Master of Technology

In

Materials Science and Engineering

Course Structure & Syllabus

Department of Materials Science and Engineering

National Institute of Technology Hamirpur

Hamirpur (HP) - 177005, India

Course Structure of M. Tech. Materials Science and Engineering

SEMESTER-I

Course No.	Course Name	Credit	Course Type
MS-611	Introduction to Materials Science and Engineering	4	Core Course
MS-612	Material Characterization Techniques	4	Core Course
MS-613	Thermodynamics of Materials	4	Core Course
MS-614	Materials Science Lab 1	2	Lab Course
MS-7MN	Programme Elective-I	4	Elective Course
MS-7MN	Programme Elective-II	4	Elective Course
	Total	**22**	

Programme Elective-I & II: List of Programme Electives is given in the Annexure.

SEMESTER-II

Course No.	Course Name	Credit	Course Type
MS-621	Science & Technology of Thin Films	4	Core Course
MS-622	Electrical and Electronic Properties of Materials	4	Core Course
MS-623	Phase Transformations in Materials	4	Core Course
MS-624	Materials Science Lab 2	2	Lab Course
MS-7MN	Programme Elective-III	4	Elective Course
MS-7N	Institute Elective	4	Institute Elective
	Total	**22**	

Programme Elective –III: List of Programme Electives is given in the Annexure.

SEMESTER-III

Course No.	Course Name	Credit	Course Type
MS-798	M. Tech. Dissertation	18	Research Work
	Total	**18**	

SEMESTER-IV

Course No.	Course Name	Credit	Course Type
MS-799	M. Tech. Dissertation	18	Research Work
	Total	**18**	

Total Credit of the Programme = 22+22+18+18 = 80

Annexure

List of Programme Electives Institute/Open Electives

Programme Elective - I

MS-711 Vacuum Science & Cryogenics
MS-712 Advanced Functional Oxide Materials
MS-713 Semiconductor Devices & Technology
MS-714 Recycling and utilization of industrial Waste
MS-715 Extractive Metallurgy

Programme Elective - II

MS-721 Polymer Science & Technology
MS-722 Electronics Ceramics
MS-723 Corrosion Science
MS-724 Green Chemistry
MS-725 Quantum Materials Technology

Programme Elective - III

MS-731 Magnetism & Superconductivity
MS-732 Nano-Structure & Technology
MS-733 Near- net Shape Processing
MS-734 Advanced Materials Processing

Institute Elective

MS- 701 Near- net Shape Processing
MS - 702 Material Characterization Techniques
MS- 703 Introduction to Materials Science and Engineering

Course Name: **Introduction to Materials Science and Engineering**
Course Code: **MS-611**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To impart knowledge about the crystal structures and bonding in the materials
- To introduce various types of materials
- To enable the students to understand the various properties of the different classes of materials

Course Content

Bonding in Crystals – Ionic bond, covalent bond, molecular bond, hydrogen bond, metallic bond & Van der Waals bond. Crystalline and Noncrystalline materials – Crystal structure, space lattice, unit cell, crystal systems, atomic packing factor, Co-ordination numbers, crystal structure for metallic elements, Crystal directions & Planes, millerindices, stacking sequence in HCP & FCC.Defects in Crystalline Materials: Point, line, surface and volume defects. Diffusion: Diffusion Mechanism, laws of diffusion- Fick's I law, II law, inter-diffusion and Kirkendall effect, Metals and Alloys: Solid solutions, solubility limit, phase rule, binary phase diagrams, intermediate phases, intermetallic compounds, iron-iron carbide phase diagram, recovery, recrystallization and grain growth. Ceramics: Structure and properties of ceramics. Polymers: Classification, polymerization, structure and properties. Different properties of materials: Mechanical properties: stress strain curves, elastic modulus, plastic deformation, slip, dislocation motion, critical resolved shear stress, strengthening mechanisms. Introduction to fatigue and creep properties of materials. Electronic Properties: Concept of energy band diagram for materials – conductors, semiconductors and insulators, electrical conductivity effect of temperature on conductivity, intrinsic and extrinsic semiconductors, dielectric properties. Magnetic Properties: Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, antiferromagnetism, ferromagnetism, ferrimagnetism, magnetic hysterisis.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe basic crystal structure and atomic bonding in the different class of materials

