MANGALORE UNIVERSITY

TWO YEAR M.Sc. DEGREE PROGRAMME IN MATERIALS SCIENCE

(CHOICE BASED CREDIT SYSTEM- 2016)

SYLLABUS AND SCHEME OF EXAMINATION

HIGHLIGHTS:

The PG Programme comprises “Core” and “Elective” Courses. Core courses are related to the discipline of the programme. This is further divided into hard core and soft core. Hard core courses are compulsorily studied by a student as a core requirement to complete the programme in the discipline. Soft core courses are electives, but related to the discipline the progamme. Open elective is a course chosen by a student unrelated to the discipline within the faculty or across the faculty. Open electives are offered in the II and III semesters. The student will have to pass the course and earn the credit for the completion of the programme, but will not be counted for the calculation of CGPA.

Total Credit requirement for M.Sc. Degree Programme in Materials Science is 86, out of which the Hard Core (H) is 53 and Soft Core(S) is 33, while the open electives (E) will have a fixed 6 credits. The distribution of courses and credits among the four semesters are as shown in the table below.

CBCS PROGRAMME STRUCTURE

SEMESTER	COURSES	TYPE	CREDTS/ COURSE	CREDITS			TOTAL CREDITS
				HARD	SOFT	ELECTIVE	
I	4 Theory	Hard	4	16	-	-	22
	2 Lab	Hard	3	06	-	-	
II	3 Theory	Hard	4	12	-	-	21+3
	1 Theory	Soft	3	-	03	-	
	2 Lab	Soft	3	-	06	-	
	1 Theory	Elective	3	-	-	03	
III	2Theory	Hard	4	08	-	-	20+3
	3 Theory	Soft	3	-	09	-	
	1 Lab	Soft	3	-	03	-	
	1 Theory	Elective	3	-	-	03	
IV	2 Theory	Hard	4	08	-	-	23
	2 Theory	Soft	3	-	06	-	
	2 Lab	Soft	3	-	06	-	
	1 Project	Hard	3	03	-	-	
Total Programme Credits				53	33	06*	86+6*

***Not to be counted for CGPA**

SCHEME OF INSTRUCTION, EXAMINATION AND EVALUATION

Semester	Courses	Type & Credits	Teaching Hours/Week/ Course	Duration of Examination Hours	Marks Exam+IA*	Total Marks/ Course
I	4 Theory	Hard 4	4	3	70+30	100
	2 Lab	Hard 3	8	4	70+30	100
II	3 Theory	Hard 4	4	3	70+30	100
	1 Theory	Soft 3	3	3	70+30	100
	2 Lab	Soft 3	8	4	70+30	100
	1 Theory	Elective 3	3	3	70+30	100
III	2Theory	Hard 4	4	3	70+30	100
	3 Theory	Soft 3	3	3	70+30	100
	1 Lab	Soft 3	8	4	70+30	100
	1 Theory	Elective 3	3	3	70+30	100
IV	2 Theory	Hard 4	4	3	70+30	100
	2 Theory	Soft 3	3	3	70+30	100
	2 Lab	Soft 3	8	4	70+30	100
	1 Project	Hard 3	4	-	70+30	100

***IA- Internal Assessment**

The duration of each lab course is 8 hours per week including tutorials.

BASIS FOR INTERNAL ASSESSMENT:

Internal assessment marks in each theory course shall be based on two tests and an assignment. Internal assessment marks in each Laboratory course is assessed by the faculty members of the department based on the regular performance in the laboratory, the viva conducted on each experiment, the internal test and the laboratory records submitted by the student.

PRACTICAL EXAMINATION: End Semester examination for each practical course is based on the consensus evaluation by both the examiners.

PROJECT REPORT: A project carried out by the student in III and IV semesters will be evaluated in the IV semester as stipulated in the regulations. The internal assessment for the project is evaluated by the faculty members of the department.

PRE-REQUISITES FOR THE COURSES: Quantum Mechanics-I is a pre-requisite for Quantum Mechanics-II. Nanoscience and Nanotechnology-I is pre-requisite for Nanoscience and Nanotechnology-II.

QUESTION PAPER PATTERN

Each hard core and Soft core theory course examination is for 70 marks. Two questions from each unit of the course, with internal choice shall be given. One question with 5 or 10 short questions/problems is compulsory. The question paper for open elective shall have 10 questions of 10 marks each out of which the student shall answer any seven questions.

COURSES OFFERED

COURSE CODE	COURSE TITLE	Credit
HARD CORE COURSES		
MSH 401	METHODS OF MATHEMATICAL PHYSICS	4
MSH 402	ELECTROMAGNETIC THEORY & ELECTRONICS	4
MSH 403	ELEMENTS OF MATERIALS SCIENCE - 1	4
MSH 404	THERMODYNAMICS & CHEMISTRY OF METALS	4
MSP 405	MATERIALS SCIENCE LAB - I	3
MSP 406	MATERIALS SCIENCE LAB - II	3
MSH 451	QUANTUM MECHANICS - I	4
MSH 452	CLASSICAL MECHANICS & STATISTICAL PHYSICS	4
MSH 453	ELEMENTS OF MATERIALS SCIENCE -II	4
MSH 501	DIELECTRIC MATERIALS	4
MSH 502	SOLID STATE ENGINEERING MATERIALS - I	4
MSH 551	MAGNETIC MATERIALS & MAGNETIC RESONANCE	4
MSH 552	SOLID STATE ENGINEERING MATERIALS - II	4
MSP 558	MINI PROJECT	3
SOFT CORE COURSES		
MSS 454	SURFACE PHENOMENA & ELECTROCHEMISTRY	3
MSP 455	MATERIALS SCIENCE LAB - III	3
MSP 456	MATERIALS SCIENCE LAB - IV	3
MSS 503	THIN FILMS	3
MSS 504	NEW MATERIALS & TECHNOLOGIES	3
MSS 505	POLYMER SCIENCE	3
MSS 506	NANOSCIENCE & NANOTECHNOLOGY - I	3
MSS 507	CRYSTAL GROWTH	3
MSS 508	QUANTUM MECHANICS - II	3
MSP 509	MATERIALS SCIENCE LAB - V	3
MSS 553	MATERIALS TESTING & CHARACTERIZATION	3
MSS 554	COMPOSITE MATERIALS	3
MSS 555	NANOSCIENCE & NANOTECHNOLOGY - II	3
MSP 556	MATERIALS SCIENCE LAB - VI	3
MSP 557	MATERIALS SCIENCE LAB - VII	3
OPEN ELECTIVES		
MSE 457	SCIENCE OF MATERIALS IN DAILY LIFE	3
MSE 510	MATERIALS IN ENERGY PRODUCTION	3

SYLLABUS

The M.Sc. Materials Science syllabus was framed based on the manpower requirements of industry and academic research.

Learning Objectives: To acquire basic knowledge in the areas of Physics, Chemistry, Mathematics, to apply them to the understanding and application of materials.

Programme outcome: The M.Sc. Materials Science graduates have been well received in academia and industry.

Programme Specific outcome: The MSc Materials Science graduates have been well received in premier research institutions such as IISc, IITs, NITs, etc. and in industries like Hind HighVac, Samsung, GE, HAL, ISRO etc.

Course Outcomes: Each of the courses are designed in such a way that they are useful in equipping the graduate with necessary knowledge for pursuing a career in materials science.

MSH 401: **METHODS OF MATHEMATICAL PHYSICS** (4 Credits)

Objectives: This course introduces the mathematical tools which are very essential for the understanding of Physics of Materials. These mathematical techniques either may be used in one of the courses in the programme to be offered in the ensuing semesters or may be required while practicing materials science either in research or in an industry.

Expected course outcomes: At the end of the course student should be familiar with the mathematical techniques, the concepts involved and should be able to apply the concepts to solve at least some simple problems.

Unit I

Complex Variables: Analytic functions. Series expansion- Laurent's Theorem. Residue Theorem and evaluation of simple contour integrals. Evaluation of Improper integrals and Integrals involving trigonometric functions by the method of residues. Group Theory: Basic concepts - multiplication tables - subgroups - direct product. Properties of groups. Representations of finite group - reducible and irreducible representations and example of C_{4V} group. 18 hours

Unit II

Matrices: Matrices as operators. Symmetric, Orthogonal, Hermitian and Unitary matrices. Eigen values and eigen vectors of a matrix. Simiarity, Orthogonal, Unitary and Congruent transformations. Diagonalisation of a real symmetric matrix. General Curvilinear Co-ordinates: Expressions for line, surface and volume elements in general curvilinear co-ordinates. Gradient, Curl, Divergence and Laplacian - Orthogonal curvilinear co-ordinates.

Tensors: Definition - Contravariant, Covariant and Mixed tensors.Sum, inner and outer products - Contraction - Quotient law. The line element and the metric tensor. Length of a vector. Raising and lowering of indices. Christoffel symbols and covariant differentiation of tensor. Stress and strain tensors. 18 hours

Unit III

Special Functions: Bessel functions of the first kind -derivation of the basic form-Recurrence relations - Fraunhofer diffraction and vibrations of bars and membranes. Legendre and Associated Legendre functions - Recurrence relations and differential equations. Legurre and Associated Legurre functions – differential equations. Hermite functions - Recurrence relations – differential equations. 18 hours

References

1. Mathematical Methods for Physicists – G Arfken (Academic Press, 1968)
2. Elements of Group Theory for Physicists – A W Joshi (Wiley Eastern, 1975)
3. Symmetry Groups and their applications – W. Miller
4. Mathematics of Physics and Chemistry – H Margenau and G M Murphy (Affiliated East West Press, 1966)
5. Matrices and Tensors in Physics – A W Joshi (Wiley Eastern, 1975)
6. Tensor Analysis – I S Sokolnikoff (John Wiley, 1974)

MSH 402: **ELECTROMAGNETIC THEORY AND ELECTRONICS** (4 Credits**)**

Objectives: The course aims to impart fundamentals of electromagnetic theory necessary to understand the optical properties of materials. The basics of electronics are required to understand the semiconductor devices and also to understand the functioning of electronic devices/equipment for the effective use of the instruments.

Expected course outcomes: At the end of the course students will be familiar with the optical phenomena and interaction of light with materials which will be helpful in interpreting the data obtained during their future engagements. Understanding the electronics part may help the students in troubleshooting any possible minor/major faults in electronic equipment that occur.

Unit I

Electromagnetic Theory: Maxwell's equations and material equations - the wave equations and velocity of light - Boundary conditions at a surface of discontinuity - Fresnel's laws of reflection and refractions - Fresnel's rhomb. Standing waves- Wiener's experiments - Lippman's colour photography.

Propagation of light in a medium: Dispersion in dielectric – Sellmeir's formula - propagation in metal - Hagen formula. Propagation in crystals - wave vector surface - ray theory - ray velocity - double refraction - optical activity - Faraday rotation.

