



**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**

**2016 -17 ONWARDS**

## M.Tech. - NANOSCIENCE AND TECHNOLOGY PROGRAMME

### REGULATION (2016-17 Onwards)

#### 1. Duration of the Course: 2 Years

#### 2. Eligibility for Admission:

A candidate having BE / B.Tech in Nanoscience and Technology, Polymer Science and Engg., Electrical and Electronics Engg., Electronics and Communication / Instrumentation Engg., Computer Science and Engg. Chemical Engg./Technology, Materials Science and Engg., Mechanical Engg., Metallurgical Engg., Biotechnology with a minimum of 55% of marks. (OR) Masters degree in Physics/Applied Physics / Chemistry / Applied Chemistry/ Materials Science / Nanoscience and Technology / Biotechnology / Bio-Chemistry with a minimum of 55% of marks.

#### 3. Examinations

End semester examinations under CBCS Scheme comprising of external question paper setting and double valuation by the course teacher and an external examiner for each theory courses. If the difference between the two valuations is more than 15%, the script will be evaluated by the third subject expert and the mark awarded by that expert will be the final. But for laboratory courses, the valuation will be done only by the Faculty in-charge.

4. Proportion of marks for internal assessment and end-semester examination for each theory and laboratory courses are 40:60, respectively.

#### 5. Guidelines for awarding marks for IV semester Research project.

Time duration for IV semester Research project is **one full semester**.

Marks for **project** awarded by the **supervisor** : 100 Marks

Marks for project **viva-voce** awarded by 2 Members Committee: 100 Marks

[The mid-term review will be conducted and the assessment shall be made by all the faculty members of the Centre (50 Marks) and then at the end public viva – voce exam will be conducted and the assessment shall be made by the **project supervisor of the Centre** and **one external examiner (50 Marks)**]

#### 6. Passing Requirements

The student should have a minimum of 40% marks in University Examination and a minimum total of 50% marks in Internal assessment and University Examination put together in all courses.

**7. Internal assessment**

Total internal marks 40; Mark distribution: Three internal tests to be conducted for 30 marks, out of which best two to be taken, and for another 10 marks to be given for Assignment and Seminar.

**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

**8. 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 Eight Questions

(Equal weightage must be given to each unit)

Question 11 To Question 18

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## M.Tech.- Nanoscience and Technology

### CURRICULUM (2016-17 Onwards)

Sem	Code No.	Subject	Course Type	Class hours	University Examination			Credit	
					Internal	External	Total		
I	NAST-611	Essentials of Quantum Mechanics and Electromagnetic theory	HC	3	40	60	100	3	
	NAST-612	Thermodynamics and Kinetics for Nanotechnology	HC	3	40	60	100	3	
	NAST-613	Elements of Materials Science and Physical Properties of Nanomaterials	HC	3	40	60	100	3	
	NAST-614	Synthesis and Characterization of Nanostructured Materials	HC	3	40	60	100	3	
	NAST-615	Nanostructure Fabrication and Metrology	HC	3	40	60	100	3	
		<b>NAST-610</b>	<b>Synthesis and Processing Laboratory</b>	<b>HC</b>	<b>6</b>	<b>75</b>	<b>25</b>	<b>100</b>	<b>3</b>
<b>Total Credits</b>								<b>18</b>	
II	NAST-621	Computational methods for Modeling & Simulations	HC	3	40	60	100	3	
	NAST-622	Polymers and Nanocomposites	HC	3	40	60	100	3	
	NAST-623	Fundamentals of Biology for Nanotechnology	HC	3	40	60	100	3	
	<b>Soft Courses (Any THREE to be selected)</b>								
	NAST-624	Surface Engineering for Nanotechnology	SC	3	40	60	100	3	
	NAST-625	Nanoelectronics and Bioelectronics	SC	3	40	60	100	3	
	NAST-626	Self-Assembly of Nanostructures	SC	3	40	60	100	3	
	XXX	Core / Soft Core Courses offered by other Departments at M.Tech level.	SC	3	40	60	100	3	
		<b>NAST-620</b>	<b>Fabrication Laboratory</b>	<b>HC</b>	<b>6</b>	<b>75</b>	<b>25</b>	<b>100</b>	<b>3</b>
	<b>Total Credits</b>								<b>21</b>