CO2: Identify the different class of materials

CO3: Assess the different properties of different classes of materials

Books and References

1. Fundamentals of Materials Science and Engineering by W D Callister Jr., John Wiley and Sons.
2. Essentials of Materials for Science and Engineering by Donald R. Askeland and Pradeep P. Phule, CL Engineering
3. The Science and Engineering of Materials by Donald R. Askeland, Chapman & Hall.
4. Materials Science and Engineering by V. Raghvan, Prentice Hall India Learning Private Limited.

Course Name: **Material Characterization Techniques**
Course Code: **MS-612**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide a thorough introduction to the principles and working of characterization techniques to study the various properties materials.
- To provide basic description of a range of common characterization methods for the determination of the structure and composition of solids

Course Content

Introduction to Materials: Scope and classification of engineering materials, Types, properties and applications of metals and alloys, Super alloy, Polymers, ceramics, Composites, Piezoelectric materials (PZT), Shape memory alloys (SMA) and Micro-electro-mechanical (MEMS) materials. Optical microscopy: Specimen preparation techniques, Elements of phase identification, Grain size determination, Inclusion analysis, Image analysis. X-ray Diffraction: Principle, Crystallography and Rietveld analysis, Quantitative and qualitative analysis, Residual stress analysis, Determination of layer thickness, Small angle X-ray scattering (SAXS), Atomic pair distribution function. Scanning Electron Microscopy: Theory and principles, construction, controls and operation of scanning electron microscopy, Electron gun parameters, Imaging parameters, Image contrast (topographic and atomic number contrasts), Environmental scanning electron microscopy, High resolution SEM imaging, EDS/EDAX analysis. Transmission Electron Microscopy: Theory and principles, construction and controls. Spectroscopy Techniques: UV-visible, FTIR , Raman and Photo- Luminescence techniques. Electron Micro Probe Analyzer: Theory and principles, Quantitative and qualitative analysis. AFM: Principle, Sample preparation and mounting, Scanning techniques, Image capturing, manipulation and analysis techniques. Thermal analysis: Principles and applications of thermal analysis, Dynamic mechanical analyzer. Mechanical Testing: Tensile, compressive, hardness, fatigues and fracture toughness

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Describe theory and practice of X-ray and electron diffraction
CO2: Identify basic elements of electron microscopy
CO3: Identify basic aspects of optical characterization methods
CO4: Understand stereographic projections and their use in characterization crystalline materials.

Books and References

1. Characterization of Materials by Elton N. Kaufman (Ed.), John Wiley and Sons.
2. Elements of X-Ray Diffraction by B.D. Cullity, Prentice Hall, New Delhi.
3. Friction and Wear of Ceramics by S. Jahanmir, CRC Press.

Course Name: **Thermodynamics of Materials** Course Code: **MS-613** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To present a comprehensive and rigourous treatment of thermodynamics of materials
- To impart knowledge about the materials/metallurgical aspects of solutions, phase diagrams and Ellinghamdiagrams
- To correlate electrochemical principles with thermodynamics
- To enable the students to understand the thermodynamics of surfaces and point defects

