THAPAR UNIVERSITY

COURSES SCHEME

&

SYLLABUS

FOR

M.TECH.

MATERIALS
&
METALLURGICAL ENGINEERING

2015

COURSES SCHEME & SYLLABUS FOR M.TECH.
(MATERIALS AND METALLURGICAL ENGINEERING)

SEMESTER – I

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PMM101	STRUCTURE AND PROPERTIES OF MATERIALS	3	1	0	3.5
2	PMM106	THERMODYNAMICS AND KINETICS OF MATERIALS	3	1	0	3.5
3	PMM107	MECHANICAL PROPERTIES OF MATERIALS	3	1	2	4.5
4	PMM105	MATERIALS CHARACTERIZATION	3	1	2	4.5
5	PMA102	RESEARCH METHODOLOGY	2	0	2	3.0
TOTAL			**14**	**4**	**6**	**19.0**

SEMESTER – II

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PMM205	PHASE TRANSFORMATION AND HEAT TREATMENT	3	1	0	3.5
2	PMM206	FAILURE ANALYSIS	3	0	2	4.0
3	PMM203	COMPUTATIONAL METHODS FOR MATERIALS USING C-PROGRAMMING	3	0	3	4.5
4	PMM204	MATERIALS PROCESSING	3	1	2	4.5
5		ELECTIVE-I	3	1	0	3.5
6	PMM291	SEMINAR				2.0
TOTAL			**15**	**5**	**6**	**22.0**

INDUSTRIAL TRAINING: SIX WEEKS **2 CR.**

SEMESTER – III

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1		ELECTIVE-II	3	1	0	3.5
2		ELECTIVE-III	3	1	0	3.5
3	PMM392	MINOR PROJECT + DISSERTATION STARTS	-	-	-	4.0
TOTAL			**6**	**2**	**0**	**11.0**

SEMESTER – IV

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PMM491	DISSERTATION	-	-	-	12.0
TOTAL			**-**	**-**	**-**	**12.0**

TOTAL NUMBER OF CREDITS: 66.0

ELECTIVE – I

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PMM215	ELECTRICAL AND MAGNETIC PROPERTIES OF MATERIALS	3	1	0	3.5
2	PMM211	ELECTRONIC AND OPTO-ELECTRONIC MATERIALS	3	1	0	3.5
3	PMM212	CRYSTAL GROWTH AND PROCESSING TECHNIQUES	3	1	0	3.5
4	PMM213	COMPOSITE MATERIALS	3	1	0	3.5
5	PMM214	ELECTRONIC POLYMERS	3	1	0	3.5

ELECTIVE – II

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PMM321	ELECTRO CERAMICS	3	1	0	3.5
2	PMM322	NANO-STRUCTURED MATERIALS	3	1	0	3.5
3	PMM324	NON-DESTRUCTIVE TESTING OF MATERIALS	3	1	0	3.5
4	PMM325	INTRODUCTION TO BIOMATERIALS	3	1	0	3.5
5	PMM326	ENERGY MATERIALS	3	1	0	3.5

ELECTIVE – III

SR. NO.	COURSE NO.	TITLE	L	T	P	CR
1	PMM331	SURFACE ENGINEERING	3	1	0	3.5
2	PMM332	SOLID STATE PHASE TRANSFORMATION	3	1	0	3.5
3	PMM333	ADVANCED IRON AND STEEL PROCESSING	3	1	0	3.5
4	PMM334	POWDER METALLURGY	3	1	0	3.5
5	PMM335	EXTRACTIVE METALLURGY	3	1	0	3.5

PMM101: STRUCTURE AND PROPERTIES OF MATERIALS

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective(s): To understand the classification of various engineering materials, Chemical bond characteristic; the crystalline, non- crystalline materials and different types of crystal structures and their defects. Also, to understand the concept of phase and different type of phase diagrams.

Materials Classification: Engineering materials and their classification: metals/ ceramics /polymers, Structure-property-processing co-relationship as a theme of materials science, Different levels of structures. Material Properties: Mechanical, electrical, thermal, dielectric, semi-conducting properties of materials.

Bonding in Solids: Primary and secondary bonds, Mixed bonding, Potential energy vs bond length criteria, Concept of bond length and nature of bonding Madelung energy, Variation in materials properties with bonding character.

Structure of Solids: Crystal structure**,** Space lattice, Bravais lattice and reciprocal lattice concept; Miller Indices of directions and planes for cubic and hexagonal system; Metallic, ionic and covalent solids; Crystal structures of NaCl, CsCl, Diamond cubic, Zinc Blende, Wurtzite, Rutile, Flourite, Fullerenes, Spinel, Perovskite etc.,

Non-crystalline Structures: General features and classification, Structure and properties of metallic glass and amorphous semiconductors.

Crystal Imperfections: Point imperfections, Burger vector, Dislocations (edge and screw) and Surface imperfections,

Phase Diagrams: Phase rule and phase diagrams, Solid solutions, Hume Rothery rules, Intermediate phases and compounds, Unary and binary systems, Isomorphous and eutectic systems, Lever rule, Various phase reactions, Introduction to different phase diagrams, Ternary system, cooling curve and its use for drawing phase diagrams, Zone refining.

Course Learning Outcomes (CLO):
Student will be able to understand:
1. Different type of materials, and their structure.
2. Structural dependence of properties.

Recommended Books:
1. *Smallman, R.E., and Bishop, R.J., Metals and Materials, Butterworth-Heinemann, Oxford University Press (1995).*
2. *Raghvan, V., Materials Science & Engineering, PHI (1998).*
3. *Callister, W.D., Materials Science & Engineering: An Introduction, Wiley & Sons (2001).*
4. *Smith, W., Principles of Materials Science and Engineering. McGraw Hill (1990).*

PMM106: THERMODYNAMICS AND KINETICS OF MATERIALS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To develop a clear understanding of laws of thermodynamics as they apply to different elements and compounds and their interactions in the solid, liquid, and gaseous forms as a function of various extensive and intensive variables. To analyze the path to thermodynamic equilibrium through studying reaction kinetics and the laws those govern mass transfer in solids. To understand the concept of boundary layer with a specific example of Slag – metal reaction kinetics.

Laws of Thermodynamics: Thermodynamics laws and their applications; Enthalpy; Entropy associated with different processes; Gibbs and Helmholtz free energy; Criteria of equilibrium; Concepts of activity, fugacity and standard states; Ellingham diagram.

Thermodynamics of Solutions: Raoult's and Henry's Laws; Ideal, real and regular solutions; Gibbs – Duhem equation.

Thermodynamics of Electrochemical Cells: Relationship between chemical and electrical driving forces, Nernst equation, concentration and formation of cells.

Free Energy Composition Diagram: Fundamentals of free energy composition diagrams for binary systems. Examples of common binary free energy diagrams.

Kinetics: Activation energy and its applications; Homogeneous and heterogeneous reactions; Factors affecting the heterogeneous reactions kinetics in solid – solid, solid – gas and solid – liquid systems; Rate controlling steps; Kinetic model equations.