<b>III</b>	NAST-731	MEMS/NEMS and Microsystems	HC	3	40	60	100	3
	NAST-732	Nanostructured Materials for Clean Energy Systems	HC	3	40	60	100	3
	NAST-733	Nano-photonics and Biophotonics	HC	3	40	60	100	3
	<b>Soft- Core Courses (Any THREE to be selected)</b>							
	NAST-734	Nanomagnetic Materials and Devices	SC	3	40	60	100	3
	NAST-735	Advanced Nanobiotechnology	SC	3	40	60	100	3
	NAST-736	Industrial Nanotechnology	SC	3	40	60	100	3
	XXX	Core / Soft Core Courses offered by other Departments at M.Tech level	SC	3	40	60	100	3
	<b>NAST-730</b>	<b>Modeling and Simulation Laboratory</b>	<b>HC</b>	<b>6</b>	<b>75</b>	<b>25</b>	<b>100</b>	<b>3</b>
<b>Total Credits</b>								<b>21</b>
<b>IV</b>	<b>NAST-741</b>	<b>Research Project (Report and Viva-Voce)</b>	<b>HC</b>	<b>One Full Semester</b>	<b>100</b>	<b>100</b>	<b>200</b>	<b>12</b>
<b>Total Credits (I,II,III &amp; IV)</b>							<b>2,100</b>	<b>72</b>

\* HC – Hard Core Course ; SC – Soft Core Course;

## Syllabus for Courses

### Semester - I

Credits: 18

### **NAST- 611: Essentials of Quantum Mechanics and Electromagnetic Theory**

**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 and 3-dimensional box. Quantum mechanics of a free particle confined to a spherical trap (Polar coordinates). Electron in a periodic potential – Bloch Theorem.

**Unit –II** (9 hrs)

**Approximation methods:** Time Independent Perturbation Theory - Degenerate and Non-degenerate case.

**Identical Particles:** Schrodinger equation– Interchange symmetry. Systems of Identical particles (Classical and Quantum View) – Experiment on Indistinguishability– Exchange degeneracy - 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 – Orbital approximation for multielectron atoms – He atom - Pauli's Anti-symmetry principle – Born – Oppenheimer approximation. Molecular orbital Theory – LCAO - Theory of  $H_2$  molecule –  $H_2^+$  - Term Symbols.

**Unit-V** (9 hrs)

#### **Review 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. Reflection and Transmission at Normal and Oblique Incidences, Complex Refractive Index and Dispersion relation.

**TEXT BOOKS**

1. Quantum Mechanics: Concepts and Applications, Nouredine Zettili, Wiley, New York, (2001), ISBN 0-471 48943 3.
2. Molecular Quantum Mechanics (3<sup>rd</sup> Edition), P.W. Atkins and R. S. Friedman, Oxford University Press, (2004), ISBN: 0-19-566751-4.
3. Introduction to nanotechnology, Henrik Bruus, (2004) MIC – Department of Micro and Nanotechnology, Technical University of Denmark.
4. Y T Tan et al. 2003 J.Appl. Phys. 94 633.
5. 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.
6. Introduction to Electrodynamics, David J. Griffiths, (ISBN: 978-81-203-1601-0), Prentice-Hall, India, (2009).

**REFERENCE BOOKS**

1. Quantum Mechanics, Vol I and Vol II, Claude Cohen-Tannaoudji, Bernard Diu, Franck Laloe, John Wiley & Sons (2005).
2. Quantum mechanics, J. L. Powell and B. Craseman, Addison-Wesley (1964).
3. Classical electromagnetism J. D. Jackson, John Wiley Publications (1999) (ISBN 0-471-30932-X).

