File Ref.No.8957/GA - IV - J1/2012/CU

UNIVERSITY OF CALICUT

Abstract

General and Academic -Faculty of Science - Syllabus of M.Tech Nanoscience and Technology Programme under CCSS PG Regulations 2019-(University Teaching Departments) with effect from 2019 Admission onwards - Implemented - Orders Issued.

G & A - IV - J

U.O.No. 14707/2019/Admn Dated, Calicut University.P.O, 18.10.2019

Read:-1.U.O.No. 4500/2019/Admn dated 26.03.2019

2. item No.1 in the Minutes of Board of Studies in Nanoscience and Technology held on 19.07.2019

3. Remarks of the Dean, Faculty of Science Dated 16.10.2019.

ORDER

The Regulations under Choice-based Credit Semester System for Post Graduate Programmes (CCSS-PG -2019) of all Teaching Departments / Schools of the University with effect from 2019 admissions has been implemented vide paper read first above.

The meeting of the Board of Studies in Nanoscience and Technology (Single Board) held on 19.07.2019 has approved the Syllabus of M.Tech Nanoscience and Technology Programme in tune with new CCSS PG Regulation implemented with effect from 2019 Admission onwards, vide paper read second above.

Dean, Faculty of Science has approved the minutes of the meeting of the Board of Studies in Nanoscience and Technology (Single Board) held on 19.07.2019, vide paper read third above.

Under these circumstances, considering the urgency, the Vice Chancellor has accorded sanction to implement the Scheme and Syllabus of M.Tech Nano science and Technology Programme in accordance with the new CCSS PG Regulations 2019, in the University with effect from 2019 Admission onwards, subject to ratification by the Academic Council.

The Scheme and Syllabus of M.Tech Nanoscience and Technology Programme in accordance with CCSS PG Regulations 2019 (University Teaching Departments), is therefore implemented in the University with effect from 2019 Admission onwards.

Orders are issued accordingly.

(Syllabus appended)

Biju George K

Assistant Registrar

To

The HoD, Department of Nanoscience and Technology

Copy to: PS to VC/PA to PVC/ PA to Registrar/PA to CE/JCE I/JCE V/DoA/EX and EG Sections/GA I F/CHMK Library/Information Centres/SF/DF/FC

Forwarded / By Order

Section Officer

UNIVERSITY OF CALICUT
DEPARTMENT OF NANOSCIENCE AND TECHNOLOGY

M TECH NANOSCIENCE AND TECHNOLOGY

RULES AND REGULATIONS REVISED (2019 JULY)

BOS Chairman

UNIVERSITY OF CALICUT
DEPARTMENT OF NANOSCIENCE & TECHNOLOGY

Name of the Programme : M.Tech Nanoscience & Technology

Duration : Four Semesters

Eligibility for Admission : BE/ B.Tech in Nanoscience and Technology, Electronics, Electrical, Mechanical, Chemical, Industrial, Engineering physics, Metallurgy and Materials engineering, Biotechnology and Biomedical Engineering. M.Sc. in Physics /Applied Physics / Electronics / Photonics/Materials Science /Chemistry /Applied Chemistry /Polymer Chemistry /or an equivalent post graduate degree with Physics, Chemistry or Mathematics as one of the subsidiaries at the undergraduate level. A Minimum of 60 % aggregate marks in the qualifying examination is essential for the eligibility for admission to this program.

Admission procedure: Admission to this course will be based on the marks secured in an entrance examination conducted by the University among the eligible candidates.

Course Structure & Syllabus – 2019

Semester – I

SI. No.	Course Code	Course Title	L	T	P	Credits
1	NST.101	Quantum Mechanics	4	0	0	4
2	NST.102	Structure and Bonding in Solids	4	0	0	4
3	NST.103	Computational Methods &Data Processing	4	0	0	4
4	NST.104	Introduction to Nanomaterials	4	0	0	4
5	NST.105	Nano Lab – 1	0	0	4	4
			Total			**20**
6	NST.106	Ability Enhancement Course (AEC)	Audit			2*

***** Credit of this course (NST.106) will not be considered while calculating the SGPA/CGPA

Semester - II

SI. No.	Course Code	Course Title	L	T	P	Credits
1	NST.201	Design and synthesis of Nanomaterials	4	0	0	4
2	NST.202	Characterization Techniques of Nanomaterials	4	0	0	4
3	NST.203	Bio- Nanomaterials	4	0	0	4
4	NST.204	Properties and Applications of Nanomaterials	4	0	0	4
5	NST.205	Nano Lab-II	0	0	4	4
			Total			**20**
6	NST.206	Professional Competency Course (PCC)	Audit			2*

***** Credit of this course (NST.206) will not be considered while calculating the SGPA/CGPA

Semester - III

SI. No.	Course Code	Course Title	L	T	P	Credits
1	NST.301	Advanced Nanomaterials	4	0	0	4
2	NST.302	Micro/Nano Electro-mechanical Systems (MEMS/NEMS)	4	0	0	4
3	NST.303	Societal and Environmental Impact of Nanotechnology	2	0	0	2
4	NST.304	Elective	4	0	0	4
5	NST.305	Mini Project	6	0	0	6
			Total			**20**

Semester - IV

SI. No.	Course Code	Course	L	T	P	Credits
1	NST.401	Major Project	20	0	0	20
			Total			**20**

TOTAL CREDITS= 80

Elective

SI. No.	Course Code	
1	NST.304-A	Nanomaterials for Energy Conversion and Storage
2	NST.304-B	Sustainable Nanomaterials

More Elective courses will be offered in due course

EVALUATION AND GRADING

The evaluation scheme for each paper shall contain two parts as given below

(1) Internal Evaluation

(2) External Evaluation

40% weight shall be given to the internal evaluation. The remaining 60% weight shall be for the end semester external evaluation.

Internal Evaluation

The internal evaluation shall be based on a predetermined transparent system involving periodic written tests, viva-voce, seminars, and assignments/records of Lab skill. The details of executing the internal evaluation shall be decided by the Departmental Council.

External Evaluation

The external examination in theory courses is to be conducted with question papers set by external examiners. The evaluation of the answer scripts shall be done by the teacher offering the paper and an external expert based on a well-defined scheme of valuation framed by them.

The external examination in practical courses shall be conducted and evaluated by two examiners- one internal and an external examiner from other science departments of the university or from other institutions.

The Departmental Council is empowered to lay down the procedure for the conduct of examinations and the valuation of answer scripts from time to time.

GRADING SYSTEM

Based on the % marks scored (internal and external marks put together), the students are graded in each course applying the following grading system.

Table I. Grading System

% Marks	Grade Point	Letter Grade
81-100	8.1-10.0	A+
71-80	7.1-8.0	A
61-70	6.1-7.0	B+
56-60	5.6-6.0	B
50-55	5.0-5.5 Grade point 5.0 is the lowest passing Grade	C
Below 50	F-0	F (Failed)

Each student shall be assigned a grade point and a letter grade in each course on the basis of the % marks scored in the course (internal and external marks taken together) as shown above. The minimum grade point required for passing a course is 5.0. The grade point for marks below 50% is taken as 0.0.

