School of Materials Science and Technology

Institute of Technology

Banaras Hindu University

Integrated Dual Degree Programme

in

Materials Science and Technology

Course Structure

III Semester :

Code	Subject	Contact hr.	Credit
Theory:			
MS2101	Introduction to Materials Science	3	3
MS2102	Phase Diagram and Phase Transformations	3	3
AM2101	Mathematical Methods	3	3
AC2101	Chemistry of Polymers	3	3
AP2102	Quantum Mechanics	3	3
AC2102	Reaction Kinetics	3	3
Practical:			
MS2301	Engineering Materials & their Microstructure	3	2
MS2302	Materials Preparation -I	3	2
AC2301	Chemistry Lab/ Polymer & Reaction Kinetics	3	2

IV Semester :

Code	Subject	Contact hr.	Credit
Theory:			
MS2203	Metals & Alloys	3	3
MS2204	Ceramic Materials	3	3
EC2215A	Electronics and Instrumentation	3	3
EE2215A	Electrical Engineering	3	3
AM2201	Numerical Analysis	3	3
CH2201	Physico-Chemical Principles	3	3
Practical:			
EC2415A	Electronic Devices & Instrument Lab.	3	2
EE2415A	Electrical Engineering Lab.	3	2
AM2401	Computer Lab.	3	2

V Semester :

Code	Subject	Contact hr.	Credit
Theory:			
MS3105	Crystallography & Crystal Structure	3	3
MS3106	Synthesis and Processing of Materials	3	3
MS3107	Physical Behaviour of Materials	3	3
AC3102	Analytical Techniques in Chemistry	3	3
AP3103	Digital Electronics & Microprocessor	3	3
AP4104	Condensed Matter Physics	3	3
Practical:			
MS3305	Diffraction Studies	3	2
MS3306	Electronic Properties of Materials	3	2
MS3307	Materials Preparations-II	3	2

VI Semester :

Code	Subject	Contact hr.	Credit
Theory:			
HU*	Open Elective	3	3
MS3209	Polymeric Material	3	3
MS3210	Science of Ceramic Materials	3	3
AC3201	Instrumental Methods for Chemical Analysis	3	3
AP3208	Statistical Mechanics	3	3
CR3204	Glass and Glass Ceramics	3	3
Practical:			
MS3408	Thermal Analysis and Heat Treatment	3	2
CR3402	Glass and Ceramic Coating Lab	3	2
MS3409	Materials Processing Lab.	3	2

***Any one of the following open elective**

1. HU 321: History of Science and Technology
2. HU 322: Industrial and Organizational Psychology
3. HU 323: Intellectual Property Rights
4. HU 324: Energy management
5. HU 325: Industrial Sociology
6. HU 326: Ethics, Philosophy and Values
7. HU 327: Entrepreneurship Development

VII Semester :

Code	Subject	Contact hr.	Credit
Theory:			
MS4113	Mechanical Behaviour of Materials (PG)	3	3
MS4114	Materials Characterization (PG)	3	3
MS4115	Industrial Polymers (UG)	3	3
AC4101	Chemical Sensors (UG)	3	3
AC4102	Corrosion (PG)	3	3
Practical:			
MS4310	Advanced Characterization Techniques	3	2
	UG Project	-	4
	Seminar	3	2
	Training/ Tour/ Viva-voce	-	2

VIII Semester :

Code	Subject	Contact hr.	Credit
Theory:			
MS4218	Composite Materials (UG)	3	3
MS4219	Magnetic Materials (UG)	3	3
MS4220	Molecular Electronics & Organic Conductor (PG)	3	3
MS4221	Electrical & Electronic Ceramics (PG)	3	3
CR4203	Refractories (PG)	3	3
Practical:			
MS4411	Mechanical Properties (PG)	3	2
CR4402	Refractory Lab (UG)	3	2
	Project/Dissertation (PG)	6	4
	Viva-voce	-	2

IX Semester :

Code	Subject	Contact hr.	Credit
Theory:			
MS5122	Nanomaterials and Nanostructures	3	3
	Elective – 1*	3	3
	Elective – 2*	3	3
	Elective – 3*	3	3
Project:			
	Dissertation	3	2
	Seminar on Dissertation	-	5
	Dissertation Interim Evaluation	9	5

Electives (any three)
MS5123 Functional Materials
MS5124 Diffraction Techniques in Materials Science
MS5125 Advanced Polymers
CR5106 Advance Refractory Engineering
CR5107 Ceramic Fabrication Processes
CR5104 Nano Ceramics
CH5113 Fuel Cell Technology
CH5110 Renewable Energy Technology
MT5239 Fracture Mechanics and Component Integrity

X Semester :

Subject	Contact hr.	Credit
PG Seminar	2	1
Dissertation Open Defense	-	5
Dissertation Evaluation	-	10

Syllabi for Dual Degree Program

III Semester

MS 2101 : Introduction to Materials Science

Classification of engineering materials and their applications : Metals and alloys, Ceramics and glasses, Polymers, Composites and Novel Materials. Price and availability of materials. Processing of engineering materials.

Chemical bonding and properties of materials: Mechanical, Electrical, Magnetic, Optical, Thermal; Oxidation and degradation behaviour of engineering materials.

Levels of structure: Nuclear structure, Crystal structure, Nanostructure, Microstructure and Macrostructure. Processing – structure – property correlations.

Recommended Books :

Materials Science & Engineering : An Introduction, W.D. Callister. Jr.
Engineering Materials: Properties & Selection, K.G Budinski, M.K. Budinski.
The Science and Engineering of Materials, D.R. Askeland.
Materials Science and Engineering, V. Raghavan.
Engineering Materials Part 1 & 2, Ashby and D.R.H. Jones
Understanding Solids, Richard Tilley.
Properties of Materials, R. E. Newnham.

MS2102: Phase Diagram and Phase Transformations

Review of general principles of chemical thermodynamics: Entropy. Internal energy. Free energy. Chemical potential. Entropy of mixing. Free energy of ideal and regular solid solutions. Phase rule.

Types of phase diagrams. Study of Fe-C, Cu-Ni, Cu-Zn, $CaO\text{-}SiO_2$ systems.