Course Content

Introduction and definition of terms - Thermodynamics systems, variables and processes, heterogeneous and homogeneous systems, extensive and intensive properties, simple equilibrium. Laws of Thermodynamics:The First law of thermodynamics - Conservation of Energy, Heat Capacity and definition of enthalpy, Reference and standard states, Enthalpy of physical transformations and chemical reactions. The second and third laws of thermodynamics - the second law and the definition of entropy, reversible and irreversible processes, conditions for equilibrium and the definition of Helmholtz and Gibbs energies, Maximum work and maximum non-expansion work, the variation of entropy with temperature, the statistical interpretation of entropy, the most probable microstate, configurational entropy and thermal entropy, the third law of entropy, Maxwell relations, properties of Gibbs energy Single component systems - One component systems, Clapeyron and Clausius-Clapeyron equations Solution thermodynamics - Ideal and regular solutions, Raoult's law, activity, Gibbs-Duhem equation, partial molar properties, partial excess properties. Phase diagrarms - Free energy-composition and phase diagrams of binary systems, phase diagrams withnon-ideal behaviour in the solid, freezing point depression, congruent and incongruent melting points Multi- component systems - Equilibrium in multi-component, multiphase systems, reactions involving gases, equilibriumconstant, extent of reaction and molar balance techniques. Reactions involving gases and solids - Ellingham diagrams, Effect of temperature on oxidation reactions, effect of phase transformations on oxidation reactions, stability of oxides, relative stability of oxides, oxygen potential and CO/CO_2 ratios, H_2/H_2O ratios and equilibrium constants in oxide, chloride, nitrate and sulphide system Systems containing components in condensed solution - Change of standard states, phase rule, common tangent construction, solubility of gases in metals. Electrochemistry:- Introduction to electrochemistry, the relationship of electromotive force to reversible work and free energy, the Nernst equation, half cell reactions, activities in aqueous solutions, standard states in aqueous cells, measurements of activities using cells and heat effects Thermodynamics of surfaces and interfaces - Surface tension, mechanical analogy of surface energy, approximate calculation of solid surface energy, effects of surface curvature, effect of surface curvature on vapour pressure and melting temperature thermodynamics of point defects

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Explain the basic concepts of thermodynamics like system, properties, equilibrium, extensive and intensiveproperties, etc.

CO2: State and explain the various laws of thermodynamics

CO3: Describe the various aspects of thermodynamics of solutions CO4:
Draw the free energy-composition diagrams of binary systems

CO4: Describe the thermodynamic aspects of electrochemistry

Books and References

1. Introduction to the Thermodynamics of Materials by D. R. Gaskell, Taylor & Francis, New York.
2. Thermodynamics of Solids by R. A. Swalin, John Wiley and Sons.
3. Chemical Thermodynamics of Materials by C. H. P. Lupis, Elsevier Science Publishing Co., New York.
4. Stoichiometry and Thermodynamics Computations in Metallurgical Processes by Y. K. Rao, Cambridge University Press.

Course Name: **Materials Science Lab 1**
Course Code: **MS-614**

Contact Hours/Week: **4P** Course Credits: **02**

Course Objectives

- Synthesize materials using sol-gel, precipitation sol-gel, redox/electrochemical, and hydrothermal methods and characterize their properties.
- Study optical properties of nanoparticles using UV-Visible spectroscopy.
- Process materials using ball milling and analyze particle size effects.
- Analyze crystallite size using XRD and Zeta-Sizer, and study chemical composition and vibrational modes using FTIR, Raman, and PL studies.

List of Experiments

1. To synthesize materials by solgel method and characterization of their properties.
2. To synthesize materials by precipitation solgel method and characterization of their properties.
3. To synthesize materials by redox/electrochemical method and characterization of their properties.
4. To synthesize different materials by Hydrothermal method and characterization of their properties.
5. Optical studies of prepared nanoparticles using UV-Visible spectroscopy
6. Processing of materials by ball milling
7. Calculate the crystallite size of particles using XRD technique
8. Calculate the crystallite size of particles using Zeta-Sizer
9. FTIR studies of prepared particles
10. Raman studies of prepared nanoparticles
11. PL studies of prepared nanoparticles
12. Morphological studies of nanoparticles by SEM analysis

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Demonstrate proficiency in synthesizing materials and characterizing their properties.
CO2: Apply UV-Visible spectroscopy for studying optical properties of nanoparticles.
CO3: Utilize ball milling for material processing and analyze particle size effects.

