

**PUNYASHLOK AHILYADEVJI HOLKAR**

**SOLAPUR UNIVERSITY, SOLAPUR**



**Name of the Faculty: Science & Technology**

**CHOICE BASED CREDIT SYSTEM**

**Syllabus: Nanotechnology**

**Name of the Course: M.Sc. I (Sem– I & II)**

**(Syllabus to be implemented from w.e.f. June 2020)**

**Punyashlok Ahilyadevi Holkar Solapur University, Solapur**  
**M. Sc. Part I Nanotechnology**

**Choice Based Credit & Grading System-CBCS**

**1) Title of the Course: M.Sc.-Nanotechnology**

**2) Introduction:** This course provides a broad overview of Nanotechnology and to produce expert hands that would have sufficient knowledge and expertise to solve the urgent problems of the region by using biotechnology. The course structure is technology-centric where students basically learn technology and are taught necessary basic subjects for that purpose.

**3) Objectives of the course:**

The objectives of M. Sc. **Nanotechnology** course are

- To provide an intensive and in-depth learning to the students in field of **Nanotechnology**.
- Beyond simulating, learning, understanding the techniques, the course also addresses the underlying recurring problems of disciplines in today scientific and changing business world.
- To develop awareness & knowledge of different organization requirement and subject knowledge through varied subjects and training methodology in students.
- To train the students to take up wide variety of roles like researchers, scientists, consultants, entrepreneurs, academicians, industry leaders and policy.

**4) Advantages of the Course:**

**Nanotechnology** has tremendous job potential including

- Trading,
- Industrial job
- Entrepreneurship
- Consultancy organizations in Pharmaceuticals, Electronics, Energy, Material Science, Medical, Defense, Agriculture, Environment Protection etc.
- Job in Scientific Research Organizations.
- Universities in India & abroad.
- Hospitals and healthcare

### **5) Eligibility of Course:**

**Eligibility:** A Candidate possessing B.Sc. Degree with Chemistry/ Physics/Electronics/Biotechnology/ Biochemistry/Chemistry/Microbiology/ Botany/ Zoology/ B. Pharm/ MBBS/ B. E./B.Tech/ B. Sc. Agri./Entrepreneur and who have passed the entrance examination conducted by the PunyashlokAhilyadeviHolkarSolapur University, Solapurshall be held eligible for admission to M. Sc. Course in **Nanotechnology**. Students from otherUniversity with B.Sc. General Degree and who have passed the entrance examination conducted by the University are also eligible.

**Admission:** Merit list based on average of Bachelors/ Undergraduates, aggregate and entranceexam conducted by PunyashlokAhilyadeviHolkarSolapur University, Solapurfor all the candidates from India and abroad.

### **6) Duration:**

The duration for this program is of 2 years with semester pattern (04 Semesters)

### **7) Medium of Instruction: English**

### **8) Structure of the Course M.Sc. Part I (SEM I & SEM II)**

- Structure of M.Sc. course in faculty of Science has total of 4 semesters for 2 years.
- M. Sc. I comprise of total two semesters and M. Sc. II comprises of total two semesters.
- Semester I and II includes four core and four practical courses
- Each semester will have four theory papers of 80 marks each for University external examination and 20 marks each for internal examination.
- Four practical courses of 40 marks each for the University external examination and 10 marks each for internal practical course.

**Punyashlok Ahilyadevi Holkar Solapur University,  
Solapur**

**Syllabus for M.Sc. Nanotechnology Part – I CBCS NEW**

**COURSE STRUCTURE**

**SEMESTER-I**

Semester	Code	Title of the Paper	Semester Examination			L	T	P	Credits
			Theory	IA	Total				
SEM-I		<b>Hard core</b>							
	HCT1.1	Fundamentals of Nano-Technology in Physics	80	20	100	4		-	4
	HCT1.2	Fundamentals of Nano-Technology in Chemistry	80	20	100	4		-	4
	HCT1.3	Nano-materials Fabrication	80	20	100	4		-	4
		<b>Soft Core (Any one)</b>							
	SCT1.1	Fundamentals of Bio-Technology	80	20	100	4		-	4
	SCT1.2	Introduction to Nanoscience and Nanotechnology	80	20	100	4		-	
		<b>Seminar/Tutorial/Industrial visit/Field Tour/ Survey</b>	-	25	25	-	1	-	1
		<b>Practical</b>							
	HCP 1.1	Fundamentals of Physics	40	10	50	-	-	3	6
	HCP 1.2	Fundamentals of Chemistry	40	10	50	-	-	3	
	HCP 1.3	Nanotechnology	40	10	50	-	-	3	
		<b>Soft core (Any one)</b>							
	SCP 1.1	Bio-nanotechnology	40	10	50	-	-	3	2
	SCP 1.2	Introduction to Nanoscience and Nanotechnology	40	10	50	-	-	3	
				<b>480</b>	<b>145</b>	<b>625</b>			

HCT=Hard Core Theory      HCP=Hard Core Practical      SCT=Soft Core Theory      OET=Open Elective  
 Theory    IA=Internal Assessment      SCP=Soft Core Practical  
 L=Lecture                                      T=Tutorials                                      P=Practical



## M. Sc. SEMESTER –I

### HCT1.1 Fundamentals of Nano-Technology in Physics

**60 Hrs**  
**(Credits-4)**

#### **Unit-I: Crystal structure, Semiconductors & Their Properties** **(15)**

Atomic structure - Atomic bonding in solids- Crystalline state of solids - Unit cells and Space lattices – Crystal structures - Crystal planes and directions- Miller Indices - Diffraction of X-rays by crystal - Bragg's equation - Correction to Bragg's equation - Reciprocal lattice - Crystal Defects - point, line and surface defects.

Band model of semiconductors - carrier concentrations in intrinsic and extrinsic semiconductors - Fermi level - variation of conductivity and mobility with temperature - law of mass action. Hall Effect - Hall coefficients for intrinsic and extrinsic semiconductors - determination of Hall constant - Hall effect devices.

#### **Unit-II: Quantum Theory of Nanomaterials** **(15)**

Development of Quantum theory of Nanomaterials: Application of Block functions in Nanomaterials. Quantum Dots: (a) Semiconductor Quantum Dots, (b) Introduction to lasers (c) Quantum Dot lasers (d) Quantum Cascade lasers and (e) Quantum Dot optical memory.

#### **Unit-III: Dielectric Properties and Free Electron Fermi Gas** **(15)**

Macroscopic electric field; Local electric field at an atom; Static dielectric constant; Electronic, ionic and Orientational polarizations; Clausius- Mossotti relation; Pyro, piezo and Ferroelectricity. Energy levels and density of states in one and two dimension; Free electron gas in three dimensions; Heat capacity of the electron gas; Electrical conductivity and Ohm's law; Thermal conductivity of metals; Wiedemann-Franz.

#### **Unit-IV: Size Dependent Properties of Nanomaterials**

**(15)**

Elucidation of the structure: chemistry and properties of Nano-structured materials. Variation in properties of micro and Nanomaterials. Length scale involved and effect on properties: mechanical, electronic, optical, magnetic and thermal properties.