Experimental determination of phase diagrams. Principle of TGA, DTA, DSC, dilatometry and their applications in phase diagram determinations.

Diffusion in solids. Diffusion mechanism. Steady and non steady state diffusion. Activation energy for diffusion.

Phase Transformations: Kinetics of phase transformations. Homogeneous and heterogeneous nucleation and growth.Continuous and discontinuous reactions. Precipitation, spinodal and eutectoidal transformation.

Heat treatment of steels and Al-alloys.

Solidification and Casting. Zone refining. Single crystal growth techniques.

Recommended Books :

An Introduction to Metallurgy, A. Cottrell.
Introduction to the Thermodynamics of Materials, David R. Gaskell
Introduction to the Principles of Ceramic Processing, James S. Reed.
Materials Science & Engineering : An Introduction, W.D. Callister. Jr.
Physical Metallurgy Principles, R.E. Reed Hill.
Solid State Transformations, V. Raghavan
Phase Transformations in Metals and Alloys, D.A. Porter and K.E. Easterling.

AM 2101: Mathematical Methods

Differential Equations: Solution in series; Bessel functions of first, second and third kind; Legendre and Hermite polynomials and their elementary properties; Orthogonality of $J_n(x)$ and $P_n(x)$.

Integral Transforms and their Applications:: Laplace d Fourier transforms; Convolution; Application to ordinary and partial differential equations; Initial and boundary value problems by operational methods.

Complex Variable: Conformal mapping; Bromwich Contour Integral.

Partial Differential Equations: One dimensional wave and diffusion equations; Laplace equation in cartesian and polar co-ordinates.

Probability and Statistics: Probability distributions and their applications; Binomial, Poisson, Normal, Gamma, Weibuil and Extreme values; Joint probability distributions of two variables. Simple linear regression and correlation analysis.

AC 2101 : Chemistry of Polymers

Introduction – Definition, classification, mechanism of polymerization, addition polymerization, condensation polymerization, thermosetting, thermoplastic polymers. Chemical geometrical structures Tg (glass transition temperature) crystallinity of polymers. Chemistry of selected organic polymers, Chemistry of selected inorganic polymers, polymer degradation mechanisms, polymer processing, molecular weight & size of polymer dissolution, thermodynamics of polymers, Florry Huggin theory, viscosity of polymer solution, size and shape of polymers.

Recommended Books :

Polymer Chemistry an Introduction, R.B. Seymour, C.E. Carraher, E. Charles, Marcel Dekker, New York.
Principle of Polymer Science, P. Bahadur & N.V. Shastry, Narosa Publishing House, New Delhi.
Polymer Science, V.R. Gowariker, N.V. Viswanathan and Jayadev Sreedhar, Halsted Press, John Wiley & Sons, New York.
Principles of Polymerization, George Odian, John Wiley & Sons. 4th Ed.
Polymer Chemistry, B. Vollmert, Springer-Verlag, Berlin.

AP 2102 : Quantum Mechanics

Foundation and formulation of quantum theory, Schrodinger equation, Potential well, Kronig Penny model, Angular momentum, Two and three dimensional problems, Degeneracy, Central potentials, Hydrogen atom, Identical particles, Symmetric and antisymmetric states, Helium atom, Schrodinger and Heisenberg pictures. Annihilation, Creation operators, Harmonic oscillator.

Approximation methods for bound states, WKB approximation, Time-independent and Time-dependent perturbation theory, Scattering theory.

AC 2102: Reaction Kinetics

Fundamental aspects of reaction kinetics, Collision and transition state. Theories of reactions rate. Potential energy surfaces and reaction dynamics, homogeneous and heterogeneous reactions. Complex reactions, fast reactions, techniques for study of fast reactions. Explosion reactions. Ionic chain reactions. Diffusion in solids, liquids and solutions.

Recommended Books :

K.J. Laidler, Chemical Kinetics, 3rd Ed. Pearson Education Inc.
J. Rajaram, J.C. Kuriacose, Kinetics and Mechanisms of Chemical Transformations, McMillan. India Ltd.

IV Semester

MS 2203: Metals & Alloys

Brief overview of commercial metals and alloys and their crystal structures. General properties of metals and alloys.

Mechanical properties: Stress-strain behaviour, elastic and plastic deformation, work hardening, other strengthening processes. Elementary ideas about creep, fatigue and fracture.

Recovery, recrystallization and grain growth.

Processing: Casting, solidification, powder metallurgy, hot workability, sheet metal forming, welding, elementary ideas of rolling, forging and extrusion.

Carbon and alloy steels, tool steels, stainless steels, cast irons. Important non-ferrous alloys: Cu, Al, Ni, Zn, Ti, Mg based alloys.

Typical applications and materials selection.

Recommended Books :

Materials Science and Engineering, V. Raghavan.
Engineering Matetials, properties and selection, K. G. Budinski and M.K. Budinski.
Introduction to Materials Science, W.D. Callister.
The Science and Engineering of Materials, D.R. Askeland.
Mechanical Metallurgy, G.E Dieter.
Metals Handbook vol. 1 8th Edition.

MS 2204 : Ceramic Materials

Types of ceramics and glasses:

Structure and bonding of ceramics: Ilmenite, Wurtzite, Rutile, Perovskite, Fluorite, Kaolinite and Muscovite structures.

Phase equilibria and phase diagram of typical ceramic systems: Silica, Al_2O_3- SiO_2, B_2O_3-SiO_2, ZrO_2-MgO, ZrO_2 -Y_2O_3.

Properties of Ceramics: Physical, thermal, mechanical, electrical, dielectric, magnetic, superconducting and optical behaviour.

Engineering ceramics: Alumina, zirconia, silica, carbides, nitrides, borides.

Electronic Ceramics: Titanates, ferrites, garnets, cuprates and manganites.

Environmental stability of ceramics.

Applications and materials selection.