18 hours

Unit II

Electronics: Active and passive components - Diodes, transistors, SCR, FET. Resistors - carbon resistors, wire wound resistors, IC resistors - thick and thin film resistors. Capacitors - Tantalum, electrolytic, oxide capacitors, junction capacitors, IC capacitors - thick and thin film capacitors. Inductors. Power supplies - Rectification and filter action - Types of voltage regulators, shunt and series regulators using transistors. Applications - SMPS, 3 pin IC regulators, voltage stabilizers (servo, CVT). Amplifiers: Types of transistor amplifiers - small signal amplifiers-design calculation, power amplifiers. Oscillators: Feed back concepts - negative and positive. Phase shift oscillators, crystal oscillators, LC oscillators - Hartly and Colpitt's oscillators. 18 hours

Unit III

Wave shaping circuits: Different types of waveforms. Integrating and differentiating circuits. Clipping circuits - diode clipper- positive and negative clippers, biased clippers - double diode clipper. Clamping circuits - positive and negative clamping, partial clamping. Multivibrators: Astable, bistable, and monostable multivibrators. Schmitt trigger.

Operational Amplifiers: Introduction - Characteristics. Applications - inverting, non-inverting, difference, and summing amplifier. Differentiation and integration circuits using opamp. 18 hours

References

1. Introduction to Modern Optics – G R Fowles (Rinehart & Winstar Inc., 1968)
2. Optics – A N Mateev (MIR, 1988)
3. Optics – Ajoy Ghatak (Tata McGraw-Hill, 1995)
4. Electromagnetics – J D Krans (McGraw Hill, 1987)
5. Semiconductor Devices – J Brophy (George Allen, 1964)
6. Solid State Electronic Devices – Ben G Streetman (Prentice-Hall, 1995)
7. Electronic Devices and Circuits – A Mottershead (Prentice-Hall, 1991)
8. Integrated Electronics – Millman and Halkias (McGraw Hill, 1995)
9. Digital Principles and Applications – A P Malvino and Lach (McGraw-Hill, 1986)
10. Microprocessors: Principles and applications –C M Gilmore (McGraw-Hill, 1995)
11. Introduction to microprocessors – A P Mathur (Tata McGraw-Hill, 1995)

MSH 403: **ELEMENTS OF MATERIALS SCIENCE – I** (4 Credits)

Objectives: The course helps to understand the relationship between different types of crystal structures with the properties of materials. The physical property of condensed matter is intimately related to their electronic structure and crystal structure. It serves as a foundation for understanding the structure-property correlation in materials.

Expected course outcomes: On completion of this course, it is expected that a student understands why materials behave the way they do. It equips them with all the basics required for a deeper understanding of the properties of metals, semiconductors and insulators which will be dealt with separately in the other courses offered in subsequent semesters.

Unit I

Formation and Structure of Materials: Condensed state of matter-crystalline and amorphous states. Ionic, covalent, metallic and molecular bindings-Bond angle, bond length and bond energy. Hybridisation - Delocalised chemical bonding. Lattice energy - Madelung constant. Inert gas crystals - van der Waals interaction - Lennard Jones' potential. Simple crystal structures - Sodium Chloride, Cesium Chloride, Diamond and Zinc sulphide structures. Close packed structures - packing efficiency and density of materials. 18 hours

Unit II

Crystal Geometry and Structure Analysis - Crystal morphology - symmetry elements - Crystal systems. Point group symmetry - derivation of point groups. space groups and Bravais lattices. Crystal planes and directions - miller indices - interplanar separations. Structure analysis by X-rays - Atomic scattering factor. Laue conditions for diffraction and Bragg's law - Geometrical structure factor - systematic absences. Reciprocal lattices - of cubic systems - Ewald's construction. Laue, Rotation and Powder methods of X-ray analysis. 18 hours

Unit III

Conductors, Resistors and Semiconductors – Types of metals - The resistivity range - free electron theory of metals - heat capacity and paramagnetism of metals - electrical and thermal conductivity of metals - Wiedemann -Franz law. Applications of conductors and resistors. Energy gap in solids - band theory of solids - effective mass and holes. Intrinsic and extrinsic semiconductor materials - carrier density . Hall effect and mobility. Simple semiconductor devices - photoconductors, IR detectors, Magnetometers, thermoelectric generators, thermistors, strain gauges. 18 hours

References

1. Elements of Materials science and Engineering – Lawrence H van Vlack (Addision Wesley,1975)

2. Materials Science and Engineering – V Raghavan (Prentice Hall India, 1993)

3. The Structure and Properties of Materials-Vol.I-IV -Rose, Shepard and Wulff (Wiley easterrn, 1987)

4. The Nature of Chemical Bond – L Pauling (Oxford & IBH, 1960)
5. Introduction to solids – L V Azaroff (McGraw Hill, 1960)
6. X-Ray Crystallography – M J Buerger (John Wiley, 1942)
7. Introduction to Solids – A J Dekker (McMillan India, 1981)
8. Solid State physics – R L Singhal (Kedarnath Ramnath, 1988)
9. Semiconductor Devices – James Brophy (McGraw Hill, 1964)
10. Electronic Processes in Materials – L V Azaroff and J.J. Brophy (McGraw Hill, 1963)
11. Materials Science and Technology – A comprehensive treatment – R W Cahn, P Haasen & E J Kramer - Electronic and Magnetic properties of metals and ceramics, Vol. -3A & -3B (VCH Weinheim, 1992 & 1994)

MSH 404: **THERMODYNAMICS AND CHEMISTRY OF METALS** (4 Credits)

Objectives: This course aims to provide the basic concepts of heat and dynamics of a substance under various thermodynamics conditions as a sound background in thermodynamics is necessary for understanding materials. The nature of bonding, energy and structure of various metal complexes based on coordination principles are also imparted.

Expected course outcomes: The students should gain understanding of various thermodynamic processes and applications of these in heat engines. In addition to this, the idea of phase diagram of materials potentiates their logical reasoning behind selection of materials of appropriate composition to solve a particular problem in their profession.

Unit 1

Thermodynamics: Basic concepts - Thermodynamic equilibrium, thermodynamic reversibility. Laws of thermodynamics - Zeroth law, First law - Internal energy, heat, work in various systems, heat capacities, enthalpy, flow processes, second law - Carnot theorem, Clausius inequality, entropy calculations for various processes, T-S diagram, engineering applications. Thermodynamic properties of pure substances in solid, liquid and vapor phases, P-V-T behavior of simple compressible substances ideal and real gases, equation of state, compressibility factor. Free energy functions and thermodynamic potentials - Helmholtz and Gibbs free energy functions, Gibbs-Helmholtz equations. General conditions for equilibrium, thermodynamic potential functions-Maxwell relations. Applications: Tds equations, energy and heat capacity equations, Joule-Thomson coefficient, compressibilities and expansion coefficient. Phase transitions: Condition for equilibrium between phases, first, second, third and higher order phase changes with specific examples interpretations, Claperon and Clausius Claperon equation. specific heat and latent heat anomalies. 18 hours

Unit II

Phase rule-Introduction, cooling curves, phase diagrams of binary alloy systems-Mixtures, Solidsolution,Compound, Eutectic, peritectic and eutectoid reactions,Microstructural changes during cooling, Lever rule, Typical systems-Ag-Pb, Cu-Ni., Pb-Sn, Iron- Carbon, Ag-Pt, Cu-Zn, TTT and CCT diagrams, Martensitic transformation. Free energy-composition diagrams, Ternary alloy systems.

Phase transformation-Free energy changes, Nucleation and grain growth, kinetics Application - Transformation in steel, Precipitation process, solidification and crystallization, glass transition. 18 hours

Unit III

Metals-Coordinate bond and metal complexes, Valence bond theory- Formation of octahedral complex-outer and inner orbital complex-Formation of tetrahedral and square planar complexes – Limitation of valence bond theory Crystal field theory – important features-crystal field splitting of d-orbitals in octahedral, tetrahedral, and square planar complexes applications of CFT-Distortion of octrahedral complex and

Jahn – Teller theorem- Crystal field stabilisation energy and its uses – Limitations of CFT. Molecular orbital theory – comparison of different theories.

Theoretical principles of extraction of Metals – Ellingham diagram. Extraction of Iron, Preparation of steel, Effect of alloying elements. Heat treatment Processes – Annealing, Normalising, Hardening, Quenching, Tempering- Heat treatment of steel.

18 hours

References

1. Heat and thermodynamics – Mark W. Zemansky, (McGraw-Hill, 1968)
2. Thermodynamics of solids – Richard A Swalin, (John Wiley & Sons. 1972)
3. Equilibrium thermodynamics – C J Adkins (Cambridge University press, 1983)
4. Solid state phase transformation – V Raghavan (Prentice Hall, 1992)
5. Principles of Materials Science and Engineering – William F Smith (McGraw Hill 1988)
6. Chemistry in Engineering and Technology (Vol 1&2;) – J C Kuriacose and J. Rajaram (Mcgraw Hill, 1988)
7. Materials Science and Engineering – V Raghavan (Printice Hall,1995)
8. An introduction to Metallurgy – A H Cottrell (Edward Arnold,1971)
9. Materials Science and Processes – B S Narang (CBS, 1983)
10. Advanced physical chemistry – Gurdeep Raj (Goel, 1992)
11. Inorganic chemistry – Mallik, Tuli and Madan (S Chand & Co,1990)
12. Chemistry of Transition elements – Atkin & Holiday (Oxford 1985)
13. Text book of Materials Science and Metallurgy – O P Khanna (Dhanpat Rai & Sons 1984)
14. Physical Metallurgy – V Raghavan (Printice Hall,1989)
15. Engineering Chemistry – Jain & Jain (Dhanpat Rai & Sons,1993)
16. Elements of Materials Science – L H Van Vlack (Addison-Wesley, 1989)
17. Phase Rule – Gurdeep Raj (Goel pub., 1991)

MSH 451: **QUANTUM MECHANICS-I** (4 Credits)

Objectives: This course introduces the concept of the language of Physics which makes use of the mathematical tools, learnt earlier, in abundance. As some of the concepts are far removed from the classical picture, they need to be understood well. The use of quantum mechanics to simple to not-so-simple textbook examples/problems is dealt with.

Expected course outcomes: The student should be on the sound footing with the concept of quantum mechanics, its mathematical tools and should develop the ability to apply the concepts and techniques to some known problems.