#### **References:**

1. C. Kittel. Introduction to Solid State Physics
2. S.O. Pillai Solid State Physics
3. A.J. Decker, Solid State Physics
4. Richard L. Liboff, Boris M. Smirnov, Physics of Atoms & Ions, Springer
5. Linus Pauling, E. Bright Wilson Corrier, Introduction to Quantum Mechanics Dover Publication
6. Edward L. Wolf, Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Wiley-VCH (2006).

#### **Learning Outcome:**

- To understand the foundational knowledge of the physics in nanotechnology and related fields.
- Impart the knowledge of crystal structure, Semiconductors & their properties
- To understand the Quantum theory of Nanomaterials.
- Understand the concept of dielectric properties and Energy levels and density of states in one and two dimension
- Help them to understand properties of nanomaterials

## **HCT1.2 Fundamentals of Nano-Technology in Chemistry**

**60 Hrs**

**(Credits-4)**

### **Unit-I: Atomic Structure and Periodic Table (15)**

Dalton's Atomic theory, Structure of atoms, Ionic compounds and Chemical Nomenclature. Nature of light, Line spectra & Bohr Atomic Theory, Matter of Waves, Quantum number in Hydrogen atom, Periodic table and electronic structures, Sizes of atoms & ions, Ionization Energy, Electron affinity, Trends in Chemistry of groups, IIA and VIIA

### **Unit-II: Chemical Bonds, Molecular structure and Bonding Theories (15)**

Ionic bonding, Covalent bonding, Formal charges & Lewis symbols resonance in Lewis structure, Bond energies and Octet rule, Valence orbitals shell Electron-Pair repulsion Model, Polarity of molecules, Valence bond theory, Multiple bonds, Molecular orbitals: Homonuclear Diatomic Molecules, Heteronuclear Diatomic Molecules & Delocalized Molecular orbitals.

### **Unit-III: Fundamentals of Nanotechnology (15)**

History & development of Nano-science and Nano-technology. Introduction to Nano-science and Nano-technology. Nano-scale material, Importance of nanotechnology study for Physics, Chemistry, Engineering & Biology. Chalcogenides & Boron Nitride and Carbon Nanomaterials

### **Unit-IV: Structures & Classification of Nanomaterials (15)**

Nano-structures: various types of nano-structures and nano-crystals. Classification: of bulk materials, 0D, 1D, 2D structures. Size Effects – Fraction of Surface Atoms, specific Surface Energy and Surface Stress, Effect on the Lattice Parameter, Phonon Density of States Nano-particles, Quantum dots, Nano-wires, Ultra-thin films, Multi-layered materials.



## REFERENCES:

1. C. Bre´chignac P. Houdy M. Lahmani, Nanomaterials and Nanochemistry, Springer Berlin Heidelberg, Germany (2006).
2. Kenneth J. Klabunde, Nanscale materials in chemistry , Wiley Interscience Publications (2001).
3. Hans Lautenshlager, Emulsions ,Kosmetik International, (2002).
4. Roque Hidalgo-Alvarez, Structure and Functional properties of Colloids , CRC Press, (2009).
5. Richard J. Fann, Chemistry and Technology of Surfactants , Wiley-Blackwell, (2006)

## Learning Outcome:

- To understand the concepts of various elements and their structural organizations.
- Understand the concept of atomic structure and periodic table.
- Learn a broad foundational knowledge of the basic concept of Chemical Bonds, Molecular structure and Bonding Theories.
- To understand the history & development of Nano-science and Nano-technology.
- Study the various types of nano-structures and nano-crystals and its classifications.

## HCT1.3 Nano-materials Fabrication

60 Hrs(Credits-4)

### Unit-I: Physical Methods of Synthesis of Nanomaterials (15)

Synthesis of Nano-structured materials : Principle and relative merits of each techniques for production of Nano-structures including ultra-thin films and multilayer by: (a) Laser Ablation technique, (b) Arc Discharge technique and (c) Mechanical Milling

### Unit-II: Physico-Chemical Methods of Synthesis of Nanomaterials (15)

Fundamentals and need of identification of pertinent parameters amenable to synthesis of nanoparticles by Physico chemical methods such as (a) CVD (Chemical Vapor Deposition) / MOCVD technique, (b) Plasma / Sputtering / Hot-Wire Plasma Enhanced CVD method, (c) Molecular Beam Epitaxy (d) Atomic Layer Epitaxy and (f) Self assembly technique

### Unit-III: Chemical Methods of Synthesis of Nanomaterials (15)

Chemical methods of synthesis and applicability of the methods

(a) Solution growth techniques of 1D-2D nano structures:- Synthesis of metallic, semiconducting and oxide nanoparticles – homo- and hetero-nucleation growth methods, (b) Template-based synthesis (*electrochemical, electrophoretic, Melt and solution, CVD, ALD*), (c) Gas Phase Synthesis of Nanopowders: – Vapor (or solution) – liquid – solid (VLS or SLS) growth – the Need for Gas/vapor State Processing – Main Stages of Gas Phase Synthesis (d) Evaporation, (e) Self assembly technique (f) Sol-gel method and (g) Spray pyrolysis.

Special features of nanoscale growth. Thermodynamics of Phase Transitions – triggering the Phase Transition – fundamentals of nucleation growth – Controlling Nucleation & Growth – Size Control of the Nanometric State – Aggregation – Stability of Colloidal Dispersions – Spontaneous Condensation of Nanoparticles: Homogeneous Nucleation – Spinodal decomposition – Other undesirable Post-Condensation Effects – Nanoparticles' morphology

#### **Unit-IV: Biogenic Methods of Synthesis of Nanomaterials**

**(15)**

Properties of living organisms such as to combat deleterious effect of heavy metals in high concentrations; resistance against metals by Modulation of their transport, Active efflux, Redox changes and Sequestration and intracellular compartmentation into detoxified complexes; Biogenic synthesis by (i) bacteria, (ii) fungi, (iii) algae and (iv) plants

#### **References:**

1. Edelestein A.S and Cammarata RC, Nano materials synthesis, properties and applications:
2. Michael Kohler, Wolfgang Fritzsche, Michael Kohler, Wolfgang Fritzsche, Nanotechnology-An Introduction to Nano structuring Techniques Wiley (Practical)
3. Brian Robinson, Self-Assembly, IOS Press
4. Tai Ran – Hsu, MEMS and Microsystems, Design, Manufacture and Nanoscale Engineering, John Wiley & Sons, 2008.
5. M. Gentili, C. Giovannella, S. Selci, Nanolithography: A Borderland between STM, EB, IB and X-Ray Lithographies (NATO ASI Series), Kluwer Academic Publishers, 1994.
6. Nicholas A. Kotov, Nanoparticle Assemblies and Superstructures , CRC, (2006).
7. Guozhong Cao, Nanostructures & Nanomaterials Synthesis, Properties G; Z, Applications, World Scientific Publishing Pvy. Ltd., Singapore 2004
8. Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, Springer Science + business media, New York (2008).
9. Kostya (Ken) Ostrikov and ShuyanXu, Plasma-Aided Nanofabrication: From Plasma Sources to Nanoassembly, WILEY-VCH Verlag GmbH & Co. KGaA (Weinheim) (2007)

#### **Learning Outcome:**

- Help them to understand in broad outline of Nanotechnology.
- Study of Synthesis and production of Nano-structured materials with ultra-thin films and multilayer.
- Understand the concept of synthesis of nanomaterials using physico-chemical Methods.
- Learning the concept of biogenic methods of synthesis of nanomaterials.