Recommended Books :

Fundamentals of Ceramics, M.W. Barsoum.
Modern Ceramic Engineering, D. W. Richerson.
Introduction to Ceramics, W.D. Kingery, H.K. Bowen and D.R. Uhlmann.
Ceramic fabrication process, W.D. Kingery.
Modern Galss Practice, S.R. Sholze.
Properties of Ceramic Raw Materials, W. Rayon.

EC 2215A : Electronics and Instrumentation

Vacuum and Semiconductor diode characteristics and load line. Half-wave and full-wave rectifiers, Filters and power supplies. Amplifying devices and their characteristics, Single and Multi stage RC coupled voltage amplifiers, high input impedance circuits, Oscillators, Operational amplifiers and their applications. Linear and non-linear wave shaping circuits, Multivibrators and counters, logic gates, transducers, ADCs and DACs, display devices, digital multimeters, Microprocesors.

EE 2215A: Electrical Engineering

Electrical Circuits: Network element-Voltage and current sources, Kirchchoff's voltage and current law, loop and nodal analysis, Superposition theorem, Thevenin's theorem, Norton's theorem, Maximum Power transfer theorem. Sinusoidal Steady State analysis-R L and C elements, power and power factor, phasor diagram ,resonance, mutual inductance and coefficient of coupling. Three-phase circuits-Line and Phase relationship, Power measurement.

Electrical Machines: Transformer – principle of working, EMF equation, equivalent circuit, voltage regulation and efficiency, open circuit and short – circuit tests, autotransformer. DC Machines-constructional features, DC-Generator-No load Magnetization and external characteristics, DC motor-stating, speed-torque characteristic, speed control, applications, induction machines-principle of operation, constructional details, torque slip characteristic, starting and speed control, synchronous machines-constructional features. Alternators-Voltage regulation and its determination by synchronous impedance method. Synchronous motor starting, V and Inverted – V curves, Application.

Distribution of electrical power: Tariff calculation, house and factory wiring.

Introduction to electrical measurements: Indicating instrument, voltmeter, ammeter, wattmeter and energy meter.

AM 2201: Numerical Analysis

Absolute, relative, round-off, truncation errors, significant digits. Estimation of errors. Tabulation of a function.

Interpolation: Ordinary differences; operators E and D, sub-tabulation, divided difference; Lagrange's formula; central differences, formulae of Gauss, Bessel, Evertt; Method of ordinary least squares; cubics splines, inverse interpolation.

Solution of systems of linear equations: method of elimination, method of relaxation, iterative methods, ill—conditioned systems, computing the inverse matrix, eigenvalues and eigenvectors, matrix decomposition.

Numerical differentiation and numerical integration: finite differences methods; Gaussian quadrature, Euler-Maclaurin series, asymptotic expansions, Newto-Cotes formula.

Numerical solution of ordinary differential equations: Series solution, methods of Milne, Adams-Bashforth, Milne-Simpson muti-step nd Runge-Kutta methods.

Differences equations: Numerical solution, relaxation method.

Solution of partial differential equations by finite difference methods.

Numerical solution of elliptic, parabolic and hyperbolic partial differential equations.

CH 2201: Physico-Chemical Principles

Change of state: Pure materials- Phase stability (Solid-liquid, Liquid-gas, Gas-solid, and Gas-liquid-solid equilibria); Bubbles Drops; Capillary action.

Simple mixtures: Partial molar quantities, Theory of mixing; Solution of non-volatile solutes; Colligative properties; Mixture of volatile liquids; Phase rule and phase equilibria.

Ionic equilibria: Activity of common ions in solution; The Deby-Huckel theory; Role of electrodes; Electrical potential at interface; Electrochemical cells; Standard Electrode potential; Reference electrodes; Thermodynamic properties from cell EMF; Simple applications of EMF measurement.

Electro-kinetic phenomena: Ion Transport, Conductivity and Ionic Interactions; Conductometric titration; Processes at electrode (Electrical double layer, Rate of charge transfer, Over potential and other related aspects); Electrochemical processes; Power generation and storage (Fuel cells, Storage batteries); Corrosion and electrolysis (Elementary idea only).

Colloids: Preparation, purification and properties (Structure, surface and stability).

Adsorption at surfaces: Growth and structure of solid surfaces; Physical adsorption, and chemical adsorption; Extent of adsorption and adsorption isotherms; Chromatography and chromatographic methods of analysis.

Atomic and molecular spectra: Spectra of simple and complex atoms; General features of spectroscopy; Rotation and vibration of molecules; Electron Spin and Nuclear Magnetic Resonance, Atomic absorption spectroscopy; UV and Visible spectro-photometry; IR absorption spectroscopy; Fluorescence spectroscopy; Mass spectroscopy; Emission spectroscopy; Introduction to NMR spectroscopy; Raman spectroscopy; Moss Bauer spectroscopy.

Recommended Books :

Khandpur, R.S., “Handbook of Analytical Instruments”, Tata McGraw-Hill Publishing Co. Ltd., New Delhi.
Ewing, G.W., “Instrumental Methods of Chemical Analysis”, McGraw-Hill Book Co.
Atkins, P.W., “Physical Chemistry”, Oxford University Press.

V Semester

MS 3105: Crystallography and Crystal Structure

Bonding and cohesive energy. Crystalline and non crystalline materials. Point group symmetries in crystals. Bravais lattices. Miller and Miller-Bravais indices. Space group and space group symmetries. Quasiperiodic lattices.

Close packing of spheres. Structure of common metals, alloys, ionic, covalent and molecular crystals, Fullerenes and high temperature superconductors.

Production and properties of x-rays: Continuous and characteristic spectrum. Absorption edges and x-ray filters. X-ray sealed tube and rotating anode generators. Synchrotron sources of x-rays. X-rays monochromators. Line and area detectors.

Interaction of x-rays with matter. Laue equations. Bragg's law. Reciprocal lattice concept and its applications to rotation, Laue and Debye Scherrer techniques. Powder diffractometry. Indexing of powder diffraction patterns.

Atomic scattering factor and structure factor. Lattice and space group extinctions. Phase problem and determination of crystal structures.

Elementary ideas about electron and neutron diffraction.