Slag – Metal Reaction Kinetics: Concept of boundary layer and its impact on reaction kinetics.

Course Learning Outcomes (CLO):
Students will be able to:

1. Understand of thermodynamics and kinetics involved in materials and processes;
2. Predict whether a reaction or a process would occur and if yes, how fast or slow a process would be;
3. Explain how to overcome the energy barrier to accomplish the transformation from the starting state to the final state, i.e., analyze the feasibility and efficiency of a materials processing technology.

Recommended Books:

1. *Gaskell D.R., Introduction to Metallurgical Thermodynamics, McGraw Hill, New York, (1973).*
2. *Upadhyay G.S. and Dubey R.K., Problems in Metallurgical Thermodynamics and Kinetics, Pergamon, New York, (1977).*
3. *Szekely J. and Themelis N.J., Rate Phenomena in Process Metallurgy, John Wiley, New York (2002)*
4. *Mohanty A.K., Rate Processes in Extractive Metallurgy, Prentice Hall of India (2002).*

PMM107: MECHANICAL PROPERTIES OF MATERIALS

L	T	P	Cr
3	1	2	4.5

Course Objective(s): To understand the materials behavior under applied stress, understanding the mechanism involved in the material deformations and strengthening and the various mechanical testing methods.

Elastic Behavior of Materials: Description of stress and strain, State of stress in two and three dimensions, Stress and strain tensors, Mohr's circles of stress and strain, Hydrostatic and shear stresses, Elastic stress-strain relationship, Strain energy.

Plasticity in Materials: True stress-strain curve, Yielding criteria for materials, Anisotropy in yielding, Invariants of stress and strain, Plastic stress-strain relationship, Slip-line field theory. Instability under tensile conditions, Stress distribution at neck, Effects of strain rate and temperature on flow properties.

Plastic Deformation of Single Crystals: Stereographic projection, Concepts of lattice defects, Deformation by slip, Slip in a perfect crystal, Dislocation and slip by dislocation movement, Critical resolved shear stress for slip, Deformation of single crystals, Stacking faults and micro-strain.

Dislocation and Related Phenomena: Concepts of dislocation and classification, Burgers vector, Dislocations in face centered cubic and body centered cubic crystals, Energies of dislocations, Forces on dislocation, Forces between dislocation, Partial dislocations, Dislocation glide and climb, Slip, Dislocation intersection, Jogs, Dislocation sources (Frank-Read and grain boundary) and multiplication of dislocations, Dislocation point defect interaction and dislocation pileups, Dislocations in ceramics and glasses.

Strengthening Mechanisms in Materials: Grain boundaries, Low angle and high angle grain boundaries, Grain boundary strengthening, Yield point phenomenon, Strain aging, Solid solution hardening, Strengthening from fine particles, Strain hardening, Bauschinger effect.

Mechanical Testing: Tensile test of Metals, ceramics and polymers; Hardness testing of materials; Hardness at elevated temperature, Tension and Torsion Tests, Creep.

Laboratory Work:
To study the stress-strain curves of different metallic samples using tensometer, Deformation by creep in metals, Thermo-mechanical behaviour of rubber, Mechanical behaviour/strength of glass, Young's modulus and strength of fiber, Rockwell, Brinell hardness of metallic samples, Effect of heat treatment on yield strength and creep resistance of metallic wire, Decomposition of austenite as a function of cooling rate and the tempering the martensite as a function of temperature in 0.8% carbon steel, The precipitation hardening of Al-alloys on Isothermal aging, Grain size and microstructure changes of metallic sample(s) with respect to heat treatment and its impact on mechanical properties, Hardness of a specimen by Vicker micro hardness tester, Wear behavior of a given metallic materials.

Course Learning Outcomes (CLO):
Student will be able to:

1. Describe and predict elastic deformation in isotropic and anisotropic engineering materials;
2. Describe and predict yielding of engineering materials under uniaxial and multiaxial states of stress;
3. Describe the major microstructural-based mechanisms of strengthening in (crystalline) materials, and apply these principles to alloy and process design;
4. Identify the microstructural based dependencies of mechanical failure in engineering materials, including yielding, fracture, fatigue, and creep; and apply these principles to design and process failure-resistant materials.

Recommended Books:

1. *Dieter George E. Mechanical Metallurgy, Mc-Graw-Hill Book Company (SI ed.) (1989).*
2. *Suryanarayana C. Experimental Techniques in Materials and Mechanics, CRC Press (1980).*
3. *Roesler J. H., Harders, and Baeker M., "Mechanical Behaviour of Engineering Materials: Metals, Ceramics, Polymers, and Composites", Springer-Verlag, (2007).*

PMM105: MATERIALS CHARACTERIZATION

L	T	P	Cr
3	1	2	4.5

Course Objective(s): To understand the principles of optical and electron microscopy for study of macro and micro-structure of materials. To gain knowledge in understanding the tools and techniques for studying the substructure and atomic structure of materials. To build an expertise in characterization of engineering materials.

Introduction: Need of materials characterization and available techniques.

Optical Microscopy: Optical microscope - Basic principles & components, Different examination modes (Bright field illumination, Oblique illumination, Dark field illumination, Phase contrast, Polarised light, Hot stage, Interference techniques), Specimen preparation, Applications.

Electron Microscopy: Interaction of electrons with solids, scanning electron microscopy Transmission electron microscopy and specimen preparation techniques, Scanning transmission electron microscopy, Energy dispersive spectroscopy, Wavelength dispersive spectroscopy.

Diffraction Methods: Fundamentals of crystallography, X-ray diffraction techniques, Electron diffraction, Neutron diffraction.

Surface Analysis: Atomic force microscopy, scanning tunneling microscopy, X-ray photoelectron spectroscopy.

Spectroscopy: Atomic absorption spectroscopies, UV/Visible spectroscopy, Fourier transform infrared spectroscopy, Raman spectroscopy.

Thermal Analysis: Thermogravimetric analysis, Differential thermal analysis, Differential Scanning calorimetry.

Laboratory Work:
Metallographic preparation and grain size measurement of metallic and ceramic samples. Determination of crystal structure and lattice parameters using X-rays diffraction technique, Determination of crystal structure and lattice parameter from electron diffractions, Study of the UV visible absorption spectra of inorganic substance, Thermal analysis of alloys, to study the thermal expansion coefficient of various specimen using dilatometer, Determination of functional group and nature of bonding by FTIR, Study of surface roughness and morphology of thin films by using AFM.

Course Learning Outcomes (CLO):
Students will be able to:

1. Apply appropriate characterization techniques for microstructure examination at different magnification level;
2. Understand the crystal structure determination and phase analysis of the materials;
3. Able to examine the electronic structure, and the thermal behavior of the materials.

Recommended Books:

1. *Gabriel, B. SEM- A Users's Manual, Plenum Press (1985).*
2. *Cullity, B.D. Elements of X-Ray Diffraction, Addison Wesley (1967).*
3. *Smallman, R.E., and Bishop, R.J., Metals and Materials – Science, Processes, Applications, Butterworth-Heinemann (1995).*
4. *Sibilia J.P., A Guide to Materials Characterisation and Chemical Analysis, VCH (1988).*

PMA102: RESEARCH METHODOLOGY

L	T	P	Cr
2	0	2	3.0

Introduction: Nature and objectives of research, Study and formulation of research problem, Scope and formulation of hypothesis, Preparation and presentation of research and project proposals, Selection of thrust research.

