly distributed Pseudo random numbers - Computer clock – Linear Congruence method – Middle square method – Test for Random Numbers – Distribution, Correlation and Run Tests – Random numbers with Exponential and Normal distribution – Box-Muller algorithm - Simulation of radioactive decay - Numerical Integration using Monte Carlo simulation techniques for 1D cases.

UNIT – V **(9 hrs)**

Partial differential equations: Types - Parabolic, Hyperbolic and Elliptic equations - Finite difference method (FDM) for Parabolic, Hyperbolic and Elliptic equations – Central divided differences - Truncation errors - consistency - stability. Introduction to finite element method (FEM)– Definition - Basic elements - Structural modelling and fem analysis - Classification of the problem - Conceptual, structural and computational models - Structural analysis by the FEM - Verification and validation of FEM results.

REFERENCE BOOKS

1. Ferziger, J. H., Numerical Methods for Engineering Applications, 2nd ed., Wiley- Interscience ISBN 978-0471116219. (1998).

2. Computational Physics, J. M. Thijssen, Cambridge University Press, Cambridge, (1999).

3. Computational methods in Physics and Engineering, 2nd Edition, Samuel S.M. Wong, ISBN: 9810230176, World Scientific-Singapore (2003)

4. Structural Analysis with the Finite Element Method Linear Statics-Volume 1. Basis and Solids: Eugenio Oñate, Springer, (2009) Spain (ISBN: 978-1-4020-8732-5)

5. Scientific Computing: An Introduction with Parallel Computing, G. Golub and J.M. Ortega, Academic Press, (1993).

6. Scientific Computing: An Introductory Survey, Michael T. Heath, McGraw-Hill, New York, (2002).

7. Numerical Recipes in Fortran / F-90 / C, W.H. Press et. al., Cambridge Univ. Press (1996)

8. A First Course in Computational Physics, P.L. DeVries, John Wiley (1994).

9. Computational physics- Problem solving with computers, Rubin H. Landau, Manuel J. Paez, John Wiley & sons (1997).

10. Guide to Neural Computing Applications, L. Tarassenko, Arnold Publishers, (1998).

11. Genetic Algorithms in Search, Optimization, and Machine Learning, D. E. Goldberg, Addison Wesley, Reading, Massachusetts, (1989).

NAST-522: 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 specialty 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)**

Elements of Polymer Science: Classification - Some basic definitions - Addition and condensation polymerizations and copolymerization - Mechanism of free radical, cationic and anionic polymerizations – Nomenclature – Tacticity; **Glassy solids:** Glass transition and melting temperatures and their determination by DSC - Factors affecting Tg, importance of Tg, relationship between Tm and Tg and their control; **Crystallinity in polymers**: Degree of crystallinity, factors affecting crysallinity of polymers, effect of crystallinity on the properties of polymers; **Polymerization Techniques:** Bulk, Solution, Suspension and Emulsion polymerizations; Polymerization using metal catalysts and surfactants.

UNIT-II **(9 hrs)**

Speciality polymers: Synthesis of aromatic polyethers, polyacetals, polyamides, polyurethane, polymers with metal in their backbone, P and S containing polymers, Bio-polymers, Bio-degradable polymers, Fire retardant polymers, Liquid crystalline polymers - **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 using DSC, TGA, DTA, and DMA.

UNIT-III **(9 hrs)**

Conducting Polymers: Discovery – Conducting mechanism – Classification of conducting polymers: Intrinsic and extrinsic conducting polymers - Chemical and electrochemical methods for the synthesis of conducting polymers – Applications of conducting polymers in corrosion protection, electrochemical energy devices and sensors.

UNIT-IV **(9 hrs)**

Nanocomposites: Introduction to Nanocomposites, Types of Nanocomposites - Methods for producing Nanocomposites – Properties of Nanocomposites.

Polymer Nanocomposites: Polymer/ Metal oxide nanocomposites - Polymer/CNTs nanocomposites - Polymer/Nanoclay based Nanocomposites and their properties and functional applications.

UNIT-V **(9 hrs)**

Other Kinds of Nanocomposites: Fractal based Glass- metal nanocomposites - Core-shell structured nanocomposites - Super hard nanocomposites and its designing and improvements in mechanical properties - Self-cleaning nanocomposites; Metal matrix nanocomposites: Metal with nanoceramic fillers such as TiO_2, SiC, ZrO_2 PTFE, CNTs and Graphene and their mechanical & corrosion resistance properties and functional applications.

TEXT BOOKS

1. Alfred Ruiden, Elements of Polymer Science and Engineering, Elsevier Science, 1998.
2. Bill Meyer, A Text Book of Polymer Chemistry, John Wiley & Sons, Singapore, 1994.
3. Gowariker and Viswanathan, Polymer Science, Wiley Eastern, 1986.
4. Nanostructured Conductive Polymers, Editor. Ali Eftekhari, Wiley, 2010.
5. Nanocomposites - Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun, Wiley-VCH, 2004.
6. A.J.Bard & L.R.Faulkner, Electrochemical methods-Fundamentals and Applications John Wiley & Sons, 3rd Edition, 2001.