Recommended Books :

Elements of X-ray crystallography, L.V. Azaroff.
X-ray diffraction, B.E. Warren.
Crystallography applied to solid state physics, A.R. Verma and O.N. Srivastava.
Fundamentals of crystallography, C. Giacovazzo.

MS 3106 : Synthesis and Processing of Materials

Ceramic powder synthesis methods: Solid state reaction method, chemical routes: Coprecipitation, spray drying, freeze drying, sol-gel method, hydrothermal and combustion. Microwave synthesis.

Characterzation of powders: Size and surface area.

Green Body Forming: dry pressing, slip and tape casting, extrusion, injection molding and sol-gel sintering. Hot pressing. Microwave sintering. Powder coating, flame and plasma spraying. Electrodeposition.

Polymer Synthesis: Types of synthesis: free radical, addition, condensation suspension polymerization, emulsion, ionic polymerization, copolymerization, black copolymer, grafting.

Composite Fabrication: Different routes to prepare composites: Hand lay-up methods, filament winding, pultrusion, injection moulding. Metal Composites: Powder Metallurgy Route, diffusion Bonding, co-continuous deformation, liquid state processes, deposition techniques, in-situ processing methods. Preparation of ceramic matrix composites.

Thin film preparations: Epitaxial, grain oriented and polycrysalline thin films, fundamentals of vacuum instruments. Thermal and electron beam evaporation. Sputtering methods: DC, RF and Magnetron. Laser ablation. Chemical vapour deposition. MOCVD. Electro-deposition. Molecular beam epitaxy.

Recommended Books :

Principles of Polymerization by G. Odian
Hand book of thin films by Maisel
Thin Film by A. Goswami
Modern Ceramic Engineering by David W. Richerson
Ceramic Processing and Sintering by M.N. Rahman.
Principles of Ceramic Processing, James S. Reed.
Art and Science of Growing Crystals, J.J. Gilman.
The Growth of Single Crystals, R.A. Laudise.

MS 3107: Physical Behaviour of Materials

Limitations of classical theory of electrical conductivity and thermal conductivity. Mathiessen's rule. Free electron theory. Sommerfield theory of electrical conductivity. Energy bands in crystals. Brillouin zones. Classification of metals, insulators and semiconductors. Two and four probe methods for resistivity measurements.

Intrinsic and extrinsic semiconductors. Intrinsic carrier concentration. Carrier mobility. Impurity conduction. Elemental, compound (II-VI, III-V) and amorphous semiconductors.

Magnetic properties: Types of Magnetism. Ferromagnetic domains. Soft and hard magnetic materials. Measurement of magnetic susceptibility. Applications of magnetic materials.

Superconductivity: Basic phenomenon. Type I and II superconducting materials. Applications of superconductors.

Dielectric properties: Dielectric polarization. AC response. Breakdown strength. Measurement of complex dielectric constant. Applications of dielectrics.

Thermal properties: Specific heat. Thermal conductivity. Thermal expansion. Thermal shock resistance. Thermoelectric effect.

Optical Properties: Birefringence. Elementary ideas about non linear optics, photoelectric emission, photoconductivity and photoluminescence. Lasers.

Nanostructured Materials: Size dependent electronic and magnetic properties.

AC 3102: Analytical Techniques in Chemistry

Basic concept of Analytical Chemistry and its application in chemical analysis, reliability and standard deviation of a group of results, Errors, Parametric test, Rejection criteria, Q test, Robust method, Method Optimization knowing functional Analysis, Classical chemical analysis and industrial analysis. Accept of various signals: Analog and Digital.

Sensitivity, detection limit, resolution, dynamic range as selectivity in analysis.

Potentiometric analysis, general principle, ion selective electrode and their applications.

Coulometric and voltammetric methods, dropping mercury electrode, continuous current polarography, pulse polarography concept of half wave potential, residual as diffusion current, application of polarograph especially in metal in determination stripping voltametry and coulometric measurements Karl-Fischer method.

Basic concept of spectrophotometry.

Recommended Books :

Analytical Chemistry: an Introduction (7^{th} Ed), Saunders, College Publishing, 1999 (ISBN: 0-03-097285-X), Skoog, West, and Harris.
Principles of Instrumental Analysis, Fifth Edition, Skoog, Holler and Nieman. Brooks/Cole-Thompson Learning Publishers.
Vogel's Quantitative Chemical Analysis, 6^{th} Edition.
Contemporary Instrumental Analysis by Kenneth A. Rubinson, copyright © 1997-2006 Culinary and Hospitality Industry Publications Services.
Electrochemical Methods: Fundamentals and Applications, 2^{nd} Edition by Allen J. Bard, Larry R. Faulkner ISBN: 0-471-04372-9, December 2000.

AP 3103 : Digital Electronics & Microprocessors

Logic families: Charaterisitics, Limitation and application SSI and MSI basic building blocks. Analog and Digital Signals, Digital Circuits, Logic Functions and Logic Gates, Binary Numbers, Combinational Logic NAND/ NOR Logic, Exclusive or Logic. Architecture of a microprocessor, Software instruction set, addressing scheme, Arithmetic logic and control schemes, Memory systems, Input/ Output interface, Technology of microprocessors. Transducers and signal conditioning, Instrumentation, amplifiers, choppers, Filters, analog multiplexers, A/D, D/A converters, Pay load design.

AP 4104 : Condensed Matter Physics

Crystal structure, point and space groups, reciprocal lattice, x-ray, electron and neutron diffraction, lattice vibrations, normal modes, Einstein and Debye models, phonons thermal conductivity and thermal expansion, Free electron theory, Drude model of conductivity, Hall effect, Bloch theorem, energy bands in solids, density of states and conductivity, effective mass, energy bands in semiconductors, Fermi surface, de Haas Van Alphen effect. Superconductivity, Meissner effect, tunneling in superconductors, Josephson junctions, high Tc superconductors, liquid crystals.

VI Semester

MS 3209 : Polymeric Materials

Polymers and chemical bonding. Polymerization mechanism. Addition and Condensation polymerization. Chain transfer reaction. Co-polymerization. Polymerization by coordination catalyst. Ring opening polymerization. Molecular weights and their distribution.