Unit I

Quantum Physics: Matter waves. Uncertainty principle. Interpretation of the wave particle dualism and complimentarity

Wave Equation and Operators: The Schroedinger equation - free particle in one and three dimensions - the operator correspondence and commutating relations. Normalization of wave functions and statistical interpretation - Box normalization the Dirac delta functions - expectation values - Ehrenfest's theorem. Stationary states - the time independent Schroedinger equation - particle in one dimensional square well potential, potential barriers - transmission and reflection coefficients. 18 hours

Unit II

Eigen values and Eigen functions; One dimensional simple harmonic oscillators - the angular momentum operator - the eigen value equation for the square of the angular momentum - orbital angular and magnetic quantum numbers - the hydrogen atom - solution of the radial equations - Rigid rotator – energy eigen values. 18 hours

Unit-III

General formalism of quantum theory: operator methods**,** Hilbert space and observables, Dirac notation, Schrodinger, Heisenberg and interaction pictures, Simple harmonic oscillator by operator method. Ladder operators, Matrix representations of angular momentum operators, Pauli matrices, Addition of angular momentum, Clebsch-Gordan coefficients. . 18 hours

References

1. Applied X-rays – G W Clark (McGraw Hill, 1955)
2. Quantum Mechanics – L I Schiff (McGraw Hill, 1968)
3. Qauntum Mechanics – Sokolov (Holt Rinehart and Winston Inc., 1966)
4. Quantum Mechanics – Mathews and Venkatesan (Tata McGraw Hill, 1981)
5. Quantum Mechanics – Powel and Craseman (Oxford & IBH, 1985)
6. The Feynman Lectures on Physics, Vol.3- R. P. Feynman, R.B. Leighton and M.Sands**,** Narosa Pub. House(1992).
7. Introduction to Quantum Mechanics- R. L. Liboff, Pearson Education(2003).
8. Introduction to Quantum Mechanics- D J Griffiths, Pearson Education (2005)

MSH 452: **CLASSICAL MECHANICS AND STATISTICAL PHYSICS** (4 Credits)

Objectives: This course is designed to introduce the student to the basics of Classical Mechanics and Statistical Physics - both of which are mathematical tools helpful in solving physical problems involving the motion of objects under the influence of forces or microscopic systems with large populations. It first familiarizes the student with very simple concepts of classical mechanics and then illustrates how these principles can be used to solve complex problems of rigid and deformable bodies. In the same vein, the statistical mechanics introduces the student to the fundamentals of classical and quantum statistics.

Expected course outcomes: This course prepares the student with the basic skills required to compute mathematical problems at both the macroscopic and microscopic level. With the theoretical background acquired, the student should be capable to understand and tackle more complex problems that he/she may encounter in the career.

Unit I

Analytical Mechanics: Mechanics of a system of material particles, constraints, degrees of freedom. D'Alembert's principle and Lagrange's equations. Simple applications of Lagrange's equations. Hamilton's principle - derivation of Lagrange's equations. Hamilton's equations - cyclic co-ordinates- Principle of least action - canonical transformation. Poisson brackets and equations of motion. Hamilton - Jacobi equations - solution of harmonic oscillator. 18 hours

Unit II

Mechanics of Rigid and Deformable Bodies: The independent co-ordinates of a rigid body - orthogonal transformations - Eulerian angles. Infinitesimal rotations, rate of change of a vector. Euler's equations of motion - motion of a symmetric rigid body with one point fixed and force free motion. Analysis of strain tensor of an elastic medium - Navier's conditions of equilibrium. Symmetric stress tensor. generalised Hooke's law - elastic constants of an isotropic homogeneous media - equations of motion - elastic waves –velocity of longitudinal and transverse waves. 18 hours

Unit III

Statistical Mechanics: Phase space - Ensembles - Thermodynamic probability - Maxwell - Boltzmann distribution - Partition functions - translational, vibrational and rotational partition functions - applications to specific heats.

Quantum Statistics: Inadequacy of classical statistics - spectra of black - body radiation. Indistinguishability of identical particles. Bosons and Fermions - Bose - Einstein statistics - black - body radiation and Bose condensation. Fermi - Dirac Statistics-degenerate electron gas. 18 hours

References

1. Classical Mechanics - H Goldstein (Addison Wesley, 1960)
2. Classical Mechanics - H C Corben and P Stehle (John Wiley, 1960)
3. Mechanics - A Sommerfeld (Academic Press, 1964)

4. Mathematical Theory of Elasticity - I S Sokolnikoff (McGraw Hill, 1956)
5. Statistical Physics – L D Landau and E M Lifshitz (Pergamon, 1968)
6. Statistical Mechanics and Properties of Matter – E S R Gopal (McMillan India, 1976)
7. Statistical Physics: Berkeley Physics(5) – F Reif (McGraw Hill,1967)
8. The Feynman Lectures on Physics – R P Feynman, R B Leighton and M Sands (Addison Wesley/Narosa, 1986)

MSH 453: **ELEMENTS OF MATERIALS SCIENCE – II (**4 Credits)

Objectives: Objective of the course is to study the basics of mechanical properties of materials. The course deals with the crystal imperfections, diffusion in solids, elastic behaviour of materials, plastic deformation and fracture, etc.

Expected course outcomes: At the end of this course, students should be able to classify various types of defects in the materials and their connection with elastic/plastic deformations and various mechanical properties of materials. This would help students in the selection of materials for various applications during their career.

Unit I

Crystal Imperfections: Point imperfections - configurational entropy - Schottky and Frenkel defects - equilibrium concentrations. Line imperfections - edge and screw dislocations - Buerger's vector in cubic crystals. Surface imperfections - grain boundary - tilt and twin boundaries.

Diffusion in solids: Fich's laws of diffusion - solutions to Fich's second law - Gaussian and error function solutions. Determination of diffusion coefficient - diffusion couple. Applications based on second law. Kirkendal effect. Atomic model of diffusion -other diffusion processes - electrical conductivity of ionic crystals.

18 hours

Unit II

Elastic Behaviour of Materials: Atomic model of elastic behaviour - the modules as a parameter in design - rubber like elasticity - Anelastic behaviour - Viscoelastic behaviour.

Elements of Physical Metallurgy: Fracture in metals – Ductile fracture, ductile brittle transition, brittle fracture-Griffith theory. Notch effect, Compressive and tensile strength - size effect, stress intensity factor, toughness measurements. Protection against fracture. Fatigue failure - Characteristic of fatigue failure-statistical nature of fatigue-correlation of fatigue strength and plastic properties. Factors affecting fatigue strength. Tribology: wear of metals–mechanisms, factors influencing wear, wear resistance-protection against wear. Metallurgical microscopes, sample preparation, grain size measurements of typical ferrous and non-ferrous alloys.
. 18 hours

Unit III

Plastic Deformation in Crystalline Materials: The tensile stress-strain curve - Plastic deformation by slip - the shear strength of perfect and real crystals - CRSS - the stress to move a dislocation. interactions between dislocations - multiplication of dislocations during deformation – Frank- Reed Source. Work hardening and dynamic recovery. Strengthening against plastic deformation – strain hardening – grain refinement – solid solution – precipitation strengthening. Creep in Crystalline Materials - Mechanism of creep and creep resistant materials. 18 hours

References

1. Elements of Materials science and Engineering – Lawrence H van Vlack (Addision Wesley, 1975)
2. Materials Science and Engineering – V Raghavan (Prentice Hall,1993)
3. Materials Science and Processes – B S Narang (CBS,1983)
4. Introduction to solids – L V Azaroff (McGraw Hill, 1960)
5. Introduction to Solid State Physics – C Kittel (II Ed. Asia publishing House, 1965)
6. The Structure and Properties of Materials-Vol.I-IV – Rose, Shepard and Wulff (Wiley Eastern,1987)
7. Physical Metallurgy – V Raghavan (Prentice Hall, 1989)
8. Materials Science and Metallurgy – O P Khanna (Dhanpat Rai & Sons, 1984)
9. Solid State Physics Source Book – Sybil P Parker (McGraw Hill, 1987)
10. Materials Science and Technology – A comprehensive treatment – (ed.) R W Cahn, P Haasen & E J Kramer – Electronic and Magnetic properties of metals and ceramics, Vol – 3A & -3B (VCH, 1992 & 1994)
11. Introduction to properties of Materials – Daniel Rosenthal and Robert M Asimow (Affiliated East-West Press, 1974)
12. Physical Metallurgy Principles – R E Reed Hill (Affiliated East –West Press, 1974)
13. Physical Metallurgy – S H Avner (Tata McGraw-Hill 1997)
14. Mechanical Metallurgy – George R Dieter (McGraw-Hill, 1988)

MSS 454: **SURFACE PHENOMENA AND ELECTROCHEMISTRY** (3 Credits)

Objectives: Surface of a material where numerous physical and chemical phenomena are possible and it is one of important aspects of Materials. Thus, this course provides a comprehensive knowledge on surface phenomena, catalysis, electrochemistry and corrosion of materials is the objective this course.

Expected course outcomes: The student should understand the theoretical aspects of catalysis and electrochemical phenomenona, which will benefit to pursue research on batteries, fuel cells and corrosion prevention techniques.

Unit I

Surface phenomena - Adsorption, characteristics of adsorption, classification of adsorbents, molecular interactions in adsorption, energetic and desorption, physical and chemical adsorption, adsorption isotherms (Freundlich, Langmuir, BET), determination of surface area of adsorbent, application of adsorption.

Catalysis: Characteristics of catalytic reaction, Classification of catalyst, Kinetics of homogeneous and heterogeneous catalytic reactions, Application of catalysis.

Solid-state chemical reactions: Introduction, Classification, and thermodynamics.

Chemical transport reaction in solid state Experimental methods to study solid state reactions, kinetic features, diffusion mechanism, factors affecting the reactivity of solid state reaction. 14 hours

Unit II

Electrochemistry - Electrolytic conduction- Debye Huckel theory of Interionic attraction-Debye Huckel Limiting Law- Energetics of electrochemical reactions-Electrode potential and EMF-Application of EMF measurements-Potentiometric titration-Electrochemical devices: Galvanic cells (primary and secondary)-concentration cells and fuel cells, polarisation, over voltage, decomposition potential and electrodeposition techniques. 14 hours

Unit III

Corrosion - Introduction and importance of corrosion studies-Theories of corrosion-factors influencing corrosion-Forms of corrosion, Corrosion control measures through Paints, metal coatings, anodic and cathodic protection, Polarization studies-corrosion rate measurement, Tafel extrapolation, passivity, analysis of corrosion failure.

14 hours

References

1. Principles of Material science and Engineering – William.F Smith (McGraw Hill, 1988)
2. Material science and Engineering – V.Raghavan (Printice Hall, 1998)
3. An introduction to Metallic Corrosion and its prevention – Raj Narayan (Oxferd and IBH, 1983)

4. Introduction to Electrochemistry – S Glasstone (East West, 1942)
5. Advanced Physical Chemistry – Gurudeep Raj (Goel, 1992)
6. Solid state Chemistry – Hannay (Printice Hall, 1967)
7. Text Book of Material science and Metallurgy – O P Khanna (Dhanpat Rai & Sons, 1984)
8. Engineering Chemistry – Jain & Jain (Dhanpat Rai and Sons, 1993)
9. Solid state Chemistry – Ram Prakash (Radha Publications, 1989)
10. Adsorption – J Oseik (Chichester: Ellis Horwood, 1982)

MSE 457: **SCIENCE OF MATERIALS IN DAILY LIFE** (open elctive-1)(3 Credits)

Objectives: Objective of the present course is to give a fundamental knowledge about technologically important materials such as metals, semiconductors, polymers, composite materials, ceramic materials and basic semiconductor devices to the non-materials science students.