REFERENCE BOOKS

1. George Odian, Principles of Polymerization, John Wiley & Sons, 1933
2. Conducting polymers with micro or nano meter structure, Meixiang Wan, Springer, 2008.
3. Polymer-Clay Nanocomposites, T.J. Pinnayain, G.W.Beall, Wiley, New York, 2001.
4. Composite Materials, Deborah D.L.Chung, Springer, 2002.
5. Yiu-Wing Mai and Zhong –Zhen Yu, Polymer-Nanocomposites, CRC Press, 2006.
6. E.Raub &K.Muller, Fundamentals of Metal deposition, Elseiver publishing Co, New York, 1967.

NAST-523: Fundamentals of Biology for Nanotechnology

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)**

Nature, Properties and Function of 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. **Nature, Properties and Function of 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 II **(9 hrs)**

Nature, Properties and Function of 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 - extra chromosomal DNA – mitochondrial, choloroplastic, plasmid and viral – microsatellites – DNA varieties – A, B, and Z – Okazaki fragment – palindrome-concatenation- polymorphism – mutation – strand breaks – genes – promoters, enhancers, structural genes - gene expression – gene silencing - transposons – telomeres.

Unit III **(9 hrs)**

Nature, Properties and Function of 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 IV **(9 hrs)**

Biology of Cell and Cell Function: Types of cells –Glials, Astrocytes, Oligodendroglia, Fibroblasts - Cell proliferation and differentiation - Cell division – pluripotency, totipotency, progenitor cells, differentiated cells, cancer cells, - sub cellular components –locomotion-chemoattractants– pinocytosis, phagocytosis –mitosis and meosis – membrane structure-membrane transport - nuclear transport - transcription, translation, transduction, conjugation – Cell communication and Cell signaling-hormones- cytokines-natural products.

Unit V **(9 hrs)**

Bioenergetics and Protein thermodynamics: High energy compounds – ATP, GTP – synthesis and utilization – reducing equivalents – chemiosmotic process – biochemical kinetics – forward and reversible reactions – reaction free energy – enthalpy - entropy - denaturation kinetics – Arrhenius plot. **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, 2009.
2. Lehninger Principles of Biochemistry, 5th edition, David L Nelson; Michael M Cox. W.H.Freeman Publishers, New York, 2012.
3. Biochemistry, 3rd edition, Donald Voet and Judith Voet. John Wiley Publishers, 2010.
4. Cell & Molecular Biology, 8th edition, E.D.P.De Robertis. Lippincott publishers, 2010.
5. Molecular biology of the cell, 6th edition, Alberts. Garland Publishing, 2014.
6. Essentials of Molecular biology, David Freifelder, Jones & Bartlett Publishers, 1993
7. Genes, 9th edition, Lewin Benjamin. CBS Publishers and Distributors, 2007
8. Molecular Cell Biology, Harvey Lodish; David Baltimore; Arnold Berk. WH Freeman and Co, 2000.

NAST-524: Surface Engineering for Nanotechnology

Outcome/Knowledge/Skill:

Knowledge:

Surfaces are present in everything and how this surface are going to interact with the environment is important (eg., bio, sensor devices). NAST-624 provides an overview on the various aspects of surface interactions with liquid-solid-gas environment. It provides a selective understanding on the surface phenomenon involved in mechanical, electrical, optical, and biological world. This course provides another dimension in the surface understanding – for eg., to look into the mechanical aspects in the bio world

Skills:

- Ability to generate functional coatings (such as hydrophilic/ hydrophobic) and the measurement of physical properties
- Surface characterization tools and interpretation of the outcome

(Soft – Core Course) **L T P C**

3 1 0 3 45L

UNIT-I **(9 hrs)**

Introduction to Surfaces

Surfaces and Interfaces – Importance of Surfaces in Nano Regime – Thermodynamics of surfaces – surface energy – notation of surface structures – surface reconstruction -Surface and interfacial tension and measurement– contact angle and wetting – surfactants, and interfacial forces – Review of Surface Characterization Techniques – optical, topographic, chemical and mechanical properties (XPS, PIXE, RBS, SIMS, LEED, RHEED)

UNIT-II **(9 hrs)**

Processes at Solid Surfaces

Adsorption – Physisorption and Chemisorption – Adsorption isotherms (Langmuir and BET) – Reaction Mechanism (Langmuir-Hinshelwood and Eley-Rideal) – Sticking Probability –Types of Catalyst – Homo vs Hetero - Properties and preparation of Catalyst – TON, TOF, E factor - Surface and electronic properties of metal and metal oxide catalyst and its principle behind catalysis – Sabatier Principle – Bronstedt – Polanyi relation - Role of Surfaces, Interfaces, Morphology in Catalysis– Active sites incatalysis & determination – porous materials and supported catalyst – spillover and reverse spillover - Sensor

UNIT-III **(9 hrs)**

Role of Surfaces in Bio-nano interactions

Adhesion and its importance – Adhesion vs cohesion – Work in adhesion and cohesion - Theories on adhesion (Bradley, Hertz, JKR) - Methods of adhesion measurement (Scotch Tape, Peel test, Scratch, Blister, Ultrasonic and acoustic microcavitation methods) – Adhesion measurement in cell (observational, probing and counting techniques) - Surface modification and adhesion - Adhesion of nanoparticles, cells and between nanoparticle & cells - Cancer cell surface interaction.