**NAST-612: Thermodynamics and Kinetics for Nanotechnology****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.

**TEXT BOOKS**

1. G. M. Barrow, Physical Chemistry (V Edition), McGraw Hill international Series, 1988.
2. S. Glasstone, Thermodynamics for chemists, Affiliated East West Press, 1965.
3. P. W. Atkins, Physical Chemistry, Sixth edition, Oxford University Press, 1990.
4. B. C. McClelland, Statistical Thermodynamics, Chapman and Hall, 1973.
5. M. C. Gupta, Statistical Thermodynamics, Wiley Eastern Limited, 1993.
6. V. Raghavan, Solid State Phase Transformations, Prentice-Hall of India Pvt. Ltd. New Delhi, 1987.
7. D.A. Porter and K.E. Easterling, Transformations in metals and alloys, 2<sup>nd</sup> Edition, CRC Press, 1992.

**REFERENCE BOOKS**

1. N. D. Smith, Elementary Statistical Thermodynamics, Plenum Press, 1982.
2. J. Rajaram and J. C. Kuriacose, Thermodynamics for Students of Chemistry, Shobanlal Nagin Chand Co, 1986.
3. L. K. Nash, Elements of classical and statistical thermodynamics, Addison-Wesley, 1970

**NAST-613: Elements of Materials Science and Physical Properties of Nanomaterials****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) - 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, Types of bond: Metallic, Ionic, Covalent, Co-ordination/dative bonds; Vander Waals interactions/Electrostatic interactions: Ion pair interactions, solvent effects, Ion-dipole and dipole – dipole interactions,  $\pi$ -interactions - Hybridization, Hydrogen bonding - hydrophobic interactions. MO theory for simple molecules such as diatomic molecules. **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)****Bonding in Nanostructures**

Graphene – Fullerenes – Carbon nanotubes - Bonding in armchair, zigzag and chiral structures -  $n-m=3q$  rule – Inorganic nanotubes: Silica nanotubes, boron nitride nanotubes, nanotubes of dichalcogenides, and nanotubes of several metal oxides – Reactivity on nanosurfaces: Functionalization of carbon nanotubes and Graphene.

**UNIT-IV (9 hrs)****Electronic Properties**

Classification of materials, Band structures, Brillouin zones – Electrical and electronic conductivity, Hall effect and its determination. **Dielectric Properties:** Different kinds of dielectric materials, dielectric constant and its determination – Piezoelectric, pyroelectric and ferroelectric materials. **Optical Properties:** Photoconductivity, Optical absorption and transmission - Photoluminescence, Jablonski diagram, fluorescence and phosphorescence - Electroluminescence .

**UNIT-V (9 hrs)****Mechanical behavior**

Stress-strain behavior, tensile strength, toughness, micro-hardness, wear resistance, corrosion resistance behavior of nanostructures. **Thermal properties:** Concept of phonon, thermal conductivity, thermal expansion and thermal expansion coefficient. **Magnetic properties:** Fundamentals of magnetism - Different kinds of magnetic materials: dia, para, ferro, ferri and anti-ferromagnetic materials - Magnetic hysteresis – Superparamagnetism – Important properties in relation to nano-magnetism.

**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-614: Synthesis and Characterization of Nanostructured Materials**

### **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. 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), Electrochemical Characterization measurements.

**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.

**REFERENCE BOOKS**

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

**NAST-615: Nanostructure Fabrication and Metrology****UNIT-I****(10 hrs)****Principles of Photo Lithography**

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.

**X-ray 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.

**TEXT BOOKS**

1. Chris Mack, Fundamental Principle of Optical Lithography, John-Wiley & Sons, Inc., Sussex, 2007.
2. Zheng Cui, Micro-Nanofabrication Technologies and Applications, Springer-Verlag, Beijing, 2005.
3. Zheng Cui, Nanofabrication Principles, Capabilities and Limits, Springer, New York, 2008.
4. U. Okoroanyanwu, Chemistry and Lithography, SPIE Press, Washington, 2010.
5. Garry P. Wiederrecht, Handbook of Nanofabrication, First Edition, Elsevier, Amsterdam, 2010.
6. Michael Quirk, Julian Serda, Semiconductor Manufacturing Technology, Prentice-Hall Inc., New Jersey, 2001

**REFERENCE BOOKS**

1. Ampere A Tseng, Nanofabrication Fundamentals and Applications, World Scientific, Singapore, 2008.
2. Mark James Jackson, Microfabrication and Nanomanufacturing, Taylor & Francis, Boca Raton, 2006.