'Credit point' (P) of a course is the value obtained by multiplying the grade point (G) by the credit (C) of the course: P = G x C. If 2 students score 78 and 73% marks in a course, then their grade points are 7.8 and 7.3 respectively, but both will be assigned the same letter grade A. If the course carries 4 credits, then the credit points of these students will be 4 x 7.8 and 4 x 7.3(31.2 and 29.2) respectively.

The student is required to pass all the core courses and the stipulated minimum number of elective courses in order to complete the programme successfully.

After the completion of a semester, the Semester Grade Point Average (SGPA) of a student in that semester is calculated. The semester grade point Average (SGPA) is the value obtained by dividing the sum of credit points (P) obtained by the student in the various courses studied in a semester by the total no. of credits taken by him/her in that semester. SGPA determines the overall performance of a student at the end of a semester. For instance, if a student has registered for 'n' courses of credits C_1, C_2……., C_n in a semester and if she/he has scored credit points P_1,P_2,…….P_n respectively in these courses, then SGPA of the student in that semester is calculated using the formula

$$SGPA = \frac{P_1+P_2+\ldots\ldots\ldots\ldots\ldots+P_n}{C_1+C_2+\ldots\ldots\ldots\ldots\ldots+C_n}$$

The minimum SGPA required for the successful completion of a semester is 5.0. However, a student with SGPA less than 5.0 in a semester is permitted to proceed to the next semester.

The Cumulative Grade Point Average (CGPA) of the student is calculated at the end of a programme. 'Cumulative Grade Point Average'(CGPA) is the value obtained by dividing the sum of credit points in all the courses opted by the student for the entire programme by the total number of credits and is calculated based on the same formula given above. CGPA shall be rounded off to the first decimal place. CGPA determines the academic level of the student in a programme and is the index for ranking students.

An overall letter grade (Cumulative Grade) for the whole programme shall be awarded to the student based on the value of CGPA using the same criterion given in Table.1 for assigning letter grade for a course on the basis of the grade point. For instance, if the CGPA of a student turns out to be 6.6. then the Cumulative Grade of that student will be B+.

The minimum CGPA required for the successful completion of a programme is 5.0, which corresponds to 50% marks.

A student who secures zero grade point (F grade) in a course (for want of sufficient marks and/or attendance) is permitted to register for repeating the course when the course is

offered to the next batch. The student registered for repeat course need not attend the classes if she/he has satisfied the requirements regarding attendance.

A student who secures a grade point of 6.0 or below in a course is permitted to appear for the re-examination, when the course is offered to next batch. The student need not attend classes for a re-examination course.

Project evaluation

III Semester Mini Project to be carried out at Department of Nanoscience and Technology (DNST) or other science departments within the University. The project will be evaluated by one internal examiner from DNST and one external examiner from other science department of this University.

IV Semester Major Project to be carried out at Department of Nanoscience and Technology (DNST) or other approved National Institutes or Universities in India. Final evaluation of the major project is to be done by one internal examiner from DNST and an external examiner from outside the University.

Internal /external marks at 40/60 shall be given. 50% of weightage shall be given for the content of the work and 50 % for presentation and viva-voce.

Pattern of question paper for external evaluation

There shall be three sections.

Section A : Eight Compulsory short answer type questions of two marks each 8x2=16 marks.

Section B : Eight paragraph answer type questions, the students shall answer five question each of four marks 5 x 4=20 marks.

Section C : Six essay type questions, the students shall answer four questions, each of six marks 4 x 6=24 marks.

MTECH NANOSCIENCE AND TECHNOLOGY

SYLLABUS REVISED (2019 JULY)

NST.101 **4 0 0 4**

QUANTUM MECHANICS

Unit I: Principles of Quantum Mechanics and Their application to Translational Motion

Detailed discussion of postulates of quantum mechanics – State function or wave function postulate, Born interpretation of the wave function, well behaved functions, orthonormality of wave functions; Operator postulate, operator algebra, linear and nonlinear operators, Non-commuting operators and the Heisenberg's Uncertainty principle, Laplacian operator, Hermitian operators and their properties, eigen functions and eigen values of an operator; Eigen value postulate, eigen value equation, Expectation value postulate; Postulate of time- dependent Schrödinger equation of motion, conservative systems and time-independent Schrödinger equation.

Free particle in one-dimension; Particle in a one-dimensional box with infinite potential walls, important features of the problem; Introduction to tunneling; Particle in a three dimensional box, Separation of variables, degeneracy, Symmetry breaking.

Unit II: Quantum Mechanics of Vibrational and Rotational Motions

One-dimensional harmonic oscillator (complete treatment):- Method of power series, Hermite equation and Hermite polynomials, recursion relation, wave functions and energies, important features of the problem, harmonic oscillator model and molecular vibrations.

Rigid rotator (complete treatment): The wave equation in spherical polar coordinates, separation of variables, the Phi-equation and the Theta-equation and their solutions, Legendre and associated Legendre equations, Legendre and associated Legendre polynomials, Rodrigue's formula, spherical harmonics (imaginary and real forms), polar diagrams of spherical harmonics. Quantization of angular momentum, quantum mechanical operators corresponding to angular momenta ((Lx, Ly, Lz), commutation relations between these operators

Unit III: Quantum Mechanics of Hydrogen-like Atoms

Potential energy of hydrogen-like systems, the wave equation in spherical polar coordinates, separation of variables, the R, Theta and Phi equations and their solutions, Laguerre and associated Laguerre polynomials, wave functions and energies of hydrogen-like atoms, orbitals, radial functions and radial distribution functions and their plots, angular functions (spherical harmonics) and their plots. The postulate of spin by Uhlenbeck and Goudsmith, Dirac's relativistic equation for hydrogen atom and discovery of spin (qualitative treatment), spin orbitals, construction of spin orbitals from orbitals and spin functions.

Unit IV: Approximation Methods in Quantum Mechanics

Many body problem and the need of approximation methods; Independent particle model; Variation method – variation theorem with proof, illustration of variation theorem using a trial function [e.g., x (a-x)] for particle in a 1D-box, variation treatment for the ground state of helium atom; Perturbation method – time-independent perturbation method (non-degenerate case only), illustration by application to particle in a ID-box with slanted bottom, perturbation treatment of the ground state of the helium atom.

Hartree's Self-Consistent Field method for atoms, Fock modification using spin orbitals & Hartree - Fock Self- Consistent Field (HF-SCF) method for atoms, the Fock operator; Pauli's antisymmetry principle - Slater determinants; Roothan's concept of basis functions – Slater type orbitals (STO) and Gaussian type orbitals (GTO).