Expected course outcomes: This course imparts basic knowledge on the topics studied to the students who are not studying materials science..

Unit I

Conductors: Metals, Alloys, Semiconductors- Definition, elementary ideas of electrical properties, optical properties, mechanical properties, thermal properties. Specific examples of metals- Copper, Aluminium, Iron, Gold, Silver. Uses of metals. Drawbacks of metals. Alloys- advantages of alloying. Examples-Brass, Bronze, Steel, Stainless steel, Gold alloys, silver alloys and their uses.

Semiconductors: Elemental semiconductors- Silicon, Germanium. Doping- n-type and p-type semiconductors, p-n junctions. Qualitative ideas of devices- diodes to ICs. Compound Semiconductors. 14 hours

Unit II

Polymers and composites: Plastics- Introduction. Types of plastics. Rubber- Types of rubber. Vulcanization of rubber. Fibres- Different types of natural and synthetic fibres. Resins, Adhesives and polymer coatings. Physical, chemical, mechanical properties and applications of polymers. Recycling of polymers.

Composites- Introduction, types. Wood, Concrete, FRP and some advanced composites. Properties and applications. 14 hours

Unit III

Ceramics and Glasses: Ceramics- Introduction, classification, raw materials, fabrication methods, properties and applications. Types of ceramics- oxide and non-oxide ceramics. Allotropes of carbon- graphite, diamond and fullerene. Primary refractory materials.

Glasses- Introduction, raw materials, manufacture of glass, properties and applications. Types of glasses, properties and Applications. Photochromic and photosensitive glasses. 14 hours

References

1. The Physics of Materials: How Science Improves Our Lives, Solid State Sciences Committee, (National Research Council, 1997)
2. The Science of the World Around Us , Solid State Sciences Committee, (National Research Council, 2007)

3. Materials Science and Engineering – V Raghavan (Prentice Hall India,1993)
4. Introduction to Solids – A J Dekker (McMillan India, 1981)
5. Plastics-How Structure determines properties- G Gruenwald (Hanser)
6. Understanding Materials Science- R E Hummel (II Ed) (Springer)
7. Materials Science- Nagpal (Khanna, Delhi)
8. Polymer Science –V R Gowarikar, N V Viswanath, Jayadev Sridhar (Wiley Eastern, 1987)
9. Composite Materials-Engineering & Science – F L Mathews & R D Rawlings (Chapman & Hall, 1990)
10. Introduction to Ceramics – W D Kingery, H K Bower and U R Uhlman (John Wiley, 1960)
11. Glasses and vitreous state – J Zarzycki (Cambridge University Press, 1982)

MSH 501: **DIELECTRIC MATERIALS** (4 Credits)

Objectives: This course introduces the student to a class of important insulating materials, viz: dielectrics and the physics responsible for their behavior. The thermal properties of dielectrics beautifully introduces the concept of heat transport by the lattice – the different modes of vibrations of the lattice, phonons etc and how they are controlled by their elastic properties.

Expected course outcomes: A good grasp on what differentiates a dielectric material from a mere insulator and how these differences make them useful in specific applications. A reasonably good understanding of lattice dynamics is also expected.

Unit I

Dielectric polarisation and atomic forces -electronic polarisation. Dielectric law and the generalisation. Atomic or ionic polarisation, orientational polarisability. Static dielectric constant of materials. Lorentz internal field. Clausius-Mosotti relation. Polarisation catastrophe. electromechanical coupling - dielectric breakdown - electric energy stored in dielectrics. general applications of dielectric materials. The complex dielectric constant, dielectric losses and relaxation time - Debye equations - theory of electronic polarisation and optical absorption. Optical Phenomena in Insulators Colour of crystals - Excitons - weakly bound and tightly bound excitons. Colour centers – F-centers and other electronic centers in alkali halides. 18 hours

Unit II

Ferroelectrics: General characteristics - piezoelectric, pyroelectric and ferroelectric materials - transducer and detector applications. Classification of ferroelectrics and representative materials. Structure of KDP and explanation for its ferroelectric behaviour. Barium titanate and its ferroelectric behaviour. Crystal structure and theory of spontaneous polarisation in barium titanate. Zeroes and poles of the dielectric function – Lyddone-Sachs-Teller relation. Ferroelectric domains. Thermodynamics of ferroelectric phase transitions. Remarks on antiferroelectric materials - Materials with paired properties like ferroelectric-ferroelastic, ferroelectric-ferromagnetic etc. 18 hours

Unit III

Thermal Properties of Insulators: Heat capacity - Einstein's model - quantisation of lattice vibration - continuum model - Debye's theory. Vibrations of monoatomic lattice - specific heat of one dimensional lattice of identical atoms. Phonon spectra of diatomic lattice and phonon modes - optical properties in infra-red region and their applications. Scattering of electromagnetic waves and neutrons by phonons. Thermal conductivity of insulators - lattice thermal resistivity - Umklapp process. Thermal expansion: Potential wells in crystal binding - anharmonic interactions and thermal expansion of insulators. 18 hours

References

1. Introduction to Properties of Materials – D Rosenthal and R M Asimov (East West, 1974)
2. Elements of Materials Science and Engineering – L H van Vlack (Addison Wesley,

1975)
3. Introduction to Solid State physics – C Kittel (II & IV Ed. Wiley & sons, 1961 & 1964)
4. Solid State Physics – A J Dekker (McMillan, 1971)
5. Advances in Solid State Physics, Vol.II & V – Seitz and Turnbull (Ed) (Academic, 1957)
6. Physics of Dielectric Materials – B Tareev (MIR, 1979)
7. Crystal Structures - Vol.1-3 – W G Wyckoff (Interscience,1963)
8. Electronic Properties of Materials – Hummel (Springer-Verlag, 1985)
9. Solid State Physics Source Book – Sybil P Parker (Ed) (McGraw Hill, 1987)

MSH 502: **SOLID STATE ENGINEERING MATERIALS – I** (4 Credits)

Objectives: The objective of the course is to teach fundamentals of the electronic structures of different types of electronic materials especially metals and semiconductors along with details about the alloys and nuclear materials. The band structures of the materials are important to understand the optical and electrical properties. With the help of theory of semiconductors, fabrication of the devices is also discussed.

Expected course outcomes: Student should understand the concepts of band structures of materials, and be able to interpret the optical and electrical data. They should be in a position to understand various aspects of alloys and familiar with the fundamentals of nuclear reactors and materials used in them.

Unit I

Metals: Band structure - Brillouin zones- Wigner Seitz approximation. Energy wave vector curves. Brillouin zones relation with Bragg planes. Density of states. Fermi surface -F.C.C & B.C.C- De Haas van Alphen effect. Electronic properties of metals – Boltzman transport equation. Electrical conductivity, thermal conductivity, Galvanomagnetic effects, thermionic and field emission in metals. 18 hours

Unit II

Semiconductors: Energy bands, effective mass. Direct and indirect band gaps. Determination of band gaps. Donors and acceptors, carrier concentrations at thermal equilibrium. Calculation of Fermi level. Degenerate and non-degenerate semiconductors. Semiconductor Crystal growth – Introduction, Methods - Bridgman, Czochralski, zone melting/refining techniques. Contact phenomenon- semiconductor-semiconductor, metal-semiconductor contacts. Schottky and Ohmic contacts. Preparation of semiconductor devices - Fabrication of junctions- wafer preparation, IC technology: monolithic IC- masking and etching - elements of lithography (brief description). 18 hours

Unit III

Alloys: Long range order theory-Super lattices and transitions. Diffusion in alloys - Darken's equations, determination of diffusion coefficient. Some special alloys - ferrous and non-ferrous. Super alloys.

Nuclear materials: General aspects of reactor design. Fissile materials used in different types of reactors- Moderator and coolant and cladding materials. Radiation effects in materials - Swelling, He-embrittlement, induced radioactivity. Erosion and fretting corrosion-stress corrosion cracking, H_2-embrittlement. 18 hours

References

1. Solid State Physics – A J Dekker (McMillan, 1985)
2. Solid State Physics – C Kittel (Wiley Eastern, 1993)
   Solid State Physics –N W Ashcroft and N D Mermin (W B saunders, Ithaca, 1976)
3. Electronic Materials and devices – D. K. Ferry (Academic Press, New York, 2001)

4. Semiconductor Physics – P S Kireev (MIR Publishers, 1978)
5. Physics of Semiconductors Devices – S M Sze (Wiley Eastern, 1991)
6. Solid State Devices – Ben G Streetman (Prentice-Hall, 1995)
7. Solid State and Semiconductor Physics – John Mckelvey (John Wiley, 1976)
8. Introduction to properties of Materials – Daniel Rosenthal and Robert M Asimow (Affiliated East-West Press, 1974)
9. Physical Metallurgy Principles – R E Reed Hill (Affiliated East –West Press, 1974)
10. Physical Metallurgy – S H Avner (Tata McGraw-Hill 1997)
11. Mechanical Metallurgy – George R Dieter (McGraw-Hill, 1988)
12. Nuclear Reactor Engineering – S Glasstone and Alexander Sesonske (CBS Pub., 1986)

MSS 503: **THIN FILMS** (3 Credits)

Objectives: The course introduces the student to an extremely important form of material, thin films. The present day technology ranging from astronomy to zoology spanning microelectronics, optical coatings, protective and decorative coatings, sensors etc. requires a sound understanding of thin film concepts. The preparation techniques, optical and electrical properties are dealt in considerable detail.

Expected course outcomes: The student should be well versed with the fundamentals of thin films, deposition parameters affecting the structure thereby properties so that without further theoretical training students can be inducted in to the industry or research in the area of thin films.

Unit I

Preparation of Thick and Thin Film Materials: Definition of thick and thin films. Physical Vapour Deposition(PVD) - thermal evaporation - Knudsen cosine law. Sputtering- DC Glow discharge and Low pressure sputtering. Chemical Vapour Deposition(CVD). MBE, MOCVD methods of preparing device grade films. Spray pyrolysis and other chemical methods of film preparation for large area applications. LB films and their applications. Thickness measurement techniques- electrical, and mechanical methods. Optical methods- spectrophotometric and interference methods. Microbalance methods – Quartz crystal oscillator technique. 14 hours

Unit II

Nucleation and Growth of Thin Films: Theories of nucleation-Capillarity theory, effect of deposition parameters. atomistic theory and rate equation approach of nucleation. Growth of thin films- Mechanisms and influence of deposition parameters. Epitaxial growth - theory of epitaxial nucleation. Durability of films - Adhesion and Internal stress.