UNIT-IV **(9 hrs)**

Tribological Aspects of Surfaces

Tribological aspects of adhesion, friction and wear – Friction and Friction Types – Theories of Macro (Amontons, Coulomb) and Nanoscale friction (Tomlinson, Frenkel- Kontorova, Bowden and Tabor models)– Difference between macro and micro/nano tribology- Wear – Wear Mechanisms and types – identification of different mechanisms – Wear theory (Archard, Rabinowictz, Bassani and D'Acunto Theory)– Characterization techniques for friction and wear – Tribometer, Friction Force Microscopy, Nanoindentation and Nanoscratching – Methods to reduce wear and Friction –Fracture–Lubrication –Surface Coatings

UNIT-V **(9 hrs)**

Surfaces in Multidisciplinary Applications

Colloids– Optical and Electrical properties – Colloids in Drug Delivery – Electrical and Electronic properties of Surfaces –zeta potential - Corrosion – Coatings for corrosion protection – High temperature issues - New coating concepts in multilayer structures – thermal barrier coatings. Bioinspired materials – Tribology in Human Body, Artificial organs and Medical devices – Nanosurfaces in Energy, Environmental, Automobile and Industrial Applications

REFERENCE BOOKS

1. Gabor A. Somorjai, Yimin Li, Introduction to Surface Chemistry and Catalysis, Second Edition, John Wiley & Sons, New Jersey, 2010, ISBN: 978-0-470-50823-7.
2. HaraldIbach, Physics of Surfaces and Interfaces, Springer-Verlag, Berlin, 2006, ISBN: 978-3-540-34709-5.
3. Pankaj Vadgama, Surfaces and interfaces for biomaterials, First Edition, CRC Press, Boca Raton, 2005, ISBN: 0-8493-3446-6.
4. Peter J. Blau, Friction Scienceand Technology- From concepts to applications, Second Edition, CRC Press, Boca Raton, 2009, ISBN: 978-1-4200-5404-0.
5. I. Chorkendorff, J.W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics, First Edition, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2003, ISBN: 3-527- 30574-2.
6. Didier Astruc, Nanopaticles and catalysis, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2008, ISBN: 978-3-527-31572-7.
7. N. Birks, G. H. Meier, F. S. Pettit, Introduction to the high temperature oxidation of metals, Second edition, Cambridge University Press, 2006, 978-0-521-48042-0.
8. Bharat Bhusan, Nanotribology and Nanomechanics, Springer, Berlin, 2005, ISBN: 978- 3-540-24267-3.

NAST-525: 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

(Soft – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT-I **(9 hrs)**

LEDs and Semiconductor Lasers

Fundamentals of Semiconductor physics, Review of quantum confinement theory, optical phenomena in various quantum structures: quantum wells, quantum wires, quantum dots, superlattices. GaAs/ GaAlAs quantum well lasers, quantum wire lasers, quantum dot lasers, white light LEDs, vertical cavity surface emitting lasers, quantum cascade lasers, quantum well infrared detectors, digital logic based on quantum wells, GaN and other visible LEDs, semiconductor lasers.

UNIT-II **(9 hrs)**

Nanoscale MOSFETs

Challenges in miniaturization, quantum effects, thin oxides, random dopant fluctuations, tunneling and subthreshold 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

Single molecular devices, Molecular nanowires, charge transport in organic materials, fabrication techniques for molecular electronics, organic LEDs, organic FETs, carbon nanotube and grapheme based FETs, Silicon nanowire based FETs,

UNIT-IV **(9 hrs)**

Single Electron Tunneling Phenomena and Devices

Single electron tunneling, charging energy, tunneling rates, single electron transistor, Coulomb blockade, Coulomb staircase, Bloch oscillations, negative differential resistance, resonant tunneling diode and resonant tunneling transistor.

UNIT-V **(9 hrs)**

Nanobioelectronics

Nanoelectronic biosensor, Nanowire, CNT and graphene based biosensors, DNA based biosensors, protein based biosensors, materials for biosensor applications, quantum dot based bioimaging, DNA based logic and computing elements

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. Overview of Nanoelectronic Devices, D. Goldhaber Gordon, Proceedings of IEEE, volume 85, 1997.
8. Nanoelectronics and Information Technology, W. Rainer, Wiley, 2003, ISBN: 978-3-527-40927-3
9. Nanosystems, K.E. Drexler, Wiley, 1992, ISBN:0-471-57518-6
10. Science of fullerenes and carbon nanotubes, M.S. Dresselhaus and G. Dresselhaus, Academic press, 1996, ISBN: 9780080540771.

NAST-526: Self Assembly of Nanostructures

Outcome/Knowledge/Skill:

Extend their knowledge of design of innovative nanostructured materials based on basic chemistry, physics, biology *via* self-assembly concepts applied to various applications including photonics, nanophotovoltaic and energy materials

Self-assembly of nanomaterials and their nanohybrids for technological applications

(Soft – Core Course)	**L**	**T**	**P**	**C**	
	3	**1**	**0**	**3**	**45L**

UNIT-I **(9 hrs)**

Self organization of nanostructured materials, Growth Mechanism, Self assembly of Nanostructures: Chemical, physical and biological self assembly, Assembling and patterning of particles, Self organization of different Nano-morphologies (Quntum Dots, Nanorods, Nanowires and Nanotubes).