## **SCT1.1 Fundamentals of Bio-Technology**

**60 Hrs**

**(Credits-4)**

### **Unit-I: Living System**

**(15)**

Cell theory- origin and evolution of cells; Organization of cellular structures- prokaryotes & eukaryotes: Molecular composition of cells- Carbohydrates- Lipids- Nucleic acids- Proteins, Cell membranes-Membrane lipids. Cell wall and extra cellular matrix- cytoskeleton- cell membrane (including plasma membrane)- Endocytosis- Cell-cell interactions. Cell cycle - Mitosis-Meiosis-Regulation of cell cycle- Molecular basis.

### **Unit-II: Suitability of living organisms as nano-factories**

**(15)**

Overview of Nano-scale activities in Bio-systems at organelle and molecular level, and what can Nano-technologists learn from Biology. Cell as nano-factory; Cell organelle (Mitochondria-Plastids-Endoplasmic reticulum- Ribosome – Endosomes - Golgi- Lysosomes -Peroxisomes-Hydrogenosomes& Centrosomes; Nucleus: Nuclear envelope- Nucleolus- Chromosomes.Prokaryotic nucleoids (bacterial & plastid genomes).Membrane functions; Cell adhesions & cell junctions. Membrane transport- Neurotransmission- Vesicular transport & membrane function (Secretory &Endocytic pathways). Membrane proteins-Transport across the membranes)

### **Unit-III: DNA, Amino acids and Proteins**

**(15)**

Introduction to DNA & DNA nanotechnology. Components of DNA –[ purine bases -pyrimidine bases deoxyribose sugar - physical and chemical properties of DNA- Protein introduction , biochemistry of proteins - cellular functions of proteins - introduction to protein based nanotechnology. Structure and reactions of amino acids - hydrophilic and hydrophobic amino acids - table of standard amino acid abbreviations and side chain properties - nonstandard amino acids-

#### **Unit-IV: Cell Signaling, Bioenergy system & Bio-sensors**

**(15)**

Cell signaling & cell transduction: - Signaling molecules & their receptors- Functions of cell surface receptors- Pathways of intracellular signal transduction. Signal transduction and cytoskeleton- Regulation of programmed cell death. Innate immunity- adaptive immunity- cells of reticulo endothelial system- introduction to antigen presenting cells, complement system & tumor immunology- life cycle of HIV Virus- monoclonal antibodies synthesis and applications.

Nature in the construction of Nano-scale biosensor devices and motors: ATP synthesis is a nanomotor with 100% thermodynamic efficiency, bacterial flagella & its energetic momentum. DNA and protein's use as actuators, chips, sensors and electronic circuits.

#### **REFERENCES:**

1. H. Baltimore, WH Freeman, Cell & Molecular Biology
2. Kimball T.W. , Cell Biology, Wesley Pub
3. Geoffrey M. Copper, The Cell A Molecular Approach ; 2nd Edition, ASM press, Sinauer Associates, Inc., Washington, (2000)
4. Harvey Lodish, Arnold Berk, S.L Zipursky, Paul Matsudaira, David Baltimore and James Daniell, Molecular Cell Biology ; 4th Ed., W.H Freeman and company, (2000).
5. E.D.P. De Robertis, and E.M.F De Robertis, —Cell and Molecular Biology . 8th Ed., Lippincott Williams and Wilkins, (2001).
6. Alberts Bruce, Alexander Johnson, Julian Lewis, Martin Raff, Keith Roberts and Peter Walter, —Molecular Biology Of The Cell”, New York: Garland Science, (2002).
7. Janis Kuby, Immunology, W H Freeman, (2006).
8. Madhuri Sharon, Maheshwar Sharon, Goldie Oza, Sunil Pandey, BIONANOTECHNOLOGY Concepts and Applications, CRC Press, USA, 2011

#### **Learning Outcome:**

- Learn a broad foundational knowledge of the basic concept of Bio-technology.
- To study the concept of Bio-systems at organelle and molecular level for Nano-technologists.
- Learn the Structure and reactions of amino acids in DNA for hydrophilic and hydrophobic amino acids.
- To understand the approach of HIV Virus- monoclonal antibodies synthesis and applications along with construction of Nano-scale biosensor devices.

## SCT1.2 Introduction to Nanoscience and Nanotechnology

60 Hrs

(Credits-4)

### **Unit 1 : Background to Nanotechnology** (15)

Scientific revolution- Atomic structures-Molecular and atomic size-Bohr radius – Emergence of Nanotechnology – Challenges in Nanotechnology - Carbon age–New form of carbon (from Graphene sheet to CNT).

### **Unit 2 : Nucleation** (15)

Influence of nucleation rate on the size of the crystals- macroscopic to microscopic crystals and nanocrystals - large surface to volume ratio, top-down and bottom-up approaches-self assembly process-grain boundary volume in nanocrystals-defects in nanocrystals-surface effects on the properties.

### **Unit 3: Types of Nanostructures** (15)

Definition of a Nano system - Types of Nanocrystals-One Dimensional (1D)-Two Dimensional (2D) -Three Dimensional (3D) nanostructured materials - Quantum dots - Quantum wireCore/Shell structures.

### **Unit 4: Nanomaterials and properties** (15)

Carbon Nanotubes (CNT) - Metals (Au, Ag) - Metal oxides (TiO<sub>2</sub>, CeO<sub>2</sub>, ZnO) - Semiconductors (Si, Ge, CdS, ZnSe) - Ceramics and Composites - Dilute magnetic semiconductor- Biological system - DNA and RNA - Lipids - Size dependent properties - Mechanical, Physical and Chemical properties.

### **Unit 5: Applications of Nanomaterials** (15)

Molecular electronics and nanoelectronics – Quantum electronic devices - CNT based transistor and Field Emission Display - Biological applications - Biochemical sensor - Membrane based water purification.