Reference

1. Donald, A. McQuarrie, *Quantum Chemistry*, University Science Books, 1983 (first Indian edition,Viva books, 2003).
2. I.N. Levine, *Quantum Chemistry*, 6th Edition, Pearson Education Inc.,
3. P.W. Atkins and R.S. Friedman, *Molecular Quantum Mechanics* , 4th Edition, Oxford University Press, 2005.
4. M.W. Hanna, *Quantum Mechanics in Chemistry*, 2nd Edition, W.A. Benjamin Inc., 1969.
5. Thomas Engel, Quantum Chemistry & Spectroscopy, Pearson Education, 2006.
6. J.P. Lowe, *Quantum Chemistry*, 2nd Edition, Academic Press Inc., 1993.
7. Horia Metiu, *Physical Chemistry – Quantum Mechanics*, Taylor & Francis, 2006.
8. L. Pauling and E.B. Wilson, *Introduction to Quantum Mechanics*, McGraw-Hill, 1935 (A good source book for many derivations).
9. R.L. Flurry, Jr., *Quantum Chemistry*, Prentice Hall, 1983.
10. R.K. Prasad, *Quantum Chemistry*, 3rd Edition, New Age International, 2006.
11. C.N. Datta, *Lectures on Chemical Bonding and Quantum Chemistry*, Prism Books Pvt. Ltd., 1998.
12. Jack Simons, *An Introduction to Theoretical Chemistry*, Cambridge University Press, 2003.

NST.102 **4 0 0 4**

STRUCTURE AND BONDING IN SOLIDS

UNIT I - Chemical Bonding

Types of chemical bonds. The octet rule. Wave Mechanical picture of chemical bonding. Valence bond and Molecular orbital theories, MO diagrams of homonuclear and hetronuclear diatomic molecules. Structure of molecules, VSEPR model. Ionic solids lattice energy, Born-Lande equation

UNIT II - Bonding in Solids:

Close packing, voids, radius ratio rule, Pauling rule-application to actual structures, variations in atomic packing-polymorphism, isomorphism, solid solutions, derivative structures. Characteristic properties of metals, crystalline and amorphous solids. Theories of bonding in solids. The free electron theory, Band and Zone Theories, the Kronig-Penny model, Classification of solids into insulators, semiconductors, conductors and super conductors. Alloys, ceramics, composite materials and conducting polymers.

UNIT III - Crystallography

Periodicity in crystals, translational periodicity, representation of a lattice, notations of planes in a lattice, relationship between planes. Crystal types, two and three dimensional crystal lattices. Symmetry elements – proper and improper rotation axes, screw axes, glide planes. Symmetry groups- point groups categories of crystal, plane groups, space lattices, space groups, super groups and subgroups.

UNIT IV – Imperfections in solids

Types of Imperfections - classification. Point defects - Schottky defects, Frenkel defect, Disordered Crystal. Line defects - Dislocation types, Dislocation theory. Plane defect - Large-angle boundaries, Small – angle boundaries, stacking faults. Colour centers in alkali halides Crystal growth - Velocity, Theories and Mechanism of crystal growth. Twinning - Growth, Deformation and transformation twins. Transformations in Crystals - Equilibrium transformations, Kinetics of transformations Elastic deformation and plastic deformation in crystals.

Text Book/References

1. Atomic structure and chemical Bond, Manas Chanta **Publisher:** McGraw-Hill Inc.,US (1 December 1974) **ISBN-10:** 0070965110
2. Concise Inorganic chemistry, J.D.Lee **Publisher:** Wiley; 5th edition edition (18 December 1998) **ISBN-10:** 0632052937
3. Inorganic Chemistry, G. Wwfsberg Unit IV **Publisher:** Pearson; 4 edition (31 May 2012) **ISBN-10:** 0273742752
4. Introduction to solids – L.V. Azaroff • **Publisher:** McGraw Hill Education; New edition edition (14 June 2001) **ISBN-10:** 0070992193
5. Introduction to solid state Physics – C. Kittel • **Publisher:** John Wiley & Sons Inc (23 July 1996) • **ISBN-10:** 0471142867
6. Elements of solids state physics, J.P. Srivastava • **Publisher:** Prentice Hall India Learning Private Limited; 4th Revised edition edition (17 December 2014) **ISBN-10:** 8120350669

NST.103 **4 0 0 4**

COMPUTATIONAL METHODS & DATA PROCESSING

UNIT I: Root finding, Interpolation and curve fitting

Roots of transcendental equations: Bisection, Regula-Falsi, Iteration and Newton-Raphson methods (SS), Interpolation: Newton's forward, backward & general formula for interpolation, Lagrange formula(SB), Least squares curve fitting : Linear and Nonlinear curve fitting (SS).

UNIT II: Numerical Integration, Linear System of Equations

NI: Trapezoidal and Simpson's methods, Gauss quadrature. LSE: Solution of linear systems,Gauss Elimination, Gauss Jordan method for inverse, LU factorization from Gauss elimination, Matrix transformation (house holder ,Givens method).

UNIT III: Computational Methods

Introduction to computational quantum chemistry. The Gaussian program, Cartesian coordinates and internal coordinates. Gaussian input file. Calculations using Gaussian program: Geometry optimization, Molecular orbital, charges, electron density. Frequency calculation, plotting the theoretical vibrational spectra, Interaction energy: Supermolecule method, BSSE correction.

UNIT IV: Data processing

Data processing using various software's for data processing: Excel, Origin, chem. Draw/Chem Sketch, Xpert highscore. Standard spectral data process techniques: curve fitting, normalization, smoothening zero filling etc.

Text Books :

1. Introductory Methods of Numerical Analysis- S.S. Sastry (SS), PHI
2. Numerical Mathematical Analysis- J.B.Scarborough (SB), Oxford & IBH
3. Computational Partial Differential Equations Using MATLAB- Jichun LI, Yi-Tung Chen (CP), CRC Press
4. D.A. Mc Quarrie, Physical Chemistry: A molecular approach, First South Asia Edition 1998

References :

1. An Introduction To Computational Physics, 2nd ed.- Tao Pang(TP), Cambridge University Press, Cambridge(2006)
2. Numerical Recipes in Fortran, The Art of Scientific Computing. W.H.Press etal(NR),Cambridge
3. Computational Physics- An Introduction- R.C. Verma, P.K. Ahluwalia and K.C. Sharma, New Age International Publishers, New Delhi(1999)
4. A first Course in Computational Physics- Pual l De Vries, John Wiley & Sons, Inc, New York (1994)

NST.104 **4 0 0 4**

INTRODUCTION TO NANOMATERIALS

UNIT – I Introduction

Feynmann's vision on nanoscience & technology, bulk vs nanomaterials, natural and synthetic nanomaterials. Quantum confinement in nanostructures- size dependent physical phenomena in semiconductor and metal nanoparticles. Classification of nanostructures, 0D, 1D and 2D nanostructures. Visualization of nanostructures and techniques related.

UNIT-II Surface Energy

Surface energy and surface stress-origin and estimation of surface energy. Surface Energy minimization:- Sintering Ostwald ripening and agglomeration. Energy minimization by Isotropic and anisotropic surfaces. Surface energy and surface curvature, Surface energy stabilization- electrostatic stabilization, steric stabilization, electro-steric stabilization..

