REGULATIONS, SCHEME AND SYLLABUS

FOR

M.Tech. PROGRAM IN

NANOSCIENCE & TECHNOLOGY

(2020 Admission)

School of Nanoscience & Nanotechnology

Mahatma Gandhi University

Kottayam, Kerala, India.

Regulations, Scheme & Syllabus of M.Tech. Program in Nanoscience & Technology

TITLE

International and Inter University Centre for Nanoscience & Nanotechnology, Mahatma Gandhi University would like to launch an M.Tech Program, which is designed to attract highly motivated science and Engineering graduates. This program would admit 12 numbers of bright, highly motivated students with excellent academic record at the graduate level. Upon successful completion of two years in the program candidates will be awarded a Master's Degree (M. Tech. Nanoscience and Technology) under the faculty of Technology and Applied Sciences.

DEFINITIONS

Program refers to the previous concept of degree carried out in a time-bound academic period.

Course means the curricular content for teaching and learning or seminar in a specific area or theme of knowledge.

Core Course means a compulsory course in a subject related to a particular program.

Elective course means an optional course which can be selected from among a group of electives provided in the program

Semester system: The M.Tech. Program will have four semesters. There shall be a minimum of 540 hours distributed over 90 working days in each semester spread over l8 five day working weeks.

Credit (c) is the unit by which a course is measured. It is the measure of total numbers of hours of training received in a course during a semester.

Grade means a letter symbol (e.g. A, B, C. etc) which indicates the broad level of performance of a student in an answer/course/semester/program.

Weight is a numerical measure quantifying the comparative range of an answer or the comparative importance assigned to different components like theory (internal and external examinations) Internship, Dissertation etc.

Grade point (G) is the weightage allotted to Grade letter

Credit point (C) refers to the product of number of credits of a course and grade point obtained by a student for a given course

Semester Grade Point Average (SGPA) refers to the performance of the student in a given semester. SGPA is a weighted average based on the total credit points earned by a student in all the courses in the semester divided by the total number of credits offered in a semester. SGPA will be computed as and when a student completes all the required courses of a semester with a minimum required grade as per the respective curriculum.

Cumulative Grade Point Average (CGPA) refers to the performance of the student for all semesters of the program. CGPA is a weighted average based on the SGPA earned by a student in all semesters of the program and the total number of credits required in the program.

CGPA is calculated on the basis of SGPA with the minimum required SGPAs of all semesters may not be sufficient to obtain the minimum fixed CGPA for pass in the program.

Grade Point Average (GPA) is the value obtained by dividing the sum of the weighted grade points obtained by a student in an examination of a course in a semester by the total weightage taken in that examination. The grade point average shall be rounded off to two decimal places.

Conditions for Admission

Eligibility for Admission

The basic requirement for admission to M. Tech. Program will be

i) M. Sc in Nanoscience and Nanotechnology, Physics, Chemistry, Materials Science, Polymer science or an Equivalent degree with not less than 50% Marks

or

ii) B. Tech in Nanoscience and Nanotechnology or Chemical Engineering/Technology or Polymer Engineering/Technology or Electronics and Communication or Biotechnology or Material Science or an Equivalent degreewith not less than 50% marks.

iii) Subject to the regulation relating to prescribed minimum of the respective qualifying examination, the minimum marks for the admission to the course of studies shall be a pass in the case of SC/ST candidates.

iv) Candidates belonging to Socially and Educationally backward classes (SEBC) referred to GO(P)208/66Edn dated 2-5-96 and subsequent amendments to the order issued by the Government shall be given a relaxation of 2% marks in the prescribed minimum for the admission

v) A relaxation of 5% marks from the prescribed minimum shall be allowed in the case of physically handicapped persons.

vi) Candidates who have passed the qualifying examination in more than one chance in the subject (excluding languages) will have their percentage marks de-rated at the rate of 5% for every additional appearance for the purpose of ranking.

Mode of Selection

Admission shall be normally restricted to those with valid GATE score on merit basis. In case, seats remain vacant due to lack of candidates with valid GATE score, candidates will be considered on the basis of an entrance test.

The proposed intake for each program is as follows.

M. Tech. in Nanoscience & Technology:

Regular Students (Indian Citizens) : 10

Other Nationalities : 02

If suitable number of applicants under other Nationalities is not received, these seats will remain unfilled.

Reservation of Seats

As per existing Government ordersfrom time to time.

Duration of the Course

The course shall extend over a period of two academic years consisting of four semesters

Courses and Credits:

Three kinds of courses are offered – Core Courses, Elective Courses and Laboratory courses. Core Courses and Laboratory courses are offered by the Centre conducting the program. Elective Courses can be selected either from the parent Centre or from some other Schools. The Faculty Advisor in each School shall help the students in selecting Electives that are relevant to the program for which they are admitted. Each course is allotted credits varying from 2 to 4 depending on the hours of instruction / practicals. (A 4- credit course, in general, is one which normally involves four hours per week of class room teaching or lecture / seminar/ practical lessons).

Credit Requirements:

The minimum total credits required for the successful completion of M.Tech. program shall be **80.**

In the first Semester,a student has to secure minimum of **24credits** [16 Credits (Core) + 8 Credits (Elective)].

In the Second Semester a student has to secure minimum of **22 credits** [14 Credits (Core) + 8 Credits (Elective)].

In **Semester III and IV** of this program, the student has to acquire **34 credits** exclusively dedicated for the project dissertation; viva and thesis defence and Comprehensive Viva voce upon successful completion of 2 semesters.

A student can with the permission of his/ her Department / School and with the consent of the faculty concerned, audit a course in any other School/ Department. The student, however, cannot earn any credit from the audited courses.

The Compulsory project/dissertation shall be prepared by the student under the guidance of a member of the faculty or, in the case of subjects, which so demand, with an external guide, to be decided by the school's faculty council, The project shall generally be offered in the last semester, though the faculty council can decide to have it in one of the earlier semesters. The topic for the project shall be selected by the student in consultation with the guide. The topic thus chosen will have to be approved by the school's faculty council before the student can start work on it. In the case of projects done out of the school one of the examiners shall be external experts.

Faculty Council:

The Faculty Council shall consist of all the regular and permanent teachers of the Department / Centre. The Head of the Department shall be the Chairman of the Faculty Council. He shall preside over the meetings. The Faculty Council shall have a secretary, elected from among the teachers of the Department. The teachers shall as a matter of duty attend the meetings of the Council. The Council shall meet at least once in every month.

Faculty Advisor:

Each student admitted to a course will be affiliated to a Faculty Advisor, who shall advise the student on the elective and other courses in the parent Department as well as in other Departments that he / she might choose.

Course Teaching:

Courses shall generally be taught by the faculty who designed the course, though it is possible for the Faculty Council to assign the teaching of a course to more than one faculty.

Internal Assessment:

The student's attendance and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form basis for internal assessment. The internal assessment will account for 40% of evaluation. The internal assessment marks shall be distributed as follows and as per regulation in 8 and 10 of CSS regulations 2020.

a) Theory

a) Components % of internal marks

1)	Two test papers	60%
2)	Assignments/Book Review/debates	20%
3)	Seminars/Presentation of case study	20%

b) Practicals

Components % of internal marks

1)	Two test papers	40%
2)	Lab Skill	25%
3)	Records/viva	25%
4)	Attendance	10%

Improvement Course:

Viva-voce:

The viva-voce at the end of the program, which accounts for 5 credits, shall be conducted by a Board of Examiners constituted by the School's Faculty Council from among themselves. The Board will in addition have an External Expert from outside the University to be appointed by the Department/School on the advice of the Faculty Council from a panel approved by the Vice Chancellor. The grading by the Board shall be by consensus.

A relaxation time of three months can only be given to those candidates with unexceptional delay in joining back after their overseas research program. Students

with extended delay after the relaxation time, he/she has to re-register for the entire semesters described in the program for completion of the course.

Scrutiny and Revaluation:

The answer scripts of examinations under CSS shall have provisions for scrutiny and revaluation. The application for scrutiny and revaluation of answer scripts shall be submitted to the Director of the concerned School within 15 days and 21 days respectively from the date of publication of the results.

Readmission: Readmission will be permitted as per the existing University rules and orders.

Grading System:

The grading system followed is that of relative grading on a ten-point scale. The following table indicates the performance range and the value of the grades (grade points) on the scale.