#### **References:**

1. M. Wilson, K. Kannangara, G Smith, M. Simmons, B. Raguse, Nanotechnology: Basic science and Emerging technologies, Overseas Press India Pvt Ltd, New Delhi, First Edition, 2005.
2. C.N.R.Rao, A.Muller, A.K.Cheetham (Eds), The chemistry of nanomaterials: Synthesis, properties and applications, Wiley VCH VerlagGmbH&Co, Weinheim, 2004.
3. Kenneth J. Klabunde (Eds), Nanoscale Materials Science, John Wiley & Sons, Inc, 2001.
4. C.S.S.R.Kumar, J.Hormes, C.Leuschner, Nanofabrication towards biomedical applications, Wiley –VCH Verlag GmbH & Co, Weinheim, 2004.
5. W. Rainer, Nano Electronics and information Technology, Wiley, 2003.
6. K.E.Drexler, Nano systems, Wiley, 1992.
7. G.Cao, Nanostructures and Nanomaterials: Synthesis, properties and applications, Imperial College Press, 2004.
8. Madhuri Sharon, THE HISTORY OF NANOTECHNOLOGY – From Prehistoric to Modern Times.

**Learning Outcome:**

- To help them understand in broad outline of Nanoscience and Nanotechnology for preparation CNT.
- To understand the concepts of preparation of Nano crystals in 1D, 2D and 3D structures.
- Preparation of Carbon Nanotubes (CNT) using Metals, Metal oxides, Semiconductors Ceramics and Biological systems
- Study of the applications in the field of molecular electronics, nanoelectronics and biological applications

## **HCP 1.1 Fundamentals of Physics**

**60 Hrs**

**(Credits-2)**

### **Fundamentals of Physics (Any six practicals)**

1. Determination of Young's modulus of a given material – Uniform / Non-uniform bending methods.
2. Determination of Rigidity modulus of a sample – Torsion pendulum
3. Determination of dispersive power of a prism – Spectrometer
4. Study of attenuation and propagation characteristics of optical fiber cable
5. Calibration of voltmeter / ammeter using galvanometer
6. Construction & study of IC regulation properties of a given power supply
7. Study of electrical characteristics of a solar cell
8. Determination of laser parameters – divergence & wavelength for a given laser source –laser grating/  
Particle size determination using laser
9. Study the performance of positive and negative clamping using diode.



## **HCP 1.2 Fundamentals of Chemistry**

**60 Hrs**

**(Credits-2)**

### **Fundamentals of Chemistry Experiments (Any six practicals)**

1. Preparation of standard solutions
2. Estimation of total, permanent and temporary hardness by EDTA method
3. Conductometric titration - determination of strength of an acid
4. Estimation of iron by potentiometry.
5. Determination of molecular weight of polymer by viscosity average method
6. Determination of dissolved oxygen in a water sample by Winkler's method
7. Determination of Na / K in water sample by Flame photometry (Demonstration)
8. Estimation of Copper in ore
9. Estimation of nickel in steel
10. Determination of total alkalinity and acidity of a water sample
11. Determination of rate of corrosion by weight loss method.

## **HCP 1.3 Nanotechnology**

**60 Hrs**

**(Credits-2)**

### **Nanotech Experiments (Any six practicals)**

1. Synthesis of micelles and inverse micelles.
2. Synthesis of dendrimers.
3. Preparation of thiolated silver nanoparticles
4. Zinc selenide quantum dot preparation.
5. Synthesis of Iron Oxide Nanoparticle
6. Thin film preparation by spin coating technique.
7. Synthesis of Nickel metal nanoparticle by urea decomposition method
8. Synthesis of Zinc Oxide nanoparticle
9. Preparation of nanoparticles by using Ball milling
10. Deposition of copper oxide thin film by SILAR method.
11. Polyaniline thin film by dip coating method.
12. Deposition of zinc oxide thin film by spray pyrolysis.
13. Synthesis of transition metal nanoparticles by swollen liquid crystal growth method.

## **SCP 1.1 Bio-Nanotechnology**

**60 Hrs**

**(Credits-2)**

### **Bio-nanotechnology Experiments (Any six practicals)**

1. Isolation of DNA from various sources
2. Determination of Electrical conduction of DNA
3. Isolation and separation of cell organelles
4. 2D- Electrophoresis technique for separation of proteins
5. Synthesis of Gold Nanoparticles by biogenic methods
6. Synthesis of Silver Nanoparticles by biogenic methods
7. Isolation of enzymes involved in biosynthesis of Nanomaterials
8. Preparation of Buffers, Stock solutions and chemicals.
9. Preparation of microbiological and synthetic media formulation for aseptic practices.

## **SCP 1.2 Introduction to Nanoscience and Nanotechnology**

**60 Hrs**

**(Credits-2)**

### **Introduction to Nanoscience and Nanotechnology (Any six practicals)**

1. Origin Plot
2. Curve fitting - straight line fit, exponential and power – law fit
3. Non-linear curve fitting: Polynomial, Gaussian and Lorentzian
4. Image processing of AFM and SEM micrograph
5. Determination of dielectric constant - LCR bridge
6. Determination of Band gap of semiconductors
7. Hall effect
8. Resistivity measurement of a thin film
9. Determination of Molecular weight by viscometry method
10. pH determination of solution

## M.Sc. SEMESTER – II

### HCP 2.1 Characterization Tools of Nanomaterials

**60 Hrs**  
**(Credits-4)**

#### **Unit-I: Electron Microscopic characterization of nanomaterials (15)**

Fundamentals of the techniques – experimental approaches, sample preparation and data interpretation – applications/limitations of Microscopic equipments: SEM, EDAX, STM, TEM and AFM. SEM/TEM – high resolution imaging – defects in Nanomaterials.

#### **Unit-II: Spectroscopic characterization of nanomaterials (15)**

Spectroscopy: – electron energy-loss mechanisms – electron filtered imaging – prospects of scanning probe microscopes – optical spectroscopy of metal/semiconductor nanoparticles.

Spectroscopic equipments: UV-VIS Spectroscopy, XRD. RAMAN Spectroscopy, EELS, XPS (X-ray Photoelectron Spectroscopy), SIMS, NMR, DLS (Dynamic Light Scattering or photon correlation spectroscopy), DPI (Dual Polarisation Interferometry), FTIR, Nano-lithographic technique and Surface area measurement & analysis technique. Analysis for evaluating Optical absorption and Nonlinear Kerr effect, Photoluminescence and Optical band gap Analysis for evaluating Optical absorption & Nonlinear Kerr effect, Photoluminescence & Optical band gap

#### **Unit-III: Mechanical, Thermal & Optical Property Characterization of**

#### **Nanomaterials (15)**

Fundamentals and need of characterization of Nano-materials: Identification of pertinent parameters amenable to characterization. Mechanical properties characterization: Young's Modulus, Poisson Ratio, Bulge Test and Surface Tension. Thermal & Optical effect characterization: Thermal conductivity, TGA and Thermal stability

Quantum structures Particle diameter by HRTEM Photoluminescent properties, Excitation wavelength, Photoluminescence by Microplate Reader Photostability, Quantum yield