Optical Properties of Thin Films: Reflection and Transmission at interface between isotropic transparent media. Reflectance and Transmitance in thin films. Methods for determining optical constants - spectrophotometer and polarimetric methods. Antireflection coatings - theory and design of single layer coatings. Double and multilayer coatings - brief description. 14 hours

Unit III

Electron Transport Phenomena in Thin Films: Electrical conduction in discontinuous metal films - Quantum mechanical tunneling model. Conduction in continuous metal films- Size effect and specular scattering. Thermoelectric power in metal films. Electrical conduction in semi-conductor and insulator films - Hybrid micro circuits, thin film resistors, thermopiles. Quantum Hall Effect- Quantum well devices.

14 hours

References

1. Handbook of Thin Film Technology – L I Maissel and R Glang (Ed) (McGraw Hill, 1970)
2. Vacuum Deposition of Thin Films – L Holland (Wiley, 1956)
3. Thin Film Phenomena – K L Chopra (Mc Graw Hill, 1969)
4. Physics of Thin Films Vol.1 - 4 - G Hass and R E Thun (Ed) (Academic, 1963)
5. Electrical Conduction in Thin Metal Films – T J Coutts (Elsevier, 1974)
6. Optical Properties of Thin Solid Films – O S Heavens (Dover, 1955)
7. Thin Film Technology and Applications – K L Chopra and L K Malhothra (Ed) (Tata Mc Graw Hill, 1985)

MSS 504: **NEW MATERIALS AND TECHNOLOGIES** (3 Credits)

Objectives: This course aims to provide a glimpse into the fascinating world of a few new unique materials like shape memory alloys, conducting polymers and nanoparticles – their properties, synthesis and applications.

Expected course outcomes: An appreciation of how manipulation of matter at the atomic level can result in materials with novel properties and how these properties can be applied for design of useful devices. It is also expected that it may provide in the students an urge to explore still newer discoveries in the field of materials science and an interest in research in the field.

Unit I

Super alloys and Smart Materials: Types of super alloys – iron based – nickel based – cobalt based super alloys –fabrication – their characteristic features – areas of application.

Introduction to smart materials – shape memory effect and martensitic transformation –SME and Superelasticity. Ti - Ni SM Alloys – Cu - based SM Alloys. Ferrous SM alloys. Fabrication of SM Alloys. Characteristic fundamental properties – Shape memory ceramics and polymers. General applications of Smart materials – design of actuators – medical and dental applications. 14 hours

Unit II

Conducting Polymers :Introduction to conducting polymers. Structural features – factors affecting conductivity of polymers - (semiconducting, superconducting) – preparation of conducting polymers – band structures of polymers –charge transport in conducting polymers – nature of charge carriers (soliton, polaron, bipolarons) – models of charge transport – structure - property relationship. Mechanisms of conduction in doped polyheterocyclics, polyaromatics, conducting co-polymers. – molecular designing of Novel conducting polymers – substitution / fusion, ladder structure formation – copolymerisation – donar - acceptor polymer formation – practical applications of conducting polymers – electronic, electrochemical, photonic applications, sensors, medical applications. 14 hours

Unit III

Nano-materials :Introduction – nanostructural materials – metals, semiconductors and ceramics. Synthesis of nanoparticles– inert gas evaporation – laser pyrolysis – sputtering techniques, plasma techniques. Various Chemical methods of synthesis. Functionalized metal nanoparticles- synthesis, characterization, organization and applications. Semiconductor nanoparticles- synthesis, characterization and applications of quantum dots. Magnetic nanoparticles- assembly and nanoastructures. Manipulation of nanoscale biological assemblies. Carbon nanotubes and fullerene as nanoclustures. Nanostructured films.

Charaterisation of nanoaprticles and nanostructures– Optical spectroscopy, Electron Microscopy, Atomic Force Microscopy, X-Ray diffraction of nanoscale materials. 14 hours

References

1. The Science and Engineering of Microelectronic Fabrication, S. A. Campbell (Oxford,1996).
2. Intrinsically conducting polymers : An emerging technology, M. Aldissi (editor), (Kluwer, 1993).
3. Quantum Chemistry Aided Design of Organic Polymers, J. M. Andre, J. Delhalle & J. L. Bredas (World Scientific, 1991).
4. Electrical properties of polymers : Chemical principles, C. C. Ku and Leilpens, (Hanser, 1987).
5. Science and applications of conducting polymers, W. R. Salaneck, D. T. Clark, E. J. Samuelson, (Adam Hilger, 1991).
6. Special polymers for Electronics and optoelectronics, J. A. Chilton, M. T. Goosey, (Chapman and Hall, 1995).
7. Longmuir - Blodgett films - Gareth Roberts (Ed), (Oxford, 1989).
8. D. Chakravorty and A. K. Giri in Chemistry of Advanced Materials (C. N. R. Rao. ed), (Blaclwell, 1992).
9. P. Jena, B. K. Rao and S. N. Khanna (eds). Physics and Chemistry of Small Clusters (Plenum Press, 1986).
10. Physics and Chemistry of Finite Systems : From Clusters to Crystals, (Kluwer, 1992).
11. Selection of Engineering Materials, G. Lewis, (Prentice Hall, 1990).
12. Engineering Materials and their applications, R. A. Flinn and P. K. Trojan, (Jaico,1998).
13. Fundamentals of Ceramics, M. W. Barsoum, (McGraw – Hill, 1997).
14. Shape Memory Materials, K. Otsuka and C. W. Wayman, (Cambridge, 1998).
15. Nanoscale Materials – (Ed) L.M. Liz-Marzan and P.V.Kamat, (Kluwer, 2003)
16. Nanostructured Materials and Nanotechnology, (Ed) H.S.Nalwa, (Academic, 2002).

MSS 505: **POLYMER SCIENCE** (3 Credits)

Objectives: Polymers are the fascinating materials for both functional and structural applications. The course provides an introduction to the various aspects of synthesis and properties of polymers. This will also provide insight in to the appropriate use of these materials.

Expected course outcomes: The student should gain a sound foundation in the area so that advanced topics in polymer science can be easily understood. Also, by learning the characterisation techniques, one can handle the analytical tools for qualitative interpretation and reasoning of experiments on polymers materials.

Unit I

Introduction - Monomers, polymers-Linear, branched, cross linked, stereo regular, thermoplastic, thermoset, copolymers, crystalline & amorphous polymers, degree of crystallinity, molecular interactions & chemical bonding, flexibility, free volume, free volume & packing density- WLF parameters & free volume, configuration and conformation, dimensions of polymer coil, polymer melting &glass transition, polymer blends & interpenetrating network.
Molecular weight distribution-weight, number & viscosity average molecular weight, determination-end group, viscosity, light scattering, ultracentrifuge, gel permeation chromatography. Criteria of polymer solubility - thermodynamics of polymer dissolution, solubility parameter, Flory Huggins theory, Newtonian & nonnewtonian flow, size & shape of polymer in solution, application of phase rule to polymer systems. 14 hours

Unit II

Synthesis & Processing- Chain polymerization-Free radical, cationic, anionic, coordination- Mechanism & Kinetics Step polymerization - polyaddition, polycondensation – Mechanism & Kinetics, Copolymerisation - Kinetics, reactivity ratios.

Methods of polymerization - bulk, suspension, solution, emulsion, condensation Processing-moulding-compression, injection, blow, extrusion, casting, spinning Synthesis, properties & applications of thermoplastics-vinyl polymers, polyvinilidine chloride, polycarbonate, polyamide, polyimide, polyurethanes, Rubber – natural and synthetic – processing, vulcanization, properties and applications. Cellulose and its derivatives. Thermosets- phenolic, amino, epoxy, polyester, silicone polymers Liquid crystal polymers, Biomaterials, Biomedical polymers, different types of packaging materials and applications, polymer adhesives. 14 hours

Unit III

Physical properties and Charecterization - Mechanical properties- Tensile testing-stress-strain plots of different types of polymers Viscoelastic behavior, Rubber elasticity, factors influencing the strength of polymer Electrical properties- Dielectric relaxation, theory & mechanism of electrical conduction, semiconducting & conducting polymers, applications.

Optical properties- refractive index, birefringence, UV, IR Spectroscopy.

Thermal properties - Heat capacity of amorphous & crystalline polymers, polymer degradation, Thermal analysis – DSC, TMA, TG.

Acoustic properties- Dynamic modulus of elasticity, loss modulus, velocity of propagation and absorption coefficient of elastic waves in polymers, experimental determination of modulus of elasticity of solid polymers. 14 hours

References

1. Polymer Science –V R Gowarikar, N V Viswanath, Jayadev Sridhar (Wiley Eastern, 1987)
2. Polymer Chemistry – Bill Meyer Fred (Wiley Interscience, 1984)
3. Polymer Chemistry - An introduction – Raymond B Seymour & Charles E carraher Jr (Marcel Dekker, 1987)
4. Polymer Chemitry – M Mishra (Wiley Eastern, 1993)
5. Physical Chemistry of Polymers – A Tager (Mir Pub., 1978)
6. An introduction to Polymer Physics – I I Perepechko (Mir Pub., 1978)
7. Principles of Polymer Science – F Rodrigues (Mcgraw Hill, 1974)
8. Acoustic Methods of investigating polymers – I I Perepechko (Mir Pub., 1975)
9. Polymer Science and technology – Joel R Fried (Printice Hall, 1993)

MSS 506: **NANOSCIENCE AND NANOTECHNOLOGY – I** (3 Credits)

Objectives: This course offers an opportunity for the interested student to get a basic knowledge about nanoscience and associated technology - one of the most researched topic in the past decade. It serves as an introductory course in the topic and is designed so that any student having just a basic knowledge of science is able to understand the fundamentals involved in synthesis and characterization of nanostructures.

Expected course outcomes: The student acquires information the about the physics behind why nanomaterials exhibit properties different from that of the bulk. The chemistry involved in their synthesis equips them with knowledge of how matter can be manipulated to give materials with new properties.

Unit I

Introduction. – Nanostructured materials, nanoparticles, nanorods, nanotubes etc. Brief survey of metals, insulators and semiconductors, Free electron and band theory, Low dimentional structures, Particles in a box, Strong and weak confinements, Excitons.

Colloid Chemistry: Introduction. Kinetic properties- Sedimentation rate, Brownian motion. Surface energy, Surface potential and Zeta potential and their consequences. Thermodynamics of surfaces. Coagulation- Kinetics of coagulation. Stability of colloids. 14 hours

Unit II

Chemical Synthesis of Nanoparticles: Bottom up approach. Chemical reduction. Microwave synthesis, Sol-gel technique, Reverse miscelle methods. Functionalized nanoparticles in different medium. Size control. Self assembly. Nanoparticle arrays. Porous nanoparticles, Nanocoatings.

Physical Methods of Nanostructure Fabrication: Top down approach. High energy ball milling, Vapour condensation, Laser ablation, MBE, MOCVD, LPE.