Letter grade	**Performance**	**Grade Point**
O	Outstanding	10
A Plus	Excellent	9
A Only	Very Good	8
B Plus	Good	7
B Only	Above Average	6
C	Average	5
P	Pass	4
F	Fail	0
Ab	Absent	0

The Grade Card given to the student at the end of each semester will indicate the grades he/she has obtained as well as the Semester Grade Point Average (SGPA) which is the weighted average of the numerical value (grade point) obtained by him / her in the semester. Weighted average is calculated by dividing the sum of the product of the grade point or numerical value obtained for each course and the

credits that it carriers by the total number of credits earned. The Cumulative Grade Point Average (CGPA) for the whole program will be calculated in the same way, which will also be indicted in the Grade Card. The minimum graduating CGPA for all programs shall be 5.0

Percentage Equivalence of Grade

Wherever an examination awards marks, either in the assessment or in the end semester examination, percentage of marks awarded will be converted into grades according to the following formula:

Range of % of Marks	**Grade**
95 % ≤ 100	**O**
85 % < 95	**A Plus**
75 % < 85	**A Only**
65 % < 75	**B Plus**
55 % < 65	**B Only**
45 % < 55	**C Only**
40 % < 45	**P Only**
Below 40	**F**
Absent	**Ab**

Consolidation and Declaration of Results and Issue of Grade Cards:

All work pertaining to the Examinations shall be held in the Schools/ Departments of study and research under the direct control and supervision of the Directors/ Heads of the Departments. The Director of each School will, in consultation with the Faculty Council, nominate a senior teacher as the Chief Examiner who will help him/her in the matter. The marks awarded for internal assessment will be displayed in the School's notice board at the end of each semester. The Pass Board will consist entirely of the faculty of the Centre and will be constituted by the director on the advice of the Faculty Council. The tabulated Grade sheets will be forwarded after

each end – semester examination to the office of the Controller of the Examinations. The CSS section in the Controller's office will check the Grade Card for any errors and notify the results after consolidating them.

On completion of the final semester a consolidated Grade Card showing the details of all the courses taken during the program will be issued to the students. The consolidated Grade Card will contain the details of all the courses with their titles, credits, grades obtained, the total credits earned, the SGPA and the CGPA.

REQUIREMENTS OF ATTENDANCE AND PROGRESS

A candidate will be deemed to have completed the requirements of study of any semester and permitted to appear each University end semester examinations (ESE) only if,

a) The candidate has not less than 75% of attendance in each of the subjects of the total number of working days of the concerned semester.

b) His/her progress has been good

c) His/her character and conduct has been good

d) She/he has minimum of 50 % of sessional marks for each subject.

A student who has an attendance and sessional marks lower than 75% and 50% respectively will not be permitted to appear for the ESE and he/she has to redo the semester at the next available opportunity. However, a candidate can repeat the course or avail condonation of attendance for temporary break of study, only once during entire program as per existing University rules

PROCEDURE FOR COMPLETING COURSE

The academic year will be divided into four semesters, the odd semester normally commencing at the beginning of the academic year and even semester ending with the academic year.

A candidate can proceed to the course of study of any semester (other than first semester) if and only if he has completed the course in the previous semester and has registered for the examination of the previous semester.

A candidate who is required to repeat the course of any semester for want of attendance / progress or who desires to rejoin the semester after a period of

discontinuance or who upon his own request is specially permitted to repeat the semester in order to improve his performance, may join the semester for which he is eligible or permitted to join.

On discontinuation of the course, the student should refund the entire stipend he/she received from the Centre within one year. The transfer certificate and other certificates will be issued only after refunding the stipend.

Faculty

Upon successful completion of two years in the program the candidates will be awarded a Master's Degree under the faculty of Technology and Applied Sciences.

Scholastic probation and Repeating of Course and Examinations: As per the provisions 12 - 13 laid down in CSS Regulations.

Revision of Regulations

The University may from time to time revise, amend or change the regulations, curriculum, scheme of examinations and syllabi. These changes unless specified otherwise will have effect from the beginning of the semester following the notification by the University.

CSS Regulations

Notwithstanding anything contained in this regulation, CSS Regulation 2020 will be binding and final.

M.Tech. Nanoscience and Technology

Course Materials

Semester I

Subject Code	Credit	Subject
SNNMPC01	3	Quantum Mechanics of Nanostructures
SNNMPC02	3	Synthesis and processing of Nanomaterials
SNNMPC03	3	Research Methodology and Intellectual Property Rights
SNNMPC04	3	Thermodynamics of Nanomaterials
SNNMPE01	*2*	Nanotechnolgy in Toxicology, food, and agriculture
SNNMPE02	*2*	Nano Magnetism
SNNMPE03	*2*	Semiconducting Nanostructures
SNNMPE04	*2*	Advanced Computing in Nanotechnology: Mathematical Modelling and Simulation
SNNMPE05	*2*	Nanotechnology for Corrosion Science and Engineering
SNNMPE06	*2*	Polymer Nano composites
Practical		
SNNMPC05	4	Synthesis of Nanomaterials and Characterization of Nanomaterials Lab

Semester II

SNNMPC06	*3*	Advanced Characterisation techniques of nanomaterials
SNNMPC07	*3*	Design and fabrication of Nanodevices
SNNMPC08	*3*	Advanced nano-biotechnology
SNNMPE07	*2*	Nanoelectronics and Nanophotonics
SNNMPE08	*2*	Nanotechnology in Energy
SNNMPE09	*2*	Nanotechnology in Colloids, Surface Science & Catalysis
SNNMPE10	*2*	Environmental Nanotechnology
SNNMPE11	*2*	Advanced carbon-based nanomaterials
SNNMPE12	*2*	Computation and Simulation Lab
SNNMPE13	*2*	Open Elective
SNNMPC09	*3*	Characterization of Nanomaterials Lab
SNNMPC10	*2*	Mini Project and Viva

Semester III

SNNMPC11	17	Project Work - Phase I

Semester IV

SNNMPC12	17	Project Work - Phase II

M. TECH. NANOSCIENCE & TECHNOLOGY

COURSE MATERIALS

SEMESTER I

Core Subject 01	***SNNMP C01***	**Quantum Mechanics of Nanostructures**

Module I

Basics of quantum mechanics

Introduction to Quantum Mechanics - Schrodinger equation – time dependent and time independent equations –Solutions of the Schrodinger equation – free particle - particle in a box – one and three dimensions - particle in a finite well - Penetration through a barrier – Tunnel effect – Single step barrier, Size effect on thermal, electrical, electronic, mechanical, optical and magnetic properties of nanomaterials- surface area and aspect ratio- band gap energy- quantum confinement size effect.

Module II

Quantum confined materials

Inorganic semiconductors, quantum wells, quantum wires, quantum dots, quantum rings. Manifestation of quantum confinement: Optical properties nonlinear optical properties. Quantum confined stark effect. Dielectric confinement effect, superlattices. Core-shell quantum dots and quantum-dot-quantum wells. Quantum confined structures as Lasing media. Organic Quantum-confined structures.

Module III

Chemistry aspects of nanomaterials

Chemistry of small surfaces: Curvature and neighbouring-charge effects on chemical reactivity and equilibria (pKa's, redox potentials)-Classical Colloid Theory: Nucleation and growth, Adsorption and Desorption Kinetics- Ostwald ripening-Homogeneous vs. heterogeneous nucleation- Anisotropic growth and shape control-Catalyzed (seeded) growth - Effect of Capping Agents on Growth Kinetics - self-assembly and fictionalisation,

Module IV

Quantum devices

Charge and spin in single quantum dots- Coulomb blockade– Electrons in mesoscopic structures- single electron transfer devices (SETs) – Electron spin transistor – resonant tunnel diodes, tunnel FETs - quantum interference transistors (QUITs) - quantum dot cellular automata (QCAs) - quantum bits (qubits).