**REFERENCES:**

1. Zhong Lin Wang, Handbook of Nanophase and Nanomaterials (Vol 1 and II) Springer
2. C.R. Brundle, C.A. Evans Jr., and S. Wilson (eds), Encyclopedia of Materials Characterization, Butterworth Heinemann, Stoneham, Ma
3. J.C. Vickerman, Surface Analysis: The Principal Techniques, John Wiley and Sons
4. Roland Wiesendanger, Scanning Probe Microscopy and Spectroscopy: Methods and Applications, Cambridge Univ press
5. T. Pradeep, Nano: The essentials, understanding Nanoscience and Nanotechnology, Tata McGraw Hill, 2007.
6. Willard, "Instrumental Methods of Analysis", Van Nostrand, 2000
7. J. Goldstein, D. E. Newbury, D.C. Joy, and C.E. Lyman et.al, Scanning Electron Microscopy and X-ray Microanalysis, Springer Publications, 2003.
8. S.L. Flegler, J.W. Heckman and K.L. Klomprens, Scanning and Transmission Electron Microscopy: An Introduction, Oxford University Press, 1993.
9. P.J. Goodhew, J. Humphreys, R. Beanland, Electron Microscopy and Analysis, Taylor and Francis, 2001
10. R. Haynes, Optical Microscopy of Materials, International Textbook Co, 1984.
11. Zhong Lin Wang, Characterization Of Nanophase Materials, Wiley-VCH, Verlag GmbH, Germany (2004).
12. W.R. Fahrner, Nanotechnology and Nanoelectronics Materials, Devices, Measurement Techniques, Springer-Verlag Berlin, Germany (2006).
13. Hans P.O., and Hopster H., —Magnetic Microscopy of Nanostructures , Springer (2004)
14. Vladimir G. Bordo and Horst-Günter Rubahn; Optics and Spectroscopy at Surfaces and Interfaces, John-Wiley and Sons, Inc., (2005).
15. William W. Parson, Modern Optical Spectroscopy, Springer, (2007).

16. Collin Banwell, Mc Cash, Fundamentals of Molecular Spectroscopy, McGraw Hill (1994).
17. Harvey Elliot White, Introduction to Atomic Spectra, McGraw Hill, (1934).
18. Francis Rouessac and AnnickRouessac, Chemical Analysis-Modern Instrumentation Methods and Techniques, (2000)
19. Joseph. R. Lakowicz Principles of fluorescence spectroscopy, Springer, (2010).
20. Pavia Lampman, Kriz, Vyvyan, Introduction to spectroscopy, Cengage learning, (2009).
21. JinJhongJhang, Optical properties and spectroscopies of Nanomaterials, World Scientific Publishing (2009).
22. Eric Lifshin (Ed.), Characterization of Materials (Materials Science and Technology: A Comprehensive Treatment, VCH (1992).
23. D. K. Schroder, Semiconductor Material and Device Characterization, 3rd Edition, Wiley-IEEE Press (2006).
24. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press (2008).
25. P. E. J. Flewitt and R K Wild, Physical methods for Materials Characterization, IOP Publishing (2003).
26. Z L Wang (Ed.), Characterization of Nanophase materials, Willet-VCH (2000).
27. JinZhong Zhang, Optical properties and spectroscopy of Nanomaterials, World Scientific Publishers (2009).
28. M Joshi *et al*, Characterization techniques for Nanotechnology applications in Textiles, Indian Journal of Fibre and Textile Research, Vol 33, 304-317 (2008).
29. Peter Torok, Fu-Jen Kao (Eds.), Optical Imaging and Microscopy: Techniques and Advanced Systems, Springer Series in Optical Sciences, Springer, 2nd Edition, (2007).
30. GuoJinghua (Ed.), X-rays in Nanoscience - Spectroscopy, Spectromicroscopy, and Scattering Techniques, John Wiley & Sons (2010).

### **Learning Outcome:**

- Understood the principles and Characterization Techniques.
- To learn the Fundamental approach in Microscopic equipment and its defects.
- Students will learn the Spectroscopic characterization of nanomaterials and Spectroscopic equipments
- Study of Mechanical, Thermal & Optical Property Characterization of nanomaterials using physical concepts.
- Preparation of Characterization of Quantum structures for nanomaterials.

## **HCT 2.2 Properties of Nanomaterials**

**60 Hrs  
(Credits-4)**

### **Unit – I: Fundamental Properties of Nanomaterials**

**(15)**

Size dependent properties: Surface to volume ratio (SVR), Size Effects on Structure and Morphology. Size and Confinement Effects, Equilibrium Shape of a Macroscopic Crystal and Equilibrium Shape of Nanometric Crystals. Nanoparticles Morphology -Equilibrium Shape of a Macroscopic Crystal - Equilibrium Shape of Nanometric Crystals - Morphology of Supported Particles. Some Physical forces do not apply at the nano-scale: Gravitational force and friction.

### **Unit - II: Optical properties of nanomaterials**

**(15)**

Luminescence, Phosphorescence, Fluorescence. Thermo-luminescence & Photoluminescence of nanoparticles. Optical properties of quantum dots: Excitons, weakly & tightly bound excitons, excitons in molecular crystals and nano structures. Non-linear Optics: non-linear optical susceptibility second and third order optical susceptibilities. Harmonic generation. Multiple photon excitation. Stimulated Raman scattering. Stimulated Brillouin scattering. Non-linear optical properties of nanomaterials.

### **Unit-III: Magnetic Properties of Nanomaterials**

**(15)**

Magnetic domains, interactions in magnetic materials, random anisotropy, particle size & magnetic Behavior, interaction between particles, nanodisks, nanorings & nanowires. Magnetic Moment in clusters/Nanoparticles – Magnetic Order – coercivity – Magnetocrystalline Anisotropy – thermal activation and Superparamagnetic effects .



#### **Unit – IV: Other Properties of nanomaterials**

(15)

Electronics and Optoelectronics:- Quantum Confinement of Superlattices and Quantum Wells – Dielectric Constant of Nanoscale Silicon – Doping of a Nanoparticle – Excitonic Binding and Recombination Energies – Capacitance in a Nanoparticle – Diffusion in Nanocrystalline Materials – Diffusion In Grain Boundaries Of Metals – Nanocrystalline Ceramics – Correlation Between Diffusion and Crystallite Growth Brief overview of mechanical properties including super-plasticity phenomena – reactivity of nanoparticles

#### **REFERENCES:**

1. Hari Singh Nalwa, Handbook of Nano structured Materials and Nanotechnology Electrical Properties Vol.3
2. Hari Singh Nalwa Handbook of Nano structured Materials and Nanotechnology Optical Properties Vol.4
3. Paras N Prasad, Nano-photonics, Wiley IEEE
4. Sergey Edward Lyshevski, Lyshevski Edward Lyshevski, Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering CRC Press
5. M. Gentili et al.(edits),Nanolithography, Springer
6. Antonio Quadraphonic et al., Electron and Photon Confinement in Semiconductors,IoS Press07BNT-103
7. SV. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1998.
8. W. Goddard, Handbook of NanoScience, engineering and technology, CRC Press, 2007
9. H. Masuhara, S. Kawata and F. Tokunga, NanoBiophotonics”, Elsevier Science, (2007).
10. B. E. A. Saleh and A. C. Teich, “Fundamentals of Photonics”, John Wiley and Sons, NewYork, (1993).
11. P. N. Prasad, Introduction to Biophotonics”, John Wiley and Sons, (2003).
12. M. Ohtsu, K. Kobayashi, T. Kawazoe and T. Yatsui, —Principals of Nanophotonics (Optics and Optoelectronics), University of Tokyo, Japan, (2003).
13. Bland J.A.C., and B. Heinrich, —Ultra thin Magnetic Structures III – Fundamentals of Nanomagnetism, Springer (2004)

#### **Learning Outcome:**

- Understand the synthesis of nanomaterials and their application and the impact of nanomaterials on environment.