3. Harry J. Levinson, Principles of Optical Lithography, SPIE Press, Third Edition, Washington, 2010.
4. Ray F. Egerton, Physical Principles of Electron Microscopy – An Introduction to TEM, SEM and AFM, Springer, New York, 2005.
5. John A. Rogers and Hong H. Lee, Unconventional nanopatterning technique and applications, John Wiley & Sons, Inc., New York, 2009.
6. Syed Rizvi, Handbook of Photomask manufacturing technology, Taylor & Francis, Florida, 2005.

## **NAST-610 : Synthesis and Processing Laboratory**

Synthesis of semiconducting and ceramic nano-materials by solution combustion, sol-gel, micro-emulsion, chemical co-precipitation, hydrothermal, sono-chemical and microwave assisted methods.

Synthesis of multi-ferrite nano-particles.

Synthesis of silver nanoparticles, and its spectral analysis.

Preparation of nano-composites, nanoporous material, colloidal solid and core –shell nanoparticles.

Preparation of quantum dots such as cadmium selenides and its optical studies.

Preparation of cadmium sulphide nanoclusters and its spectral studies.

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**Semester - II****Credits: 21****NAST-621: Computational methods for modeling, design and simulations****UNIT – I (9 hrs)****Analytical methods**

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

**UNIT – II (9 hrs)****Numerical Methods**

**Numerical Algorithms** - Computer programs. **Numerical Differentiation** - Numerical solution of a system of ordinary differential equations: RungeKutta method and adaptive step size control - predictor and corrector method. **Numerical integration**: Newton-Cotes integration formulae and Gauss quadrature method.

**UNIT – III (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 – IV (9 hrs)**

**Random numbers and Monte Carlo methods**: Uniformly distributed Pseudo random numbers, Normally distributed Pseudo random numbers, Testing of pseudo random number sequences - Simulation of radioactive decay. Numerical Integration using Monte Carlo simulation techniques for 1D cases.

**UNIT – V (9 hrs)**

**Partial differential equations**: Finite difference method (FDM) for Parabolic, Hyperbolic and Elliptic equations –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.

**TEXT 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, 2<sup>nd</sup> 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)

### REFERENCE BOOKS

1. Scientific Computing: An Introduction with Parallel Computing, G. Golub and J.M. Ortega, Academic Press, (1993).
2. Scientific Computing: An Introductory Survey, Michael T. Heath, McGraw-Hill, New York, (2002).
3. Numerical Recipes in Fortran / F-90 / C, W.H. Press et. al., Cambridge Univ. Press (1996)
4. A First Course in Computational Physics, P.L. DeVries, John Wiley (1994).
5. Computational physics- Problem solving with computers, Rubin H. Landau, Manuel J. Paez, John Wiley & sons (1997).
6. Guide to Neural Computing Applications, L. Tarassenko, Arnold Publishers, (1998).
7. Genetic Algorithms in Search, Optimization, and Machine Learning, D. E. Goldberg, Addison Wesley, Reading, Massachusetts, (1989).

## NAST-622: Polymers and Nanocomposites

### 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 – Glassy solids: Glass transition and melting temperatures and their determination by DSC - Factors affecting T<sub>g</sub>, importance of T<sub>g</sub>, relationship between T<sub>m</sub> and T<sub>g</sub> and their control - Crystallinity in polymers: Degree of crystallinity, factors affecting crystallinity 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)

**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. **Speciality polymers:** Bio-polymers, Bio-degradable polymers, Fire retardant/Thermally stable polymers, Polymer electrolytes, Liquid crystalline polymers.

### UNIT-III (9 hrs)

#### Conducting Polymers

Discovery – Structural characteristics and doping concept - Charge carriers and conducting mechanism – Classification of conducting polymers: Intrinsic and extrinsic conducting polymers - Chemical and electrochemical methods of the synthesis of conducting polymers – Applications of conducting polymers in corrosion protection, sensors, electronic and electrochemical energy devices.