Module V

Diffusion and surface defects

Fick's Law-mechanisms of diffusion - influence of pressure and temperature-Kirkendall effect - surface defects in nanomaterials - effect of microstructure on surface defects - interfacial energy

References

1) Bransden. B.H, and Joachain. C.J "Quantum Mechanics", Pearson, 2007.
2) David. J, Griffiths, "Introduction to Quantum Mechanics", Pearson, 2009.
3) Richard. L, Liboff, "Introductory Quantum Mechanics", Pearson, 2003.
4) Mark Lundstrom, "Fundamentals of Carrier Transport", Cambridge University Press, 2000.
5) Yoav Peleg, Reuven Pnini, Elyahu Zaarur, and Eugene Hecht, "Schaum's Outline of Quantum Mechanics", Tata McGraw Hill, 2010.
6) Eugen Merzbacher, "Quantum Mechanics", John Wiley & Sons, 1999.
7) Mathews. P.M and Venkatesan. K, "Quantum Mechanics", Tata McGraw Hill, 2010.
8) Ajoy Ghatak and S. Lokanathan, "Quantum Mechanics", Macmillan, 2009.
9) Michael. A, Nielsen & Isaac. L, Chuang, "Quantum Computation and Quantum Information", Cambridge University Press, 2002.
10) Processing & properties of structural nanomaterials - Leon L. Shaw, Nanochemistry: A Chemical Approach to Nanomaterials, Royal Society of Chemistry, Cambridge UK 2005.
11) Rao. C. N, Muller. A, Cheetham. A. K "Nanomaterials chemistry", Wiley-VCH, 2007

Core Subject 02	*SNNMP C02*	**Synthesis and Processing of Nanomaterials**

Module I

Physical Approaches

Bottom-Up versus Top-Down; Top-down approach with examples. Ball milling synthesis, Arc discharge, RF-plasma, Plasma arch technique, Inert gas condensation, electric explosion of wires, Ion sputtering method, Laser pyrolysis, Molecular beam epitaxy and electrodeposition. Electrospinning, Physical Vapor Deposition (PVD) – Chemical Vapour Deposition (CVD) - Atomic Layer Deposition (ALD) – Self Assembly- LB (Langmuir-Blodgett) technique.

Module II

Chemical Approaches

Chemical precipitation methods- Coprecipitation, Arrested precipitation, Sol-gel method, Chemical reduction, Photochemical synthesis, Electrochemical synthesis, Microemulsions or Reverse Micelles, Sonochemical synthesis, Hydrothermal, Solvothermal, Supercritical fluid process.

Module III

Biological Approaches

Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Role of plants in nanoparticle synthesis, synthesis of nanoparticles using proteins and DNA templates

Module IV

Self-Assembly and catalysis

Process of self-assembly, semiconductors islands, monolayers, nature of catalysis, porous materials, pillared clays, colloids, and biometrics. Nanoporous Materials – Silicon - Zeolites, mesoporous materials - nanomembranes and carbon nanotubes transparent conducting oxides –molecular sieves – nanosponges.

Module V

Wafer Growth, Epitaxial Deposition, lithography

Crystal Growth - CZ, Float zone technique; Basic Properties of different substrates (e.g. semiconductor, glass); Wafer cutting; Sources and related effects of various contamination; Wafer processing; Epitaxial growth- Growth kinetics of epitaxy, Doping, Growth modes, M based nanolithography and nanomanipulation, E beam lithography and SEM based Nano lithography and Nano manipulation, Ion beam lithography, Deep UV lithography, X-ray based lithography.

References

1) Guozhong Cao. Ed Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, World Scientific Series in Nanoscience and Nanotechnology, 2011.
2) G.A. Ozin and A.C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, Royal Society of Chemistry, 2009.
3) Microfabrication and Nanomanufacturing- Mark James Jackson
4) Chemistry of nanomaterials: Synthesis, properties and applications by CNR Rao et.al.
5) Nanoparticles: From theory to applications – G. Schmidt, Wiley Weinheim 2004.
6) Fabrication of fine pitch gratings by holography, electron beam lithography and nano-imprint lithography (Proceedings Paper) Author(s): Darren Goodchild; Alexei Bogdanov; Simon Wingar; Bill Benyon; Nak Kim; Frank Shepherd
7) A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion Final Milling in a FIBSEM
8) Instrument E L Principe, P Gnauck and P Hoffrogge, Microscopy and Microanalysis (2005), 11: 830- 831 Cambridge University Press.
9) Processing & properties of structural naonmaterials - Leon L. Shaw (editor)
10) Nanochemistry: A Chemical Approach to Nanomaterials – Royal Society of Chemistry, Cambridge UK 2005. 1. Nanocomposite science and technology – P.M. Ajayan, L.S. Schadler, P.V. Braun, Wiley, New York.
11) G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties &Applications, Imperial College Press, 2004

Core Subject 03	***SNNMPC03***	**Research Methodology and Intellectual Property Rights**

Module I

Introduction to research methodology

Definition of research, motivation for research, types of research, research approaches, scientific method, research process. Defining the Research Problem. Problem Formulation and Statement of Research.

Module II

Introduction to Research design

Features of good design, important concepts, different research designs. Basic principles of experimental design, sampling design, sample survey, sampling design, implications and steps, characteristics and criteria for sampling design, types of sampling designs, random sampling, complex random sampling designs.

Module III

Measurement and scaling techniques

Sources of error in measurements, tests of good measurement. Scaling: scaling techniques, measurement uncertainty, uncertainty estimation. Methods of data collection: observation, interview, questionnaire, selection of appropriate methods, processing and analysis of data, types of analysis. Statistics in research. Regression analysis.

Module IV

Sampling fundamentals

Definitions, sampling distributions, central limit theorem, sampling theory, Sandler's A-test, standard error estimation, estimating population mean, proportion, sample size and determination, determination of sample size. Testing hypotheses: basic concepts, procedure and flow diagram, measuring the power of a hypothesis test, tests of hypotheses.

Module V

Research ethics, fundamentals of documentation

Ethics of research, ethical standards, authorship of paper, scientific misconduct, fabrication, obfuscation, plagiarism, misappropriation of data, responsibilities of

authors and institutions. Data interpretation and Report writing – techniques of interpretation, precautions, significance of report writing, guidelines for writing research papers and reports.

Intellectual Property Rights (IPR) – Analysing and understanding the Interpretation of IP laws, need for protecting IP. Forms of IPR, application of different forms of IPR

References

1. Management Research: Guide for Institutions and Professionals, Roger Bennett, Nitish
2. De, 3rd Edn., International Labour Office (1983)
3. Research Methodology, Methods and techniques C. R. Kothari, New Age International

Publishers, New Delhi (2004)

4. Research Methodology, R. Panneerselvam, Prentice Hall of India, New Delhi (2011)
5. Research Methodology, A step by step approach, Ranjit Kumar, Pearson Publishers,

New Delhi (2005)

6. Exploring Research, 9th Edn., Neil J. Salkind, Pearson Education (2016).

Core Subject 04	***SNNMP C04***	**Thermodynamics of Nanomaterials**

Module I

Thermodynamics of small systems

Non-intensivity and Nonextensivity of Nanosystems, The Gibbs Equation for Nanosystems-Statistical Mechanics and Thermodynamic Property Predictions, Standard polymorphs-formalisms of controlled nucleation and growth of nanocrystallites from a vitreous state-thermodynamics of polymorphic transformations in non-porous and nanoporous solids.

Module II

Nanothermodynamics

Different approaches to nanothermodynamics, surface thermodynamic, Phase transitions in nanoparticle, quasi chemical description of solid nanoparticles, size dependent interface energy, thermodynamics of confined fluids in nanopores, structural properties of nanoclusters-Hill's approach to Nanothermodynamics, Phase transition in nanosystems-symmetry of fullerenes-PI index of some carbon nanotubes.

Module III

Non-equilibrium thermodynamics

Thermostated Dynamical Systems, The Transient Fluctuation Theorem Thermodynamic Interpretation of the Dissipation Function, The Dissipation Theorem Nonequilibrium Work Relations, Nonequilibrium Work Relations for Thermal Processes, Corollaries of the Fluctuation Theorem and Nonequilibrium Work Relations, Generalized Fluctuation Theorem, Integrated Fluctuation Theorem, Second Law Inequality, Nonequilibrium Partition Identity, The Steady State Fluctuation Theorem Minimum Average Work Principle.

Module IV

Non-equilibrium Nanosystems

Basics, Nanosystems Driven by Time, Dependent Forces-Jarzynski's Nonequilibrium Work Theorem, Mechanical Nanosystems, Friction in Double-Walled Carbon 60, Nanotubes-Electromagnetic Heating of Microplasmas, Mechanochemical Nanosystems, F1-ATPase Motor-Continuous state description-Discrete state description, Chemical Nanosystems, Chemical Transistor, Chemical Clocks in Field Emission Microscopy, DNA replication.

Module V

Thermodynamics of biological nano systems

Crystal, melt interfacial energies and solubilities for nanosized systems, Via the Ostwald-Freundlich equation, the size-selective growth process of nanoparticles, Bulk membrane partition, Nano thermodynamics of a Single Molecule, The Concept of Pseudoequilibrium, Cellular and Subcellular Systems.