- To know the details study of nanomaterial in Optical properties for Luminescence, Phosphorescence, Fluorescence, etc
- To know the details study of nanomaterial in magnetic properties for Magnetic domains and Magnetocrystalline Anisotropy.
- To know the details study of nanomaterial in electronic properties in dielectrics for doping, diffusion and Crystallite Growth.

## **SCT 2.1 Carbon and Nanoforms of Carbon**

**60 Hrs  
(Credits-4)**

### **Unit –I: Introduction to Carbon**

**(15)**

Introduction to various forms of Carbon: Diamond, Diamond Like Carbon, Graphite, Carbon Fibers, Carbon Black and Activated Carbon. Active carbon fibers, coal derived carbons: Structure, properties and uses.

### **Unit – II: Nanoforms of Carbon**

**(15)**

Structure and bonding in Carbon Nano-material: Arm-chair, Zigzag and chiral patterns. Theory of formation of different structures and growth process of CNT single walled carbon nanotubes and multi walled carbon nano tubes, graphite and diamond. Different types of carbon Nano-materials: CNT, CNF, CNB, their structure and properties. Properties of CNM and conventional Carbon materials: Physical, Chemical and Electronic properties

### **Unit – III: Synthesis of Nano-Carbon**

**(15)**

Methods of CNM synthesis: Arc-discharge, Chemical Vapor Deposition (CVD), Pulsed Laser deposition (PLD), Thermal Vapor Deposition of CNM thin films. Synthesis of Nano-catalysts for CNT synthesis preparation & purification of CNM. Synthesis of Nano-diamonds (amorphous Carbon) and DLC

Nano-Graphene Structure, Properties and fabrication (Physical & Chemical methods) Carbon dots: Structures. Properties (Optical, Photocatalytic, Chemical Inertness & Water Solubility. Synthesis of carbon dots by: Chemical, Electrochemical, Combustion, Thermal, Hydrothermal and Acidic Oxidation of Carbon Precursors, Pulsed Laser Irradiation, Laser Ablation of Graphite, Arc Discharge, Plasma Treatment, Opening of Fullerene Cage, Ultrasonic-/Microwave-Assisted and Biogenic methods.

**REFERENCES:**

1. Laurie Kelly, Meyyappan Meyyappan, Carbon Nano tubes: Science and Applications, CRC Press
2. R.A. Shatwell, Fuel Storage on Board Hydrogen Storage in Carbon Nanostructures - in Fuel cell technology handbook, CRC Press, 2003
3. Ali Javey and Jing Kong, Carbon Nanotube Electronics Springer Science media, (2009).
4. Michael J. O'Connell, Carbon nanotubes: Properties and Applications , CRC/Taylor & Francis, (2006).
5. Francois Leonard, The Physics of Carbon Nanotube Devices , William Andrew Inc., (2009).
6. R. Saito and M. S. Drbselmus, Physical properties of Carbon Nanotubes, Imperial College Press, (1998)
7. Prof. Madhuri Sharon and Prof .Maheshwar Sharon, CARBON NANO FIBER-FUNDAMENTALS AND APPLICATIONS, Willey Publishers, 2019
8. Madhuri Sharon and Maheshwar Sharon, Graphene - An Introduction to the Fundamentals and Industrial Applications Willey Publishers, 2015
9. Madhuri Sharon and Ashmi Mewada, Carbon Dots as Theranostic Agent, Willey Publishers, 2015 Willey Publishers, 2015 Willey Publishers, 2018
10. Maheshwar Sharon and Madhuri Sharon, Carbon Nanoforms and Applications, McGraw Hill, New York, 2007

**Learning Outcome:**

- Understand the concept of carbon and nanoforms of carbon and their synthesis and characterization techniques.

- Study of Nanoforms of Carbon and different types of carbon Nano-materials: CNT, CNF, CNB, their structure and properties.
- Study the synthesis of Nano-Carbon using various deposition methods such as CVD, PLD and thermal methods.
- To understand the structure and properties of Nano Graphene& Carbon-dots.

## **SCT 2.2 Nano-Electronics**

**60 Hrs**

**(Credits-4)**

### **Unit – I Basics of Nano-Electronics**

**(15)**

Introduction, Fundamentals of Nano-Electronics & Nano-fabrication; Molecular electronics and basic properties of molecular materials; Optical & electron beam lithography, Molecular beam lithography. MEMS and NEMS: Development of micro electronics - Region of Nanostructures - methods and limits on microminiaturization in semiconductors- micro electro mechanical systems.

Silicon micromachining- semiconductors and insulators - Microsystems fabrication techniques - Silicon MEMS fabrication technology - Single crystal reactive etching and metallization process. Non-silicon MEMS and fabrication techniques - SIC MEMS - Biomedical-MEMS techniques - Integration of microsystems with electronics – RF MEMS – Applications

Polymers in Microsystems - Packaging of MEMS devices by anodic/fusion bonding - Pressure sensors and packaging - MEMS performance and evaluation. Nanoelectro mechanical systems - fabrication and process techniques - integration of nanosystems and devices - applications and future challenges.

### **Unit – II Electronics and Nano Optical application**

**(15)**

Single Electron Devices.; Optical amplifiers and Lasers; Application of LED in Emission of visible light; optic electronic device. Electron field emission and its application (Flat plate TV screen, laptop-screen and portable X-ray, Physics of organic LED, Photodiodes, FETs). Sensors: Principle, design, types of sensor & application of Nanotechnology.

### **Unit – III Role of Nanotechnology in harvesting Solar Energy**

**(15)**

Introduction to Energy, different forms of energy & mode of harnessing. Carbon Solar cell: Physics of semiconductor, p:n junction, Schottky junction, preparation of p:n junction, photovoltaic module, types of photovoltaic cells, carbon homo/hetero junction solar cells and fabrication of a such cell.

Hydrogen Fuel Cell: Thermodynamics of conversion of chemical energy into electrical energy, Basic design of fuel cell, comparison of fuel cell with battery, types of fuel cell and their merits & demerits, Hydrogen Storage: as liquid and gaseous form, Thermodynamics of storage of hydrogen by metal hydride, different types of metal hydrides & their properties, hydrogen storage by carbon Nanomaterials. Super Capacitors: Theory of double layer capacitor, determination of capacitance by electrochemical method – Galvanostatic & Potentiostatic methods, application of super capacitor in energy storage. Introduction to various types of batteries. Lithium batteries and application of Carbon and Nano-carbon in Lithium batteries.