UNIT-II **(9 hrs)**

Self Assembled Monolayers (SAM), Guided Self Assembly - Nanolithography - Surface Topography - Surface Wetting - Electrostatic force; Nanomanipulators - Grippers – design - gripper arm geometry.

UNIT-III **(9 hrs)**

Bottom-up manufacturing: bottom-up approach, Self-assembly of single electron transistors, Photovoltaic related devices, Langmuir Bladgett films (LB): principle of formation of monolayer formation – from molecules to nanoparticles, compression of monolayer-fabrication of LB films-applications.

UNIT-IV **(9 hrs)**

Self-Assembly by micro contact printing- creating the stamp, substrate- creating self assembled monolayers -applications, Macroscopic expressions of Natural Nanomaterials- Hierarchical Ordering in Natural Nanoscale Materials

UNIT-V **(9 hrs)**

Bio-Inspired Approach for Complex Superstructures and Biological World, Self Assembly in biological systems: Superhydrophobicity, Self cleaning property, Multi scale ordering and function in Biological Nanoscale Materials: Proteins, Lipids, DNA and RNA 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.

NAST-520: Fabrication and Characterization Laboratory

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.

Acquire hands on training on most of fabrication techniques for fabrication of different nanomaterials.

(Hard – Core Course)

L	T	P	C	
0	2	4	3	45L

- Fabrication of thin films by thermal evaporation.
- Thin film fabrication by electron beam evaporation.
- Photocatalytic film fabrication by doctor-blade method and its photocatalytic studies on organic dyes.
- Nanocrystalline thin film by spin coating.
- Chemical bath deposition by dip coating.
- Fabrication of self standing film with QD embedded structure and optical property analysis
- Preparation polymer-semiconductor nanocrystalline films and study its electrical properties
- Fabrication of TiO_2 nanofibers on ITO glass substrate by Electro-spinning.
- Electrodeposition of polyaniline on ITO substrate.
- Electroless deposition of Ag or Au on Si substrate
- Electrical resistivity measurement by four probe method.
- Band gap determination by diffuse reflectance spectroscopy method.
- Polymer membrane electrolyte preparation and its porosity, electrolyte uptake and ionic conductivity studies.
- Electrophoretic deposition of tricalcium phosphate.
- Determination of thermal expansion of Nano-ceramic material by dilatometer.
- Film thickness measurement by ellipsometer.
- Nano indentation on a polycarbonate substrate using AFM for hardness determination.
- Mechanical evaluation of Nanomaterials.
- Clean Room: Familiarizing with essential terms, tools and practices.

- Synthesis of CNTs by CVD method.
- Dip-pen lithography using AFM with molecularinks.
- Nano-patterning by AFM lithography.
- Nanosphere lithography using silica Nanospheres
- Surface topography of a sputtered Au using AFM /STM.
- Surface topography of a sputtered Au using AFM / STM.
- Electrical resistivity measurement by Four probe method.
- Polymer membrane electrolyte preparation and its porosity, electrolyte uptake and ionic conductivity measurements.
- Determination of thermal expansion of Nano-ceramic material by dilatometer.
- Film thickness measurement by ellipsometer.
- Device fabrication like solar photovoltaics and energy storage
- LED conversion materials

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Semester - III **Credits: 21**

NAST-631: MEMS/NEMS and Microsystems

Outcome/Knowledge/Skill:

Knowledge:

Tailor made microelectro mechanical device fabrication has generated huge opportunity and challenges for the students. Though NAST-731 gets exposed to design, selection of materials, and fabrication of devices / testing in addition to issues in properties at lower dimension.

Skills:

Students get to understand the MEMS technology – fabrication as well as dimensional issues. The generic approach impart the skills of the student to face the real industrial scenario across different domains of application

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT- I **(9 hrs)**

Mechanics and Materials

Overview of MEMS and Microsystems – Thin film growth and models –Mechanical, Electrical, Thermal properties for Thin Films/MEMS –Measurement techniques – Materials for MEMS-Semiconductors, Metals and Metal alloys, Ceramics, Polymers – Silicon and other substrate materials.

UNIT- II **(9 hrs)**

Processing of MEMS/NEMS and Microsystems

Silicon processing, Structure & properties – Single crystal growth - Overview of Lithographic process – Additive processes for Semiconductors, Ceramics, Metals and polymers - MEMS Fabrication – Doping process - Bulk micromachining - Wet & Dry Etching- Isotropic and anisotropic etching and mechanism - Etch stop techniques – DRIE and other processes- Surface Micromachining – LIGA and laser assisted processing – Nanomechanical system fabrication - Fundamentals of Design and Simulation.

UNIT- III **(9 hrs)**

Interconnects and Bonding

Interconnects – requirements of interconnects –Metallization Techniques — Damascene process-silicide and refractory metals - Multilevel and nanostructured interconnects – Bonding Techniques.