References

1. Ragone. D. V "Thermodynamics of Materials", John Wiley & Sons, 1994.

2. David. R, Gaskell, "Introduction to the Thermodynamics of Materials", Taylor & Francis, 2002.
3. Michael Rieth and Wolfram Schommers, "Handbook of Theoretical and Computational Nanotechnology", American Scientific Publishers, 2005.
4. Lupis. C. H. P, "Chemical Thermodynamics of Materials", Prantice Hall, 2000.
5. Christian. J. W,"Theory of Phase Transformations in Metals and Alloys", Pergamon Press, 2001.
6. Günter Radons, Benno Rumpf and Heinz Georg Schuster, "Nonlinear Dynamics of Nanosystems", Wiley publishers, 2010.

ElectiveSubject 1	***SNNMP E01***	**Nanotechnology in Toxicology, food, and agriculture**

Module I

Nanotoxicology - overview

Concept of Nanotoxicology- Entry Routes into the Human Body Lung, Intestinal Tract, Skin, Nano particle Size - Surface and Body Distribution; - Nanoparticles and Cellular Uptake, Methodology for Nanotoxicology- Toxicity testing Experimental Models in Nanotoxicology - In vitro Models, In Vivo Models, Toxicological Studies and Toxicity of Manufactured CNTs- case study; Toxicity of CNTs and Occupational Exposure Risk; Toxicity of MWCNTs/SWCNTs and Impact on Environmental Health.

Module II

Toxicology of Nanoparticles in Environmental Pollution

Toxicology of Airborne and Manufactured Nanomaterials in the Environment, Effects of Nanoparticle on the Cardiovascular System, Nervous system- Liver and gastrointestinal tract. Endothelial Dysfunction and Endogenous Fibrinolysis-coagulation and thrombosis, Ethical- Legal and social implications- Nanoparticle Toxicology and Ecotoxicology, The Role of Oxidative Stress- Development of Test Protocols for Nanomaterials- Regulation of Engineered Nanomaterials in Europe, USA and India

Module III

Dosimetry, Toxicology and Epidemiology of Nanoparticles

Epidemiological Evidence for Health Effect Associations with Ambient Particulate Matter; Toxicological Evidence for Ambient Particulate Matter Induced Adverse Health Effects; Toxicological Plausibility of Health Effects Caused by Nanoparticles; Inhaled Nanoparticle Dosimetry; Integrated Concept of Risk Assessment of Nanoparticles.

Module IV

Nanotechnology in Agriculture

Nanotechnology in Agriculture, Precision farming, Smart delivery systems, Insecticides using nanotechnology, Potential of nano-fertilizers, Potential benefits in Nanotechnology in Food industry, Global Challenges, Product innovation and Process improvement, Consumer benefits

Module V

Nanotechnology in food

Food processing, Packaging, Packing materials; physical properties, Improvements of mechanical and barrier properties, Antimicrobial functionality, Active packaging materials,

Information and communication technology, Sensors, RF identification, Food safety, Intelligent packaging, Nanoengineered Food ingredients, Potential risks to Nanofood to consumers

References

1. Challa. S. S. R, Kumar, "Nanomaterials - Toxicity, Health and Environmental Issues", Wiley-VCH publisher, 2006.
2. Nancy. A, Monteiro-Riviere, Lang Tran. C, "Nanotoxicology: Characterization, Dosing and Health Effects", Informa healthcare, 2007.
3. Drobne. D, "Nanotoxicology for safe and Sustainable Nanotechnology", Dominant publisher, 2007.
4. Zafar Nyamadzi. M, "A Reference handbook of nanotoxicology", Dominant publisher, 2008.
5. Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, (2006).
6. Lynn J. Frewer, Willehm Norde, R. H. Fischer and W. H. Kampers, Nanotechnology in the Agri-food sector, Wiley-VCH Verlag, (2011).
7. Q. Chaudry, L.Castle and R. Watkins Nanotechnologies in Food, RSC

Publications, 2010.

Elective Subject 2	***SNNMP E02***	**Nanomagnetism**

Module I

Nanostructure magnetism, magnetostriction, Effect Bulk nanostructuring of magnetic property, Nanomagnetic materials, Classical and Quantum Magnetism, Magnetism of Atoms, Magnetic Ordering, Micromagnetism, Domain and Hysteresis, Paramagnetism, Ferromagnetism, Anti-ferromagnetism, Ferrimagnetism, Landau theory of Ferromagnetism Magnons, Exchange Interactions, superparamagnetism, blocking temperature, magnetic ultrathin films, magnetic surface and interface anisotropies, Physiological aspects - Toxic effects of magnetic nanoparticles

Module II

Magnetic Nanostructures and Applications

Magnetic sensors and Optically transparent materials, Soft ferrites- Nanocomposite magnets, Magnetic refrigerant, Ferro/biofluids, Biomedical applications of magnetic nanoparticles, Diagnostic applications, Therapeutic applications, Nuclear Magnetic Resonance, Magnetic Resonance Imaging. Neutron Diffraction, SQUID.

Module III

Introduction to spin electronics

Magnetoresistance, Giant Magnetoresistance mechanism of GMR, spin dependent scattering of electrons, interlayer exchange coupling (RKKY coupling), exchange biasing, spin valves, quantum tunnelling, tunnelling magnetoresistance (TMR), magnetic oxides and phase transformations: colossal magnetoresistance (CMR), magnetic semiconductors, multiferroics.

Module IV

Fabrication and Imaging

Molecular nanomagnets, Mesoscopic magnetism, Particulate nanomagnets, Geometrical nanomagnets, Fabrication techniques scaling, Characterization using various techniques, Neutron Diffraction, SQUID. Imaging magnetic micro spectroscopy, Optical Imaging, Magnetic Resonance Imaging Lorentz Microscopy,

Electron Holography of Magnetic Nanostructures, Magnetic Force Microscopy

Module V

Magnetic data storage

Magnetic recording overview, recording medium, particulate recording media, thin film recording materials, longitudinal versus perpendicular recording, write heads, read heads, magnetic random-access memory (MRAM), outlook and fundamental limits to recording, patterned media

References

1. Coey, J. M. D., Magnetism and Magnetic Materials, (Cambridge University Press, 2009).
2. Cullity, B. D. and Graham C. D., Introduction to Magnetic Materials, 2nd Edition, (Wiley IEEE Press, 2008).
3. Peddie, W., Molecular Magnetism, (Nabu Press, 2011). 2. Spaldin, N. A., Magnetic Materials: Fundamentals and Applications, 2nd Edition, (Cambridge University Press, 2010)
4. Molecular Nanomagnets by Dante Gatteschi, Roberta Sessoli, Jacques Villain, OUP Oxford, ISBN10: 0199602263.
5. Nanofluids: Synthesis, Properties and Applications by SohelMurshed, C A Nieto Castro, Nova Science Publishers ISBN-10: 1633216772.
6. Nanofluids Properties and Their Applications byDebendra Das Devdatta Kulkarni LAP Lambert Academic Publishing, ISBN-10: 365916609X.
7. Introduction to Magnetism and Magnetic Materials by D.C. JilesSpringer, ISBN 10: 0412386402 5. Magnetic Materials by Rainer Hilzinger, Werner Rodewald, Wiley VCH, ISBN10: 389578352

Elective Subject 03	***SNNMP E03***	**Semiconducting Nanostructures**

Module I

Introduction to Nanoelectronics

Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of

semiconductor devices, Quantum statistical mechanics, Energy bands in silicon, Metal Oxide Semiconductor Field Effect Transistors (MOSFET), MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage characteristics, Finite Element Modelling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect.

Module II

Semiconductor processing and microfabrication

Introduction to semiconductor device processing, Necessity and different types of clean rooms-construction and maintenance of a clean room, Microfabrication process flow diagram, Chip cleaning, coating of photoresists, patterning, etching, inspection, Process integration, Etching techniques, Reactive Ion etching, RIE reactive ion etching-Magnetically enhanced RIEIBE Ion beam etching.

Module III

Two-terminal junction transistors

Basic CMOS process flow; MOS scaling theory; Issues in scaling MOS transistors; Requirements for non-classical MOS transistor; PMOS versus NMOS; Design and construction of MOS capacitor; Integration issues of high-k MOS, interface states, bulk charge, band offset, stability, reliability; MOS transistor and capacitor characteristics. UNIT III GATE TRANSISTORS 9 Metal gate transistors, motivation, basics and requirements; quantum transport in nano MOSFET; Ultrathin body silicon on insulator (SOI) , double gate transistors, Vertical transistors, FinFET and surround gate FET; compound semiconductor MOSFET, Hetero-structures MOSFET.