Introduction to Statistical Analysis: Measures of Central Tendency and Dispersion, Mean, Median, Mode, Range, Mean deviation, Standard Deviation.

Random Variables and Probability Distribution: Definition, Distributions, Functions, Mathematical Expectation, Binomial, Poisson, Geometric, Negative binomial, Exponential, Normal and log-normal distributions.

Hypothesis Testing: Tests of Significance based on normal, t and chi-square distributions, Analysis of variance technique

Linear Regression and Correlation: Linear regression, least square principle and fitted models, Karl Pearson's correlation coefficient, Rank Correlation, Lines of regression.

Design of Experiments: Completely randomized design, Random block design, Latin square design, Statistical analysis and variances of estimates, Analysis of covariance.

Laboratory Work:
Implementation of statistical techniques using statistical packages *viz*., SPSS, Mathematica including evaluation of statistical parameters and data interpretation, Regression Analysis, Covariance, Hypothesis testing and analysis of variance.

Course Learning Outcome (CLO):
Students will be able to:
1. Develop testable hypotheses, differentiate research design and/or statistics, evaluate aptness of research conclusions, and generalize them appropriately.
2. Design and conduct quantitative or qualitative research studies in laboratory or field settings.
3. Use research data to formulate or evaluate new research questions, using reason and persuasion in a logical argument.

***Recommended Books**:*

1. *Dowdy, S., Wearden, S. and Chilko, D., Statistics for Research, Wiley Series (2004)*
2. *Walpole, R.E., Myers, R.H., Myers, S.L. and Ye, K., Probability and Statistics for Engineers and Scientists, Pearson Education (2002).*

PMM205: PHASE TRANSFORMATION AND HEAT TREATMENT

L	T	P	Cr
3	1	0	3.5

Course Objective: To understand variation in structure of different metallic System with variation in composition and heat treatment procedures

Introduction: Review of phase diagrams and phase reactions, Some common phase diagrams, Cu-Zn, Al-Cu, FeO-SiO_2, Evolution of microstructure on cooling.

Diffusion: Concept of diffusion, Fick's laws of diffusion, Kirkendell effect

Iron - cementite Phase Diagram: Allotropic changes in iron, Fe-Fe_3C phase diagram, role of alloying elements, types of steels.

Basics of Heat Treatment: Formation of austenite, decomposition of austenite, TTT diagram, Pearlitic transformation, Bainitic transformation, Martensitic transformation, Retained austenite.

Heat Treatment Process: Stress relieving, Annealing, Normalizing, Spheroidizing hardening, Tempering, Austompering, Martemporing, sub-zero treatment, Patenting

Hardness and Hardenability: Significance of hardness and hardenability, Hardenability with transformation rates, Determination of hardenability, Factors influencing hardenability.

Quenchants: Heat transfer during quenching, Different types of quenchants, Quenching media, Synthetic quenchants.

Chemical Heat Treatment of Steels: Carburizing (solid, liquid, gas vacuum), Post carburizing treatment, Cyaniding and Carbonitriding, Nitriding, Boronizing, Chromizing.

Surface Hardening: Flame hardening, Induction hardening, Electron beam hardening, Laser hardening, Case depth measurement.

Thermo-mechanical Treatment: Classification (HTMT, LTMT), Ausforming, isoforming, Marstraining, cryoforming.

Cast Iron and Their Heat Treatment: Grey, white, malleable, Heat treatment of non-ferrous materials, SG iron, Alloy cast irons,

Course Learning Outcomes (CLO):
Student will be able to selecting proper composition and heat treatment cycles to end applications of metallic materials

Recommended Books:

1. *Reed, R.E., Physical Metallurgy Principles, Tata McGraw Hill (1991).*
2. *Rajan, T.V., Sharma, C.P. Sharma, Ashok, Heat Treatment Principles and Techniques, PHI (1997).*
3. *Sidney H.H, Introduction to Physical Metallurgy, Tata McGraw Hill (1974).*

PMM206: FAILURE ANALYSIS

L	T	P	Cr
3	0	2	4.0

Course Objective: To understand the different type of materials failure and examine the causes of material failure

Introduction: Reliability and durability of materials. Bath tub curve of component failure. Concept of Mean Time Failure and related statistics. Failure Mode Effect Analysis (FMEA), Methodology of failure analysis, Fractography. Distortion failure, Primary and secondary process defects, Effect of defects on service properties, Ductile and brittle fracture. Basic fracture modes (shear mode, cleavage mode, intergranular and transgranular fractures, Fatigue fracture, creep fracture), Factors affecting the ductile brittle relationship.

Testing Techniques: Procedural steps for investigation, Non-destructive testing, Fractrographic examination, Metallurgical tests, Analysis of service parameters and Simulated tests.

Mode of Fractures: Brittle fracture, Brittle fracture of normally ductile steels, Characteristics of brittle fracture, Microstructural aspect of brittle fracture, Combined fracture modes, Ductile fracture, Characteristics of ductile fracture, Microstructural aspects of ductile fracture, Fatigue fracture, Types of fatigue fracture, Stages of fatigue fracture, Microscopic and macroscopic characteristics of fatigue fracture, Relationship of stress to strength in fatigue, Statistical aspects of fatigue.

Different Type of Failures: Wear failure, Abrasive and adhesive wear, fretting wear, Wear failures-fatigue, Corrosion failure, Life cycle of a metal, Basic nature of corrosion, Forms of corrosion (Galvanic corrosion, Uniform corrosion, Crevice corrosion, Stress-corrosion cracking), Corrosion fatigue, Hydrogen embrittlement in alloys, Elevated-temperature failure, Creep, Elevated-temperature fatigue, Thermal fatigue, Metallurgical instabilities, environmentally induced failure, Cooling methods.

Case study and documentation

Laboratory Work:
Inspection of surface defects occurred during solidification of a given metallic sample. Detecting the voids and blowholes in as-cast material by UFD, Welding a given metallic sample and observing the HAZ (Heat Affected Zone) defects under optical microscope, Rolling a given metallic specimen and discussing the rolling defects, Forging a given metallic specimen and discussing the forging defect, To Study the fracture surface of brittle and ductile materials under SEM, Studying the fracture surface of a material failed under cyclic loading, Observation of wear surface and subsurface and evaluating the mode of failure, Observation of corroded metallic material to evaluate the form of corrosion.

Course Learning Outcomes (CLO):
Student will be able to:

1. Analyze the reasons for failure and suggest remedial actions
2. To document the cause of failure, its effect on the operation / service and mode of failure
3. Prevents further failures by influencing design, material selection, manufacture, testing techniques or operating conditions

Recommended Books:

1. *Wulpi, D.J., Understanding How Components Fail, ASM International Technical Books (2004).*
2. *Das A.K., Metallurgy of Failure Analysis, Tata McGraw Hill (1986).*

PMM203: COMPUTATIONAL METHODS FOR MATERIALS USING C-PROGRAMMING

L	T	P	Cr
3	0	3	4.5

Course Objective: The aim of the course is to introduce the students to C programming and various models in materials engineering.