UNIT-III Size and shape dependence of nanoparticles :

Size effect on the morphology of free or supported nanoparticles, Equilibrium shape of macroscopic crystal. Wulff theorem, equilibrium shape of nanometric crystals. Wulff-Kaichew theorem, equilibrium shape of supported nanoparticles. Kinetics of phase transformations, Homogeneous & Heterogeneous nucleation. Controlling nucleation, growth and aggregation in nanoparticle growth, and crystalline Phase Transitions in Nanocrystals.

UNIT-IV Fabrication of nanostructures

Bottom-up approaches for nanostructure fabrication:- Self assembly. Top down approaches for nanostructure fabrication- Lithography- Photolithography- Laser lithography and SPM based lithography (AFM & STM) and nanomanipulation.

Text Books :

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao, Imperial college Press, (2006). (for UNIT I & II, 2nd Chapter, Unit III – Chapter 4 (3.2), Unit IV- Chapter 7
2. Nanomaterials and Nanochemistry by C. Brechignac.P. Houdy M. Lahmani Springer-Verlag (2007). (For Unit III-Part I Chapter I)
3. Materials Science and Engineering-An Introduction 7e, William D. Callister, (Wiley, 2007). (Chapter 10. section 1-.2 and 10.3) Unit II.

NST.105 **NANO LAB –I** **0 0 4 4**

List of Experiments:

1. Synthesis of different sized Ag nanoparticles by aqueous method, Size distribution studies using DLS
2. Synthesis of different sized Au nanoparticles by aqueous method, Size distribution studies using DLS
3. Green Synthesis of Nanoparticles.
4. Chemical synthesis of CdSe Quantum dots with different sizes.
5. Band gap estimation of CdSe quantum dots by using optical spectroscopy
6. Exciton and plasmon interaction studies of Au-CdSe system by using optical spectroscopy.
7. Sol-gel synthesis of ZnO nanoparticles.
8. Analysis of optical properties of ZnO nanoparticles
9. Geometry optimization and frequency calculation using Gaussian program.
10. Curve fitting using Origin program.
11. Structure and physical property elucidation of small molecules using Chem Draw/Chem Sketch.

ABILITY ENHANCEMENT COURSE (AEC)

This course mainly aims to get skill and experience for students in their respective field of study. This course is intended for post-graduate students of science subjects. Basic concepts of research and presentation is included in this course to motivate young researchers. For the benefit of young researchers, industrial visit and internship is included, which provide a platform for them to interact with eminent scientists.

UNIT I: RESEARCH METHODOLOGY

Research- what is research, need of research, types of research, application of research in business. Research process- selection of topic of interest, formulation of a research problem, design a research, construct instrument for data collection, reliability and validity of instrument, sample, data collection, data processing and analysis, displaying results, repeatability, questionnaire designing, research report.

UNIT II: INDUSTRIAL/RESEARCH INSTITUTION VISIT

Understanding basic concepts of research/research process, motivation and objective of research, research problem, familiarize with instruments for data collection.

UNIT III: INTERNSHIP

Experience in new environment, selection of a new topic, formulating a new research problem, data collection, data analysis, discussion of results, presentation of results, research report and publications.

UNIT IV: RESEARCH PRESENTATION

Importance of conferences, seminars, workshops, publications in peer reviewed national / international journals, patents. Power point preparation- Introduction/preample, data display, discussion of results, conclusion, time management, communication.

Reference:

Research methodology: (Concepts and Cases) Deepak Chawla, Neena Sondhi,
Research methodology (Methods and Techniques) CR Kothari, Gaurav Garg

NST.201 **4 0 0 4**

DESIGN AND SYNTHESIS OF NANOMATERIALS

UNIT – I: Physical Methods

Introduction- Spontaneous growth, Evaporation condensation growth, fundamentals of evaporation condensation growth. Vapor –Liquid-Solid (VLS) growth, SWCNT and MWCNT growth mechganisms. Physical Vapour deposition techniques (PVD): Sputtering & Evaporation. Atomic layer deposition, Chemical vapour deposition method (CVD), Molecular beam epitaxy(MBE), & Electrospinning. Laser ablation, Laser pyrolysis, Ball Milling

UNIT – II : Chemical Methods

Nanoparticles through homogeneous & heterogenous nucleation in solution:- Co-precipitation method, Hydrothermal/ Solvothermal synthesis, Template based synthesis, Electrochemical synthesis, Sonochemical routes, Sol- gel, Micelles and microemulsions. Self assembly methods and Langmuir Blodgett (LB) method.

UNIT III : Biological Methods of Synthesis

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

UNIT IV : Lithographic Techniques

Ebeam lithography and SEM based nanolithography. X-ray Lithography, Focused Ion beam lithography, Near field scanning optical microscopy (NSOM). Atomic Force Microscope Lithography - Dip pen lithography. Microcontact printing, nanoimprint.

Text Books:

1. Nanostructures and Nanomaterials- Synthesis, Properties & applications by Guozhong Cao , Imperial college Press, (2006). **Publisher:** World Scientific Publishing Company; 2 edition (4 January 2011) **ISBN-13:** 978-9814324557
2. An introduction to Electrospinning and Nanofibers by Seeram Ramakrishna, Kazutoshi Fujihara, Wee Eong Tee, Teck Cheng Lim, Zaveri Ma, World Sci. Pub. Ltd. Singapore, 2005. • **Publisher:** World Scientific Publishing Co Pte Ltd (8 May 2005) **ISBN-13:** 978-9812564542
3. Springer Handbook of Nanotechnology - Bharat Bhusan • **Publisher:** Springer-Verlag (15 May 2006) **ISBN-13:** 978-3540343660
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009. **Publisher:** CRC Press (15 December 2008) **ISBN-13:** 978-1420047790
5. Introduction to Nanoscale Science & Technology, Di Ventra, Evoy, Heflin, Springer Science, NY, 2004. • **Publisher:** Springer; 1 edition (30 June 2004) **Sold by:** Amazon Asia-Pacific Holdings Private Limited
6. Nanofabrication- Fundamentals and Applications, By Ampere A Tseng, World Scientific, Singapore 2008. • **Publisher:** World Scientific Publishing Co Pte Ltd (18 March 2008) **ISBN-13:** 978-9812705426
7. Nanoparticles and Nanostructured Films- Preparation Characterization and Applications by Janos H. Fendler, WILEY-VCH Verlag GmbH. D-69469 Weinheim (Federal Republic of Germany), 1998. • **Publisher:** Wiley VCH (28 May 1998) **ISBN-13:** 978-3527294435
8. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens • **Publisher:** Wiley-Interscience; 1 edition (30 May 2003) **Sold by:** Amazon Asia-Pacific Holdings Private Limited

NST.202 **4004**

CHARACTERIZATION TECHNIQUES OF NANOMATERIALS

UNIT- I – Spectroscopic Techniques

X-ray Spectroscopy: Powder XRD, Small angle X-ray diffraction, GIXRD, and Single crystalline X-ray diffraction. X-ray fluorescence spectroscopy (XAFS). X-ray Photoelectron Spectroscopy (XPS), Ultraviolet Photoelectron Spectroscopy (UPS). Vibrational Spectroscopy: Raman and IR spectroscopy. Fourier Transfrom techniques- FT-IR and FT Raman. Electronic Spectroscopy: Absorption and Emission Spectroscopy.