Module IV

Sensors and actuator characteristics

Types and working principles of sensors and actuators; Characteristic features: Range, Resolution, Sensitivity, Error, Repeatability, Linearity and Accuracy, Impedance, Nonlinearities, Static and Coulomb Friction, Eccentricity, Backlash, Saturation, Dead-band, System Response, First Order System Response, Under-damped Second Order System Response, Frequency Response.

Module V

Memory devices

Nano ferroelectrics, Ferroelectric random-access memory, Fe-RAM circuit design, ferroelectric thin film properties and integration, calorimetric sensors, electrochemical cells, surface and bulk acoustic devices, gas sensitive FETs, resistive semiconductor

gas sensors, electronic noses, identification of hazardous solvents and gases, semiconductor sensor array.

References

1. Fundamentals of nano electronics by George W Hanson Pearson publications, India 2008
2. Introduction to photoelectron Spectroscopy (Chemical Analysis Vol. 67) by P.K. Ghosh; Wiley Interscience
3. Nanophotonics by P. N. Prasad – Springer Education series.
4. Nanotechnology and Nano Electronics – Materials, devices and measurement Techniques by WR 19 Fahrner – Springer
5. K.E. Drexler, "Nano systems", Wiley, (1992).
6. M.C. Petty, "Introduction to Molecular Electronics"1995.
7. W. Ranier, "Nano Electronics and Information Technology", Wiley, (2003).

Elective 04	***SNNMP E04***	**Advanced Computing in Nanotechnology: Mathematical Modelling and Simulation**

Module I

Matrices and linear systems of equations

Linear Systems: Cramer's Rule - Gaussian elimination and Gauss Jordon methods - Cholesky decomposition method – Gauss Seidel iteration method - Eigenvalue problems: Power method with deflation for both symmetric and non-symmetric matrices and Jacobi method for symmetric matrices.

Module II

Interpolation, differentiation and integration

Lagrange's interpolation - Newton's divided differences - Hermite's interpolation – Newton's forward and backward differences – Numerical differentiation – Numerical integration: Trapezoidal and Simpson's 1 3 rules - Gaussian quadrature: 2 and 3-point rules.

Module III

Differential equations

Initial value problems for first and second order ODEs: Single step methods - Taylor's

series method – Euler's and modified Euler's methods, Runge - Kutta method of fourth order - Multi step methods: Milne's and Adam Bash forth methods - Boundary value problems: Finite difference approximations to derivatives - Finite difference method of solving second order ODEs. Formation of partial differential equations – Classification of second order partial differential equations

Module IV

Probability

Introduction to probability: Probability, Sample space and events- Probability- the axioms of probability, some elementary theorems-conditional probability Bayes' theorem Random Variables- Discrete and continuous – distribution- distribution function Distribution Binomial and poison distributions and normal distribution – related properties, Neural networks.

Module V

Simulation and monte carlo methods

Random numbers: Random number algorithms and generators – Estimation of areas and volumes by Monte Carlo techniques - Numerical integration - Computing volumes – Simulation: Loaded Die Problem - Birthday problem - Buffon's needle problem - Two dice problem and Neutron shielding problem.

References

1. Advanced engineering mathematics, by Erwin Kreyszig, wiley publications
2. Probability and statistics, scham series, Arnold o. allen, academic press
3. Probability and statistics for engineers, miller and john e. freund, prentice hall of india.
4. A primer for the monte carlo method, llya M. Sobol' CRC Press
5. The monte carlo method, popular lectures in mathematics by sobol.i.m. Burden, R.L. and Faires, J.D.
6. "Numerical Analysis", 9th Edition, Cengage Learning, Delhi, 2016.
7. Cheney, W and Kincaid D., "Numerical Mathematics and Computing", 7th Edition, Cengage Learning, Delhi, 2014.
8. Jain, M.K., Iyengar, S.R.K. and Jain R.K. "Numerical Methods for Scientific and Engineering Computation", 5th Edition, New Age International Pvt. Ltd., Delhi, 2010.

9. Landau, D.P. and Binder, K., "A Guide to Monte - Carlo Simulations in Statistical Physics", 3rd Edition, Cambridge University Press, Cambridge, 2009.
10. Maki, D P and Thompson, M., "Mathematical Modelling with Computer Simulation", Cengage Learning, Delhi, 2011.
11. Taha, H.A. "Operations Research", 9th Edition, Pearson Education India, Delhi, 2016.

Elective Subject 05	***SNNMP E05***	**Nanotechnology for Corrosion Science and Engineering**

Module I

Introduction to corrosion

Principle of corrosion, types of corrosion, electrochemical aspect of corrosion, environmental effects, forms of corrosion, corrosion testing, factors affecting corrosion.

Module II

Nanotechnology and corrosion

Corrosion/oxidation behaviour of nanostructured materials, nanomaterials in corrosion prevention, thermodynamic and kinetic factors affecting corrosion.

Module III

Corrosion protection of metals using nanostructured alloys. Corrosion resistance of nanostructured metals and alloys, corrosion resistance of electrodeposited nanomaterials.

Module IV

Corrosion protection of metals using nano inhibitors and self-assembled monolayers. Surface modified nanoparticles as corrosion inhibitors, functionalised nanoparticles and nanostructures as carriers, self-assembled nanofilms as corrosion inhibitors

Module V

Corrosion protection of metals using nanocoating's

Introduction to anticorrosion coatings, metallic nanocomposite coatings, ceramic nanocomposite coatings, organic nanocomposite coatings, polymeric nanocomposite coatings, sol-gel coatings.

References

1. Corrosion Protection and Control Using Nanomaterials, R. M. Cook, Elsevier Science (2012)
2. Corrosion Protection at the Nanoscale, Susai Rajendran, Tuan Anh Nguyen, SaeidKakooei, Elsevier Science (2020)
3. Corrosion Science and Engineering, Pietro Pedeferri, Springer International publication (2019)
4. Corrosion for science and engineering, Kenneth Richard Trethewey, John Chamberlain, Longman (1995).

Elective Subject 06	***SNNMP E06***	**Polymer Nanocomposites**

Module I

Introduction to nanocomposites

Composite materials, classification, introduction to polymer composites, Classification based on the dimensionality: nanoparticles, nanoclusters, nanorods, nanotubes, nanowires, nanofibers and nanodots. Polymeric matrices, thermoplastics, thermosets and rubbers. Polymer nanocomposites: reinforcement, polymer-filler interactions, use of coupling and bonding agents.

Module II

Polymer /Ceramic nanocomposites

Introduction of ceramic nanomaterials: TiO_2, SiO_2, ZnO, nanoclay, hBN, MoS_2, WS_2, preparation of polymer/ceramic nanocomposites. Modification of nanomaterials like CNT, Graphene and Clay for polymer nanocomposites.

Module III

Synthesis techniques for Polymer nanocomposites

Solution techniques, latex stage mixing, melt mixing and in-situ polymerization, precipitation. Polymer nanocomposite preparation by emulsion and suspension polymerization. Dispersion and nucleating effects, intercalation and exfoliation. Application of layered and nonlayered nano particles in polymer modification.

Electrospinning of polymer nanocomposites.

Module IV

Elastomeric nanocomposites

Different types of elastomers: NR, SBR and TPE, nanofillers for elastomer reinforcement, reinforcement mechanism. Preparation of bucky paper and fiber spinning of CNT and Graphene for reinforcing polymer nanocomposite. Mechanical and thermal properties of elastomeric polymer nanocomposite. Advantages and disadvantages of nanosized fillers in polymer nanocomposite, 2D polymers: Synthesis and applications.

Module V

Properties and applications of polymer nanocomposites

Enhancement in thermal, physical, chemical, electrical, gas barrier properties, factors affecting properties of polymer nanocomposites. Applications of polymer nanocomposites: energy, environment, space, biomedical, defence and structural applications.

References

1. Handbook of composites, G. Lubin, Van Nostrand, (1982)
2. Chemical Functionalization of CarbonNanomaterials:Chemistry and Applications, Vijay Kumar Thakur, Manju Kumari Thakur, Taylor & Francis Group (2015)
3. Nanomaterials Handbook, YuryGogotsi, CRC Press (2006).
4. Polymer nanocomposites: Synthesis characterization andmodeling, R. Krishnamoorti and R.A. Vaia,Americal Chemical Society (2002)
5. Polymer Clay Nanocomposites, Pinnavaia T.J. and Beall G.W., John Wiley (2000)

Laboratory 1	SNNMP C05	**Synthesis of Nanomaterials Lab 1**
Laboratory 2	***SNNMP C06***	**Characterization of Nanomaterials Lab 2**

Bulk synthesis

Top down and bottom up approaches, Mechanical alloying and mechanical ball milling, Mechano chemical process, Inert gas condensation technique, Arc plasma and laser ablation.