Introduction: Algorithms, Flow charts, Problem solving methods, Need for computer language, C-character set, Identifiers and keyword, Data types, Declarations, Expressions, statements and symbolic constants, Input-output statements, Preprocessor commands, Preparing and running a complete C-program.

Operators and Expressions: Arithmetic, Unary, Logical, Bit-wise, Assignment and conditional operators, Library functions.

Control Statements: While, Do-while, For statements, Nested loops. If else, Switch, Break, continue and goto statements, Comma operator.

Functions: Defining and accessing: Passing arguments function prototypes, Recursion, Use of library functions, Storage classes: Automatic, External and Static variables.

Arrays and Strings: Defining and processing, Passing to a function, Multi-dimensional arrays, Operations on strings.

Introduction of Modeling: Concept of model, Modeling in materials science, Simulation vs. modeling, Numerical solution of differential equations.

Monte Carlo Methods: Introduction, Metropolis Monte Carlo algorithm, Ising model, Resident time algorithm, Diffusion.

Molecular Dynamics: Introduction, Interatomic potentials, Equations of motion, Integration, Correlation functions, and their examples.

Phase-field Models: Introduction, Allen-Cahn model, Energy functional, Numerical solution methods, examples.

Laboratory Work:
Programs related to computational methods along with basic programs will be carried out in C language.

Course Learning Outcomes (CLO):
The student will be able to:
1. Understand concept of programming in C
2. Understand modelling and simulation
3. Appreciate monte-carlo, molecular dynamics and phase-field models.

Recommended Books:

1. *Kemighan, B. W. and Ritchie, D.M., The C Programming Language, PHI (1988).*
2. *Wolfson, M. M. and Pert, G. J., An Introduction to Computer Simulation, Oxford University Press (1999).*
3. *Raabe, D., Computational Materials Science, Wiley-VCH (1998).*
4. *Koonin, S. E. and Meredith, D. C., Computational Physics, Addison-Wesley (1990).*

PMM204: MATERIALS PROCESSING

L	T	P	Cr
3	1	2	4.5

Course Objective: Understanding the influence of different processing parameters on microstructures and properties. To learn about available methods for metals, and ceramics processing. To use fundamentals of materials science and engineering to perform basic materials selection and to determine processing conditions needed to achieve desired shapes and properties.

Solidification from Liquid and Vapour Phase: Nucleation and growth, Homogeneous and heterogeneous nucleation, Interface stability, Development of micro structure, Faceted and non-faceted structure, Super cooling, Equilibrium phase diagrams, Eutectic and peritectic solidifications and their microstructures, Foundry techniques such as sand casting, Permanent mould casting, Investment casting and die casting, Casting defects and their inspection.

Forming Processes: Fundamentals of metal forming, Hot working process; Rolling, Forging, Extrusion, Piercing, Cold working processes; Bending, Shearing, Squizing etc.

Metals Joining: Welding, Brazing, and soldering: Conventional and Laser techniques and their application

Ceramic Processing / Powder Processing: Synthesis of common ceramic powders such as Al_2O_3, ZrO_2, Si_3N_4, and SiC, Powder characterization, Binders, Lubricants, Defloculants and flocculants as processing aids, shaping techniques such as powder compaction, Extrusion, Injection moldings, Slip casting, Solid state and liquid phase sintering.

Laboratory Work:
Observation of Nucleation phenomenon in some organic and inorganic salts, Observation of Growth phenomenon of dendrites in transparent liquid, Estimation of cooling rates in different metallic systems, Structural analysis of different metals and alloys after mechanical working, Observation of weld zone in different metallic specimen, Synthesis of different ceramic powders, Observation of green density and sintered density in different metallic and ceramic compacts at different loads.

Course Learning Outcomes (CLO):
Student will be able to:

1. Adopt proper working conditions for a particular material to be used in different engineering components;
2. Process different ceramic powders and bulk by different processing techniques.

Recommended Books:

1. *Chalmner, B., Principles of Solidification, Wiley (1977).*
2. *Degarmo, E.P., Black, J.T. Kosher R.A, Materials and Processing in Manufacturing, PHI (1986).*
3. *Martin, D.H. & Jones, Polymer Processing, Chapman and Hall (1989).*
4. *Fleming, M.C., Solidification Processing, McGraw Hill (1974)*
5. *Richerson, B.W., Modern Ceramic Engineering: Properties, Processing and Use in Design, Marcel Dekker (1983).*

PMM215: ELECTRICAL AND MAGNETIC PROPERTIES OF MATERIALS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To study the electrical conduction in metals and alloys. Application of these materials in superionic conductors. To learn the dielectric and magnetic properties of materials and their applications in industry.

Introduction: Review of quantum mechanical concepts, Inadequacies of free electron theory, Electron in metals-consequences of interaction with lattice, Brillouin zones and nearly free electron model, Tight binding model for d-states.

Electrical conducting materials: Electrical resistivity of metals, Alloys, Multiphase solids and Mattheissen rule, Nordheims Rule, Kondu and spin glass alloys, Ionic and superionic conductors, their Properties and applications.

Dielectric and insulating Materials: Review of polarization, Clausius Mosotti equation, Mechanisms of polarization, Dielectric permittivity and loss (in brief), Dielectric break down in materials, High K dielectric, Non-linear dielectrics: Ferroelectric, Piezoelectric pyroelectric phenomena, Materials properties including case studies, Ferroelectric thin films, Integrated ferroelectrics, Actuators and Smart materials.

Magnetic materials: Classification of magnetic materials, Ferromagnetism and exchange interactions, Ferromagnetic domains, Magnetic anisotropy, Magnetic behaviour of polycrystalline materials, Hard and soft magnetic metallic and intermetallic materials and their characteristics, Ultrafine grain size materials, Garnets, soft and hard ferrites, their properties and applications, Magnetic properties of superconductors and Polymer magnets.

Course Learning Outcomes (CLO):

Students will be able to

1. Explain mechanism of electrical / ionic conduction in metals and alloys;
2. Chose an appropriate conductor / dielectric / magnetic / spintronic material for specific application(s).

Recommended Books:

1. *Solymar, L. and Walsh, Lectures on Electrical Properties of Materials, Oxford University Press (2004).*
2. *Kasap, S.O., Principles of Electrical Engineering Materials and Devices, McGraw Hill (1996).*
3. *Hummel, R.E., Electronic Properties of Materials, Springer Verlag (2004).*
4. *Ashcroft, N.W. and Mermin, N.D., Solid State Physics, Thomson (2007).*

PMM211: ELECTRONIC AND OPTO-ELECTRONIC MATERIALS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To provide theoretical framework of semiconducting materials and an overview of the wide variety of different semiconductors used for various optoelectronic devices. To introduce basics of semiconductor physics (including semiconductor junctions) to understand the functioning of semiconductor devices. To introduce the semiconductor processing techniques including methods of doping. To explain fundamentals of optical processes in semiconductors, which are critical to the optoelectronic applications including Laser, LED, optical communication devices, etc.