Packaging and Failure: Packaging Fundamentals – Packaging Techniques– Electrical and thermal requirements - Packaging Reliability and failure modes and analysis – MEMS process integration- Tribological issues

UNIT- IV **(9 hrs)**

Engineering Mechanics

Microsystem design – Static bending of thin films –Mechanical vibration– thermomechanics– fracture mechanics – Thermofluidics

UNIT- V **(9 hrs)**

Design and Applications

Scaling laws in miniaturization – Design considerations – Process and Mechanical design – Finite element method (FEM), Computer aided design CAD – Mircosensors and Microactuators– Optical, chemical, thermal, gas, pressure, bio and mechanical sensors – Nanosensors– Applications in automobile, aerospace, health care, industrial, consumer and telecommunications

REFERENCE BOOKS

1. Tai-Ran Hsu, MEMS and Microsystems – Design, Manufacture, and Nanoscale Engineering, Second Edition, John Wiley & Sons, Inc., New Jersey, 2008, ISBN: 978-0- 470-08301-7.
2. Reza Ghodssi, Pinyen Lin, MEMS Materials and Processes Handbook, Springer, New York, 2011, ISBN: 978-0-387-47316-1.
3. Nadim Maluf and Kirt Williams, An introduction to Micro electro mechanical systems Engineering, Second Edition – Artech House, Inc., Boston, 2004, ISBN: 1-58053-590-9.
4. Sami Franssila, Introduction to Microfabrication, Second Edition, John Wiley & Sons, Sussex, 2010, ISBN: 978-0-470-74983-8.
5. Marc Madou, Fundamentals of Microfabrication, Second Edition, CRC Press, Boca Raton, 2002, ISBN: 0-8493-0826-7.
6. Francisco J. Arregui, Sensors based on nanostructured materials, First Edition, Springer-Verlag, New York, 2009, ISBN: 978-0-387-77752-8.
7. Bharath Bhushan, Springer Hand Book of Nano Technology, Third Edition, Springer- Verlag, New York, 2010, ISBN: 978-3-642-02524-2.
8. Sergey Edward Lysherski, MEMS and NEMS Systems, devices, and structures, First Edition, CRC Press, Boca Raton, 2002, ISBN: 9780849312625.
9. H. Baltes, O. Brand, G. K. Fedder, C. Hierold, J. G. Korvink, O. Tabata, Enabling Technology for MEMS and Nanodevices, Wiley-VCH, Weinheim, 2013, ISBN: 978-3- 527-33498-8..
10. Danny Banks, Microengineering, MEMS, and Interfacing - A Practical Guide, Taylor & Francis, Boca Raton, 2006, ISBN: 978-0-8247-2305-7.
11. C.P. Wong, Kyoung-Sik (Jack) Moon, Yi Li, Nano-Bio- Electronic, Photonic and MEMS Packaging, Springer, New York, 2010, ISBN: 978-1-4419-0039-5.
12. Sandra Carrara, Nano-Bio-Sensing, Springer, New York, 2011, ISBN: 978-1-4419-6169-3.

NAST-632: Nanostructured Materials for Clean Energy Systems

Outcome/Knowledge/Skill:

Fundamental concepts and understanding of the structure-composition-performance relationships of materials for clean energy conversion and storage technological application. Fabrication and evaluation of prototype clean energy conversion & storage devices (Hydrogen generation & storage, DSSC and Perovskite based solar cells, lithium batteries, redox-flow batteries, supercapacitors, and fuel cells) for made-in-India program for our country sustainability and developing human resource in the clean energy areas.

(Hard – Core Course)	**L**	**T**	**P**	**C**	
	3	**1**	**0**	**3**	**45L**

UNIT-I **(9 hrs)**

Fundamental Concepts in 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 Energy Conversion Systems

Issues and Challenges of functional Nanostructured Materials for electrochemical Energy, Conversion Systems, Hydrogen generation & Storage, 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-III **(9 hrs)**

Nanomaterials for Photovoltaic Solar Energy Conversion Systems

Principles of photovoltaic energy conversion (PV), Types of photovoltics Cells, Physics of photovoltaic cells, Organic photovoltaic cell cells, thin film Dye Sensitized Solar Cells, Quntum dot (QD) Sensitized Solar Cells (QD-SSC), Perovskite solar cells, Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Solar-water splitting, Current status and future trends.

UNIT-IV **(9 hrs)**

Nanomaterials for 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, redox-flow batteries for HEV/EV transportation and stationary applications, Nanostructured Carbon based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.

UNIT-V **(9 hrs)**

Nanomaterials for Energy Storage (Capacitor) Systems

Capacitor, Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon based materials, porous materials for Redox capacitor Nano- Oxides, conducting polymers based materials, Current status and future trends.

REFERENCE BOOK

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, Kulwer Acdemic 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.
9. Photoelectrochemical hydrogen generation, theory, materials advances, and challenges, by Pooja Devi, Springer Publications 2022, ISBN: 978-981-16-7285-9
10. Redox flow batteries, Fundamentals and applications by Zhang Huamin, CRC Press publications, ISBN: 9781498753944

NAST-633: Nanophotonics and Biophotonics

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.
- Learn the applications of Bioderived and Bioinspired materials for photonic applications.
- Concepts of quantum dots and their application in nanotechnology for bioimaging is studied.
- Will be Competent to make photonic materials for advanced technologies such as optoelectronics, quantum computation, optical transmission etc.