**REFERENCES:**

1. W.R. Fahrner, *Nanotechnology and Nanoelectronics: Materials, Devices, Measurement Techniques*, Springer, 2005.
2. K. Goser, P. Glosekotter & J. Dienstuhl, *Nanoelectronic and Nanosystems From Transistors to Molecular Quantum Devices*, Springer, 2004.
3. S. E. Lyshevski, “MEMS and NEMS: Systems, Devices and Structures”, CRC Press, 2002.
4. Gregory Timp, *Nanotechnology*, Springer, 1999.
5. Vijay K Varadan, K J Vinoy, S Gopalakrishnan, *Smart Material Systems and MEMS: Design and Development*, John Wiley & Sons, 2006
6. K. Goser, P. Glosekotter & J. Dienstuhl, *Nanoelectronic and Nanosystems – From Transistors to Molecular Quantum Devices*, Springer, 2004
7. Rainer Waser, *Nanoelectronics and Information Technology: Advanced Electronic Materials Novel and Devices*, Wiley VCH, 2005.
8. Branda Paz, “A Handbook on Nanoelectronics”, Vedams books, 2008
9. V. Mitin, V. Kochelap, M. Stroscio, —*Introduction to Nanoelectronics*, Cambridge University Press (2008).
10. Rainer Waser, *Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices*, Wiley-VCH (2003).

**Learning Outcome:**

- Understand the concept of nano-electronics fabrication in various applications.

- To know the concepts of Silicon micromachining- semiconductors and insulators along with polymers in Microsystems.
- To understand the Electronics and Nano Optical applications in Optical amplifiers, Lasers and photodiodes.
- To know the role of Nanotechnology in harvesting Solar Energy.
- Applications of Nanotechnology in Energy saving techniques for batteries and other uses.



## OET 2.1 Nano-Medicine

60 Hrs

(Credits-4)

### UNIT - I NANOMOLECULAR DIAGNOSTICS - ARRAY AND CHIPS (15)

Introduction -Nano diagnostics -Rationale of Nanotechnology for Molecular Diagnostics - Nanoarrays for Molecular Diagnostics. Nanofluidic/Nanoarray Devices to Detect a Single Molecule of DNA-Self Assembling Protein Nanoarrays -Fullerene Photo detectors for Chemiluminescence Detection on Micro fluidic Chips - Protein Microarray for Detection of Molecules with Nanoparticles Protein Nanobiochip Nanoparticles for Molecular Diagnostics -Gold Nanoparticles -Quantum Dots for Molecular Diagnostics Magnetic Nanoparticles -Use of Nanocrystals in Immunohisto chemistry -Imaging Applications of Nanoparticles Study of Chromosomes by Atomic ForceMicroscopy-Applications of Nanopore Technology for Molecular Diagnostics DNA-Protein and DNA-Nanoparticle Conjugates.

### UNIT - II NANOPHARMACEUTICALS

(15)

Introduction -Nanobiotechnology for Drug Discovery -Gold Nanoparticles for Drug Discovery -Use of Quantum Dots for Drug Discovery -Nanolasers for Drug Discovery -Cells Targeting by Nanoparticles with Attached Small Molecules -Role of AFM for Study of Biomolecular Interactions for Drug Discovery Nanoscale Devices for Drug Discovery -Nanotechnology Enables Drug Design at Cellular Level Nanobiotechnology-Based Drug Development - DendrimersasDrugs- Fullerenes as Drug Candidates – NanobodiesNanobiotechnology in Drug Delivery - NanoscaleDelivery of Therapeutics -Nanosuspension Formulations Viruses as Nanomaterials for Drug Delivery -Nanoparticle-Based Drug Delivery -Self-Assembling Nanoparticles for Intracellular Drug Delivery -Nanoparticle Combinations for Drug Delivery Liposomes -Liposome-Nanoparticle Hybrids-Nanospheres-Nanotubes -Nanocochleates.-Nanomolecular Valves for Controlled Drug Delivery.

### UNIT - III ROLE OF NANOTECHNOLOGY IN BIOLOGICAL THERAPIES

(15)

Introduction - Development of nano medicines – Nano Shells – Nano pores – Tectodendrimers – Nanoparticle drug system for oral administration – Drug system for nasal administration – Drug system

for ocular administration – Nanotechnology in diagnostic application. Preformulation Studies: on various dosage forms such as tablets, capsules, suspension, creams, emulsion, injectables, ophthalmic and aerosols etc. Biomedical nanoparticles – Liposome's – Dendrimers – Different types of drug loading – Drug release – Biodegradable polymers – Applications Nanobiotechnologies for Single-Molecule Detection -Protease-Activated QuantumDot Probes - Nanotechnology for Point-of-Care Diagnostics - Nanodiagnosics for the Battle Field - Nanodiagnosics for Integrating Diagnostics with Therapeutics.

## **UNIT - IV APPLICATION IN CANCER THERAPY & NANOMEDICINE**

**(15)**

Introduction and Rationale for Nanotechnology in Cancer Therapy -- Passive Targeting of Solid Tumors: Pathophysiological Principles and Physicochemical Aspects of Delivery Systems -Active Targeting Strategies in Cancer with a Focus on Potential Nanotechnology Applications - Pharmacokinetics of Nanocarrier-Mediated Drug and Gene Delivery - Multifunctional Nanoparticles for Cancer Therapy- Neutron Capture Therapy of Cancer: Nano-Oncology- Nanoneurology- Nanocardiology- Nano-Orthopedics- Nano-Ophthalmology

### **References:**

1. Kewal K. Jain, *The Handbook of Nanomedicine* Humana Press, (2008).
2. Zhang, *Nanomedicine: A Systems Engineering Approach* 1st Ed., Pan Stanford Publishing, (2005).
3. Robert A. Freitas Jr., —*Nanomedicine Volume IIA: Biocompatibility*, Landes Bioscience Publishers, (2003).

### **Learning Outcome:**

- To understand the nanomolecular diagnostics for DNA-Self Assembling Protein Nanoarrays and Protein Nanobiochip chips levels.
- To impart understanding on Nanoparticle based Drug Delivery and nanopharmaceuticals.
- To know the role of nanotechnology in biological therapies in nano medicines.
- To understand the impact of cancer therapy & nanomedicinal concepts as applications.

## **OET 2.2 Green Manufacturing Technology**

**60 Hrs**

**(Credits-4)**

### **UNIT - I GREEN MANUFACTURING TRENDS**

**(15)**

Green Manufacturing: Fundamentals and Applications - basic definitions and issues surrounding green manufacturing at the process, machine and system - government motivations for green manufacturing – traditional manufacturing to green manufacturing -economic issues- surrounding green manufacturing - the areas of automotive, semiconductor and medical areas as well as in the supply chain and packaging areas Green Manufacturing.