Physical basis of Semiconductors: Review of energy bands, Effective mass, Fermi level in intrinsic and extrinsic semiconductors, Effect of temperature, Carrier concentration and mobility on Fermi level and electrical conductivity. Hall effect, Drift and diffusion currents, Einstein relation, Element and compound semiconductor materials: Classification of semiconductors into element, Binary, Ternary and quaternary compounds, Conduction mechanisms, Amorphous semiconductors, Oxide and magnetic semiconductors.

Junctions and Junction Devices: Contact potential explanation based on band structure, M-S contact and its properties, Barrier layer, P-N junction, Potential barrier and barrier width, Forward and reverse saturation current junction capacitance.

Processing of Semiconductor Materials: Purification, Zone refining and zone floating methods, Czochralski and Bridgemann techniques, Epitaxial growth methods, Liquid phase, Vapour phase and molecular beam epitaxy, Thin film techniques.

Optical Processes in Semiconductors: Radiative and non-radiative recombination, Absorption in semiconductors. Luminescence from quantum well, Photo luminescence and phosphorescence, Phototransistors electro luminescence process, LED's; their structures and choice of materials, Polymer LEDS.

Materials for Optical Communication: Optical fibers, Single and multimode electro-optic effect, Kerr and pockels effect liquid crystal displays and display materials, TN and STN effect.

Course Learning Outcomes (CLO):
Students will be able to:

1. Acquire fundamental understanding of optical processes in the semiconductors for optoelectronic devices and application;
2. Develop detailed knowledge about the suitability of materials for a specific optoelectronic application;
3. Know about need-specific processing of semiconductors;
4. Develop basic understanding of devices such as light emitting diodes, Lasers, optical communication devices, etc. Develop an overall understanding of the scope of the optoelectronic industry and its impact on our daily lives.

Recommended Books:

1. *Sze, S.M., Physics of Semiconductor Devices, Wiley (2007).*
2. *Bhattacharya, P., Semiconductor Opto-electronic Devices, PHI (2006).*
3. *Wilson, J. & Hawkes, J.F.B., Optoelectronics- PHI (1988).*

PMM212: CRYSTAL GROWTH AND PROCESSING TECHNIQUES

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To provide a clear understanding of super-saturation, and nucleation of phases, different crystal growth processes. To familiarize with single crystal growth processes such as Czochralski and Bridgman method. To introduce the recent trends in crystal growth, Quantum wells and superlattices, Heterostructures.

Introduction: Crystal growth, Velocity of growth, Theories and mechanism of growth, Twinning, growth twins, Deformation twins, Transformation twins, Growth in the solid state recrystallization and grain growth.

Crystal Growth Techniques: Growth from melt, Thermodynamic principles and crystal growth equilibria, Nucleation from solution, Melt, vapour and solid phase.

Preparation of Single Crystals: Czochralski method, Bridgman method growth from epitaxy.

Purification: Zone refining and floating zone methods.

Epitaxial Growth: Lattice matching in epitaxial growth, Liquid –phase epitaxy, Vapour phase epitaxy, Molecular beam epitaxy, Growth for polycrystalline materials, Quality assessment by X-ray diffraction and optical techniques, Current trends in crystal growth, Quantum wells and superlattices, Heterostructures.

Course Learning Outcomes (CLO):

Student will be able to:

1. Explain crystal growth and epitaxy and the necessary concepts in thermodynamics and kinetics;
2. Explain the connection between growth parameters and the quality and properties of the grown material;
3. Know about recent trends in crystal growth, super lattices and heterostructures;
4. Evaluate and select a crystal growth method, suitable for a specific situation.

Recommended Books:

1. *Azaroff, L.V., Introduction of Solids, McGraw Hill (1960).*
2. *Vere, A.W., Crystal Growth, Principles and Progress, Springer (1988).*
3. *Streetman, B.G., Solid State Electronic Devices, PHI, (2005)*
4. *Fleming, M.C., Solidification Processing, McGraw Hill (1974)*

PMM213: COMPOSITE MATERIALS

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective(s): To classify composites, introduce common types of fibers and matrices, manufacturing of composites, mechanical properties and applications of composites. To understand the overview of mechanical and physical properties of a range of composite materials systems. To understand the mechanisms of composite deformation and fracture.

Introduction: Composites and their classification, Particulate composites, Hybrid composites, Long aligned fiber composites.

Reinforcements: Glass fibers, Boron fibers, Carbon fibers, Organic fibers, Ceramic fibers, Non-oxide fibers, Comparison of different types of fibers.

Matrix Materials: Polymers, metals, Ceramic matrix materials and their properties

Processing of Composites: Hand lay-up, Pre peg processing, Press molding, Vacuum molding, Filament winding, extrusion, Pultrusion, liquid metal infiltration process, Diffusion bonding and powder metallurgy methods, joining of composites, Basic properties of GRP, CFRP, Al-B, Casting and Particulate composites.

Interfaces: Wettability, Crystallographic nature of interface, Interactions at the interface, Types of bonding at the interface, Test for measuring interfacial strength.

Failure/ Fracture of Composites: Tensile strength, Compressive strength, Fractures modes in composites, Maximum stress theory, Maximum strain criterion, Maximum work criterion, Comparison of failure theories.

Properties and Applications: Modulus, Strength, Thermal characteristics, Aging, Fatigue, Creep, Transport properties, Matrix connectivity, Aerospace application, Structural, Defense biomedical application, Machine tools, Automobiles applications

Course Learning Outcomes (CLO):

Student will be able to:

1. Asses the applicability and selection of a composite material for a specific application;
2. Mechanics analysis of composite materials;
3. Self-directed learning, incorporating researching properties of composite materials.

Recommended Books:

1. *Chawla K.K., Composite Materials, Springer (2008)*
2. *Harris B., Engineering Composite Materials, Maney Publishing (1998).*
3. *Callister, W.D., Materials Science & Engineering: An Introduction, Wiley & Sons (2007*)

PMM214: ELECTRONIC POLYMERS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): Study the basic properties of polymers, their fabrication techniques and classification schemes. Establish the structure property relationship in various types of polymers. Study the charge transport properties of various types of polymers.

Introduction: Classification and structure of polymers, Glass transition, Linear viscoelasticity, Stress relaxation and dynamic experiments, Mechanical models, Superposition principles, Effect of structure on mechanical properties, Rubber elasticity, Yield and fracture, Rheology, Polymer fabrication techniques.

Types of Polymers Electroactive polymers, Electronic structures in crystallographically ordered conjugated polymers, Ferroelectric polymers (PVDF, etc), Liquid crystal polymers, etc

Properties and Applications of Polymers: Electronic properties of polymers, Mechanisms of charge transfer, Electrical conducting polymers like poly pyrrole, Polythiophene, Polyaniline their properties and applications, Polymers for molecular electronics, Non-linear and electro-optic properties of polymers.