Nanopatterning- Lithography- Optical, X-ray and Electron beam lithography. Ion-beam lithography, SPM, Dip pen lithography. 14 hours

Unit III

Analysis of Nanostructures: Atomic Force Miscroscope, Scanning Tunneling Microscope, High Resolution Transmission Electron Microscope, Field Emission Scanning Electron Microscope, X-ray Diffraction, Small angle X-ray diffraction, UV-Vis-NIR spectroscopy, Photoluminiscence, IR spectroscopy, Raman spectroscopy. Zeta potential measurements. Micro SQUID Magnetometry. 14 hours

References:

1. The Science and Engineering of Micro electronic Fabrication -S. A. Campbell (Oxford,1996).
2. Nanoscale Materials - (Ed) L.M. Liz-Marzan and P.V.Kamat, (Kluwer, 2003)
3. Nanostructured Materials and Nanotechnology - (Ed) H.S.Nalwa, (Academic, 2002).
4. Colloidal and Surface Chemistry - M Satake, Y Hayashi, Y Mido, S A Iqbal, M S Sethi (Discovery, 1996)
5. Colloid Chemistry – S Voyutsky (MIR, 1978)
6. Introduction to Nanotechnology – C P Poole and F J Owens (Wiley- Intersci., 2006)
7. Nanotechnology and Nanoelectronics – W R Fahrner (ed) (Springer, N Delhi, 2006)
8. Quantum Dots - L.Jacak, P Hawrylak, A Wojs, (Springer, 1997)
9. Physics of Low Dimensional Structures, J H Davis, (Cambridge, 1998)
10. Sol-Gel Science, Scherrer and Brinker

MSS 507: **CRYSTAL GROWTH (**3 Credits**)**

Objectives: Objective of the course is to provide a fairly detailed knowledge on the various crystal growth processes. In particular, single crystal growths in bulk form and in epitaxial thin film forms which are essential for various research and development/technological applications.

Expected course outcomes: The student should be familiar with the crystal growth techniques with the necessary nucleation-growth theory. Good foundation on these topics would be helpful during their career in research or industry.

Unit I

Crystal growth phenomena: Significance of single crystals – crystal growth techniques. Ideal growth laws – crystal-ambient phase equilibrium – criteria for equillibria in crystal growth – phase diagrams. Classification of growth processes.

Theories of nucleation- energy of formation - homogeneous nucleation – Gibb's Thompson equation for vapour, melt and solution, equilibrium shape of crystals. Heterogeneous nucleation – cap and disc shaped nuclei –constitutional supercooling - velocity of growth. Atomistic, thermodynamical models of crystal growth - Kossel and BCF theory. 14 hours

Unit II

Crystal growth techniques : Bulk crystal growth – solution growth methods - supersaturation - aqueous solution, flux, hydrothermal methods. Melt growth – Kryopoulos, Bridgman – Stockbarger, Czochkralski, float zone and zone refining techniques. Impurity levelling factor – segregation coefficient. Verneuil method.

Low and high temperature solution growth – methods of crystallization – temperature gradient methods - growth of KDP and KTP crystals. 14 hours

Unit III

Epitaxial growth methods – advantages - PVD – chemical vapour deposition – liquid and chemical vapour phase epitaxy – hot wall epitaxy- molecular beam epitaxy – MOCVD. Surface impurity contamination, defects and dislocations, determination of dislocation density.

Application: Si and Ge in semiconductor industry- IC technology: monolithic IC-masking and etching - elements of lithography- resist systems and patterning.

14 hours

References

1. M.A. Wahab, Essentials of Crystallography, 2nd Edition (Narosa Publishing House Pvt. Ltd, 2011)
2. Saito Yukio, Statistical Physics of Crystal Growth (World Scientific, Singapore, 1996)

3. Ivan V. Markov, Crystal Growth for Beginners: Fundamentals of Crystal Growth, Nucleation and Epitaxy (World Scientific, Singapore, 1996)
4. R.C. Ropp, Solid state Chemistry,(Elsevier, 2003)
5. H.V.Keer, Principles of the Solid State (Wiley Eastern,1993)
6. Crystal Growth 1974, Proc. Of 4th Int. Conf. on Crystal Growth, Tokyo, Japan 24-29 March 1974, Eds. K.A.Jackson, N.Kato and J.B.Mullin.
7. Current Trends in Crystal Growth and Characterization, Byrappa.K (MIT,1991)
8. Physics of Crystal Growth, Pimpinelli Alberto (Cambridge University 1998)
9. The Growth of Crystals from Liquids, Brice J.C (North Holland Press, Amsterdam,1973)

MSS 508: **QUANTUM MECHANICS –II** (3 Credits)

Objectives: This course introduces the students to the advanced concepts of quantum mechanics like time dependent problems, perturbation theory, scattering theory, relativistic quantum mechanics etc. if one is interested in going deeper in o the theoretical realm.

Expected course outcomes: The student is expected to gain a strong hold on some of the aspects of quantum mechanics required to be used for the theoretical treatment of modern concepts in physics.

Unit-I

Time dependent problems: Two level systems in a harmonically varying external potential. Example of spin in an external sinusoidal magnetic field. Time evolution of spin vector. The Schrodinger, Heisenberg and Interaction pictures. Equations of motion.

Time dependent perturbation theory: Perturbation expansion. Formal solution of the Schrodinger equation in a time dependent perturbing potential. Harmonic perturbation. Fermi golden rule. Atom-Radiation interaction, dipole approximation. Spontaneous decay. Einstein A and B coefficients using Fermi golden rule. 14 hours

Unit II

Time independent scattering Theory: Scattering cross section. Boundary conditions. scattering amplitude and differential cross section. Born approximation, validity, example of Yukawa potential, Rutherford scattering formula.

Method of partial waves: Motivation, Partial wave expansion, scattering amplitude, phase shifts, partial wave amplitude, differential and total cross sections for short range potentials. Optical theorem. Low and high energy scattering from a hard sphere. Low energy scattering from a potential well and bound states, scattering length. Resonance scattering and quasi-bound states. 14 hours

Unit -III

Relativistic Quantum Mechanics: The Klein-Gordon(KG) equation. Plane-wave solutions. KG equation in a electromagnetic field. Continuity equation. Limitations of KG equation and its correct interpretation. Non-relativistic reduction of KG equation. Application to two-body problem of two spinless particles in a Coulomb potential.

Dirac Equation: The free particle Dirac equation. Pauli-Dirac representation. Continuity equation. Plane wave solutions of the Dirac equation in the Pauli-Dirac representation, Normalisation. Dirac equation in an electromagnetic field. Non-relativistic approximation. Spin in Dirac theory, Conservation of angular momentum. Helicity. Negative energy solutions and Hole theory. Covariant formulation of Dirac equation, Gordon decomposition of vector current. Brief discussion on application of Dirac theory to the hydrogen atom. 14 hours

References

1. E. Merzbacher, Quantum Mechanics, 3rd edition, John Wiley (1994).
2. V. K. Thankappan, Quantum Mechanics, Wiley Eastern (1985).
3. P. M. Mathews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw-Hill (1977).
4. R. L. Liboff, Introduction to Quantum Mechanics, Pearson Education (2003).
5. R. Shankar, Principles of Quantum Mechanics, 2nd edition,Plenum US (1994).
6. A.Ghatak and S Lokanathan, QuantumMechanics: Theory and Applications, Macmillan (2004)
7. L I Schiff, Quantum Mechanics, 3rd ed. McGraw-Hill, 1968
8. B. Bransden,C.Joachain, Quantum Mechanics, 2nd edition, Pearson/Prentice Hall (2000).
9. J. J. Sakurai, Modern Quantum Mechanics, Addison Wesley (1985).
10. J. J. Sakurai, Advanced Quantum Mechanics, Addison Wesley (1967).
11. R. P. Feynman, R.B. Leighton and M.Sands, The Feynman Lectures on Physics, Vol.3, Narosa Pub. House (1992).
12. J. S. Townsend, A Modern Approach to Quantum Mechanics, 2nd ed, McGraw Hill.
13. C. Cohen-Tannoudji, B. Diu, F. Laloe, Quantum Mechanics (2 vol. set), Wiley-Interscience (1996).

MSE 510: **MATERIALS IN ENERGY PRODUCTION -OPEN ELECTIVE-2**
(3 Credits)

Objectives: Objective of the course is to impart a basic knowledge about global energy scenario, energy consumption in various sectors, renewable energy sources and energy production. Course also gives brief idea on energy production with solar cells, fuel cells, etc. The course also provides basic knowledge on superconductivity and superconducting materials.

Expected course outcomes: The students should gain knowledge on global energy scenario such as production and consumption by various sectors. Students would have a basic knowledge about the solar cells and fuel cells for the energy production along with energy saving application like superconductors. Students are expected to learn to use energy resources effectively and efficiently.

Unit I

Global Energy Scene Energy consumption in various sectors, projected energy consumption for the next century, Definition and units of energy, power, Forms of energy, Conservation of energy, second law of thermodynamics. Solar Cells – Photovoltaic effect- light absorption- carrier generation and recombination,p-n junction: homo and heterojunctions, Metal-semiconductor interface; Equivalent Circuit of the Solar Cell, Analysis of PV Cells: Dark and illumination characteristics; solar cell- Efficiency limits; Variation of efficiency with band-gap and temperature-Efficiency measurements-High efficiency cells. Types of Solar cells. Solar Cell Fabrication Technology. 14 hours

Unit II

Hydrogen energy – merits as a fuel – production of hydrogen – fossil fuels, electrolysis, thermal decomposition, photochemical and photocatalytic methods. Hydrogen storage – metal hydrides, metal alloy hydrides, carbon nanotubes, sea as source of deuterium. Fuel cells – introduction – difference between batteries and fuel cells, components of fuel cells, principle of working of fuel cell, performance characteristics of fuel cells, efficiency of fuel cell, fuel cell stack, fuel cell power plant: fuel processor, fuel cell power section, power conditioner, Advantages and disadvantages of fuel cell power plant. Types of fuel cells - Solid oxide fuel cells (SOFC), Molten carbonate fuel cells (MCFC), Phosphoric acid fuel cells (PAFC) Polymer Electrolyte fuel cells. Application of fuel cells – commercially available fuel cells. 14 hours

Unit III

Superconductors - development in the field of superconductivity – properties of superconductors - perfect diamagnetism, Meissner effect – critical field and current – BCS theory. Types of superconductors - high T_c superconductors – properties - synthesis of high Tc superconductors. Applications of Superconductors in Energy Superconducting wires and their characteristics, High field magnets for production of energy by magnetic fusion, Energy generation-Magnetohydrodynamics (MHD), energy storage, electric generators and role of superconductors. Large scale applications of superconductors Electric power transmission, Applications of superconductor in medicine - Magnetic Resonance Imaging (MRI), Superconducting Quantum Interference Devices (SQUID). 14 hours

References:

1. J. Larminie and A. Dicks, Fuel Cell Systems Explained, 2nd Edition, Wiley (2003)
2. Xianguo Li, Principles of Fuel Cells, Taylor and Francis (2005)
3. S. Srinivasan, Fuel Cells: From Fundamentals to Applications, Springer (2006)
4. O'Hayre, S. W. Cha, W. Colella and F. B. Prinz, Fuel Cell Fundamentals, Wiley (2005)
6. Solid State Devices – Ben G Streetman (Prentice-Hall, 1995)
5. High efficiency silicon Solar Cells – M. A. Green (Tran. tech., 1987)
7. Solar Cells: Materials, Manufacture and Operation, eds. Tom Markvart, Luis castaner (Elsevier, 2010)
8. Solar Voltaic Cells, Johnston W.D. (Marcel Dekker, 1980)
9. Introduction to superconductivity – A C Rose-Innes and E H Rhoderick (Pergamon Press, 1978)
10. Physics of High T_c superconductors – J C Phillips (Academic Press, 1989)

MSH 551: **MAGNETIC MATERIALS & MAGNETIC RESONANCE** (4 Credits)

Objectives: Magnetic materials is an important class of materials particularly in the present day technology apart from its importance in understanding the basic phenomena in condensed matter. This course introduces to the different class of magnetic materials, their origin, and the theories to understand their behaviour. The magnetic resonance concept is introduced with the rigour of the theory for making it useful in research and other applications.