CO4: Interpret data from XRD, Zeta-Sizer, FTIR, Raman, PL, and SEM analyses to evaluate material properties and morphology.

Course Name: **Science and Technology of Thin Films** Course Code: **MS-621** Course Type: **Core**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To teach the theory of evaporation, sputtering, ablations and chemical vapour deposition.
- Nucleation and growth mechanisms.
- Various techniques of thin film depositions using Physical Vapour deposition and Chemical Vapour depositions.
- Role of substrate to grow the amorphous, oriented and epitaxial thin films.

Course Content

Physical Vapor Deposition - Hertz Knudsen equation; mass evaporation rate; Knudsen cell, Directional distribution of evaporating species Evaporation of elements, compounds, alloys, Raoult's law; e -beam, pulsed laser and ion beam evaporation, Glow Discharge and Plasma, Sputtering - mechanisms and yield, dc and rf sputtering, Bias sputtering, magnetically enhanced sputtering systems, reactive sputtering, Hybrid and Modified PVD- Ion plating, reactive evaporation, ion beam assisted deposition, Chemical Vapor Deposition - reaction chemistry and thermodynamics of CVD; Thermal CVD, laser & plasma enhanced CVD, Chemical Techniques - Spray Pyrolysis, Electrodeposition, Sol-Gel and LB Techniques, Nucleation & Growth: capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth, stages of film growth. & mechanisms, amorphous thin films, Epitaxy - homo, hetero and coherent epilayers, lattice misfit and imperfections, epitaxy of compound semiconductors, scope of devices and applications.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Students will learn the theory of PVD and CVD.

CO2: They will learn about the various techniques of depositions.

CO3: The growth mechanism and defects in thin films.

CO4: Epitaxial, oriented and amorphous thin film growth.

Books and References

1. The Materials Science of Thin Films by Milton Ohring, Academic Press Sanden.
2. Thin Film Phenomena by Kasturi L. Chopra, Mc Graw Hill, New York.
3. Thin Film Deposition; Principles and practices by Denald L. Smith, McGraw Hill.
4. Principles of Chemical Vapor Deposition by D. M. Dolokin, M.K. Zwrow, Kluwer Academic Publisher.
5. Chemical Vapor Deposition by Pradeep George, VDM Verles Dr. Mueller E.K.

Course Name: **Electrical and Electronic Properties of Materials** Course Code: **MS-622** Course Type: **Core**
Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To introduce the fundamentals of electrical and electronic materials, their properties and examples.
- To expose the properties and applications of functional materials in modern technology.
- To familiarize the students with various concepts related to electronic and magnetic properties and their exploitation to develop the useful materials based on the structure, chemistry and the processing techniques.

Course Content

Electrical properties of metals & alloys: Classical theories of conductivity, Quantum mechanical theory of conductivity, Experimental results & their interpretations: metals, alloys, ordering & phase stability, Superconductivity: theory & experiment. Electrical properties of semiconductors: Band structure, Intrinsic & Extrinsic semiconductors, Hall effect, Compound semiconductors, Electrical properties for device applications. Magnetic properties of materials: Basic concepts in magnetism, Classical theory of magnetic phenomena & their interpretations: Diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism, Quantum mechanical considerations of the magnetic phenomena, Applications: Soft magnetic materials, Hard magnetic materials, Magnetic recording & magnetic memories, Applications to novel materials: Ferromagnetic shape-memory alloys & Dilute magnetic semiconductors. Dielectric Properties: Claussius-Mossoti relation, dielectric dispersion and losses, piezo-, ferro- and pyroelectricity. Optical Properties: Reflection, Refraction, Transmission, Optical constants, Atomistic theory of optical properties, band transitions.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Learn the basics of materials used in present electrical and electronic industry.