Course Learning Outcomes (CLO):
Students will be able to:
1. Understand basics of polymer, their types and various methods of polymer synthesis;
2. Explain the structural dependence of electrical, optical and mechanical properties of polymers;
3. Explain charge transport in electronic polymers based molecular electronics.

Recommended Books:

1. *Prasad, P.N., and Ulrich, D.R., Non-linear, Optical and Electroactive Polymers, Plenum Press (1988).*
2. *Aldissi, M., Intrinsically Conducting Polymers: An emerging Technology, Kluwer (1993)*
3. *Skotheim, T.A., and Reynolds, J.R., Handbook of Conducting Polymers, CRC (2007).*

PMM321: ELECTRO CERAMICS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To understand basics of difference in metallic and ceramic structure; Influence of point defects on properties of ceramics. Different processing methods of electroceramics. Understanding of various functional electroceramics and their application.

Introduction: Structural differences in metals and ceramics, Rules of structure formation in Oxides/Ionic solids

Defects and Defect Chemistry: Role of defects in ionic conduction, Defects equilibrium, Diffusion through defects, Ionic and electronic conductivity for ceramics, Kröger–Vink notation, Arrhenius equation.

Ionic and Electronic Transport: Basic concepts of diffusion, Tracer diffusion, Self-diffusion, Chemical diffusion, Ambipolar diffusion, Ionic conduction in crystalline solid, Intrinsic and Extrinsic ionic conduction, Transference number, Nernst-Einstein relationship, and Conductivity-Diffusion relationship, Polaron theory, metal-ceramic interfaces and electronic transport into and through a dielectric material, Conduction mechanism in terms of Mott insulators, Semiconductors, Measurement techniques, Examples of ionic transport, in important applications.

Non-linear Dielectrics Polar and Nonpolar Ceramics: Crystal structure and Noncentrosymetricity, Tensor representation of properties, Piezoelectrics, Pyroelectrics, Ferroelectrics, Antiferroelectrics, Relaxors, Phenomenological theory (phase transitions) and soft mode theory, domain switching and domaindynamics., Measurement methods, Applications

Thermoelectric Oxides See-back and Peltier effect, Materials and applications

Magnetic Ferrites Ferrites structure and properties and their applications

Multiferroics and Magnetoelectrics: Principles, Classification, Magnetoelectric coupling, Materials, issues and possible applications.

Course Learning Outcomes (CLO):

Student will be able to:

1. Know the relationships between ceramic structure (electronic, microstructure and defect structure) and properties;
2. Learn how these variety of phenomena can be exploited in useful applications like fuel cells, sensors, and piezoelectric transducers;

Access current research in electronic, magnetic, and optical ceramics.

Recommended Books:

1. *Moulson A.J and Herbert, J.M., Electroceramics: Materials, Properties and Applications, Wiley (2003).*
2. *Hench L.L and West J.K, Principal of Electronic Ceramics, Wiley (1990).*
3. *Rahaman M.N, Ceramic Processing and Sintering, CRC, (2003).*
4. *Reed, J. Principles of Ceramics Processing, John Wiley & Sons, (1995).*
5. *Kingery W.D, Introduction to Ceramics, Wiley (1976).*

PMM322: NANO-STRUCTURED MATERIALS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): Understand the influence of dimensionality of the object at nanoscale on their properties. Various synthesis techniques for the preparation of 0-D, 1-D and 2-D nanostructures, industrial applications of nanostructures in future technologies.

Introduction to Nanomaterials: Features of nanosystems, Characteristic length scales of materials and their properties, Density of states in 1-D, 2-D and 3-D, Variation of density of states and band gap with crystal size.

Quantum Size Effect: Electron confinement in infinitely deep square well, Confinement in one dimensional well, Idea of quantum well structure, Formation of quantum well, Quantum dots and quantum wires.

Synthesis of Nanoscale Materials: Top down and bottom up approach, Cluster beam evaporation, Ion beam deposition, Chemical bath deposition with capping techniques and mechanical milling methods, Chemical methods and self-assembly.

Nanomaterials: Nanoparticles, Nanocoatings and Nanocomposites, Nanotubes, Fullerenes, Thin film chemical sensors-gas sensors, and biosensors, Smart materials, Fuel and solar cells, Drug delivery systems and Optoelectronic devices.

Course Learning Outcomes (CLO):

Students will be able to:

1. Acknowledge the influence of dimensions of the object(s) at nanoscale on their properties;
2. Choose appropriate method and conditions for synthesis of desired nanostructures;
3. Make selection of appropriate nanostructures for various industrial applications.

***Recommended Books**:*

1. *Bimerg, D., Grundmann, M., and Ledentsov, N.N., Quantum Dot Heterostructures, John Wiley (1999).*
2. *Jain, K.P., Physics of Semiconductor Nanostructures, Narosa (1997).*
3. *Fendler, J.H., Nano particles and Nano-structured Films, John Wiley &Sons (1998).*
4. *Timp, G., Nanotechnology, Springer-Verlag (1999).*

PMM324: NON-DESTRUCTIVE TESTING OF MATERIALS

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective: Understanding the basic principles of various NDT methods with fundamentals approach. Selection of NDT methods for different products like forging, rolling, casting, welding and used components.

Visual Inspection- Tools, Applications and limitations. Liquid Penetrant Inspection - principles, types and properties of penetrants and developers. Advantages and limitations of various methods of LPI.

Magnetic Particle Inspection- Principles, Applications, Advantages and limitations.

Ultra-Sonic Testing (UT) - Nature of sound waves, Wave propagation, modes of sound wave generation, Various methods of ultrasonic wave generation, Types of UT Principles, Applications, advantages, Limitations, A, B and C scan, Time of Flight Diffraction (TOFD).

Radiography Testing (RT) – Principles, Applications, Advantages and limitations of RT. Types and characteristics of X ray and Gamma radiation sources, Principles and applications of Fluoroscopy/Real-time radioscopy, Advantages and limitations, Recent advances.

Eddy Current Testing - Principles, types, applications, advantages and limitations of eddy current testing.

Case Studies: Weld, Cast and Formed components.

Course Learning Outcomes (CLO):
Student will be able to:
1. Assist in product development, screen or sort incoming materials;
2. Verify proper processing such as heat treating;
3. Verify proper assembly;
4. Inspect for in-service damage.

Recommended Books:

1. *Raj Baldev, Practical Non – Destructive Testing, Narosa Publishing House (1997).*
2. *Hull B. and John V., Non-Destructive Testing, Macmillan (1988)*
3. *Krautkramer, Josef and Krautkramer Hebert, Ultrasonic Testing of Materials, New York, Springer-Verlag (1983).*

PMM325: INTRODUCTION TO BIOMATERIALS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): Understand various classes of biomaterials and their importance in biomedical engineering. Study essential properties of biomaterials and mechanisms of their clearance in *in-vivo* applications. Study the *in-vitro* and *in-vivo* clinical applications of biomaterials in diagnostics and treatment.

Introduction: Classes of materials used in medicine, Metals, Ceramics, Synthetic polymers, Composites, Hydrogels, Bioresorbable and Biodegradable materials, Natural materials, Structure and properties relationships of biological materials.