Microstructure of polymer chains. Configuration and conformation. Simple and hindered rotation. Radius of gyration and end-to-end distances. Crystallinity and melting. Glass transition. Physical states of polymers and mode of motions of polymer chain. Measurement of viscosity. Cohesive energy density. Compatibility and solubility parameters. Polymer additives, blends and composites.

Mechanical properties: Rheology of polymers. Rubber elasticity. Viscoelasticity. Creep and stress relaxation. Dynamic behaviour. Strength and fracture of rubber and glassy polymers.

Flow properties of polymer: Bulk deformation, elongational and shear flow. Hagen Poiselli equation for polymers, non-Newtonian flow. Extrusion. Injection moulding. Blow moulding. Compression and transfer moulding. Spinning of fibers.

Polymer Fabrication Techniques: Vulcanization of rubber. Flat film and sheet formations. Laminations. Forming of foam.

MS 3210 : Science of Ceramic Materials

Bonding and crystal structure of ceramics. Effect of bonding, crystal structure and microstructure on physical properties of ceramics. Point defects in ionic compounds. Effect of partial pressure of oxygen and temperature on defect concentration. Non-stoichiometry. Effect of alliovalent impurities on concentration of defects. Electronic properties of ceramic materials.

Synthesis of ceramic powder and nanoparticles and their consolidation. Sintering and grain growth mechanisms.

Theoretical fracture strength, Griffith's theory of brittle fracture, toughness and fracture toughness, factors influencing the strength of ceramic materials. Toughening mechanisms, transformation toughening, R-curve behaviour and designing with ceramics. Weibull modulus. Creep and fatigue in ceramics materials.

Thermal expansion, thermal conductivity, thermal stresses and thermal shock resistance. Spontaneous microcracking. Thermal tempering.

Recommended Books :

Fundamentals of ceramics, W.M. Barsoum.
Handbook of advanced ceramics, vol.1 & II, S. Somiya
Modern ceramic engineering, D.W. Richerson.

AC 3201: Instrumental Methods for Chemical Analysis

The basic theory instrumentation, laboratory techniques and analytical application of the following :

Absorption spectrophotometry: UV-visible, IR, FTIR, AAS, NMR and ESR. Emission Spectrophotometry: ICP-AES (XPS) and Direct reading spectrometers. X-ray Diffractometer and X-ray Fluorescence Spectrometer, X-ray photoelectron Spectroscopy Mass spectrometry chromatographs, spectrographic analysis, thermo analytical methods.

Recommended Books :

Skoog, West, and Harris, Analytical Chemistry: an Introduction (7^{th} Ed), Saunders, College Publishing, 1999 (ISBN: 0-03-097285-X)
Principles of Instrumental Analysis, Fifth Edition, Skoog, Holler and Nieman. Brooks/ Cole-Thompson Learning Publishers.
Vogel's Quantitative Chemical Analysis, 6^{th} Edition.
Contemporary Instrumental Analysis by Kenneh A. Rubinson, Copright © 1997-2006 Culinary and Hospitality Industry Publications Services.
Electrochemical Methods: Fundamentals and Applications, 2^{nd} Edition by Allen J. Bard, Larry R. Faulkner ISBN: 0-471-04372-9, December 2000.

AP 3208: Statistical Mechanics

Review of thermodynamics and kinetic theory, Phase space, Liouville theorem, the most probable distribution-in-energy, distinguishable and indistinguishable systems, Boltzmann, Bose-Einstein and Fermi-Dirac statistics, partition function, Boltzmann statistics and its applications to ideal gas, Bose-Einstein statistics and its application to black-body radiation, Fermi-Dirac statistics and its applications to free electron gas. Grand canonical ensemble.

CR 3204 : Glass and Glass-Ceramics

Glassy State: Kinetic and thermodynamic criteria for glass formation, use of Na_2O-SiO_2 and Na_2O-CaO-SiO_2 phase diagrams in glass manufacture, types of glasses and their chemical compositions, Physical properties of glasses, density, refractive index and dispersion, design of lenses, thermal expansion and thermal stresses, thermal endurance of glass, toughening of glasses, strength and fracture behaviour of glass and its articles, surface tension, viscosity and its measurement, effect of temperature and composition on the physical properties of glasses.

Absorption and colours in glasses; role of transition metal ions in glass, sulphur and selenium in glass, oxidation-reduction equilibria in glass, application of redox reactions in glass industry for coloration, decolorization and refining of glasses. Oxygen ion activity in glasses. Chemical durability of glasses; mechanism of reactions of solutions with glass surfaces, factors affecting the chemical durability, measurements of chemical durability of glass.

Glass ceramics; Nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics.

VII Semester

MS 4113: Mechanical Behaviour of Materials

Mechanical testing: Concept of stress/strain. Tensile, compression, shear, hardness and impact testing.

Measurement of stress and strain: Load cells. Optical, electrical and electronic strain measuring devices.

Nondestructive testing techniques: Ultrasonic testing. Radiography. Acoustic emission. Eddy current testing. Liquid penetration technique. Magnetic method of crack detection.

Elastic behaviour of materials: Atomic basis. Anelasticity. Thermoelastic effect. Damping capacity. Viscoelasticity.

Structural imperfections: Point defects in metals and ionic crystals. Theoretical yield strength. Dislocations and their types. Energy of dislocations, their interaction and movement in crystals. Dislocation multiplication. Dislocations in crystals. Partial dislocations and stacking faults. Role of dislocations in plastic deformation.

Plastic deformation of materials: Slip and twinning. Concept of critical resolved shear stress.

Yield point, work hardening and plastic instability. Annealing and recovery phenomena. Strengthening mechanisms: Grain refinement, solute and precipitation hardening.

Creep, fatigue, fracture. Superplasticity. Mechanical Properties of nanomaterials.

Recommended Books :

Materials Science & Engineering : An Introduction, W.D. Callister. Jr.
Mechanical Metallurgy, G.E. Dieter.
Materials Science and Engineering, V. Raghavan.
Engineering Materials Part 1 & 2, Ashby and D.R.H. Jones.

MS 4114: Materials Characterization

Scope and methods used for materials characterization.