**UNIT-IV****(9 hrs)****Polymer Nanocomposites**

Definition of nanocomposites - Nanofillers, Classification of nanofillers, Synthesis and properties of nanofillers - Types of nanocomposites – Synthesis of nanocomposites: Direct mixing, solution mixing, In-situ polymerization - Polymer/ Metal oxide nanocomposites, diblock copolymer based nanocomposites, Polymer/CNTs and Polymer/Nanoclay based composites 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 - Self-cleaning nanocomposites - Metal matrix nanocomposites: Metal with nanoceramic fillers such as SiC, CeO<sub>2</sub>, TiO<sub>2</sub>, ZrO<sub>2</sub> PTFE, CNTs 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.

**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.

**NAST-623: Fundamentals of Biology for Nanotechnology****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 pairing – DNA, RNA-tRNA, mRNA, rRNA, antisense RNA – linear and circular forms, single and double stranded– hypo and hyperchromicity - extra chromosomal DNA – mitochondrial, chloroplast, 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 meiosis – 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.

**TEXT BOOKS**

1. Harper's Biochemistry, 28<sup>th</sup> 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, 5<sup>th</sup> edition, David L Nelson; Michael M Cox. W.H.Freeman Publishers, New York, 2012.
3. Biochemistry, 3<sup>rd</sup> edition, Donald Voet and Judith Voet. John Wiley Publishers, 2010.

## REFERENCE BOOKS

1. Cell & Molecular Biology, 8<sup>th</sup> edition, E.D.P.De Robertis. Lippincott publishers, 2010.
2. Molecular biology of the cell, 6<sup>th</sup> edition, Alberts. Garland Publishing, 2014.
3. Essentials of Molecular biology, David Freifelder, Jones & Bartlett Publishers, 1993
4. Genes, 9<sup>th</sup> edition, Lewin Benjamin. CBS Publishers and Distributors, 2007
5. Molecular Cell Biology, Harvey Lodish; David Baltimore; Arnold Berk. WH Freeman and Co, 2000.

## NAST-624: Surface Engineering for Nanotechnology

### 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, Rabinowicz, 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

#### **TEXT BOOKS**

1. Gabor A. Somorjai, Yimin Li, Introduction to Surface Chemistry and Catalysis, John Wiley & Sons, New Jersey, 2010.
2. HaraldIbach, Physics of Surfaces and Interfaces, Springer-Verlag, Berlin, 2006.
3. Pankaj Vadgama, Surfaces and interfaces for biomaterials, First Edition, CRC Press, Boca Raton, 2005.
4. Peter J. Blau, Friction Scienceand Technology- From concepts to applications, Second Edition, CRC Press, Boca Raton, 2009
5. B. Bhusan, Modern Tribology Handbook, CRC Press, Boca Raton, 2005.
6. N. Birks, G. H. Meier, F. S. Pettit, Introduction to the high temperature oxidation of metals, Second edition, Cambridge University Press, 2006.

#### **REFERENCE BOOKS**

1. I. Chorkendorff, J.W. Niemantsverdriet, Concepts of Modern Catalysis and Kinetics, First Edition, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2003.
2. Didier Astruc, Nanoparticles and catalysis, Wiley-VCH Verlag GmbH & Co. KGaA, Weinheim, 2008.
3. Ryan Richards, Surface and Nanomolecular Catalysis, Taylor & Francis, Boca Raton, 2006.
4. Jeremy Ramsden, Biomedical Surfaces, Aptech House, Inc., Boston, 2008.
5. Renate Forch, HolgerSchonherr, and A. Tobias A. Jenkins, Surface Design: Applications in Bioscience and Nanotechnology, Wiley -VCH Verlag GmbH & Co. KGaA, Weinheim, 2009

## **NAST-625: Nanoelectronics and Bioelectronics**

#### **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**

Molecular nanowires, organic LEDs, organic FETs, carbon nanotube and graphene based FETs, Silicon nanowire based FETs,

**UNIT-IV (9 hrs)****Single Electron Tunneling Phenomena and Devices**

Single electron tunneling phenomena, Coulomb blockade, Coulomb staircase, Bloch oscillations, resonant tunneling diode and resonant tunneling transistor,