Chemical approaches

Sol gel processing-Solvothermal, hydrothermal, precipitation, Spray pyrolysis, Electro spraying and spin coating routes, Self-assembly, self-assembled monolayers (SAMs). Langmuir Blodgett (LB) films, micro emulsion polymerization- templated synthesis, pulsed electrochemical deposition.

Physical approaches

Vapor deposition and different types of epitaxial growth techniques (CVD, MOCVD, MBE, ALD)- pulsed laser deposition, Magnetron sputtering, lithography: Photo/UV/EB/FIB techniques, Dip pen nanolithography, Etching process: Dry and Wet etching, micro contact printing.

Nanoporous materials

Zeolites, mesoporous materials, nanomembranes, Carbon nanotubes and graphene , Core shell and hybrid nanocomposites.

Characterization of Nanomaterials

UV Visible Spectroscopy, XRD, Raman Spectroscopy, DLS, Post processing of row data using Softwares.

A S Edelstien, RC Cammarata, Nanomaterials: Synthesis, Properties and Application; Taylor & Francis. 1996.

1. G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Imperial College Press, 2004.
2. J.George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.
3. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
4. S.P. Gaponenko, Optical Properties of semiconductor nanocrystals, Cambridge University Press, 1980.
5. W.Gaddand, D.Brenner, S.Lysherski and G.J.Infrate(Eds.), Handbook of

NanoScience, Engg. and Technology, CRC Press, 2002.

SEMESTER II

Core Subject I	***SNNMP C06***	**Advanced Characterisation techniques of nanomaterials**

Module I

Spectroscopic Techniques

Introduction to Molecular Spectroscopy and Differences-With Atomic Spectroscopy- Infrared (IR) Spectroscopy and Applications- Microwave Spectroscopy- Raman Spectroscopy, Surface enhanced Raman Spectroscopy, UV-Vis Spectroscopy, and Photoluminescence, Electron Spin Resonance Spectroscopy; NMR Spectroscopy; Dynamic Nuclear Magnetic Resonance; Dynamic light scattering (DLS).

Module II

X-Ray methods

X-ray powder diffraction, single crystal diffraction techniques, Quantitative determination of phases; Structure analysis, Determination of accurate lattice parameters, particle size analysis using Scherer formula, electron and neutron diffractions- X-Ray Photoelectron Spectroscopy, Energy Dispersive Analysis of X-rays.

Module III

Morphological Analysis

Matter-electron beam interaction; Principle, Basic instrumentation and applications of Transmission electron microscopy (TEM),Specimen preparation for TEM, Application of HR-TEM in Nano-structures, SAED, Instrumentation principle and application of Scanning electron Microscopy (SEM), Field emission Scanning electron Microscopy (FESEM), Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy, static and tapping mode, advanced mode of AFM, Conductive AFM; Scanning force microscopy (SFM), BET-surface area analysis for nanomaterials.

Module IV

Mechanical and electrical properties measurement

Nanoindentation principles, elastic and plastic deformation, mechanical properties of

materials in small dimensions, Hardness testing of thin films and coatings, Principle and applications of Cyclic voltammetry, Impedance Spectroscopy, Measurement of resistivity by 4-prob method.

Module V

Thermal and Magnetic Properties measurement

Instrumentation, working principle and applications of Thermogravimetric Analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning calorimetry (DSC), Thermomechanical analysis (TMA), Vibration Sample Magnetometer, PPMS, Measurement of Magnetic and electrical properties of nanomaterials.

References

1. Elements of X-ray Diffraction B. D. Cullity, Addison Wesley, 1977
2. Transmission Electron Microscopy: A Textbook for Materials Science David B Williams, C Barry Carter, (1996) Plenum Press, New York
3. Impedance Spectroscopy: Theory, Experiment, and Applications, E. Barsoukov and J. Ross Macdonald (Editors) (2000) John Wiley & Sons (P) Ltd.
4. Fundamentals of Fourier Transform Infrared Spectroscopy, Brian C Smith, (1995) CRC Press
5. Nanoindentation, By Anthony C Fischercripps, Anthony C., Springer science and Bussiness media publications, 2011
6. Nanomaterials, Nanotechnologies and Design: An Introduction for Engineers, Daniel L. Schodek, Paulo Ferreira, Michael F. Ashby, Elsevier, 2009.
7. Principles of Instrumental analysis by D.A. Skoog, F.J. Hollen and T.A. Nieman
8. Characterization of nanostructured materials by Z.L. Wang
9. Introduction to Magnetic Materials, 2nd Edition, L. C. Cullity and C. D. Graham, IEEE Press, Willey.
10. Principles of Nanomagnetism, Guimarães, Alberto P., Springer, 2009.

Core subject II	***SNNMP C07***	**Design and fabrication of Nanodevices**

Module I

The science of miniaturization

The Science of Miniaturization of Electrical and Electronic Devices, Moore 's law and technology road map, Quantum Mechanical Aspects, Simulation of the Properties of Molecular Clusters, Formation of the Energy Gap, Confinement Effects, Discreteness of Energy Levels, Tunnelling Currents. Nanofabrication by Photons, Nanofabrication by Ion Beam, Nanofabrication by Scanning Probes

Module II

Fabrication of micro/nano devices microfluidic devices

Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Microreaction chambers. Lithium Ion Battery and Super capacitors device fabrication, Operating and structure of Solar cells, CIGS solar cells, Dye-Sensitized solar cells, and Perovskite solar cell. MEMS and NEMS based devices

Module III

Introduction &sensor characteristics

Nanotechnology, Sensors, Nanotechnology Enabled Sensors, Sensor Characteristics and Terminology, Static Characteristics, Dynamic Characteristics, Physical Effects Employed for Signal Transduction, adsorption studies.

Module IV

Sensors & physical effects

Photoelectric Effect, Photo-dielectric Effect, Photoluminescence Effect, Electroluminescence Effect, Chemiluminescence Effect, Doppler Effect, Barkhausen Effect, Hall Effect, Nernst/Ettingshausen Effect, Thermoelectric (Seebeck/Peltier and Thomson) Effect, Thermoresistive Effect, Piezoresistive Effect, Piezoelectric Effect, Pyroelectric effect, MagnetoMechanical Effect (Magnetostriction), Mangnetoresistive Effect, Faraday-Henry Law. Introduction-types of sensors-Mechanical, optical, spintronic, electrochemical, thermal and magnetic sensors-surface modification-surface materials, bioreceptors and interactions

Module V

Future Nano systems

Nano machines, nano robots, electronics based on carbon-based materials, molecular Electronics. Quantum Computation: Future of Meso/Nanoelectronics, Interfacing with the Brain, towards molecular medicine, Lab-on-Biochips- Guided evolution for challenges and the solutions in Nano, Manufacturing technology

References

1. Mark. J Jackson, "Micro and Nanomanufacturing", 2007.
2. Edelstein. A. S, and Cammarata, "Nanomaterials: Synthesis, Properties and Applications Institute of Physics", Bristol, Philadelphia: Institute of Physics, 2002.
3. Mahalik. N. P, "Micro manufacturing and Nanotechnology", Springer Berlin Heidelberg New York 2006.
4. Zheng Cui, "Nanofabrication, Principles, Capabilities and Limits", 2008.
5. Sergey Edward Lyshevski, Lyshevski Edward Lyshevski, "Micro-Electro Mechanical and Nano-Electro Mechanical Systems, Fundamental of Nano-and Micro-Engineering "– 2nd Ed., CRC Press, 2005.
6. Kalantar–Zadeh. K, "Nanotechnology Enabled Sensors, Springer," 2008.
7. Serge Luryi, Jimmy Xu, Alex Zaslavsky, "Future trends in MicroElectronics", John Wiley & Sons, Inc. Hoboken, New Jersey 2007.
8. Chemical Sensors-An Introduction for Scientists and Engineers, Peter Gr¨undler, Springer publications (2006)

Core Subject III	***SNNMP C08***	**Advanced Nanobiotechnology**

Module I

Biological nanostructures

Nanobiotechnology, Challenges and opportunities associated with biology on the Nanoscale, biologically relevant molecular nanostructures, Carbon nanotubes, quantum dots, metal-based nanostructures, nanowires, polymer-based nanostructures, protein and DNA based nanostructures, Nano bioelectronic devices and polymer nanocontainers. Microbial based inorganic nanoparticles.