Expected course outcomes: The student is expected to get an understanding of the basic differences and causes of various types of magnetic materials, magnetic resonance and magnetic interactions. Student should be able to calculate the different parameters to get a feel of the subject.

Unit I

Introduction to magnetic materials – magnetic susceptibility and permeability. Classification – dia- para- and ferro-magnetic materials. Amperian concepts. Langevin's theory of diamagnetism. Origin of magnetic moments. Quantum theory of paramagnetism- Curie law- Effective number of Bohr magneton- Quenching of orbital magnetic moments- Experimental determination of diamagnetic and paramagnetic susceptibility- anisotrophy in susceptibility. Cooling by adiabatic demagnetization. Ferromagnetism – Characteristic features- hysteresis loop. Weiss concepts- Curie-Weiss law. 18 hours

Unit II

Exchange interaction and spontaneous magnetization in ferromagnetic materials - temperature dependence- Heisenberg's theory- gyromagnetic experiments. Ferromagnetic domains - origin of domains - anisotropy energy - Bloch wall - magnetostriction. Hard and soft magnetic materials – iron loss – applications - Transforamers, Electromagnets, permanent magnets – magnetic recording - memory devices.

Antiferromagnetism - sub lattice model - Neutron diffraction in magnetic structure analysis – Super-exchange phenomena - Ferrimagnetism and structure of ferrites and their applications. Spin waves - quantisation of spin waves - magnons. 18 hours

Unit III

Magnetic Resonance and material analysis - Nuclear Magnetic Resonance - Elements of theory - rate of energy absorption – Spin-lattice and spin-spin relaxation processes -Bloch equations – Wide line NMR – applications of NMR – Paramagnetic resonance – principles and comparison of PMR with NMR. Electron spin resonance - areas of applications.

Mossbauer effect - Elements of theory – Mossbauer spectroscopy – centre shift, chemical shift, Zeeman shift, Experimental techniques and applications. 18 hours

References

1. Modern Magnetism – L F Bates (Cambridge University Press, 1963)
2. Elements of Materials Science and Engineering – L H van Vlack (Addison Wesley, 1975)
3. Introduction to Properties of Materials – D Rosenthal and R M Asimov (East West, 1974)
4. Introduction to Solid State physics –C Kittel (II & IV Ed. Wiley & sons, 1961 & 1964)
5. Solid State Physics – A J Dekker (McMillan, 1971)
6. Advances in Solid State Physics, Vol.II & V – Seitz and Turnbull (Ed) (Academic, 1957)
7. Mossbauer Effect and its Applications – V G Bhide (Tata McGraw Hill,1973)
8. Magnetic Resonance – C P Slichter (Harper and Row, 1985)
9. Solid State Chemistry – C N R Rao (Ed) (Marcel Dekker, 1974)
10. Solid State Physics Source Book – Sybil P Parker (Ed) (McGraw Hill, 1987)
11. Materials Science and Technology – A comprehensive treatment – (ed.) R W Cahn, P Haasen & E J Kramer - Electronic and Magnetic properties of metals and ceramics, Vol 3A & 3B (VCH Weinheim, 1992 & 1994)

MSH 552: **SOLID STATE ENGINEERING MATERIALS – II (**4 Credits)

Objectives: Objective of this course is to provide a detailed basic knowledge about technologically important materials such as superconducting materials, liquid crystalline materials, ceramics, etc. the studies of semiconductor devices such as Lasers and solar cells are included to provide essential knowledge on the modern optoelectronic devices.

Expected course outcomes: This course provides good basic knowledge to the students about the superconductivity, liquid crystals, lasers, solar cells and ceramic materials. This would help them to perform research work in these areas and it is also useful in continuing their career in many industries.

Unit I

Superconductivity: Nature and properties of superconducting materials - Type I and II superconductors - Phenomenological theories - BCS theory – concept of energy gap. Superconducting tunneling phenomena: metal-insulator-superconductor (MIS) and superconductor-insulator-superconductors (SIS). AC and DC Josephson effect. Applications - superconducting magnets, super density switches, SQUID and magnetic levitation. superconducting composites. Nb_3Sn/Cu. High temperature (High T_c) superconductors: material preparation - ceramic and thin film technique, structure.

Liquid Crystalline Materials: Introduction - classification of thermotropic liquid crystals. Elementary ideas on material. Properties of liquid crystals - birefringence, dielectric anisotropy, viscosity, conductivity anisotropy and elasticity of liquid crystals, electro-optic, thermo-optic effects and LCD devices and applications.

18 hours

Unit II

Lasers and applications: Spontaneous emission - stimulated transitions and rate equation balance, amplifications in a medium, population inversion methods, oscillation threshold, optical resonator theory. Gas lasers - applications.

Solid state lasers: Semiconductor lasers – absorption-direct and indirect band gaps, material requirement, conditions for laser oscillations, homojunction and heterojunction lasers - applications.

Photovoltaic and solar cells: material requirement, efficiency, efficiency limits, spectral response, types of solar cells-conventional tandem-junction solar cells, heterojunction solar cells, thin film solar cells, amorphous silicon solar cells. 18 hours

Unit III

Ceramics: Ceramics and their structure- silicate structure - polymorphism and allotrophy: Processing - Recrystallization and grain growth, sintering, hot pressing, fire shrinkage. Basic refractory materials.

Glasses: Preparation and structure - Types of glasses -borate glasses, silicate glasses, oxide glasses, metallic and semiconducting glasses. Properties of glasses – electrical,

optical, thermal, mechanical properties, Applications - photo sensitive, photochromic glasses, optical fiber- principle of fiber communication.
Optical properties: Luminescence: Frank Condon principle, excitation process - thermoluminescence and electroluminescence. Luminescent materials and industrial applications. 18 hours

References

1. Introduction to superconductivity – A C Rose-Innes and E H Rhoderick (Pergamon Press, 1978)
2. Superconductivity and Superconducting Materials – A V Narlikar and S N Ekbote (South Asian Pub., 1983)
3. Physics of high T_c superconductors – J C Phillips (Academic Press, 1989)
4. Liquid Crystals – S Chandrasekhar (Cambridge University Press, 1977)
5. The Physics of Liquid Crystals – P G de Gennes (Oxford, 1975)
6. Electronic Materials and devices – D K Ferry (Academic Press, New York, 2001)
7. Semiconductor Physics – P S Kireev (MIR Publishers, 1978)
8. Physics of Semiconductors Devices – S M Sze (Wiley Eastern, 1991)
9. Solid State Devices – Ben G Streetman (Prentice-Hall, 1995)
10. High efficiency silicon Solar Cells – M A Green (Tran. tech., 1987)
11. Solid State and Semiconductor Physics – John Mckelvey (John Wiley, 1976)
12. Introduction to Ceramics – W D Kingery, H K Bower and U R Uhlman (John Wiley, 1960)
13. Glasses and vitreous state – J Zarzycki (Cambridge University Press, 1982)
14. Materials Science and Technology Vol. 9: Glasses and amorphous materials, (Ed.) R W Cahn, P Haasen, E J Kramer, (VCH Weinheim, 1991)
15. Optical fiber communications – G Keiser (McGraw-Hill, 2000)

MSS 553: **MATERIALS TESTING AND CHARACTERIZATION** (3 Credits)

Objectives: The objective of the course is to provide a brief idea about the requirements of characterization/testing of materials using various techniques. It also introduces vacuum techniques as most of the characterization as well as synthesis require clean environment.

Expected course outcomes: The students to be in a position to select suitable characterization techniques to study the given property of the materials, understand the basic working principles. The student is also expected to have a good understanding of creation and measurement of vacuum for various applications.

Unit I

Fundamentals of Vacuum Techniques: Basic concepts of pumping: Ideal gas - pressure, density, mean free path. Regions of gas flow. Conductance of a pipework - fundamental equation of vacuum technology. Vacuum pumps: Operating limits of a pump. Rotary, Vapour diffusion, Turbomolecular and Cryogenic pumps - a brief survey of working principles. Vacuum measurement: Thermal conductivity gauges - Pirani and thermocouple gauges.Ionisation gauges-Hot and cold cathode ionisation gauges- working principle and operating limits. Vacuum materials. 14 hours

Unit II

Non- Destructive Testing of Materials : Ultrasonics: Principles - Ultrasonic receivers and oscillators - transducers, probes. Reference and calibration blocks. Identification and seizing of defects.

X-Ray Radiography: Principles -Factors affecting contrast and resolution.

Neutron Radiography: Neutron sources and detectors. Methods- Criteria for evaluating flaw detection by neutron radiography method. Factors limiting the contrast. Comparison of X-ray and neutron radiography methods.

Mechanical Testing of Materials: Tensile and Compression tests- Brittle and ductile failure-

Universal Testing Machine. Hardness test - Indentation hardness- Brinell, Vicker and Rockwell hardness numbers. Impact test - Izode and Charpy tests. Fatigue test - A brief discussion. 14 hours

Unit III

Materials Characterisation - Electron Microscopy- Transmission Microscopy(TEM) - Principles, sample preparation. Kinamatic theory of contrast. Scanning Microscopy (SEM) - Principles, beam diameter, image contrast. Applications to microstructure determination.

