SOLAPUR UNIVERSITY, SOLAPUR

Proposed Syllabus

Of

M.Sc. Nano-Technology

Choice Based Credit System-CBCS

With Effect from 2016-2017

SOLAPUR UNIVERSITY, SOLAPUR

M. Sc. NANOTECHNOLOGY

Choice Based Credit & Grading System-CBC&GS

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

2) Introduction: This course provides a broad overview of Nanotechnology and to produces 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 Solapur University shall 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 entrance exam conducted bySolapur University for 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:

- 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 two practical course
- Semester III comprising four core theory papers and twopractical courses
- Semester IV comprising three core theory papers and one elective paper and two practicals courses in which one practical course comprising research project.
- Each semester will have four theory papers of 70 marks each for University external examination and 30 marks each for internal examination
- Two practical courses of 70 marks each for the University external examination and 30 marks each for internal practical course.

SOLAPUR UNIVERSITY, SOLAPUR

Syllabus for M.Sc. Nanotechnology Part - I

COURSE STRUCTURE

SEMESTER-I

Semester	Code	Title of the Paper	Semester exam			L	T	P	Credits
First		**Hard core**	**Theory**	**IA**	**Total**				
NT	**HCT1.1**	Fundamentals of Nano-Technology in Physics	70	30	100	4		-	4
	HCT1.2	Fundamentals of Nano-Technology in Chemistry	70	30	100	4		-	4
	HCT1.3	Nano-materials Fabrication	70	30	100	4		-	4
		Soft Core (Any one)							
	SCT1.1	Fundamentals of Bio-nanotechnology	70	30	100	4		-	4
	SCT1.2	Introduction to Nanoscience and Nanotechnology	70	30	100	4		-	
		Tutorial			25		1	-	1
		Practical							
	HCP 1.1	Physics	35	15	50	-	-	2	6
	HCP1.2	Chemistry	35	15	50	-	-	2	
	HCP1.3	Nanotechnology	35	15	50	-	-	2	
		Soft core (Any one)							
	SCP1.1	Bio-nanotechnology	35	15	50	-	-	2	2
	SCP1.2	General Lab	35	15	50	-	-	2	
		Total for first semester	**420**	**180**	**625**				**25**

SEMESTER-II

Semester	Code	Title of the Paper	Semester exam			L	T	P	Credits
Second		**Hard core**	**Theory**	**IA**	**Total**				
NT	**HCT2.1**	Characterization Tools of Nanomaterials	70	30	100	4		-	4
	HCT2.2	Properties of Nanomaterials	70	30	100	4		-	4
		Soft core (Any one)							
	SCT2.1	Carbon and Nanoforms of Carbon	70	30	100	4		-	4
	SCT2.2	Nano-electronics	70	30	100	4		-	
		Open elective (Any one)							
	OET2.1	Nano-medicine	70	30	100	4		-	4
	OET2.2	Green Manufacturing Technology	70	30	100	4		-	
		Tutorial			25		1	-	1
		Practical							
	HCP 2.1	Synthesis & Purification of Nano-materials	35	15	50	-	-	2	4
	HCP2.2	Properties of different Nano-materials	35	15	50	-	-	2	
		Soft core (Any one)							
	SCP2.1	Characterization of Nano-materials	35	15	50	-	-	2	2
	SCP2.2	Nano-electronics	35	15	50	-	-	2	
		Open elective (Any one)							
	OEP2.1	Nanomedicine	35	15	50	-	-	2	2
	OEP2.2	Green Manufacturing Technology	35	15	50	-	-	2	
		Total for second semester	**420**	**180**	**625**				**25**

M. Sc. SEMESTER –I

HCT1.1 FUNDAMENTALS OF NANOTECHNOLOGY IN PHYSICS

60 Hrs

Total marks: 100

(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: PhysicalProperties and Ferroelectric & Piezoelectric Material (15)

Static dielectric constant, electronic, ionic and orientation polarizations - Internal or local fields in solid and liquids. Lorentz field in cubic materials - Clausius-Mosotti equation - complex dielectric constant - determination of dipole moment for polar substances - dielectric losses - frequency dependence of electronic, ionic, orientation polarisabilities - optical absorption, luminescence - Thallium activated alkali halides - electro luminescence.