Novel Biomaterials: Hydrogels, Self-assembling peptides, Implants materials; Metallic implant materials (stainless steels, Co-based alloys, Ti based alloys), Ceramic implant materials (aluminum oxides, hydroxyapatite glass ceramics carbons), Polymeric implant, Polymers for drug delivery.

Properties of Biomaterials: Biocompatibility, Properties of biomaterials, Physical, Thermal, Electrical and Optical, Surface properties and adhesion of bio-materials and their application to processing, Testing and clearance of biomaterials.

Applications of Biomaterials: *In-vitro* Applications, *in-vivo* applications, Biomedical application: Cardiovascular, Dental implants, Orthopedic application, Skin, Ophthalmologic applications, Wound healing, Biomedical and Biosensor applications.

Course Learning Outcomes (CLO):

Students will be able to:

1. Classify biomaterials based on their properties / applications.
2. Select appropriate biomaterial(s) for desired *in-vitro* or *in-vivo* clinical application(s).

Recommended Books:

1. *B. D. Ratner, A. S. Hoffman, F. J. Schoen and J. E. Lemons, Biomaterials Science, Second Edition: Wiley Science (2004).*
2. *L. Hench and J. Jones, Biomaterials, Artificial Organs and Tissue Engineering (Woodhead Publishing in Materials (2002).*
3. *J. Breme, R. Thul and C. J. Kirkpatrick, Metallic Biomaterial Interfaces Wiley (2008).*
4. *Temenoff J.S. and Mikos A.G., Biomaterials: The intersection of Biology and Materials Science, Pearson, (2009).*
5. *Kinam Park, Controlled Drug Delivery: Challenges and Strategies. Washington (DC): American Chemical Society (1997).*

PMM326: ENERGY MATERIALS

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To familiarize the students about depletion of conventional energy resources and the necessity of alternate energy resources. To introduce a number of alternative energy sources such as solar energy, thermoelectricity, electrochemical and hydrogen energy. To explain how material properties, limit the efficiency; This can be developed through understanding of chemistry and physics of energy conversion and storage, specific to an energy source. To provide a deep understanding of material characteristics required for specific energy applications – thermoelectric materials, semiconductors for photovoltaics, electrochemical energy materials and materials for harnessing hydrogen energy.

Photovoltaic Solar Energy Materials: Solar cell principles and its characterization. Absorption and minority carrier life time, Single crystalline and polycrystalline silicon solar cells, Amorphous silicon solar cells, Cadmium Telluride thin film solar cells, Transparent conductive oxide materials, Chalcopyrite based solar cells, Organic and dye sensitized solar cells.

Thermoelectric Materials: Physics of thermoelectricity, Peltier, Seebeck and Thomson effects, Thermoelectric materials: Na_xCoO_2, $AgSbTe_2$, $CoSb_3$, $Y_{14}MnSb_{11}$, Thermoelectric generators, Peltier cooler.

Electrochemical Energy Materials: Fundamentals of electrochemical energy conversions, Primary batteries - Zn-MnO_2 system, carbon-zinc and carbon-zinc chlorides performance characteristics and zinc-silver oxide. Secondary batteries – lead acid, nickel cadmium, nickel metal hydride, silver oxide zinc system, lithium ion, lithium polymer, Introduction to super capacitors, types of super capacitors, Introduction to fuel cells, Types of fuel cells and technology development.

Hydrogen Energy: Hydrogen; its merit as a fuel; Applications, Hydrogen production methods, Production of hydrogen from fossil fuels, Electrolysis, Thermal decomposition, Photochemical and photo-catalytic methods, Hydrogen storage methods, Metal hydrides, Metallic alloy hydrides, Carbon nano-tubes, Sea as source of Deuterium.

Course Learning Outcomes (CLO):

Students will be able to:

1. Analyze the potentials for improving energy and material technologies;
2. Develop understanding of properties of materials for harnessing thermoelectric, photovoltaic, electrochemical and hydrogen energy;
3. Understand how thermoelectric, photovoltaic, electrochemical and hydrogen energy devices work;
4. Identify key issues to increase energy efficiencies in different sectors and design materials suitably;
5. Work in the energy sector that specializes in thermoelectric, photovoltaic, electrochemical and hydrogen energy.

Recommended Books:

1. *Tom Markvart and Luis Castaner, Solar Cells-Materials, Manufacture and Operation, Elsevier, (2005)*
2. *G.S. Nolas, J. Sharp, J. Goldsmid M.M. Schwartz, Thermoelectrics: Basic Principles and New Materials Developments Springer, (2001).*
3. *M. Graziani and P. Fornasiero, Renewable resources and renewable energy- A global challenge, CRC-Taylor and Francis, (2007).*

PMM331: SURFACE ENGINEERING

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To familiarize the students with basic principles of various surface modification techniques in engineering materials. To provide ideas on the importance of surface engineering techniques and their impacts in industrial applications. To give introduction to important surface characterization techniques.

Introduction: Importance of surfaces and wear surface properties in engineering applications, Current status of surface engineering. Wear modes; Categories of wear, Low stress, High stress and Goughing abrasion, Cavitation, Slurry erosion, Impingement erosion, Fretting wear, Adhesive wear, Seizure, Galling, Oxidative wear, Spalling, Impact wear brinelling.

Plating Processes: Fundamentals of electroplating, Electrodeposition from plating baths, Electroless plating, Mentalliding, Selective plating, Hard anodizing, Other plating processes, Applicability of plating for wear resistance.

Thin Film Coatings: Thermal evaporation, PVD and CVD, Sputter coating, Ion plating, Thin film for wear application, Coating specifications.

Special Surfacing Processes: Rebuilding and surface cements, Wear tiles, Electrospark deposition coatings, Fused carbide cloth ceramic coatings, Wear sleeves, Wear plates.

Hard facing processes and applications: Shielded metal arc welding, Gas tungsten arc welding, Gas metal arc welding, Flux coaxed are welding, Submerged arc welding, Plasma arc welding oxyacetylene welding, Furnace fusing, Thermal spray processes and their applications, Hardfacing transformation, Fusion alloys, Non fusion materials. Hardfacing in new designs, Hardfacing for repairs, Hardfacing with fusion processes, Nonfusion deposits, Weldability considerations, Finishing considerations.

Course Learning Outcomes (CLO):
Students will learn fundamentals of some of the very important techniques used in metallurgical industries to enhance materials' mechanical as well as corrosion and erosion properties.

Recommended Books:

1. *Budinski, K.G., Surface Engineering for Wear Resistance, Prentice Hall (1988).*
2. *Mathews, A., Advanced Surface Coatings: A Hand book of Surface Engineering, Spinger (1991).*
3. *Hocking, M.G., Metallic and Ceramic Coatings, John Wiley (1989).*
4. *Strafford, K.N., Datta, P.K., and Gray, J.S., Surface Engineering Practice, Processes, Fundamentals and Applications in Corrosion and Wear, Ellis Harwood (1990).*

PMM332: SOLID STATE PHASE TRANSFORMATION

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To introduce the students with various phase transformations involved in materials processing in solid state. To provide the students scientific backgrounds (thermodynamics and kinetics) of the above phase transformations. Provide ideas on the importance of these phase transformations in materials designing for specific applications.