(Hard – Core Course)

L	T	P	C	
3	1	0	3	45L

Unit I **(10 hrs)**

Introduction to photonics

Light and Matter on a nanometer scale – Nanophotonics classification – electron and light confinement – quantum optics – Nanoplasmonics - Electromagnetic properties of nanostructures – Wavelength - Dispersion laws for photons and electrons – Density of states for 1D – Extension to 2D and 3D cases – Maxwell and Helmholtz equations – Photonic band-structure and photonic band gap - Propagation of light in periodic media – Bloch waves and Band structure in periodic media – 1D case – Origin and size of

bandgap based on dielectric contrast – Evanescent Waves.

Unit II **(10 hrs)**

Photonic Crystals – Definition of 1-, 2- and 3-D photonic crystals – Bragg Mirror – Yablonovite structure - Fabrication – 1-D Phototonic crystal by sputtering method – 2-D photonic crystal by Biomineralization – 2-D photonic crystals by Microfabrication– 3-D photonic crystals by Self-assembly – Colloidal crystals by Sedimentation – Convective Self-assembly of Opaline thin films - Photonic Crystals with Tunable Properties.

Unit III **(9 hrs)**

Photobiology

Interaction of light with cells: Light absorption in cells – Proteins, DNA, RNA, NADH and Water - Light induced cellular processes – Autofluorescence and Fluorophores –Green Fluorescent Protein – Photochemical Processes - **Interaction of light with tissues:** Nature of Optical interactions – Raman scattering – Optical Loss by scattering – Optical Transparency of a tissue - Measurement of optical properties of a tissue – The Double Integrating Sphere Method - Light-induced Processes in Tissues – Autofluorescence - Photochemical processes - thermal effects – photoablation - plasma induced ablation and photodisruption.

Unit IV **(8 hrs)**

Nanotechnology for biophotonics: The interface of bioscience, nanotechnology and photonics - Semiconductor quantum dots for bioimaging – Quantum confinement – Size dependent band gap – Advantages – Major issues and solution – Metallic nanoparticles for Biosensing - Surface plasmon resonance – Localized SPR – SPR based sensor using Au nanoparticles – Up-converting nanophores - Nanoparticles for Upconversion – Pebble nanosensors for Invitro Bioanalysis - Nanoclinics for optical diagnostics and Targeted therapy – Hyperthermic effect in Nanoclinic.

Unit – V **(8 hrs)**

Biomaterials for Photonics: Four types of Biomaterials for photonics – Bioderived materials - Baceriorhodopsin – Structure – Application to Holographic memory – Storage mechanism - Angular multiplexing & Optical correlation - Green Fluorescent Protein – Structure – characteristics – Variants – Environmental stability - A photonic application of GFP – Molecular photodiode with MIM structure – Naturally occurring DNA - Bio-objects and biocolloids – Bioinspired materials – light-harvesting dendrimer – Biotemplates - DNA and Viruses as templates.

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: Physics and Technology, (Eds.) C. Sibilia, T. M. Benson, M. Marciniak, T. Szoplik, (ISBN: 978-88-470-0843-4) (2008)
3. 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)
4. Introduction to Biophotonics, Paras N. Prasad, (John Wiley and Sons, New Jersey), ISBN: 0-471-28770-9 (2003)
5. Photonic Crystals:Towards Nanoscale Photonic Devices, J.-M. Lourtioz, H. Benisty, 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, Motoichi Ohtsu, 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 and Stoyan Tanev, 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)

NAST-634: 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	1	0	3	45L

UNIT-I **(9 hrs)**

Magnetism of the solid state

Basics of magnetic materials, magnetic flux, magnetization, magnetic induction, susceptibility and permeability, diamagnetism and diamagnetic susceptibility, Paramagnetism, Curie law and Curie-Weiss law, Pauli paramagnetism, Ferromagnetism, hysteresis, magnons, domain theory, ferrimagnetism, antiferromagnetism

UNIT-II **(9 hrs)**

Giant magnetoresistance

Introduction to spintronics, magnetoresistance in normal metals, MR ratios, Giant magnetoresistance in ferromagnetic multi layers and superlattices, co-operative phenomena and magnetization reversal, applications in spin valve and read heads, comparison of GMR and AMR, oscillation of coupling energy, non-coupling type GMR, CPP and CIP GMR, GMR in nanograins, mechanism of GMR.

UNIT-III **(9 hrs)**

Tunnel magnetoresistance

Introduction to tunnel magneto resistance, ferromagnetic tunnel junctions, experiments for TMR, phenomenological theory of TMR, MR ratio and spin polarization, factors influencing TMR, MR ratio for Fe/MgO/ Fe system, oscillations in TMR, tunnel junctions with manganites, Heusler alloys, nanoscale granules, Coulomb blockade in tunnel junctions.