UNIT – II – Microscopic Techniques

Scanning Electron Microscopy (SEM), Transmission Electron Microscopy (TEM).. Scanning Probe Microscopy: Atomic Force Microscopy, Scanning Tunneling Microscopy (STM), Near field scanning optical microscopy (NSOM). Confocal Laser Scanning Microscopy.

UNIT – III - Techniques for Thermal & Mechanical Analysis

Thermal Analysis: TGA, DTG, DTA, DSC - combustion calorimetry- Thermal diffusivity by the laser flash technique- simultaneous techniques including analysis for gaseous products. Mechanical testing- Introduction, tension testing, High strain rate testing of materials, Fracture Toughness testing methods, Hardness testing.

UNIT - IV - Magnetic & Electrochemical Techniques

Magnetic Vibrating Sample Magnetometer, Mossbauer spectroscopy, ESR, NMR. Magneto-optic Kerr effect. Electrochemical Techniques: Cyclic voltammetry, Electrochemical Impedance, Scanning electrochemical Microscopy, The quartz crystal micro balance.

Text Books

1. Introduction to Nanoscience and Nanotechnology, by K K Chattopadhyay, PHI Learning Pvt. Ltd. New Delhi 2019, **ISBN-13:** 978-81-203-3608-7.
2. Characterization of Materials Vol 1 &2, by Elton N. Kaufmann, John Wiley and Sons Publication, 2003. New Jersey.
3. Principles of instrumental analysis, Douglas A Skoog, Donald M West, Saunders College, Philadelphia. • **Publisher:** Cengage; 6 edition (1 November 2014) **ISBN-13:** 978-81-315-25579.
4. NANO: The Essentials- Understanding Nanoscience and Nanotechnology, by T Pradeep, Tata McGraw Hill Education Pvt. Ltd. New Delhi) **ISBN-13:** 978-0-07-061788-9
5. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander • **Publisher:** Wiley-Blackwell; 2nd Revised edition edition (1 January 1974) **ISBN-13:** 978-0471493693
6. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter • **Publisher:** Springer; 1st ed. 1996. Corr. 6th printing edition (15 April 2005) **ISBN-13:** 978-0306453243
7. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton • **Publisher:** Springer; Softcover reprint of hardcover 1st ed. 2005 edition (12 October 2010) **ISBN-13:** 978-1441938374
8. Springer handbook of Nanotechnology ed. Bharat Bhushan (Springer) • **Publisher:** Springer-Verlag (15 May 2006) **ISBN-13:** 978-3540343660

NST.203 **4 0 0 4**

BIO-NANOMATERIALS

UNIT – I Biomimetics /Bio-inspired Nanomaterials

Biomimetic approach - biomineralization-extracellular, intracellular and intercellular. biominerals-structure, properties and examples. $CaCO_3$ mineralization - calicite, aragonite, valerite and amorphous. Natural nanocomposite systems as spider silk, sea urchin, abalone, crab shell, bones.
Bio-inspired approach for the synthesis of nanoparticles. Bio-controlled growth of oxides and metallic nanoparticles, hydrogels based on bio-inspired assemblies for injectable biomaterials, bioassay.

UNIT – II Nanomaterials for Diagnostics and Therapeutics

Nano-carriers – application and requirements. Liposomes, polymers (dendrites, polymer drug conjugates, polymer-protein conjugates, polyplexes, micelles, nanogels), quantum dots, metal nanoparticles and magnetic nanoparticles for diagnostic and therapeutic application of Cancer, Drug and gene delivery. Needs and requirements, injectable nanoparticles. Molecular labels-metal nanoparticles, quantum dots, magnetic nanoparticles.

UNIT – III Nanomaterials for Tissue Engineering

Introduction, Artificial implants, scaffolds used for tissue engineering based on nanomaterials – bones, skin and neurons. Osteogenisis : Different grafting methods - merits and demerits, Simulated Body Fluid (SBF), Bone-bonding mechanism of bioactive materials, Bioactive Nano-hybrids-Silicate, Methacryloxy compounds, other than Silicate, calcium phosphates, Bone-like Hydroxyapatite and Polymers.

UNIT – IV Nanomaterials for Bio Electronics

Nanoparticle-biomaterial hybrid systems for bioelectronic devices, nanoparticle-enzyme hybrids; bio-recognition. Biomaterial based metallic nanowires, networks and circuitry. DNA as functional template for nanocircuitry; Protein based nanocircuitry. MEMS and NEMS in medicine and surgery, Biosensor and Biochips.

TEXT Books

1. Bio-inorganic Hybrid Nanomaterials - Strategies, Syntheses, Characterization and Applications, by Eduardo Ruiz-Hitzky, Katsuhiko Ariga and Yuri Lvov, **2008** WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. **Publisher:** Wiley VCH; 1 edition (12 December 2007) **ISBN-13:** 978-3527317189
2. Bionanotechnology: Lessons from Nature by David S. Goodsell **Publisher:** Wiley India Pvt Ltd (30 October 2012) **ISBN-13:** 978-8126538362
3. Nanobiotechnology; ed. C.M.Niemeyer, C.A. Mirkin. **Publisher:** Wiley India Pvt Ltd (29 October 2012) **ISBN-13:** 978-8126538409
4. Nanocomposite Science & Technology Ajayan, Schadler & Braun **Publisher:** Wiley VCH (12 September 2003) **ISBN-13:** 978-3527303595
5. BioMEMS (Microsystems) - Gerald A. Urban **Publisher:** Springer; 2006 edition (3 April 2006) **ISBN-13:** 978-0387287317
6. Nanosystems: Molecular Machinery, Manufacturing, and Computation - K. Eric Drexler **Publisher:** Wiley; 1 edition (October 13, 1992) **ISBN-10:** 0471575186
7. Nanofabrication towards biomedical application: Techniques, tools, Application and impact – Ed. Challa S., S. R. Kumar, J. H. Carola. **Publisher:** Wiley-VCH; 1 edition (April 15, 2005) **ISBN-10:** 3527311157
8. Tissue Engineering-Bernhard O. Palsson , Sangeeta N. Bhatia **Publisher:** Prentice Hall; 1 edition (August 9, 2003) **ISBN-10:** 0130416967
9. Principles of Tissue Engineering - Robert Lanza, Robert Langer, and Joseph P **Publisher:** Academic Press; 4 edition (November 29, 2013) **ISBN-13:** 978-0123983589

NST.204 **4 0 0 4**

PROPERTIES AND APPLICATIONS OF NANOMATERIALS

UNIT I Electronic and Electrical properties

Introduction- Nano electronics - Fundamental types of electronic nanomaterials. Microelectronics - Band structure- conductor and semiconductor. Electrical conductivity in nanotubes and nanorods and nanocomposites. Photoconductivity of nanorods. Electronic transport in nanostrutures, Quantum waveguides, single electron transfer devices (SETs), Electron spin transistor – resonant tunnel devices - quantum interference transistors (QUITs).