**UNIT-V (9 hrs)****Nanobioelectronics**

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

**TEXT BOOKS**

1. Nanoscale transistors- device physics, modeling and simulation, M. Lundstrom and J. Guo, Springer , 2005
2. Nanoelectronics- principles and devices, M. Dragoman and D. Dragoman, Artech House publishers, 2005
3. Fundamentals of modern VLSI devices, Y. Taur and T. H. Ning, Cambridge University Press, 1998

**REFERENCE BOOKS**

1. Nanoelectronics and nanosystems: from transistors to molecular and quantum devices, K. Goser, P. Glosekotter and J. Dienstuhl, Springer 2005
2. Handbook of Thin Film Materials, volume 5, edited by H.S Nalwa, American Scientific Publishers, 2002
3. Encyclopedia of nanoscience and nanotechnology, Edited by H.S. Nalwa, American Scientific Publishers, 2007
4. Overview of Nanoelectronic Devices, D. Goldhaber Gordon, Proceedings of IEEE, volume 85, 1997
5. Nanoelectronics and Information Technology, W. Rainer, Wiley, 2003
6. Nanosystems, K.E. Drexler, Wiley, 1992
7. Science of fullerenes and carbon nanotubes, M.S. Dresselhaus and G. Dresselhaus, Academic press, 1996

## **NAST-626: Self Assembly of Nanostructures**

### **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 (Quantum 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 Blodgett 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.

### **TEXT 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.

### **REFERENCE BOOKS**

1. Hand Book of Nanotechnology, by Bharat Bhushan, 2007, Springer Science+Business Media, Inc, NY, USA.
2. Prospects in Nanotechnology: Toward Molecular Manufacturing, Markus Krumpal and James Lewis (Editors), Wiley 1995.

## **NAST-620: Fabrication and Characterization Laboratory**

- Clean Room: Familiarizing with essential terms, tools and practices.
- Fabrication of thin films by Sputtering, Electron beam and Spray pyrolysis methods.
- Fabrication of TiO<sub>2</sub> nanofibers on ITO glass substrate by Electro-spinning technique.
- Synthesis of CNTs by CVD method.
- Nanocrystalline thin film by spin coating.
- Chemical bath deposition by dip coating.
- Electrodeposition of polyaniline on ITO substrate.
- Electroless deposition of Ag or Au on Si substrate
- Band gap determination by diffuse reflectance spectroscopy method.
- Nano indentation on a polycarbonate substrate using AFM for F-D curves and hardness determination.
- Dip-pen lithography using AFM with molecular inks.
- Nano-patterning by AFM lithography.
- Nanosphere lithography using silica nanospheres
- 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.

**Semester - III**

**Credits: 21**

## **NAST-731: MEMS/NEMS and Microsystems**

### **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

**TEXT BOOKS**

1. Tai-Ran Hsu, MEMS and Microsystems – Design, Manufacture, and Nanoscale Engineering, Second Edition, John Wiley & Sons, Inc., New Jersey, 2008.
2. Reza Ghodssi, Pinyen Lin, MEMS Materials and Processes Handbook, Springer, New York, 2011.
3. NadimMalut and Kirt Williams, An introduction to Micro electro mechanical systems Engineering, Second Edition – Artech House, Inc., Boston, 2004.
4. Sami Franssila, Introduction to Microfabrication, John Wiley & Sons, Sussex, 2004
5. Marc Madou, Fundamentals of Microfabrication, Second Edition, CRC Press, Boca Raton, 2002.

**REFERENCE BOOKS**

1. Francisco J. Arregui, Sensors based on nanostructured materials, First Edition, Springer-Verlag, New York, 2008
2. BharathBhushan, Springer Hand Book of Nano Technology, Springer-Verlag, New York, 2004.
3. Sergey Edward Lysherski, MEMS and NEMS Systems, devices, and structures, CRC Press, Boca Raton, 2000.
4. H. Baltes, O. Brand, G. K. Fedder, C. Hierold, J. G. Korvink, O. Tabata, Enabling Technology for MEMS and Nanodevices, Wiley-VCH, Weinheim, 2004.
5. Danny Banks, Microengineering, MEMS, and Interfacing - A Practical Guide, Taylor & Francis, Boca Raton, 2006.
6. C.P. Wong, Kyoung-Sik (Jack) Moon, Yi Li, Nano-Bio- Electronic, Photonic and MEMS Packaging, Springer, New York, 2010.