UNIT-IV **(9 hrs)**

Ballistic magnetoresistance and Magnetic nanostructures

Ballistic magneto resistance, conductance quantization in quantum confined semiconductors,

metals. Anisotropic magneto resistance and applications, magnetism of nanoparticles, nanoclusters, nanowires, hard and soft magnetic materials and their applications, media for extremely high density recording, magnetic sensors, ferro fluids, spinglass- magnetic properties and electronic structure

UNIT-V **(9 hrs)**

Nanobiomagnetism

Magnetic targeting, magnetic separation and detection, magnetic tweezers, drug and gene delivery, chemo therapy, MRI, magnetic contrast agents, hyperthermia, application of various nanomagnetic materials in biotechnology, superparamagnetism, core-shell structures and their applications, iron oxide and novel Nanomaterials.

REFERENCE BOOKS

1. Physics of Magnetism and Magnetic Materials, K.H.J Buschow, F.R. de Boer, Springer, 2003, ISBN: 9780970467041, 0970467044.
2. Advanced Magnetic Nanostructures, Ed. D. Sellmyer, R. Skomski, Springer, 2009, ISBN: 9780387233093, 0387233091.
3. Nanostructured Magnetic Materials and their Applications, Ed. D. Shi, B. Aktas, L. Pust, F. Mikailov, Springer, 2002, ISBN: 9783540368724
4. Introduction to Magnetic Materials, B. D. Cullity, Wiley, 1972, ISBN: 9780471477419.
5. Magnetism in the Solid State, Peter Mohn, Springer series in solid-state sciences, 2006, ISBN: 3540293841, 9783540293842.
6. Handbook of Thin Film Materials, Volume 5, Edited by H.S Nalwa, American Scientific Publishers, 2002, ISBN: 9780125129084, 9780080533247.
7. Encyclopedia of Nanoscience and Nanotechnology, Edited by H.S. Nalwa, American Scientific Publishers, 2007, ISBN: 1588830012, 1588831590
8. Magnetism – Fundamentals, Edited by E. du Tremolet de Lacheisserie, D. Gognoux, M. Schlenker, Springer, 2003, ISBN: 9780387229676.
9. Advances in Nanoscale Magnetism, Ed. B. Aktas, F. Mikailov, Springer, 2009, ISBN: 9783540698821
10. Spintronics: Fundamentals and Applications, I. Zutic, J. Fabian and S. Das Sarma, Rev. Mod. Phys, 76, 323 (2004).

NAST-635: Advanced Nanobiotechnology

Outcome/Knowledge/Skill:

On Completion of the course the student will be able to

- Understand the research oriented concepts of tissue engineering and drug delivery.
- Understand the toxicity of Nanomaterials, and evaluation of biocompatibility of nanomaterials.

(Soft – Core Course)

L	T	P	C	
3	1	0	3	45L

Unit –I **(9 hrs)**

Synthetic Materials in Medicine, properties of Materials: Bulk Properties of Materials, Surface Properties of Materials. Classes of Materials Used in Medicine: Structure and Properties of Metals, Ceramics, Glasses, and Glass-Ceramics, Polymers, Hydrogels, Family of Carbon Nanomaterials, Bioresorbable and Bioerodible Materials, Composites, Thin Films, Grafts and Coatings, Biologically Functional Materials.

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, Cell Adhesion, Interactions with Hard Tissues, The Vroman Effect, Adhesion of Osteoblasts, Osseointegration, Fibrous Capsule Formation, Safety Testing of Biomaterials.

Unit –III **(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, Predicting Penetration and Fate of Nanoparticles in the Body, Toxicity Mechanisms - Mechanisms for Radical Species Production, General Genotoxicity Mechanisms, Detection and Characterization of Genotoxicity.

Unit –IV **(9 hrs)**

Tissue engineering

Introduction, Stem cells, Morphogenesis, Generation of tissue in the embryo, Tissue homeostasis, Cellular signaling, Extracellular matrix as a biologic scaffold for tissue engineering, Natural polymers in tissue engineering applications, Degradable polymers for tissue engineering, Degradation of bioceramics.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. Delivery of Nanoparticles: Brain Delivery, Ocular Drug Delivery, Gene Delivery Systems, Carriers in Cancer Therapy, Cardiovascular System, Vascular Delivery to the Lungs, Targeting Lymphatics.

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, Ranieri Cancedda, Joost de Bruijn, Jérôme Sohier, Academic Press, Elsevier, 84 Theobald's Road, London WC1X 8RR, UK, 30 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. 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. 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.
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
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. 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, ISBN-10 3-527-31115- 7.

NAST -636: Industrial Nanotechnology

Outcome/Knowledge/Skill:

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

- Educate students about the interactions at molecular scale.
- Understand the influence of Nanotechnology based applications on each industry.
- Understand the future technologies advantages and increasing role of Nanotechnology in each industry.

(Soft – Core Course)

L	T	P	C	
3	1	0	3	45L

UNIT- I **(9 hrs)**

Nanotechnology in Agriculture and Food Industries

Agricultureindustry: - Precision farming, Smart delivery system – Insecticides using Nanotechnology – Nanofertilizers -Nanofertigation - Nano-seed Science.

Food industry: Nanopackaging for enhanced shelf life - Smart/Intelligent packaging - Food processing and food safety and bio-security –Electrochemical sensors for food analysis and contaminant detection.