UNIT II Optical and photonic Properties:

Interaction of light with matter. The nano perspective. The surface plasmon – SPR and scattering – color generation from nanoparticles and nanostructures- applications of nanoplasmonics. Quantum dots – Optical properties related to quantum confinement.Special luminescent nanocomposites- electroluminescence- photochromic and electrochromic nanomaterials.

Confinement and propogation of photons. Internal reflection and evanescent waves, Near Field Optics- near field scanning optical microscopy (NSOM or SNOM). Nanophotonic and Plasmonic Applications: nanolasers; nanoantennas; photonic crystals; optical communication; sensing; negative refraction; metamaterials; cloaking; nanostructures for large-area opto-electronics.

UNIT III Magnetic Properties:

Introduction – magnetic phenomena and their classical interpretation- the nanoperspective. Introduction to nanomagnetism- characteristics of nanomagnetic materials- Magnetization and nanostructures. Superparamagnetic particles- susceptibility and related phenomena in superparamagnets- Magnetism in reduced dimensional systems- Two, one and zero dimensional systems. Physical properties of magnetic nanostructures - exchange coupled magnetic nanomaterials- spin –polarized tunneling- magnetoresistivity, GMR. Spintronics, Magneto electrical effects, ferrofluids, molecular nanomagnets, data storage applications of magnetic nanoparticles, Spintronic devices and applications.

UNIT IV Mechanical & Thermal properties:

Nanomechanics- Introduction- three atom chain- lattice mechanics- linear elasticity relations – molecular dynamics. Structure and mechanical properties of carbon nanotubes- nanomechanical measurement techniques- AFM – Nanoindentation. Nanothermodynamics:- Thermodynamics the nano perspective – Background- application of classical thermodynamics to nanomaterials- small system thermodynamics. Modern nanothermodynamics- Nonextensivity and nonintensivity – nanothermodynamics of a single molecule – modeling nanomaterials.

Text Books/References:

1. Nanomaterials – An Introduction to synthesis, Properties and Applications, by Dieter Vollath, Wiley – VCH Verlag GmbH & Co. Germany, 2008.
2. Properties of nanomaterials by Charles P. Poole
3. The Physics & Chemistry of Nanosolids by Frank J. Owens and Charles P. Poole Jr. , John Wiley & Sons, Inc. New Jersey 2008.
4. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009.
5. Introduction to Nanoelectronics, by V. Mitin, V. Kochelap, M. Stroscio, **Cambridge University Press (2008).**
6. Nanoelectronics and Photonics: From Atoms to Materials, Devices,and Architectures by Anatoli Korkin l Federico Rosei, **2008 Springer Science, Business Media, LLC.**
7. Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices, by Rainer Waser, **Wiley-VCH (2003).**

8. Nanoelectronics and Nanosystems, by Karl Goser, Peter Glosekotter, Jan Dienstuhl, **Springer (2004**).
9. Nanotechnology & Nanoelectronics, Materials, devices, measurement techniques, by W. R. Fahrner(Editor), **Springer, 2005**
10. Principles of Nanophotonics, by Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe,Takashi Yatsui,Makoto Naruse**, CRC press 2008 by Taylor & Francis Group**
11. Semiconductor Quantum Dots, L. Banyai and S.W.Koch, **World Scientific (1993).**
12. NanoBiophotoics, H. Masuhara, S. Kawata and F. Tokunga, **Elsevier Science, (2007).**
13. Fundamentals of Photonics, B. E. A. Saleh and A. C. Teich, John Wiley and Sons, NewYork, (1993).
14. Introduction to Biophotonics, P. N. Prasad **John Wiley and Sons, (2003).**
15. Molecular Nanomagnets, Dante Gatteschi, Roberta Sessoli, Jacques Villain, Oxford **University Press 2006, USA.**
16. Concepts in Spin Electronics, Sadamichi Maekawa, **Oxford University Press (2006).**
17. Nanomagnetism and Spintronics: Fabrication, Materials, Characterization and Applications
18. Farzad Nasirpouri , Alain Nogaret **Publisher:** World Scientific Publishing Company; edition (December 21, 2010) **ISBN-10:** 9814273058
19. Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Edward L. **Wolf Wiley-VCH (2006).**
20. Biomineralization: Principles and Concepts in Bioinorganic Materials Chemistry. Mann, S., **2001. New York, Oxford University Press.**
21. Nanoscale Technology in Biological Systems, Edited by Ralph S. Greco, Fritz B. Prinz, R. Lane Smith**, CRC Press, USA, 2005.**
22. Nanoparticle Technology for Drug delivery, Ram B.Gupta, Uday, B.Compella, **2006 Taylor & Francis Group, LLC, NY.**
23. Nanoparticulates as Drug Carriers, Vladimir Ptorchilin, **Imperial College Press, London, 2006.**
24. Hybrid Nanocomposites for Nanotechnology, Electronic, Magnetic, Optical and Biomedical Applications,by Lhadi Merhari, **Springer USA 2009.**

NST.205 NANO LAB – II 0 0 4 4

List of Experiments:

1. Operation of Electrochemical Workstation
2. Deposition of Polyaniline on ITO/FTO using Electrochemical Workstation.
3. Structural elucidation of Electrodeposited polyaniline using FTIR
4. Chemical Synthesis of Magnetic nanoparticles and size determination.
5. Electrochemical synthesis of TiO2 Nanostructures. Optical Studies by using UV-VIS spectrophotometer. Electronic structure analysis by using Cyclic Voltammetry.
6. Electrochemical Synthesis of ZnO nanorods - Optical Studies by using UV-VIS spectrophotometer. Electronic structure analysis by using Cyclic Voltammetry.
7. Thin film deposition of TiO_2 and ZnO by Electrochemcial method – Study the optical and electronic properties.
8. Compare the results of 1D structure with 2D thin films of both TiO_2 and ZnO.
9. Thin film preparation using spin coating method and thickness measurement using Profilometer.
10. Hall measurements of electrodeposited TiO2 thin films

PROFESSIONAL COMPETENCY COURSE (PCC)

UNIT I - Scientific Writing and Communication Skill

Writing and communication skill is very much essential to express scientific ideas or results clearly to validate their significance. For the successful publication of a research work, development of scientific writing skill is essential. Writing Research report, research proposals. Every aspect of writing scientific grants from funding agencies. Introduction to every aspect of grant writing, including selecting funding mechanisms, writing individual grant sections and understanding administrative policies. Strategies for effective scientific writing-core elements of each sections- Principles of writing research manuscript by composing and editing the sections- Familiarization with reference manager- how to peer review an article from the perspective of a researcher- reviewer- journal editor – complete and submit a research manuscript (based on an abstract given). Patent filing.