Module II

Nanotechnology in regenerative engineering

Basics of regenerative engineering, Factors affecting regeneration, Scaffolds for tissue regeneration, Materials for scaffold fabrication, scaffolds fabrication techniques: particulate leaching, phase separation, three-dimensional pore formation, nano fibers, nanocomposite scaffolds, micro and nanopatterned scaffolds, Engineering of biomaterial to control cell function, Engineering of nanomaterials as implant material:

Physico-chemical, in vitro and in vivo evaluations.

Module III

Implant nanobiotechnology

Advantages of nanomaterials as implants-biological response of implanted materials, desirable and undesirable reactions of the body with implanted materials. Bioactive nanomaterials as bone implants, cartilage implants, bladder implants, dental implants, skin implants, Muscle implants, neural implants, Tendon implants, Ligament implants, cardiac implants, anti-adhesive membranes.

Module IV

Nanopharmaceuticals

Types of therapeutic nanoparticles, Types of nanostructured nanoparticles, Nanoparticle based drug delivery. Gold nanoparticles for drug discovery, Use of Quantum Dots and Nano lasers for Drug Discovery, Cells Targeting by Nanoparticles with Attached Small Molecules. Self-assembled nanoparticles for Intracellular Drug Delivery, Nanoparticle Combinations for Drug Delivery, Multi-targeted drugs, Delivery of nucleic acids, Dendrimers and Fullerenes as Drug Candidates. Barriers to therapeutic applications, interaction of organic molecules of the drug with pathological tissue, biocompatible core-shell nanoparticles for medicine.

Module V

Current Application of Nanoparticles in Clinics

Nanoparticles for Cancer Therapy, Nanoparticles for Infectious Disease Therapy, Nanoparticles for Autoimmune Disease Therapy, Nanoparticles for Cardiovascular Disease Therapy, Nanoparticles for Neurodegenerative Disease Therapy, Nanoparticles for Ocular Disease Therapy, Nanoparticles for Pulmonary Disease Therapy, Nanoparticles for Regenerative Therapy.

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 BiosciencePublishers, (2003).
4. Challa Kumar- Biological and pharmaceutical Nanomaterials, Wiley-VCH

Verlag GmbH & Co. KGaA.

5. Cato T. Laurencin and Lakshmi S. Nair, Nanotechnology and Tissue Engineering the Scaffold, CRC Press taylor& Francis Group.
6. K.K.Jain, Nano Biotechnology, Horizions Biosciences, 2006 5.
7. C. Kumar, Nanomaterials for medical diagnosis and therapy, Wiley –VCH, 2007, USA
8. Nano bio-technology: Concepts, Applications and Perspectives, Christ of M. Niemeyer, Wiley, 2004

Elective Subject I	***SNNMP E07***	**Nanoelectronics and Nanophotonics**

Module I

Overview of nano-electronics

Introduction to Nanoelectronics Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of semiconductor devices, Quantum statistical mechanics, Energy bands in silicon, Metal Oxide Semiconductor Field Effect Transistors (MOSFET), MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage characteristics, Finite Element Modelling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect

Module II

Advances in Nanoelectronics

Molecular nanoelectronics, Electronic and optoelectronic properties of molecular materials, TFTs OLEDs- OTFTs, logic switches, SPINTRONICS: Spin tunnelling devices - Magnetic tunnel junctions- Tunnelling spin polarization, spin diodes, Magnetic tunnel transistor, Memory devices and sensors, ferroelectric random-access memory- MRAMS

Module III

Fundamental of Nanophotonics

Photons and electrons: similarities and differences, freespace propagation. Confinement of photons and electrons. Propagation through a classically forbidden

zone: tunnelling. Localization under a periodic potential: Band gap. Cooperative effects for photons and electrons. Nanoscale optical interactions, axial and lateral nanoscopic localization. Nanoscale confinement of electronic interactions, Quantum confinement effects, Optical properties nonlinear optical properties, nanoscale interaction dynamics, nanoscale electronic energy transfer. Cooperative emissions.

Module IV

Nanophotonic Devices

Resonant cavity quantum well lasers and light-emitting diodes, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavity LED. Microcavity-based single photon sources.

Module V

Photonic crystals

Important features of photonic crystals, Presence of photonic bandgap, Anomalous Group Velocity Dispersion, Microcavity, Effects in Photonic Crystals, Fabrication of photonic crystals, Dielectric mirrors and interference filters, Photonic Crystal Laser, PC based LEDs, Photonic crystal fibers (PCFs), Photonic crystal sensing.

References

1. M.C. Petty, "Introduction to Molecular Electronics"1995.
2. W. Ranier, "Nano Electronics and Information Technology", Wiley, (2003).
3. Yuan Taur and Tak H. Ning, Fundamentals of Modern VLSI Devices, Cambridge
4. Karl Goser, Peter Glosekotter, Jan Dienstuhl, —Nanoelectronics and Nanosystems, Springer (2004)
5. Cyril Prasanna Raj P., Designing with FINFETs and CNTFETs, MSEC E-Publication (2016)
6. SadamichiMaekawa, —Concepts in Spin Electronics‖, Oxford University Press (2006)
7. Lucas Novotny and Bert Hecht, "Principles of Nano-Optics", Cambridge University Press, 2012.
8. B.E.A. Saleh and A.C.Teich, Fundamentals of Photonics, John-Weiley & Sons, New York, 1993.

9. M.Ohtsu, K.Kobayashi, T.Kawazoe, and T.Yatsui, Principles of Nanophotonics (Optics and Optoelectronics), University of Tokyo, Japan, 2003.

10. K.E. Drexler, "Nano systems", Wiley, (1992).

Elective Subject II	***SNNMPE 08***	**Nanotechnology in Energy**

Module 1

Renewable Energy Technology

Energy challenges, development and implementation of renewable energy technologies, nanotechnology enabled renewable energy technologies, Energy transport, conversion and storage- Nano, micro, and poly crystalline and amorphous Si for solar cells, Nano-micro Si-composite structure, various techniques of Si deposition

Module II

Nanomaterials for Energy Storage Systems

Issues and Challenges of functional Nanostructured Materials for electrochemical Energy Storage Systems, Primary and Secondary Batteries (Lithium ion Batteries), Cathode and anode materials, Capacitor Electrochemical supercapacitors, electrical double layer model, Principles and materials design, Nanostructured Carbon-based materials, Nano-Oxides, Novel hybrid electrode materials, Current status and future trends.

Module III

Nanomaterials in Fuel Cell and Storage Technology

Micro-fuel cell technologies, integration and performance for micro-fuel cell systems, thin film and microfabrication methods, design methodologies, micro-fuel cell power sources, Supercapacitors, Specific energy, charging/discharging, EIS analysis.

Module IV

Nanomaterials for Hydrogen Storage and Photocatalysis

Hydrogen storage methods, metal hydrides, size effects, hydrogen storage capacity, hydrogen reaction kinetics, carbon-free cycle, gravimetric and volumetric storage capacities, hydriding/dehydriding kinetics, multiple catalytic effects, degradation of

the dye, nanomaterials based photocatalyst design, kinetics of degradation.

Module V

Nanomaterials for Photovoltaic Solar Energy Conversion Systems

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

References

1. Twidell. J. and Weir. T "Renewable Energy Resources", E & F N Spon Ltd, 1986.
2. Martin A Green, "Solar cells: Operating principles, technology and system applications", Prentice Hall Inc, Englewood Cliffs, 1981.
3. Moller. H J "Semiconductor for solar cells", Artech House Inc, 1993. 4. Ben G Streetman, "Solid state electronic device", Prentice Hall of India Pvt Ltd.,1995
4. D. Linden Ed., Handbook of Batteries, 2nd edition, McGraw- Hill, New York (1995).
5. Handbook of fuel cells: Fuel cell technology and applications by Vielstich. Wiley, CRC Press
6. G.A. Nazri and G. Pistoia, Lithium Batteries: Science and Technology, Kulwer Acdemic Publishers, Dordrecht, Netherlands (2004).
7. J. Larmine and A, Dicks, Fuel Cell System Explained, John Wiley, New York (2000).
8. Science and Technology of Lithium Batteries-Materials Aspects: An Overview, A. Manthiram, Kulwer Academic Publisher (2000).
9. Hydrogen from Renewable Energy Sources by D. Infield 2004

Elective Subject III	***SNNMP E09***	**Nanotechnology in Colloids, Surface Science & Catalysis**

Module I

Surface Nanoscience

Introduction to surface active agents. Theory and applications. Types of surfactants. Classification, synthesis of surfactant - Shape, size and structure of surfactants. Micelle,

Emulsions, Microemulsions & Gels. Kraft temperature, surfactant geometry and packing. surface defects in nanomaterials, effect of microstructure on surface defects, interfacial energy.