Atomic and Molecular Spectroscopies: Atomic Absorption, Infra - Red, and Raman spectroscopies for the determination of impurities. Low Energy Electron Diffraction (LEED), X-ray Photoelectron Spectroscopy (XPS/ESCA) and Auger Electron Analysis - Principles and applications for surface studies. Electron Probe Micro analysis (EPMA) and Energy Dispersive Analysis of X-Rays (EDAX) - Principles and applications for compositional analysis. 14 hours

References

1. Fundamentals of Vacuum Techniques – A Pipco et al (MIR, 1984)
2. Ultrasonics – B Carlin (Mc Graw Hill, 1960)
3. Handbook on Ultrasonic Testing of Materials – Ramesh B Parikh (Electronic & Engineering Co., 1984)
4. Principles of Neutron Radiography – N D Tyufyakov and A S Shtan (Amerind, 1979)
5. Modern Metallographic Techniques and Their Applications – V A Phillips (Wiley Interscience, 1971)
6. Applied X-Rays – George L Clark (Mc Graw Hill, 1955)
7. Testing of Metallic Materials – A V K Suryanarayana (Prentice Hall India, 1990)
8. Physical Metallurgy Part 1 – R W Cahn and P Haasen (Ed) (North Holland, 1983)
9. Instrumental Methods in Chemical Analysis – G W Ewing (Mc Graw Hill, 1975)

MSS 554: COMPOSITE MATERIALS (3 Credits)

Objectives: This course provides an introduction to the composite material of different types, the effect of reinforcing materials and matrices, their properties and applications. The course also tries to emphasize on nature of interface and micromechanics involved in various types of composite materials, their properties and applications.

Expected course outcomes: An understanding of basics of interfacial interactions, properties of various metal, polymer and ceramic based composite materials is expected which would enable them to solve the problems in design of new materials for various applications.

Unit I

Introduction - Classification, Matrix materials, Reinforcing materials, Interfaces in composites, micromechanics of composites - Density, Mechanical properties – prediction of elastic constants, Thermal properties – Heat capacity, longitudinal and transverse conductivity, thermal expansion coefficient, Mechanism of load transfer from Matrix to fiber – (fiber elastic – matrix elastic , fiber elastic- matrix plastic).

Strength, Fracture and fatigue: Tensite strength, Compression Strength, Fracture m odes in Composite, Designing with Composite Materials. 14 hours

Unit II

Reinforcing Materials - Fabrication, Structure, Preparation, application of glass, Carbon, aramid and ceramic fibers Concrete making Materials - Structure, Composition, properties and applications, special concrete, Reinforced and prestressed concrete. Polymer matrix composites- Fabrication, structure, interface, properties and applications. Advanced thermoplastic composites, Wood-microstructure, properties, wood-plastic composites, polymer-concrete composites.

14 hours

Unit III

Metal matrix composites- Fabrication, interface, properties and applications, Dispersion strengthened, particle reinforced, fiber and laminate reinforced composites, fiber reinforced super alloy composites, Superconducting composites-Introduction type and fabrication.

Ceramic matrix composites - Fabrication, interface, properties and applications

Carbon fiber composites- Fabrication, interface, properties and applications, Advanced C-C composites. 14 hours

References

1.Composite Materials-Engineering & Science – F L Mathews & R D Rawlings (Chapman & Hall, 1990)
2. Composite Materials- Science & Engineering – K K Chawla (Springer-Verlag, 1987)

3. Principles of Materials Science & Engineering – William F Smith (McGraw-Hill, 1988)
4. A text book of Materials Science & Metallurgy – O P Khanna (Dhanpat Rai pub., 1999)
5. Selection of Engineering Materials – Gladis Lewis (Printice Hall, 1990)
6. Engineering Materials & their applications – R A Flinn & P K Trojan (Jaico pub., 1998)
7. Composite Materials – S C Sharma. (Narosa, 2000)

MSS 555: **NANOSCIENCE AND NANOTECHNOLOGY – II** (3 Credits)

Objectives: This course deals with the advanced concepts in the subject focusing on the properties of metal and semiconductor nanomaterials with emphasis on their applications in electronics and optics. Also, special nanomaterials such as fullerenes, carbon nanotubes and nanocomposites are introduced.

Expected course outcomes: Student is expected to gain a good knowledge of the size dependent properties of nanostructures which make them a unique class of materials. Further it is expected that a student attains a broad perspective of still newer materials of interest in this category, such as fullerenes and nanotubes.

Unit I

Metal Nanoparticles: Introduction. Optical, Electrical and Magnetic properties. Surface plasmon resonance. GMR and CMR materials. Spintronics Applications of metal nanoparticles.

Semiconductor Nanoparticles: Introduction. Optical properties- Band gap variation with size- Brus equation. Photoluminiscence. Nonlinear optical processes. Applications of semiconductor nanoparticles. 14 hours

Unit II

Fullerenes: Preparation, properties, nanostructured fullerene films, applications.

Carbon Nanotubes: Introduction. Single-walled and multiple–walled nanotubes. Synthesis, Purification and Structure. Methods of opening and filling nanotubes. Physical properties. Non-carbon nanotubes. Applications of nanotubes. Biological applications of nanotechnology. Brief idea of Nanobiotechnology. 14 hours

Unit III

Nanocomposites: Introduction to composites and nanocomposites. Ceramic, Metal, Polymer Nanocomposites. Thin-Film and CNT-Based Nanocomposites. Polymer and rubber based nanoclay composites. Nanoscale Fillers - Nanofiber or Nanotube Fillers. Nanotube Processing. Inorganic Filler/Polymer Interfaces. Processing of Nanocomposites. Nanocomposites for electrical, optical and magnetic applications.

Mechanical Properties - Modulus and the Load-Carrying Capability of Nanofillers - Failure Stress and Strain Toughness. Glass Transition and Relaxation Behavior

Natural Nanocomposite Materials - Biologically derived synthetic Nanocomposites, Templating. Natural Nanobiocomposites, Biomimetic Nanocomposites. 14 hours

References

1. Nanoscale Materials – (Ed) L.M. Liz-Marzan and P.V.Kamat, (Kluwer, 2003)
2. Nanostructured Materials and Nanotechnology, (Ed) H. S. Nalwa, (Academic, 2002).
3. Introduction to Nanotechnology – C P Poole and F J Owens (Wiley- Intersci. 2006)
4. Nanotechnology and Nanoelectronics – W R Fahrner (ed) (Springer, N Delhi, 2006)
5. Quantum Dots - L.Jacak, P Hawrylak, A Wojs, (Springer 1997)
6. Physics of Low Dimensional Structures, J H Davis, (Cambridge 1998)
7. Nanostructured Magnetic Materials and Applications- Shi D et al (Springer, 2002)
8. Nanobiotechnology- Concepts, applications and Perspectives – Niemeyer C
9. Nanocomposite Science & Technology, Pulickal M. Ajayan et.al (Wiley-VCH, 2003)
10. Introduction to Nanocomposite Materials- Thomas Twardowski, (DEStech, 2001).
11. Polymer-Clay Nanocomposites, T.J. Pinnavaia, G.W. Beall, (Wiley, 2004)

MSP 405, MSP 406, MSP 455, MSP 456, MSP 509, MSP 556, MSP 557 – MATERIALS SCIENCE LAB. I – VII

Objectives of the courses: These laboratory courses are designed to impart the hands on experience on the measurement of various properties of different materials covered in the theory courses. These courses also expose the students to various simple measurement techniques. Almost all kinds of materials dealt in theory are covered in the laboratory courses with an emphasis on the understanding of the measurement as well as the material properties. As far as possible, within the constraints of the equipment, the experiments are distributed in the semesters where the theory is taught.

Expected course outcomes: The students should gain an understanding of the techniques used as well as the properties of materials dealt in each of the experiment.

MSP 405: **MATERIALS SCIENCE LAB.- I** (3 Credits)

1. Thermistor Thermometer
2. Energy Gap of a Semiconductor - Four Probe Method
3. Hall Effect
4. SCR Characteristics
5. Full Wave Rectifier and Regulated Power Supply
6. R.C. Coupled Amplifier
7. R.C. Coupled Phase Shift Oscillator
8. Operational Amplifier
9. Verification of Fresnel's Laws
10. Diffraction using He-Ne laser

MSP 406: **MATERIALS SCIENCE LAB.- II** (3 Credits)

1. Birefringence of Mica
2. Determination of Heat of Solution
3. Thermal Conductivity of a Metal Bar
4. Thermal Conductivity of Insulators
5. Thermal Conductivity of Amorphous Solids
6 Phase Diagram of Two Component System
7. Phase diagram of Three component system
8. Analysis of Bronze
9. Analysis of Brass

MSP 455: **MATERIALS SCIENCE LAB. – III (**3 Credits)

1. Energy band gap in p-n junctions
2. Young’s modulus of glass
3. Activation energy of point defects
4. Creep in materials
5. Strain gauge measurement of Young’s modulus
6. Refractive index of liquids using He-Ne laser
7. Electrical conductivity of amorphous solids
8. Estimation of Cr and Ni in stainless steel by spectrophotometry
9. Study of temperature dependence of Hall coefficient

MSP 456: **MATERIALS SCIENCE LAB. – IV** (3 Credits)

1. Conductivity of ionic salts
2. Poisson's ratio of rubber
3. Diffraction from powder particles- diameter of lycopodium powder
4. Youngs modulus of polymer
5. Adsorption studies
6. Corrosion studies
7. Conductometric titration
8. Determination of molar absorption coefficient
9. pH measurement
10. Potentiometric titration

MSP 509: **MATERIALS SCIENCE LAB. – V** (3 Credits)

1. Study of junction capacitance and it's variation
2. Electrical conductivity of metals and estimation of Fermi energy
3. Energy gap of CdS thin films
4. Dielectric constant of ferroelectric materials
5. Thickness of thin films
6. Determination of molecular weight by viscosity measurement
7. Functional group analysis of polymer
8. Glass transition temperature
9. Dimension of polymer coil

MSP 556: MATERIALS SCIENCE LAB. – VI (3 Credits)

1. Ferromagnetic transition temperature
2. Hardness testing of materials
3. Diamagnetic and Paramagnetic susceptibility using Gouy balance
4. Hysterisis loss and determination of Curie temperature
5. Reverse saturation current and material constant
6. Magnetoresistance
7. Electron spin resonance
8. Junction voltage and band gap
9. Study of shape memory alloys
10. Preparation and Characterization of Nanoparticles

MSP 557: MATERIALS SCIENCE LAB. – VII (3 Credits)

1. Crystal Structure Analysis using X-Ray Diffraction

   a) Simple Cubic structure b) Face Centered Cubic structure

   b) Hexagonal structure d) Tetragonal Structure

2. Metallurgical Microscope – Grain Size Measurements

   a) Ferrous alloys b) Non-ferrous Alloys

3. Phase diagram of Pb-Sn system

4. Conducting studies of polyaniline
5. Viscosity of polymer blends
6. Solar cell I-V characteristics
7. F-centre in alkali halides
8. Thermoluminescence activation energy
9. Preparation of Composite Materials

MSP 558: MINI PROJECT (3 Credits)

Objectives: This mini project aims at exposing the student to the recent topics in research, the literature survey, material preparation, characterization. As this is not a full semester project, the course aims at training the students to take up research as a career.

Expected course outcomes: The student is expected to learn the methods of literature survey, carry out some preliminary experiments on synthesis and characterization, report writing etc.