Optical microscopy techniques including polarized light and phase contrast. Quantitative metallography and its applications.

Transmission electron microscopy: Description of TEM. Formation of images and selected area diffraction patterns. Interpretation of electron diffraction patterns. Specimen preparation techniques.

Scanning electron microscopy: Description of SEM. Image formation methods in SEM.

Scanning probe microscopy: STM and AFM.

Analytical Electron Microscopy: EDS and WDS and EELS. Electron probe microanalysis (EPMA).

Auger electron spectroscopy. Electron spectroscopy for chemical analysis (ESCA). X-ray fluorescence analysis. SIMS. XPS.

UV-visible and IR spectroscopy

Corrosion behaviour of materials and corrosion testing techniques.

Recommended Books :

Metals Handbook Vol. 8, 8th edition.
Principles of Metallographic Laboratory Practice, G.L. Kehl
Principles of Instrumental Analysis, D. A. Skoog, F.J. Holler and T.A. Nieman

MS 4115 : Industrial Polymers

Preparation of polymers: Petroleum based, plant products and synthetic routes. Polymers in fiber industry: Fiber forming polymers. Synthesis, structure and properties of fibers. Application of fibers.

Polymers for paints and coatings: Basics of paint technology. Polymeric binders, pigments, extenders and additives. Essential concepts of paint formulations. Properties of paints.

Polymers as adhesives: polymer based adhesives. Adhesion improvers. Thermal and mechanical behaviour of adhesives. Mechanism of adhesion.

Electronic polymers: Polymers used in electronic industries. Physical, chemical and morphological properties of electronic polymers and their applications. Piezo and pyroelectric polymers. Electric and dielectric properties of polymers.

Polymers in information technology: Polymers in optical media data storage devices.

Various types of polymers used in information technology, their synthesis and properties. Fabrication of CD substrates.

Polymers in tyre industries.

AC 4101: Chemical Sensors

Introduction to chemical sensing; Potentiometry: fundamental principles, membrane potentials, Applications of potentiometry: ion-selective electrodes, amperometry: fundamental principles, diffusion limited currents, Applications of amperometry: the Clark oxygen electrode, glucose sensors in diabetes: more enzyme electrodes, immunosensors, ELISA, piezoelectric devices: quartz crystal microbalance, luminescent sensors and electrochemiluminescence. Optical sensors: Selective detection of gases and applications in atmospheric chemistry and environmental science, Selected topics from: miniaturization and lab-on-a-chip devices, applications in molecular biology and clinical chemistry and elementary idea of MEMS Technology.

Recommended Books :

Encyclopedia of Sensors, American Scientific Publisher, ISBN 1-5883-056-X.
Principles of Instrumental Analysis, D. A. Skoog, F.J. Holler and T.A. Nieman
Chemical Sensors, T.E. Edmonds, Chapman and Hall, 1987.
Principles of Chemical Sensors, J. Janata, Plenum Press, 1989.
Chemical Sensors, R.W. Cattrall, Oxford University Press, 199
Enzyme and Microbial Biosensors: Techniques and Protocols. Humana Press, Totwa, NJ.

AC 4102: Corrosion

Corrosion and its economical aspects, thermodynamics of corrosion – Pourbaix diagrams, Immunity, corrosivity and passivation. Mechanism and kinetics of corrosion testing, methods of corrosion control and corrosion in industries.

Recommended Books :

Corrosion Engineering, M.G. Fontana, Mc Graw Hill International Book Co. London.
Corrosion, Vol I and Vol II, L.L. Shreir, Newness Butterworths, Edward Arnold Ltd, London.

VIII Semester

MS 4218 : Composite Materials

Types of composites and their advantages.

Reinforcements: Glass, boron, carbon, organic and ceramic fibers, their structure, properties and processing.

Matrix materials: Polymer, metal and ceramic matrices, their structure, properties and processing. Wettability and interface bonding.

Polymer matrix composites: Lamina, laminate composites. Primary and Secondary manufacturing: Lay-up, Filament winding, Pultrusion, Compression moulding. Machining, drilling and routing. Applications.

Metal matrix composites: Processing techniques and applications.

Ceramic matrix composites: Processing techniques and applications.

Introduction to Nanocomposites and applications.

Micromechanics: Mechanical properties, thermal properties and load transfer.

Macromechanics: Elastic behaviour. Fracture, fatigue and creep behaviour of composites.

Tribological and electrical behaviour of composites.

Degradation of composites due to various environmental conditions and corrosion resistance of composites.

Designing with composites. Biomedical applications of composites.

MS 4219 : Magnetic Materials

Magnetic moments of electron and free atom

Kinds of Magnetism: Dia-, para-, ferro-, ferri- and antiferro-magnetism

Theories of para-magnetism and ordered magnetism

Magnetic phenomena: Hysteresis and related properties. Magnetic anisotropy. Magnetostriction. Magnetoresistance.

Magnetic domains: Domain theory. Observation of domains. Energy considerations. Domain configurations. Magnetization processes in terms of domain theory. Domain wall. Properties of domain walls and domain wall motion

Soft Magnetic Materials: Preparation, structure, electrical, magnetic, magneto-optical properties and applications of ferrites, garnets, permalloy and super-permalloy and their applications

Hard magnetic materials: Properties and applications of hard ferrites, Nd-Fe-B alloy, AlNiCo alloys, rare earth-Co alloys.

Magnetic recording: Materials used and their applications.

CMR Materials: their properties and applications.

Recommended Books :

Introduction to Magnetism and Magnetic Materials, Darel Jiles.
Introduction to Magnetism Materials, Luting.
Solid State Physics, C. Kittel.

MS 4220: Molecular Electronics and Organic Conductors

Molecular electronics: Basic concepts. Molecular materials and their classifications. Liquid crystals. Conducting crystals. Processes responsible for photochromism. Electrochromism. Display devices and optical data storage. Charge transfer complexes. LB thin film formation and technological application.

Conducting Polymers: Types of conducting polymers. Basic principle and structure. Delocalised electronic states of conjugated polymers. Electronic conduction in conjugated polymers. Transport of charge in conducting polymers. Chemical and electrochemical routes of synthesis and doping of conducting polymers. Charge storage and semiconducting devices based on conducting polymers.