UNIT II - Integrity in Scientific Research

Familiarize the graduate students with the basic ethical issues confronted by the scientist. To gain insight into how one can responsibly conduct research throughout their career - To know how to properly address unethical situations- To realize that new ethical issues/ concerns will arise and that the best way to tackle these will be to discuss ethical situations with colleagues, seek guidance from proper channels, and routinely participate in conduct of research training courses/ seminars. Importance of team work, group discussion and collaborative research (MOU etc.), Know about plagiarism.

UNIT III - Individual Development Plan

Individual development plan is intended for the graduate students before they go on to job market. Give opportunity to the participants to evaluate their own values and interests as they relate to their professional careers. Introduce the students to three or four different career tracks such as industry (profit or non profit), government sector, academic, scientific institution, etc.. ask the student to identify the skill areas they would like to develop.

UNIT IV - Fundamentals of Technology Commercialization

Innovative transformation of scientific and technical knowledge into commercial products and services. Importance of cross-disciplinary teams of students to asses real technologies for commercial applications with a specific focus on developing an understanding of the commercialization process, and skills in licensing and new venture development. Introduce concepts that improve and accelerate the commercialization process. From decisions made by scientists at the research bench, through the development, patenting, and licensing of new technologies, to the formation of entrepreneurial enterprises and monetization of assets. Data sharing with stake holders.

NST.301 **4 0 0 4**

ADVANCED NANOMATERIALS

UNIT – I Carbon Nanostructures

Introduction:- Diamond – Graphite- Fullerenes, CNTs and Graphene. Synthesis: CVD, Laser and Electrochemical and other methods. Functionalization and reactivity of CNTs, Covalent Functionalization -Oxidative Purification, Defect Functionalization –Sidewall Functionlaization, Noncovalent Exohedral Functionalization, Endohedral Functionalization.

UNIT- II Special Nanomaterials

Micro & Mesoporous Materials - Ordered mesoporous structures, Random mesoporous structures, Crystalline microporous materials: zeolites. Core – Shell Structures - Metal-oxide structures, Metal-polymer structures, Oxide-polymer structures. Organic-Inorganic Hybrids- Class I hybrids, Class I1 hybrids, Intercalation Compounds.

UNIT III Ultra Hard Smart Materials

Introduction- synthesis properties and applications of ultra nanocrystalline diamond-growth,electronic properties and application of nanodimond. Dimond like materials- CNTS and Nitrides, C_3N_4-Boron nitride etc.

UNIT – IV Nanocomposites

Introduction to Nanocomposites – Layered Silicates-Polyamide-clay nanocomposites. Epoxy nanocomposites based on layered silicates and other nanostructured fillers. Biodegradable polymer silicate nanocomposites. Metal Polymer Nanocomposites-synthesis- Ex-situ and in-situ approaches-Optically anisotropic metal –polymer nanocomposites. Conducting nanocomposite systems- Introduction, classification and host guest materials for nanocomposite systems.

Text Books & References

1. Carbon Materials & Nanotechnology, By Anke Krueger, Wiley VCH Verlag **GmbH & Co. KGaA, 2010, Weinhein.**
2. Dimond Nanotechnology- Synthesis and Applications, by James Sung, Pan **Stanford Publishing (July 31, 2009)**
3. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, **Imperial college press, 2004.**
4. Polymer nanocomposites, Edited by Yiu-Wing Mai and Zhong-Zhen Yu, **CRC Press, Woodhead Publishing Limited, 2006.**
5. The New Frontiers of Organic and Composite Nanotechnology, Victor Erokhin, Manoj Kumar **Ram and Ozlem Yavuz, 2008 Elsevier Ltd.**
6. Metal – Polymer nanocomposites by Luigi Nicolais and Gianfranco Carotenuto, **John Wiley & Sons, Inc. 2005.**
7. Nanoscale materials -Liz Marzan and Kamat **Publisher:** Wiley; 2 edition (2009)
8. Synthesis functionalization and surface treatment of nanoparticles - Marie Isabelle Baraton
9. Physical properties of Carbon Nanotube-R Satio **Publisher:** Am. Sci. Publishers (2002)
10. Applied Physics Of Carbon Nanotubes : Fundamentals Of Theory, Optics And Transport devices , S. Subramony & S.V. Rotkins **Publisher:** Springer; 2005 edition.
11. Carbon Nanotubes: Properties and Applications- Michael J. O'Connell **Publisher:** CRC Press; edition (2006)
12. Nanotubes and Nanowires- CNR Rao and A Govindaraj RCS Publishing **Publisher:** Royal Society of Chemistry.
13. Nanosilicon by Vijay Kumar, Elsevier Ltd. UK ,2007. **Publisher:** Elsevier Science (2014)

NST.302 **4 0 0 4**

MICRO/NANO ELECTRO MECHANICAL SYSTEMS (MEMS/NEMS)

UNIT I

Overview of micro electro mechanical devices and technologies. Introduction to architecture design, Process flow, Fabrication, Packaging and testing. MEMS Fabrication, Deposition, lithography, and etching, Surface micromachining, Bulk micromachining, Bonding technologies, LIGA technology and related fabrication methods

UNIT II

MEMS device concepts (micro sensors/actuators), Use of capacitive, Inductive, Optical, piezoresistive, Piezoelectric methods for sensing. MEMS Applications, Accelerometers and gyros, Pressure sensors, Micro optics, etc. Microsystems Packaging

UNIT III

Introduction to existing and next-generation metrology tools for MEMS and NEMS inspection and qualification. Theoretical principles of metrology and experimental work on characterization of prototype MEMS and NEMS devices.

UNIT IV

Cross-disciplinary application of MEMS and NEMS to the biological sciences. Interaction of living cells/tissues with nanofabricated structures, Microfluidics for the movement and control of solutions - the development of I/O architectures for efficient readout of bioreactions.

References

1. Mohamed Gad – el – Hak, "The MEMS Handbook", Second Edition, CRC Press, 2005.
2. James J. Allen, "Micro Electro Mechanical System Design", CRC, 2005.
3. K. Subramanian, "Micro Electro Mechanical Systems: A Design Approach", Springer, 2008.
4. Tai-Ran Hsu, MEMS and Microsystems- Design, Manufacture and Nanoscale Engineering, John Wiley & Sons, INC. 2008. **ISBN:** 978-0-470-08301-7.

NST.303 **2 0 0 2**

SOCIETAL & ENVIRONMENTAL IMPACT OF NANOTECHNOLOGY

UNIT I Ethics and Society

Introduction to societal issues- societal implications – the background- breadth of societal implications – meet the experts- the nano perspective. Ethical implications – Ethics in the context of research and applied science- principle of respect for communities- principle of the common good- principle of social justice- you as moral agent. Public perception: Factors influencing public perception- nano and public opinion polls- A call for two way communications.