Module II

Colloidal Nanoscience

Introduction to colloidal material, surface properties, origin of colloidal particles, preparation & characterization of colloidal particles. Brownian motion and Brownian Flocculation. Applications of super hydrophilic hydrophobic surfaces, self-cleaning surfaces. Surface viscosity, Applications of oil recovery.

Module III

Surfaces in Multidisciplinary Applications

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

Module IV

Adsorption phenomenon

Chemisorption & Physisorption, adsorption isotherms and methods of determination of pore size and surface area of materials using the adsorption isotherms, Adsorption isotherms (Langmuir and BET), Reaction Mechanism (Langmuir-Hinshelwood and Eley-Rideal). Intermolecular Forces, Van der Waals forces (Kessorn, Debye, and London Interactions). Dynamic properties of interfaces, Contact angle. Surface free energy.

Module V

Catalysis

Catalysis – Definition, Catalysis in environmental protection & green process, Industrial catalytic wet air oxidation processes, water purification, types of catalysis with suitable examples, Introduction to photocatalysis: Principle- Band energy engineering, characteristics of a catalyst, selectivity or specificity of the catalyst, activation and deactivation of catalysts, catalytic poisoning, Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared

clays, colloids and porous materials (viz. mesoporous materials).

References

1. Gabor A. Somorjai, Yimin Li, Introduction to Surface Chemistry and Catalysis, John Wiley & Sons, New Jersey, 2010.
2. HaraldIbach, Physics of Surfaces and Interfaces, Springer-Verlag, Berlin, 2006.
3. Peter J. Blau, Friction Science and Technology- From concepts to applications, Second Edition, CRC Press, Boca Raton, 2009
4. N. Birks, G. H. Meier, F. S. Pettit, Introduction to the high temperature oxidation of metals, Second edition, Cambridge University Press, 2006
5. P.C Hiemen and R.Rajgopalam, Principle of colloid and surface Chemistry, NY Marcel Dekker, 1997.
6. D.J.Shaw, Colloid and surface chemistry, Butterworth Heineman, Oxford, 1992.
7. Heterogeneous Catalysis, D.K. Chakrabarty and B. Viswanathan, New Age International (P) Limited, 2008
8. Nanoporous Materials: Synthesis and Applications, Edited by Qiang Xu, CRC Press, 2013
9. Catalysis: Principles and Applications, Edited by B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Narosa Publishing House, 2011
10. New and Future Developments in Catalysis, Edited by Steven L. Suib, Elsevier, 2013.

Elective Subject IV	***SNNMPE 10***	**Environmental Nanotechnology**

Module I

Environmental Nanotechnology

Introduction, properties of nanomaterials, major applications of nanotechnology, types of nanoparticles, types of engineered nanoparticles. Environmental uses of nanotechnology: air purification, water purification, nano monitoring: bio sensors for pesticide detection, biosensors for plant pathogen detection, Nanobioremediation, pesticide degradation, soil, structure and remediation.

Module II

Green Nanotechnology

Green synthesis of metal, metal oxide and organic nanoparticles, biological synthesis of nanomaterials: natural nanomaterials, natural polymers, natural adsorbents, nano biomaterials, clays, nanocomposites.

Module III

Applications of nanotechnology in waste water treatment

Techniques for water purification, nano-absorbents, membrane filtration, nanomaterials for water treatment, photocatalysts. Role of nanotechnology in energy sector, sustainable energy applications.

Module IV

Advanced Instruments: Characterisation of nanomaterials

Atomic absorption spectrometry, inductively coupled plasma spectrometry, chromatography, thermal methods, hyphenated techniques.

Module V

Nanoparticles: Health and Environmental effects

Health hazards, physicochemical properties of nanoparticles, toxicity of nanoparticles, toxicity to plants, exposure and risk assessment, dose-response, ecotoxicological impacts of nanomaterials.

References

1. Environmental Nanotechnology, M. H. Fulekar, Bhawana Pathak, CRC Press (2017)
2. Environmental Nanotechnology: Applications andImpacts of Nanomaterials, Wiesner, M.R., Bottero, J.Y. (Ed.) McGraw-Hill, New York (2007)
3. NanotechnologyApplications for Clean Water, Diallo, M., Duncan, J., Savage, N., Street, A., Sustich, R. (Eds)., William Andrew (2008)
4. Environmental and Human Health Impacts of Nanotechnology, Lead J., and Smith, E., John Wiley & Sons (2009).
5. Introduction to Environmental Engineering and Science, Masters, G.M., Ela, W.P., Prentice Hall (2007)

Elective Subject V	*SNNMP E11*	**Advanced carbon-based nanomaterials**

Module I

Introduction

Carbon molecules, nature of carbon bonds, structure and chemistry of different carbon allotropes. Classification of carbon nanomaterials: fullerenes, carbon nanotubes (CNT), graphene and other carbon nanomaterials.

Module II

Introduction to Fullerenes

Structure of Higher Fullerenes, Growth Mechanisms; Production and Purification: Pyrolysis of Hydrocarbons, Partial Combustion of Hydrocarbons, Arc Discharge Methods, Resistive Heating, Rational Syntheses. Physical Properties, Spectroscopic Properties, Thermodynamic Properties. Chemical Properties: Hydrogenation, Halogenation, Nucleophilic Addition to Fullerenes.

Module III

Introduction to Carbon nanotubes (CNT)

The Structure of Carbon Nanotubes, Single Walled Carbon Nanotubes, Multiwalled Carbon Nanotubes. Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman Spectroscopy of CNTs. Purification and Functionalization of CNTs by Flame, CVD, Laser & Arc-discharge process, Fluidized bed reactor.

Module IV

Introduction to graphene

Structure of graphene, synthesis of graphene: Modified Hummer's method, electrochemical exfoliation and CVD method., Electronic Properties Band structure of Graphene -Mobility and Density of Carriers - Quantum Hall Effect -Spectroscopic Properties of graphene.

Module V

Applications of Fullerene, CNT, Graphene and other carbon nanomaterials. Mechanical, Thermal, Electronic and biological Applications of carbon nanomaterials.

References

1. Encyclopaedia of Nanotechnology, M.Balakrishna rao and K.Krishna Reddy, Vol

I to XCampus books (2006).

2. Nano:The Essentials – Understanding Nano Scinece and Nanotechnology, T.Pradeep; TataMc.Graw Hill (2008).
3. Carbon Nanotubes: Properties and Application, Michael J. O'Connell, CRC Press (2018).
4. Nanotubes and Nanowires, CNR Rao and A Govindaraj, RCS Publishing (2005)
5. Carbon Nanotechnology: Recent Developments in Chemistry, Physics, Materials Science and Device Applications, Liming Dai, Elsevier Science (2006)

Open Elective	SNNMPE13	Other Options for Elective

1. Polymer Nanocomposite: Preparation, Characterization and Applications
2. Lithography and Nanofabrication
3. Mechanical Processing and Properties of Nanomaterials
4. Micro and Nano-fluidics

Laboratory 3	***SNNMP E12***	**Computation and Simulation - Lab**

Basic Computational methods

Numerical programme to plot the first four Eigen functions of a one - dimensional rectangular potential well with infinite potential barrier. Numerical solution of the Schrodinger wave equation for a rectangular potential well with infinite potential barrier using numerical programme. Toy model in molecular electronics

MATLAB

Introduction to MATLAB Programming, Program assembly, Execution, Data processing and graphic analysis, Study of Fermi – Dirac distribution function, Introduction to symbolic math computations, MATLAB program to plot the one-dimensional rectangular potential well with infinite potential barrier, Introduction to Simulink and SimElectronics

Laboratory 4	**SNNMP C09**	**Material Characterisation Lab**

Morphological analysis, Thermal analysis, Spectroscopic methods and wet chemistry methods

Imaging Techniques SEM, TEM, AFM, STEM

Semester III

Project Work	*SNNMPC11*	Phase I

Semester IV

Project Work	SNNMPC12	Phase II