7. Sandra Carrara, Nano-Bio-Sensing, Springer, New York, 2011.

## **NAST-732: Nanostructured Materials for Clean Energy Systems**

### **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, 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 photovoltaic 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-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, 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, Redox capacitor Nano-Oxides, Conducting polymers based materials, Current status and future trends.

### **TEXTBOOK**

1. Electrochemical methods: Fundamentals and Applications, Allen J. Bard and Larry R. Faulkner, 2<sup>nd</sup> Edition John Wiley & Sons. Inc (2004)
2. D. Linden Ed., Handbook of Batteries, 2<sup>nd</sup> edition, McGraw-Hill, New York (1995)
3. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kluwer Academic Publishers, Dordrecht, Netherlands (2004).
4. J. Larminie and A. Dicks, Fuel Cell System Explained, John Wiley, New York (2000).



## REFERENCE BOOK

1. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).
2. M. S. Whittingham, A. J. Jacobson, Intercalation Chemistry, Academic Press, New York (1982).
3. M. Wakihara, O. Yamamoto, (Eds.) Lithium Ion Batteries: Fundamentals and Performance, Wiley –VCH , Weinheim (1998).
4. Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun.

## NAST-733: Nanophotonics and Biophotonics

### Unit I (10 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 - Propagation of light in periodic media. Band structure in periodic media – 1D and 2D cases.

### Unit II (10 hrs)

#### Photonic Crystals

**Fabrication of photonic crystals:** Photonic crystals by self-assembly - Photonic Crystals by Microfabrication - Photonic Crystals with Tunable Properties.

**Harmonic generation in photonic nanostructures:** Metal nanoparticles, Nanoparticles in monolayer – planar photonics structures - photonic crystals.

### Unit III (9 hrs)

#### Photobiology

**Interaction of light with cells:** Light absorption in cells – Light induced cellular processes – photochemistry induced by exogenous photosensitizers – Interaction of light with 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 IV (8 hrs)

**Nanotechnology for biophotonics:** The interface of bioscience, nanotechnology and photonics - Semiconductor quantum dots for bioimaging – Metallic nanoparticles and nanorods for Biosensing – Up-converting nanophores - Inorganic nanoparticles – Pebble nanosensors for Invitro Bioanalysis - Nanoclinics for optical diagnostics and Targeted therapy

### Unit – V (8 hrs)

**Biomaterials for Photonics:** Photonics and Biomaterials – Bioderived materials (Bacteriorhodopsin, Green Fluorescent Protein, DNA, Bio-objects and biocolloids) – Bioinspired materials – Biotemplates (DNA and Viruses as templates) – Bacteria as synthesizers for photonic polymers.

**TEXT 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)

**REFERENCE BOOKS**

1. 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)
2. Principles of Nanophotonics, Motoichi Ohtsu, et al. ISBN : 13: 978- 1- 58488- 972- 4, by Taylor & Francis Group, LLC (2008)
3. Advances In Biophotonics, (Eds.) Brian C. Wilson Valery V. Tuchin and Stoyan Tanev, IOS Press, ISBN 1-58603-540-1, (2005)
4. 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
5. 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-734: Nanomagnetic Materials and Devices****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, spin-glass- 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.

#### **TEXT BOOKS**

1. Advanced magnetic nanostructures, Ed. D. Sellmyer, R. Skomski, Springer, 2009
2. Magnetic nanostructures, Ed. M.A. Reed, American Scientific Publishers, 2002
3. Nanostructured magnetic materials and their applications, Ed. D. Shi, B. Aktas, L. Pust, F. Mikailov, Springer, 2002.
4. Introduction to Magnetic Materials, B. D. Cullity, Wiley, 1972.