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. Kittle. Introduction to Solid State Physics
2. S.O. Pillai Solid State Physics
3. A.J. Decker, Solid State Physics
4. Richard L. Liboff, Borns M. Smirnov, Physics of Atoms & Ions, Springer
5. Linus Pauling, E. Brignt 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).
7. Arthur Baiser -

HCT1.2 FUNDAMENTALS OF NANOTECHNOLOGY IN CHEMISTRY

60 Hrs

Total marks: 100

(Credits-4)

Unit-I: Atoms, Molecules, Ions, Electrons & Periodic trends (15)

Dalton's Atomic theory as foundation for chemistry, Structure of atoms, Ionic compounds and Chemical Nomenclature. Nature of light, Line spectra & Bohr Atom, Matter of Waves, Quantum number in Hydrogen atom, Energy level of multi-electron atom, Electrons in multi-electron atoms. 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)

Lewis symbols, Ionic bonding, Covalent bonding, Formal charges & resonance in Lewis structure, Molecules that do not satisfy the octet rule, Bond energies. Valence –orbitals shell Electron-Pair repulsion Model, Polarity of molecules,Valence bond theory, Multiple bonds, Molecular orbitals: Homonuclear Diatomic Molecules, Heteronulear Diatomic Molecules & Delocalized Molecular orbitals.

Unit-III: Fundamentals of Nanotechnology (15)

Introduction to Nano-science and Nano-technology, Nano-scale material, implications for Physics, Chemistry, Engineering & Biology, and Motivation for Nanotechnology study. History & development of Nano-science and Nano-technology with the emphasis on history of Nano-metals, Chalcogenides& Boron Nitrite and Carbon Nanomaterials

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

Nano-structures: various types of nano-structures and nano-crystals. Classification: of bulk Nano-structured 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)

HCT1.3 NANO-MATERIALS STRUCTURE & FABRICATION **60 Hrs**

Total marks: 100

(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 Bean 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 highconcentrations; 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)

SCT1.1 FUNDAMENTALS OF BIO-NANOTECHNOLOGY **60 Hrs**

Total marks: 100

(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 -Peroxysomes-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).

SCT1.2 INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY

60 Hrs

Total marks: 100

(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 (TiO2, CeO2, 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 Verlag Gmbh&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, Naostructures and Nanomaterials: Synthesis, properties and applications, Imperical College Press, 2004.

HCP 1.1 PHYSICS

60 Hrs
Total marks: 50
(Credits-2)

Physics Experiments (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

HCP 1.2 CHEMISTRY

60 Hrs
Total marks: 50
(Credits-2)

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
Total marks: 50
(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. Synthesis of Gold Nanoparticles by chemical and biogenic methods
5. Zinc selenide quantum dot preparation.
6. Synthesis of Iron Oxide Nanoparticle
7. Thin film preparation by spin coating technique.
8. Synthesis of Nickel metal nanoparticle by urea decomposition method
9. Synthesis of Zinc Oxide nanoparticle
10. Preparation of nanoparticles by using Ball milling

SCP 1.1 BIO-NANOTECHNOLOGY

60 Hrs
Total marks: 50
(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

SCP 1.2 GENERAL LAB

60 Hrs
Total marks: 50
(Credits-2)

General Lab Experiments (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

Total marks: 100

(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 Spectroscope, XRD. RAMAN Spectroscope, EELS, XPS (X-ray Photoelectron Spectroscope), SIMS, NMR, DLS (Dynamic Light Scattering or photon correlation spectroscope), 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

Unit – IV: Characterization of Quantum structures (15)

Quantum structures Particle diameter by HRTEM Photoluminescent properties, Excitation wavelength, Photoluminescence byMicro plateReaderPhotostability, 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. Klomparens, 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 OfNanophase 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. LakowiczPrinciples of fluorescence spectroscopy, Springer, (2010).
20. Pavia Lampman, Kriz, Vyvyan, Introduction to spectroscopy, Cengage learning, (2009).
21. Jin JhongJhang, 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. Jin Zhong 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).