Construction of modified electrodes. Conducting polymer as intermediate layer and matrices for immobilization of chemicals. Sensor and biosensor applications of conducting polymers.

MS 4221 : Electrical and Electronic Ceramics

Symmetry and other criteria of ferroelectricity, ferroelectric transitions in $BaTiO_3$, $PbTiO_3$ and other related materials. Effect of compositional modifications and grain refinement. Relaxor ferroelectrics. Performance categories of ceramic capacitors with typical compositions. Powder synthesis, electroding and packaging of discrete, multilayer and barrier layer capacitors.

Symmetry considerations and equations of state for piezoelectric and electrostrictive effects. Poled ferroelectric ceramics. Measurement of coupling factor and strain coefficient. Phase diagram, preparation and properties of PZT ceramics. Thin films of PZT. Piezoelectric positioners, loud speakers and gas igniters.

Pyroelectric and electro-optic ceramics and their applications.

NTC and PTC thermistors, ZnO varistors, and their applications.

Classification and structural features of superionic solids. Applications in oxygen sensors, fuel cells, high density energy storage batteries.

Magnetic ceramics and their crystal structure. Effect of composition on magnetic behaviour. Processing, microstructure, properties and applications of magnetic ceramics.

CR 4203: Refractories

Different kinds of Monolithics Refractiories and their design aspects. Advantages of monolithic refractories over shaped refractories. Magnesia carbon, alumina carbon refractories, Manufacturing and properties. Slide gate plate, SEN and shrouds. Spinel, zircon, borides, carbides, nitride refractories. Manufacturing and properties of synthetic raw materials. Insulating refractories of different kinds, their manufacturing and properties. Carbon refractories manufacturing and properties. Application of refractories in blast furnace, coke oven, hot metal mixer, basic oxygen furnace, electric arc furnace, ladles and continuous casting. Refractory application in copper, aluminium, cement and lime, rotary kiln, glass industry, Microstructure study and its importance to characterize Refractory product. Application of sintering, phase diagram in refractory technology.

IX Semester

MS 5122 : Nanomaterials and Nanostructures

Preparation methods: Thermal and ultrasound decomposition methods. Reduction methods. Coprecipitation, spray drying, sol-gel and hydrothermal methods. Capped semiconductor nanoparticles. High energy ball milling and mechanical attrition. Thermal evaporation. Sputtering. Laser ablation. Chemical vapour deposition. Molecular beam epitaxy. Thermal spraying. Electro and electroless deposition.

Characterization techniques: TEM, SEM, AFM and STM. Optical and vibrational spectroscopy.

Properties: Quantum wells, wires and dots. Size and dimensionality effects. Excitons. Single electron tunneling. Applications in infrared detectors and quantum dot lasers. Magnetic properties of nanocrystalline materials. Nanostructured ferroelectric materials and nanocomposites. Nanostructured materials in catalysis and electrocatalysis. Carbon clusters compounds, Preparation and properties of carbon nanotubes. Inorganic nanotubes and nanorods, nanoporous materials.

Recommended Books :

Nanostructures and Nanomaterials, G. Cao.
Introduction to Nanotechnology, Charles P. Poole Jr. and F. J. Owens.
Nanostructured Materials, Carl C. Koch.

MS 5123 : Functional Materials

Definition of functional materials.

Shape memory effects and shape memory alloys. Novel magnetic shape memory alloys. Invar alloys.

Functional materials in computer memory devices: Ferroelectric RAM. Phase change materials in optical media storage devices.

Giant and colossal magnetoresistance materials and their applications.

Multiferroic materials and their applications as sensors and actuators.

Functionally graded materials and their applications.

Hydrogen storage materials and their applications.

Smart gels: Materials, synthesis and applications.

Membranes and Fuel Cell electrode materials.

MS 5124 : Diffraction Techniques in Materials Science

Space group symmetries. Coordinates of equivalent points related by symmetry.

General procedure for working out the details of space groups with illustrations from triclinic, monoclinic and orthorhombic systems. Wyckoff positions. Elementary ideas about magnetic groups.

Principles of crystal structure analysis. Structure factor calculations. Space group extinctions. Experimental determination of space group and inversion symmetry. Electron density functions. Phase problem. Patterson functions. Refinement procedures. Direct methods in crystallography.

Debye Scherrer, Guinier and Bragg-Brentano geometries for powder diffractometers. General intensity expression for powder diffraction. Rietveld refinement technique. Quantitative phase analysis and microstructure determination. Limitations of powder method. Single crystal diffractometers.

Recommended Books :

Elements of X-ray Crystallography, L.V. Azaroff.
Crystallography Applied to Solid State Physics, A.R. Verma and O.N. Srivastava
X-ray Diffraction, B.E. Warren.
Elements of X-ray Diffraction, B.D. Culity.
The Rietveld Method, R.A. Young.

MS 5125: Advanced Polymers

Solid and gas phase polymerization. Group transfer polymerization. Living free radical polymerization.

Butyl rubber. Nitrile rubber. Styrene butadiene rubber. Telechelic polymers. Hetero-chain polymers. Ethylene propylene diene rubber (EPDM). Nanocomposites.

Foams. Thermosetting Resins. Ionomers. Hydro-gel. Polymeric liquid crystals. Polymeric gel. Heat resistant polymers. Multiphase polymeric systems. Interpenetrating networks. Graft and block copolymers. Molecular composites.

Conducting polymers: Types of conducting polymers. Chemical and electrochemical routes of synthesis. Doping and dedoping of conjugated polymers. Solatron and polaron formation in conducting polymers. Conduction mechanism.

Bio and natural polymers: Proteins, nucleic acids, lipids, cellulose and polysaccharides.

Medicinal and biomedical applications of polymers. Introduction of Inorganic Polymers and application. Biodegradable polymers. Polymer waste management.