#### **REFERENCE BOOKS**

1. Magnetism in the solid state, P. Mohn, Springer series in the solid state, sciences,
2. Handbook of Thin Film Materials, volume 5, edited by H.S Nalwa, American Scientific Publishers, 2002
3. Encyclopedia of nanoscience and nanotechnology, Edited by H.S. Nalwa, American Scientific Publishers, 2007
4. Magnetism – fundamentals, Edited by E. du Tremolet de Lacheisserie, D. Gagnoux, M. Schlenker, Springer, 2003
5. Advances in nanoscale magnetism, Ed. B. aktas, F. Mikailov, Springer, 2009
6. Spintronics: fundamentals and applications, I. Zutic, J. Fabian and S. Das Sarma, Rev. Mod. Phys, 76, 323 (2004)
7. Spin electronics, M. Ziese and M.J. Thornton, Springer, 2001

## **NAST-735: Advanced Nanobiotechnology**

#### **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.

**TEXT 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 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 0WF, 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. 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.
5. 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
6. 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

## REFERENCE BOOKS

1. Nanoparticle Technology for Drug Delivery. Edited by Ram B. Gupta, Uday B. Kompella, 2006, Taylor & Francis Group, 270 Madison Avenue, New York, NY 10016.
2. Biological Nanostructures and Applications of Nanostructures in Biology. Electrical, Mechanical, and Optical Properties. Edited by Michael A. Stroschio 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
3. 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.
4. Dendrimer based Nanomedicine, Edited by Istvan J. Majoros, James R. Baker, 2008, Pan Stanford Publishing Pte. Ltd.
5. 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

## NAST -736: Industrial Nanotechnology

### 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 - Memory storage – Lighting and displays – Filters (IR blocking) – Quantum computers –

Energy devices – Medical diagnosis – Conductive additives - Lead-free solder – Nanocoatings –EMI shielding.

## **UNIT-II**

**(9 hrs)**

### **Nanotechnology in Textiles and Cosmetics**

Textiles: Nanofibre production - Electrospinning – Controlling morphologies of nanofibers – Nano-fillers embedded polypropylene 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), Nanopolymers in medical textiles.

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

## **UNIT- III**

**(9 hrs)**

### **Nanotechnology in Defence**

Military applications of Nanotechnology - Artificial intelligence materials - Propulsion – Vehicles - Propellants and Explosives – Camouflage distributed sensors - Armour protection - Conventional weapons - Soldier systems - Implanted systems, Body manipulation - Autonomous systems - Mini-/Micro robots - Bio-technical hybrids - Small satellites and Space launchers - Nuclear weapons - Chemical weapons - Biological weapons - Chemical/Biological protection.

## **UNIT- IV**

**(9 hrs)**

### **Nanotechnology in Agriculture and Food Technology**

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

Nanotechnology in 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-V**

**(9 hrs)**

### **Nanotechnology in Environmental and Health Effects**

Environmental pollutants in air, water, soil, hazardous and toxic wastes - Application of Nanotechnology in remediation of pollution in Industrial and waste water treatment – Drinking water and Air/Gas purifications - The challenge to occupational health and hygiene, toxicity of nanoparticles, effects of inhaled nanosized particles, skin exposure to nanoparticles, impact of CNTs on respiratory systems, hazards and risks of exposure to nanoparticles, monitoring nanoparticles in work place and sensors.

## **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, Willehm Norde, 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).

### **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.

### **NAST-730: Modeling and Simulation Laboratory**

1. Construction of fullerene & its energy calculations by ARGUS Lab.
2. Construction of carbon nanotubes by ARGUS Lab.
3. Simulation with MATLAB: Programme assembly, execution, data processing and graphic analysis.
4. Image processing with MATLAB
5. MATLAB programme to plot the first four Eigen functions of a one dimensional rectangular potential well with infinite potential barrier.
6. Monte Carlo Simulation-Determination of mean, medium and standard deviation.
7. Atom manipulation and Patterning.
8. Study of single electron transistor using MOSES 1.2 simulator.
9. Simulation of I-V characteristic for a single junction circuit with a single quantum dot using MOSES 1.2 simulator.
10. To determine the surface roughness of raw and processed AFM images of glass, silicon and films made by different methods using offline SPIP software.
11. Simulation with VASP and GIBBS
12. Numerical simulation of SOFC for impedance analysis

**Semester - IV****Credits: 12****NAST-741: Research Project (Report and Viva-Voce)**

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 from among the faculty members of the centre of NST 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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