### **UNIT - II WASTE MANAGEMENT**

**(15)**

Sustainability and global conditions - Material and solid waste management - Energy management - chemical waste management and green chemistry - Climate change and air emissions management - Supply water and waste water management - Environmental business management .

### **UNIT - III INDUSTRIAL ECOLOGY**

**(15)**

Introduction-Material flows in chemical manufacturing-Industrial parks-Assessing opportunities for waste exchanges and by product synergies-Life cycle concepts-Product stewardship and green engineering - Regulatory, social and business environment for green manufacturing.- Metrics and analytical tools.- Green supply chains.- Present state of green manufacturing.

## UNIT - IV GREEN PLASTICS MANUFACTURING

(15)

Introduction to commercial plastics and elastomers -Natural Rubber (NR), modified NR and blends - Polyesters from microbial and plant biofactories (polylactic acid and poly hydroxyalkanoates) - Plastics from vegetable oils -Cellulose and starch based materials -Natural fillers, fibers, reinforcements and clay nanocomposites -Biodegradability, life cycle assessment and economics of using natural materials.

### References:

1. T. David Allen and David R. Shonnard, *Green engineering*, Prentice Hall NJ, (2002).
2. David Dornfeld, *Green manufacturing fundamental and applications*, Prentice hall (2002).
3. G. Sammy Shinga, *Green electronics design and manufacturing*, Prince publications (2008).
4. James clark, *Green chemistry*, Blackwell publishing (2008).
5. Paulo Davim, *Sustainable Manufacturing*, Wiley publications (2010).
6. Frank Kreith, George Tchobanoglous, *Solid waste management*, McGraw Hill (2002).
7. E. S. Stevens, *Green plastics*, Princeton university press (2002).
8. U. Robert Ayres, *A Handbook of Industrial Ecology*, Edward elgar publishing (2002).

### Learning Outcome:

- To understand the basic concept of green manufacturing technology.
- To study the waste management in climate change and water management methods.
- Understand the concept of industrial manufacturing methods in waste managements.
- To know the green plastics manufacturing methods in PolyestersNatural fillers, fibers, reinforcements and clay nanocomposites.

## **PRACTICALS**

### **HCP 2.1 Characterization of Nano-Materials**

**60 Hrs**

**(Credits-2)**

#### **CHARACTERIZATION OF NANO-MATERIALS (Any six practicals)**

1. Analysis of absorption spectra of thin films of Nano-materials.
2. Thickness measurement of thin films
3. Analysis of FTIR spectra
4. Analysis and calculation of average particle size of Nanomaterials by SEM and TEM images
5. Calculate aspect ratio of CNT and CNF
6. Band gap calculation by UV visible spectroscopy
7. Particle size calculation by UV VIS spectra
8. Determination of absorption coefficient
9. XRD data analysis, lattice parameter, and miller indices
10. Calculate average crystallite size by XRD data

## HCP 2.2 Properties of Nano-Materials

**60Hrs**

**(Credits-2)**

### **Properties of Nano-Materials(Any SixPracticals)**

1. Measurement of Electrical conductivity of ZnO thin films prepared by Spin Coating method with Effect of temperature.
2. Measurement of Electrical conductivity of TiO<sub>2</sub> thin films prepared by Spin Coating Method with Effect of temperature.
3. Measurement of Electrical conductivity of NiO thin films prepared by Dip Coating with Effect of temperature.
4. Measurement of Electrical conductivity of ZnO thin films prepared by Dip Coating with Effect of temperature.
5. Measurement of Electrical conductivity of TiO<sub>2</sub> thin films prepared by Spray Pyrolysis Method with Effect of temperature
6. Measurement of Electrical conductivity of NiO thin films prepared by Spray Pyrolysis Method with Effect of temperature.
7. Measurement of Electrical conductivity of graphene thin films prepared by CVD Method with Effect of temperature.
8. Measurement of Electrical conductivity of TiO<sub>2</sub> thin films prepared by doctor-blade method with Effect of temperature.

## SCP 2.1 Carbon and Nanoforms of Carbon

60Hrs

(Credits-2)

### Carbon and Nanoforms of Carbon(Any Six Practicals)

1. Synthesis of Carbon Nano-materials by Chemical Vapor Deposition (CVD) method at
  - i. Different temperatures
  - ii. Duration of Pyrolysis
  - iii. Effect of flow rate of carriers
  - iv. Using different chemical precursors
  - v. Using Biological precursors
  - vi. Effect of different catalysts (Fe, Ni, Co) on Nanomaterial formation
2. Nano-material Synthesis by Sputtering technique: Using following parameters
  - i. Voltage
  - ii. Current
  - iii. Distance between substrate & filament
  - iv. Precursor quantity
  - v. Under vacuum
  - vi. Using Argon, Nitrogen and Hydrogen gas
3. **PURIFICATION OF CARBON NANO-MATERIALS**
  - Purification of synthesized Nano-materials by
  - Physical techniques.
  - Chemical method

**SCP 2.2 Nano-Electronics**

**60 Hrs**

**(Credits-2)**

**Nano-Electronics (Any Six Practicals)**

1. Perform the characteristic of LED.
2. Perform the characteristic Photodiode.
3. Experiment on Advance Semiconductor Devices.
4. Experiment on MEMS.
5. Experiment on NEMS.
6. Experiment on Analog IC design.
7. Perform the preparation of p:n junction.
8. Perform the preparation Carbon Solar cell.
9. Perform the preparation Schottky junction.
10. Perform the preparation Lithium batteries.



## **OEP 2.1 Nano-Medicine**

**60 Hrs**

**(Credits-2)**

### **Nano-Medicine(Any six Practicals)**

1. Anti-Oxidant activity of synthesized nanoparticles.
2. Anti-bacterial activity of synthesized Nanoparticles.
3. Anti-fungal activity of synthesized Nanoparticles.
4. Characterization of nanoparticles by AFM (Atomic Force Microscopy).
5. Determination of MIC (Minimal inhibitory Concentration) of nanoparticles.
6. Synthesis of c-dots and their characterization.
7. Dialysis and purification of C-dots for downstream processing.
8. PEGylation of Nanoparticles and their characterizations.
9. Preparation of Magnetic nanoparticles (MNP).
10. Effect of different parameters (Temperature, Ph, precursor concentration and water) on synthesized nanoparticles.

## **OEP 2.2 Green Manufacturing Technology**

**60 Hrs**

**(Credits-2)**

### **Green Manufacturing Technology (Any six Practicals)**

1. Estimation of chlorophyll from plant leaves (spinach).
2. Separation of photosynthetic pigments by paper chromatography.
3. Isolation and Characterization of microorganisms from Crude Petroleum Oil and Contaminated Soil samples.
4. Isolation of microorganisms from sewage samples by serial dilution technique.
5. Total estimation of BOD (Biological Oxygen Demand ) from water sample.
6. Total estimation of COD (Chemical Oxygen Demand) from water sample.
7. Preparation of Bioplastic from biological precursor.
8. To test for an alternative plant pod powder as nutritive source in microbiological media and its suitability to culture bacteria, fungi, other organisms.