HCT 2.2 PROPERTIES OF NANOMATERIALS

60 Hrs

Total marks: 100

(Credits-4)

Unit – I: Fundamental Properties of Nanomaterials (15)

Size dependent properties: Surface to volume ratio (SVR), Size Effects on Structure and Morphology of Free or Supported Nanoparticles - Size and Confinement Effects - Fraction of Surface Atoms - Specific Surface Energy and Surface Stress - Effect on the Lattice Parameter - Effect on the Phonon Density of States - 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)

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. Simulated Raman scattering. Stimulated Brillion 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 Superparamagneticeffects .

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 PropertiesVol.3
2. Hari Singh Nalwa Handbook of Nano structured Materials and Nanotechnology Optical PropertiesVol.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, NanoBiophotoics", Elsevier Science, (2007).
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11. P. N. Prasad, Introduction to Biophotonics", John Wiley and Sons, (2003).
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13. Bland J.A.C., and B. Heinrich, ―Ultra thin Magnetic Structures III – Fundamentals of Nanomagnetism, Springer (2004)

SCT 2.1 CARBON AND NANOFORMS OF CARBON

60 Hrs

Total marks: 100

(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

Unit – IV: Nano Graphene & Carbon-dots (15)

Nano-Graphene Structure, Properties and fabrication (Physical &Cheical 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:

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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)

SCT 2.2 NANO-ELECTRONICS

60 Hrs

Total marks: 100

(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.

Unit – IV Applications of Nanotechnology in Energy (15)

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 NanosystemsFrom 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

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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).

OET 2.1 NANO-MEDICINE

60 Hrs

Total marks: 100

(Credits-4)

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

Introduction -Nano diagnostics -Rationale of Nanotechnology for Molecular Diagnostics - Nanoarrays for Molecular Diagnostics. NanoProTM System -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 NANOMACHINES AND NANOBARCODES, NANOBIOSENSORS (15)

DNA Nanomachines for Molecular Diagnostics -Nanobarcodes Technology –Nanobarcode Particle Technology for SNP Genotyping –Qdot Nanobarcode for Multiplexed Gene Expression Profiling - BiobarcodeAssay for ProteinsSingle-Molecule Barcoding System for DNA Analysis Nanoparticle-Based Colorimetric DNA Detection Method Cantilevers as Biosensors for Molecular Diagnostics – CarbonNanotube Biosensors -FRET-BasedDNANanosensors. Ion Channel Switch Biosensor Technology -Electronic Nanobiosensors -Electrochemical Nanobiosensors -Quartz Nanobalance Biosensors -Viral Nanosensors -PEBBLENanosensors -Microneedle-Mounted Biosensors OpticalBiosensors- Nanowire (NW) Biosensors -Nanoscale ErasableBiodetectors.

UNIT - III 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 - Dendrimers asDrugs- Fullerenes as Drug Candidates –Nanobodies Nanobiotechnology in Drug Delivery - NanoscaleDelivery of Therapeutics -Nanosuspension Formulations Viruses as Nanomaterials for Drug Delivery -Nanoparticle-Based Drug Delivery -Trojan Nanoparticles -Self-Assembling Nanoparticles for Intracellular Drug Delivery -Nanoparticle Combinations for Drug Delivery Liposomes -Liposome–Nanoparticle Hybrids-Nanospheres-Nanotubes -Nanocochleates.-Nanomolecular Valves for Controlled Drug Release -Nanomotors forDrugDelivery.