UNIT II Intellectual Property Rights (IPR)

Types of IP: Patents, Trademarks, Copyright & Related Rights, Industrial Design, International framework for the protection of IP. International Databases; Country wise patent searches (USPTO, EPO, India etc.). Indian and International Patents; Patent application forms and guidelines, fee structure, time frames, Financial assistance for patenting. IPR policy of Government of India, Indian & International Patent laws,

UNIT III Health and Environmental risk

Developing Environmental Regulations Pertinent to Nanotechnology, Analyses of Nanoparticles in the Environment, , Ecological hazards of nanomaterials. Assessing nanotechnology health risk, treatment of nanoparticles in waste water, nanoparticles in pollutioncontrol, Development of sustainable nanotechnology.

UNIT -IV Toxicology and Safe Handling

Toxicology and risk assessment, determination of potential toxicity, nanoparticles in work place, biodistribution and interaction of nanoparticles, nanoparticle dose in humans- issues and challenges.

Text Books:

1. Nanotechnology: Ethics and Society, Deb Bennett-Woods, CRC Press, Tylor & Francis Group New York,2008.
2. Nanotechnology , Legal Aspects, by Patrick M. Boucher, CRC Press, Tylor & Francis Group New York,2008.
3. Nanotechnology and the Environment, Kathleen Sellers, Christopher Mackay, Lynn L. Bergeson,Stephen R. Clough, Marilyn Hoyt, Julie Chen, Kim Henry, Jane Hamblen, CRC Press, Tylor & Francis Group New York,2009.
4. Nanotechnology: Health and Environmental Risks, Jo Anne Shatkin, CRC Press, Tylor & Francis Group New York, 2008.
5. Nanotoxicology, Characterization, Dosing and Health Effects, Nancy A. Monteiro-Riviere, C. Lang Tran, Informa Healthcare USA, Inc. 2007.
6. Introduction to Nanoscience & Nanotechnology by Gabor L. Hornyak, Harry F. Tibbals, Joydeep Dutta, John J. Moore, CRC Press, Tylor & Francis Group New York, 2009.
7. P. Narayanan, Intellectual Property Laws, Eastern Law House.2001
8. Meenu Paul, Intellectual Property Laws, Allahabad Law Agency.2009
9. Intellectual Property Law containing Acts and Rules, Universal Law Publication Company.

NST.304-A **4 0 0 4**

NANOMATERIALS FOR ENERGY CONVERSION AND STORAGE

UNIT – I Primary perspective in energy conversion

Current energy scenario; Energy and climate:- Green house effect, conventional energy sources Vs non conventional energy sources. Outline of alternative energy schemes – solar, wind, biomass, hydro, and nuclear. Clean low cost, sustainable energy development, prospects of renewable energy.

UNIT –II Electrochemical Energy conversion

Electrochemical Cell, Polarization losses in electrochemical cells, Thermodynamics of electrochemical energy conversion, Efficiency of electrochemical energy conversion, and Electrode kinetics. Fuel Cells- relevance and importance, classification of fuel cells, Proton exchange membrane fuel cells (PEMFC); Direct methanol fuel cells (DMFC); Solid-oxide fuel cells (SOFC), Issues and challenges of functional nanostructured materials for electrochemical energy conversion systems.

UNIT-III Photovoltaic Solar Energy Conversion

Properties of sunlight: Solar radiation at earth's surface- Air Mass. Principles of photovoltaic energy conversion (PV), Types of photovoltaic Cells. Si solar cells- Structure, and working. Fundamentals of nanostructured solar cells, nanostructures in conventional thin film solar cells. Dye sensitized solar cells(DSSC), Quantum dot sensitized solar cells (QDSSC), Organic solar cell, Organic-Inorganic Hybrid Bulk Hetero Junction (BHJ-SC) Solar cells, Nanostructured ETA solar cells, Current status and future direction.

UNIT-IV Energy Storage

Primary and Secondary Batteries-Lithium ion Batteries, nanostructured cathode and anode materials. Capacitors, Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon based materials, nano-Oxides, and conducting polymers based materials, Issues and Challenges.

Text Book/Reference

1. Nanostructured Materials for Solar Energy Conversion, By Tetsuo Soga, 2006 Elsevier B.V. All rights reserved.
2. PVCDROM, http://pveducation.org/pvcdrom
3. Aldo V. da Rosa, *Fundamentals of Renewable Energy Processes, 2nd Edition* (Elsevier Academic Press, 2009).
4. Fuel cells- principals and Applications, by B.Viswanathan, M.Aulice Scibioh, Universities Press, India, 2006.
5. Green Chemistry and Chemical Engineering, Pronton Exchange Membrane Fuel Cells Contamination and Mitigation Strategies, By hui Li, Shanna Knights, Zheng Shi, John W. Van Zee, Jin Jun Zhang, Taylor and Francis Group, 2010, USA.
6. Martin A. Green, *Solar Cells: Operating Principles, Technology, and System Approaches* (Prentice-Hall, 1998)
7. Jenny Nelson, *The Physics of Solar Cells* (Imperial College Press, 2003)
8. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw-Hill, New York (1995)
9. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kulwer Acdemic Publishers, Dordrecht, Netherlands (2004).
10. J. Larmine and A. Dicks, Fuel Cell System Explained, John Wiley, New York (2000).

NST.304 – B **4 0 0 4**

SUSTAINABLE NANOMATERIALS

UNIT – I

Environmental pollution and hazards: Toxicity of chemicals and their characterization, R&S Numbers, material safety data sheet (MSDS), highly toxic nanomaterials.

UNIT – II

Environmental Pollution content Act (USEPA) 1990, Green chemistry, 12 principle of green chemistry, atom economy, alternative solvents, renewable materials, etc.

UNIT – III

Green methods for nanomaterial synthesis, use of supercritical carbon dioxide, ionic liquids, RESS process, use of green reagents (citrate and glucose based synthesis of metal nanoparticles) biosynthesis of nanostructures, template-free synthesis of mesoporous silica and metal oxide

UNIT-IV

Environmental application of nanomaterials. Water purification system, systems for harvesting solar energy, mesoporous materials for naked eye detection of toxic metal ions in water (mesosporous silica) self –cleaning materials, non-wetting glasses, super hydrophobic coatings etc.

References

1. Paul T. Anastas and John C. Warner, Green Chemistry : Theory and Practice, Oxford University Press (2000)
2. Paul M. Matlack, Introduction to Green Chemistry, CRC Press, 2nd ed. (2010)
3. Geoffrey B. Smith, Green Nanotechnology: Solutions for Sustainability and Energy in the Built Environment, CRC Press (2010)
4. P. Raveendran, Jie Fu & S.L. Wallen. Completely “green” synthesis and stabilization of metal nanoparticles. J.Am.Chem.Soc.(2003), 125, 13940-41