UNIT- II **(9 hrs)**

Nanotechnology in Textiles and Cosmetics Industries

Textiles Industry: Production of Nano-woven fibers from electrospinning – Controlling parameters and morphologies of nanofibers – Nanocomposite fibers; **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.

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

UNIT-III **(9 hrs)**

Nanotechnology in Chemical and Electrochemical Industries

Nanocatalysts – Smart Materials – Nanostructures for molecular recognition (0D, 1D and 2D) – Molecular encapsulation and its applications – Nanoporous Zeolites – Nano-reactors – Solid lubricants – Nanotechnology in Electrometallurgy, Electroplating industry and Corrosion protective organic coatings – Electrolytic production of metal nanopowders, Electrochemical exfoliation for the production of Graphene and other metal chalcogenides – Electrochemical preparation of Nanostructured conducting polymers.

UNIT- IV **(9 hrs)**

Nanotechnology in Defence

Military applications of Nanotechnology –Nano-Battle suit – Nano-drones – Nano- Satellites – Nano-Propellants and Explosives – Camouflage distributed sensors - Amour protection - Implanted Nano-systems - Mini-/Micro robots - Small satellites and Space launchers –Nano- Nuclear, Chemical and Biological weapons - Chemical/Biological protection.

UNIT- V **(9 hrs)**

Nanotechnology in Environmental and Health Effects

Overview of physical, chemical and biological processes concerning the environment- Nanomaterial based adsorbents and photocatalysts for water and waste water treatment – Nanomaterials for adsorption of heavy metals – Nanoparticles for degradation of organic and organic compounds – Treatment of Arsenic using Nano TiO_2 and other nanoparticles – Nanomembranes in drinking water purification and desalination – Environmental impacts of Nanomaterials on human and animal health – Safety issues and regulatory practices in handling Nanomaterials – Environmental hazard in processing of Nanomaterials – Emerging issues of nano/microplastics - Green synthesis/zero-waste processes.

TEXTBOOK

1. P. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead publication, London, 2006.
2. J. Altmann, Routledge, Military Nanotechnology: Potential Applications and Preventive Arms Control, Taylor and Francis Group, 2006.
3. Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, (2006).
4. Lynn J. Frewer, WillehmNorde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, (2011).
5. P. J. Brown and K. Stevens, Nanofibers and Nanotechnology in Textiles, Woodhead Publishing Limited, Cambridge, (2007).
6. Q. Chaudry, L.Castle and R. Watkins Nanotechnologies in Food, RSC Publications, 2010.
7. W.N.Chang, Nanofibers Fabrication, Performance and Applications, Nova Science Publishers Inc., (2009).
8. M.R. Rifi and F.H.Covitz, Industrial Electrochemistry, Marcel Dekker Inc, New York, 1974.
9. K.I.Popov, S.S.Djokic and B.N.Grgur, Fundamentals of Electrometallurgy, Kluwer Academic Publishing 2002.
10. A.J.Bard & L.R.Faulkner, Electrochemical methods-Fundamentals and Applications John Wiley & Sons, 3rd Edition, 2001.

REFERENCE BOOK

1. Y-W. Mai, Polymer Nano composites, Woodhead publishing, (2006).
2. Udo H. Brinker, Jean-Luc Mieusset (Eds.), Molecular Encapsulation: Organic Reactions in Constrained Systems, Wiley Publishers (2010).
3. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun.
4. E.Raub & K.Muller, Fundamentals of Metal deposition, Elseiver publishing Co, New York,1967.

NAST-630: Modeling and Simulation Laboratory

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

- Fortran programming for basic matrix handling.
- Fortran programming for Numerical methods such as Runge-Kutta method, Gauss-elimination, Gauss-Seidel methods.
- Simulation of wave function and energy levels of the particle in a 1-D potential using Fortran program.
- Simulation of Radioactive decay using uniformly distributed Random numbers.
- Deconvolution of the experimental spectra using FitYK freeware.
- Image analysis by SciLab (Freeware)
- Construction of fullerene & its energy calculations by ARGUS Lab.
- Construction of carbon nanotubes by ARGUS Lab.
- Simulation with MATLAB: Programme assembly, execution, data processing and graphic analysis.
- Image processing with MATLAB
- MATLAB programme to plot the first four Eigen functions of a one dimensional rectangular potential well with infinite potential barrier.
- Nanomaterials optical bandgap simulation using MATLAB.
- Monte Carlo Simulation-Determination of mean, medium and standard deviation.
- Atom manipulation and Patterning.
- Study of single electron transistor using MOSES 1.2 simulator.
- Simulation of I-V characteristic for a single junction circuit with a single quantum dot using MOSES 1.2 simulator.
- To determine the surface roughness of raw and processed AFM images of glass, silicon and films made by different methods using offline SPIP software.
- Simulation with VASP and GIBBS
- Numerical simulation of SOFC for impedance analysis

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Semester - IV Credits: 12

NAST-641: Research Project (Report and Viva-Voce)

Outcome/Knowledge/Skill:

- Supports advance research capabilities undertaking a major, individual, related project
- Develop 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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