UNIT - IV 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 – Dentrimers – Different types of drug loading – Drug release – Biodegradable polymers – Applications Nanobiotechnologies for Single-Molecule Detection -Protease-Activated QuantumDot Probes - Nanotechnology forPoint-of-Care Diagnostics -Nanodiagnostics for the Battle Field - Nanodiagnostics for Integrating Diagnostics with Therapeutics.

UNIT - V APPLICATION IN CANCER THERAPY & NANOMEDICINE

(15)

Introduction and Rationale for Nanotechnologyin 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:

Nanoparticlesand High Molecular Weight Boron Delivery Agents. Nano-Oncology-NanoneurologyNanocardiology- 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).

OET 2.2 GREEN MANUFACTURING TECHNOLOGY

60 Hrs

Total marks: 100

(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 SUSTAINABLE GREEN MANUFACTURING (15)

Introduction - sustainable green manufacturing -green manufacturing sustainability processes, requirements, and risk - The sustainable lean and green audit process. International green manufacturing standards and compliance. Green rapid prototyping and rapid manufacturing. Green flexible automation. Green collaboration processes . Alternative energy resources. Globally green manufacturing supply chains and logistic networks. Sustainable green manufacturing system design.

UNIT - III 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 - IV INDUSTRIAL ECOLOGY (15)

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

UNIT - V 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 hyroxyalkanoates) - 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).

L T P

HCP 2.1 SYNTHESES & PURIFICATION OF NANO-MATERIALS

60Hrs

Total marks: 100

(Credits-4)

SYNTHESIS NANO-MATERIALS

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

HCP 2.2 PROPERTIES OF DIFFERENT NANO-MATERIALS

60Hrs
Total marks: 50
(Credits-2)

PROPERTIES OF DIFFERENT NANO-MATERIALS

1. Measurement of Electrical conductivity of thin films of different Nano-materials.
    i. Effect of temperature
    ii. Effect of vacuum
    iii. Effect of different gases (Ar, H_2 & N_2)

SCP 2.1 CHARACTERIZATION OF NANO-MATERIALS

60 Hrs
Total marks: 50
(Credits-2)

CHARACTERIZATION OF NANO-MATERIALS

1. Analysis of absorption spectra of thin films of Nano-materials.
    i. Transmission/absorption spectra in range of 300nm to 1500nm
    ii. Determination of absorption coefficient for different wavelength
    iii. Determination of band gap using Lau model
2. Electron Microscopic observation of synthesized Nano-materials.
    i Study the morphology of nanomaterials and determine its dimensions.
    ii. XRD study of powder nanomaterials and determination of its characteristics

SCP 2.1 NANO-ELECTRONICS

60 Hrs
Total marks: 50
(Credits-2)

NANO-ELECTRONICS]

1. In this course, the students are expected to read and present research papers on current topics in Nanotechnology leading to advances in Nanotechnology or Nano-electronics

2. Each student is expected to present minimum of 10 lectures of 30 min each followed by questions and discussion.

3. Background knowledge related to the topic would be considered as the part of the presentation.

OEP 2.1 NANO-MEDICINE

60 Hrs
Total marks: 50
(Credits-2)

NANO-MEDICINE

1. In this course, the students are expected to read and present research papers on current topics in Nanotechnology leading to advances in Nanotechnology or Nano-Medicine

2. Each student is expected to present minimum of 10 lectures of 30 min each followed by questions and discussion.

3. Background knowledge related to the topic would be considered as the part of the presentation.

OEP 2.2 GREEN MANUFACTURING TECHNOLOGY

60 Hrs
Total marks: 50
(Credits-2)

GREEN MANUFACTURING TECHNOLOGY

1. In this course, the students are expected to read and present research papers on current topics in Nanotechnology leading to advances in Green Manufacturing Technology

2. Each student is expected to present minimum of 10 lectures of 30 min each followed by questions and discussion.

3. Background knowledge related to the topic would be considered as the part of the presentation.