Ordering: Ordered and disordered transformation, Intermediate phases and compounds, Superlattices, Degree of order, Ordered domain and their boundaries, Kinetics of ordering.

Nucleation and Growth: Nucleation and transformation, Rate concepts, Precipitation, Ostwald ripening, Spinodal transformation, Discontinuous precipitation, Martensitic transformation, Nucleation of martensite, Pearlitic transformation, Massive transformation.

Transformation in Steel: TTT diagram for Fe-Fe_3C system, Transformation in steels, Effect of alloying elements, Various heat treatment processes, Transformation in alloy steels, Superalloys.

Cast Iron: Heat treatment of cast irons, Thermomechanical treatments.

Non-Ferrous Alloys: Ni based alloys, Ti alloys, Al alloys, Cu alloys and their transformation behaviour.

Course Learning Outcomes (CLO):
The course would serve as a prerequisite for more advanced level courses such as bulk heat treatment and surface engineering which would use principles of phase transformations elaborated in the present course, for application specific metallurgical processes.

Recommended Books:

1. *Rajan, T.V., and Sharma, C.P., Heat Treatment, PHI (1997).*
2. *Polmear, J.P., Light alloys, Arnold (2005).*
3. *Haasan P., Physical Metallurgy, Cambridge Press (1996).*
4. *Jena, A.K., Chaturvedi, M.C., Phase Transformation, McGraw Hill (1991).*
5. *Raghavan, V., Phase Transformation, PHI (1992).*

PMM333: ADVANCED IRON AND STEEL PROCESSING

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To become familiar with iron making and steel making. To become conversant with the role of thermodynamics and kinetics in IMSM. To get a feel for what is happening in the steel industry.

Iron Making: Modern blast furnace, Raw materials for iron making, Metallurgical coke, Treatment of iron ores, Agglomeration and sintering, Testing of burden materials, Blast furnace operation, Reactions in blast Furnace, Modern trends in blast furnace practice, Sponge iron production.

Steel Making: Introduction to steel making, Lay-out of steelmaking shop, Steels and their classification, Thermodynamics and kinetics of refining, Thermal principles of refining, Deoxidation of steel, Plain and alloy steel production, Source for metallic iron, Oxidation agents, Fluxes, Source of heat, Deoxidizers and alloying additions.

Bulk Steel Making Processes: Bessemer furnace, Open hearth furnace, Electric arc furnace, LD furnace, Kaldo furnace, LDAC furnace, OBM furnace, Hybrid furnace, Secondary steelmaking process. Casting pit practice, Solidification of steel in ingot moulds, Ingot defects and remedies, Gases in steel, Vacuum treatment of liquid steel, Continuous casting of steel, Iron and steel making in India.

Course Learning Outcomes (CLO):
Student will be able to:

1. Apply the principles of physical chemistry and transport phenomena (heat, mass and momentum) to the process steps in Iron and Steelmaking as practiced in integrated steel plants;
2. Understand basic layout of blast furnace, steelmaking shop and continuous casting process;
3. Understand the Functioning of an integrated steel plant/corporate center and R&D ventures.

Recommended Books:

1. *Tupkary, R.H., Tupkary, V.R., An Introduction to Modern Iron Making, Tata McGraw Hill (2005).*
2. *Ghosh Ahindra, Chatterjee Amit, Ironmaking and Steelmaking: Theory and Practice, PHI learning (2008).*

PMM334: POWDER METALLURGY

L	T	P	Cr
3	**1**	**0**	**3.5**

Course Objective(s): To introduce the students with important materials processing technique. To familiarize the students with the principles of powder metallurgical technique. To introduce the students with few case studies where powder metallurgical techniques are successfully used to produce super-hard and intricate materials parts.

Fabrication Techniques: Introduction, Different methods of powder production viz Milling, atomization, Reduction, Electrolysis, Carbonyl process.

Characterization: Chemical composition, Structure, Morphology, Shape, Size, Distribution, Surface area, Powder flow, Apparent density, Tap density, Compressibility, Porosity.

Consolidation: Powder mixing and blending, Compaction techniques, Uniaxial, Isostatic compaction, Extrusion, Forging, Rolling, Injection molding, Tape forming, Slip casting, Sol-gel casting, Types of processes, Tooling and Die design.

Sintering: Solid state sintering, Liquid phase sintering, Reaction sintering, Hot pressing, Hot isostatic pressing, Self-propagating combustion sintering, Sintering atmosphere.

Applications: Application and uses of P/M products viz Filters, Contact materials, Bearing, Structural parts.

Course Learning Outcomes (CLO):

1. Students would learn a host of processing techniques which have industrial utility;
2. Students could employ some of these techniques in their own research.

Recommended Books:

1. *Randall M. German, Powder Metallurgy Science, Metal Powder Industires Federation, Princeton, New Jersey (1984).*
2. *ASM Hand book, Vol. 7: Powder Metallurgy, ASM International, (2010).*
3. *W.D. Kingery, H.K. Bowen and D.R. Uhlmann: Introduction to Ceramics, John Wiley & Sons, New York, (2009).*
4. *G. S. Upadhyaya: Powder Metallurgy Technology, Cambridge International Science Publishing, (2002)*

PMM335: EXTRACTIVE METALLURGY

L	T	P	Cr
3	1	0	3.5

Course Objective(s): To provide overall descriptions of unit processes of mineral beneficiation and extractive metallurgy, particularly for non-ferrous metals. To provide backgrounds of the individual processes involved in different stages of extraction.

Ores and Minerals: Important ores and minerals and their occurrence in India; beneficiation of ores and minerals, various comminution processes, its theories description and applications.

Concentration of Ores: Various concentration techniques and their applications, Mineral dressing circuits and Flow sheets.

Refractory: Types, classification, Properties and testing, their selection and applications. Unit processes in pyrometallurgy, Calcinations, Roasting, Agglomeration, Reduction smelting, Matte, smelting, Flash smelting, Converting, Distillation, Refining with suitable examples.

Unit Processes in Hydrometallurgy: Leaching, Purification of leach liquor, Solvent extraction and ion exchange process, Techniques of metal recovery from aqueous phase and their applications.

Unit Processes in Electrometallurgy: Faraday's laws of electrolysis, Concept of over voltage, Limiting current density, Electro-winning and Electro-refining with reference to Cu, Zn, Al etc. Flow sheets and numerical calculations including material balance and heat balance.

Course Learning Outcomes (CLO):
Students will be able to understand different industrial techniques associated with the process metallurgy of non-ferrous metals.

Recommended Books:

1. *Mohanty A.K., Rate Processes in Extractive Metallurgy, Prentice Hall of India, (2009).*
2. *Principles of Extractive Metallurgy, Terkel Rosenqvist, Tapir Academic Press, (2004).*
3. *Principles of Extractive Metallurgy, H. S. Ray and A. Ghosh, New Age International, (1991).*