CR-5106: Advanced Refractory Engineering

Manufacture and properties of conventional and non conventional refractories. Application of sintering, microstructure and phase diagram in refractory technology and their influence on refractory property. Application of refractories in metallurgical and non metallurgical industries. Latest development and trends of refractories for iron and steel making. Functional refractories e.g. purging, refractories, tap not e refractories, refractory lance ceramic fitters, vacuum forward insulating products. Borides, corbids, nitrides and silicids. Refractory for nuclear reactors. Refractory metals and refractory coatings innovation in refractory materials and application. Non destructive testing. Methods used in refractory technology. Status of refractory industries and research in India.

CR 5107: Ceramic Fabrication Processes

Raw Materials: Processing of raw materials, powder preparation by solid state reactions, chemical methods and vapour phase reactions. Freeze drying and spray drying and sol-gel processing of ceramic powders.

Colloidal Processing: Types of colloids, electrostatic and polymeric stabilization of colloids, rheology of colloidal suspensions. Clay water system, thixotropy, slip casting and tape casting.

Powder consolidation and forming of ceramics: Packing of particles, additives and their selection in the forming process. Extrusion, dry and semi-drying pressing methods, isostatic pressing, hot pressing. Plastic forming methods, injection moulding. Drying of formed bodies and removal of binders.

Sintering of Ceramics: Driving forces for sintering, defects and diffusion in solids, solid state and viscous sintering, liquid phase sintering, grain growth. Clinkering and vitrification. Microstructure control during firing. Microwave sintering.

Recommended Books :

Processing and Sintering of Ceramics by M.N. Rahman.

CR-5104 : Nano Ceramics

Introduction to nanotechnology, its emergence and challenges classification of nano-materials: Zero, one, two and three dimensional nano-structured materials.

Synthesis of nano-particles through homogenous and heterogenous nucleation, kinetically confirmed synthesis of nano-particles synthesis of nano-wire, rod, tubes and thin films. Special nano-materials: carbon fulrenes and carbon, nano-tubes, nano and microporous materials, core shell structure and nano-composites.

Electrical, magnetic, optical, thermal and mechanical properties of nano-structured materials.

Applications of nano-materials in molecular electronics, nano-electronics, catalysis, photoelectrochemical cells, photonics, quantum well, quantum dot and quantum wire devices.

Recommended Books :

Nano structure and nano-materials by Guozhong (AO. (Imperial College Press, London), 2004.
Introduction to Nano technology by Charles P. Poole, Jr and Frauk J. Owens. (Wiley Interscience, New Jersey, 2003).
Nano-structured materials: Processing, properties and Potential Applications by Carl. C.Koch. (Noyes Publication and William Andrew Publishing) New Yark 2002.

CH5113: Fuel Cell Technology

Fundamentals and classification of fuel cells; Thermodynamic efficiency.

Electromotive force of fuel cells: Standard electrode potentials; Effect of concentration; Nernst equation.

Rate of electrode processes: Types of polarization; Surface reactions; Oxygen electrodes; Hydrogen electrodes; Overall performance.

Low temperature fuel cells: Hydrogen–oxygen fuel cells– alkaline and polymeric membrane types; Active catalyst and its dispersion; Heat and mass transfer; Construction and design; Limiting problems; Low temperature fuel cells of other types – methanol fuel cell, hydrocarbon fuel cell.

High temperature fuel cells: Advantages; Molten electrolyte fuel cell; Solid electrolyte fuel cell; Construction.

Air depolarised cells; Biochemical fuel cells; Regenerative cells; Micro fuel cells.

Fuel cell operation: Supply of fuel; Electrical arrangement; Removal of products; Materials for battery construction; Production and purification of fuels.

Application of fuel cell systems: Large scale power generation; Power plant for vehicles; Domestic power; Fuel cells in space.

Fuel cell economics; Future trends in fuel cells.

CH 5110: Renewable Energy Technology

Principles of renewable energy: Fundamentals; Scientific principles, technical implications, and social implications.

Solar radiation: Extraterrestrial solar radiation; Measurement and estimation of solar radiation.

Solar heating devices: Solar water heaters; Sheltered and unsheltered heaters; Systems with separate storage; Selective surfaces; Solar ponds, Solar concentrators and other devices.

Principles of photovoltaic generation of electricity; Silicon cell; Photon absorption; Cell efficiency; Solar cell construction; Types and usage of photovoltaic systems.

Bio-fuels: Bio-fuel classification; Combustion, pyrolysis, gasification and other thermo-chemical processes; Production of alcohol and biogas.

Bio-diesel: Fundamentals; Transesterification of vegetable oils for biodiesel production; Characterization of biodiesel; Economics, current trends and future prospects in usage of biodiesel.

Hydrogen energy: Hydrogen energy system and analysis; Hydrogen infrastructure; Safety, codes and standards.

Hydrogen production: Electrolysis; Thermochemical; Hydrogen from fossil fuel, biomass and renewable sources of energy.

Hydrogen storage: Carbon storage materials; Metal hydrides and chemical hydrides; Cryogenic hydrogen storage.

Hydrogen fuel cells.

MT 5239 : Fracture Mechanics and Component Integrity

Brief review of the basic concepts of linear elastic and elastic-plastic fracture mechanics, stress intensity parameter, J integral and crack tip opening displacement as fracture criteria, standard procedures for experimental determination of these parameters. Correlation of fracture toughness with other mechanical properties and microstructure.

Sub-critical crack growth under fatigue. Stress and crack length correlations with fatigue crack propagation, fatigue life calculations, crack initiation and propagation mechanisms, ΔK_{Th} short crack growth behaviour, crack closure, effects of overloads and variable-amplitude loading, microstructural aspects.

Environment assisted sub-critical crack growth, stress corrosion cracking, hydrogen embrittlement and liquid metal embrittlement, threshold stress intensity factor (K_{IEAC}), crack growth mechanisms, major variables affecting crack growth, life prediction.

Corrosion fatigue, true corrosion fatigue and stress corrosion fatigue, superposition models, mechanisms of crack growth.

Applications of fracture toughness. Design of structures, life prediction and failure analysis, 'fail-safe' and 'safe-life' design concepts and 'leak-before-break' design. Determination of inspection intervals and preventive maintenance schedules.