CO2: Explain the behavior of conductivity of metals and classifications of semiconductor materials

CO3: Explain the importance of magnetic properties.

CO4: Realize the dielectric properties of insulators in static and alternating fields.

Books and References

1. Solid-State Physics: An Introduction to Principles of Materials Science by Harald Ibach and Hans, Springer.
2. Introduction to Solid State Physics by Charles Kittel, Wiley
3. The Solid State: An Introduction to the Physics of Crystals for Students of Physics, Materials Science, and Engineering by H. M. Rosenberg, Oxford Physics Series
4. Solid State Physics: An Introduction by Philip Hofmann, Wiley Science.

Course Name: **Phase Transformations in Materials**
Course Code: **MS-623**
Course Type: **Core**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To develop an understanding among students about why phase transformations occur in materials and microstructures using the concepts of material thermodynamics
- To impart knowledge about the various types of phase transformations that occur in materials
- To introduce the fundamental concepts of heat treatment of metals and alloys

Course Content

Thermodynamics order of transformations, Theory of nucleation-Kinetics of homogeneous, transient and heterogeneous nucleation, Theory of thermally activated growth, Interface controlled growth, Diffusion controlled growth, Interface instability and Widmanstatten growth, Eutectoid growth, Discontinuous precipitation, Massive transformation, Transformation Kinetics- Johnson-Mehl equation, Avrami model, Transformation kinetics in diffusion-controlled transformations, Isothermal and continuous cooling transformation diagrams, Precipitation and particle coarsening, Kinetics of recrystallization, Theory of grain growth, Effect of second phase particles, Martiensitic transformations- nature of martensitic transformations, Bain distortion, Nucleation and growth of martensite, Athermal, isothermal and burst transformations. Thermoelestic transformations, Spinodal Decomposition- diffusion equation in spinodal region, Effect of gradient energy and elastic strain energy, Solidification- Nature and growth of solid-liquid interfaces, Rapid solidification, Glass transition, metallic glasses. Heat treatment – IT and ICT diagrams in steels, quench hardening and tempering of martensity, hardenablity of steels, surface hardening processes, tool steels and their heat treatments, heat treatment of cast irons, heattreatment of Ni-base superalloys and Ti alloys, Thermo-mechanical treatments. Metallic glasses – Thermodynamics and kinetics.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Classify the various of types of phase transformations and explain the reasons behind such transformations

CO2: Describe diffusional transformations in solids such as precipitation hardening, spinodal transformation, cellular precipitation etc.

CO3: Discuss martensitic transformations

CO4: Draw TTT and ICT diagrams and discuss their utility

CO5: Explain the principles of heat treatment of metals and alloys

Books and References

1. Phase transformation in metals and alloys by D. A. Porter and K. E. Easterling, Chapman and Hall.
2. Theory of Transformations in Metals and Alloys by J. W. Christian, Pergamon Press.
3. Phase Transformations in Materials by P. Haasen (Ed.), VCH Publications, New York.
4. Theory of Structural Transformations in Solids by G. Khachaturyan, Wiley Interscience.

Course Name: **Materials Science Lab 2** Course Code: **MS-624**	
Contact Hours/Week: **4P**	Course Credits: **02**

Course Objectives

- Provide practical skills in metallography sample preparation and optical microscopy.
- Understand and apply heat treatment processes for various carbon steels.
- Analyze the effects of plastic deformation on metals like aluminum and copper.
- Gain hands-on experience in corrosion testing, tensile testing, hardness testing, and impact testing.

List of Experiments

1. Sample preparation for metallography (Cutting, grinding, polishing and etching)
2. Optical microscopy; imaging and analysis
3. Heat treatment; annealing, normalizing, quenching, tempering of low carbon steel.
4. Heat treatment; annealing, normalizing, quenching, tempering of medium carbon steel.
5. Heat treatment; annealing, normalizing, quenching, tempering of high carbon steel.
6. Plastic deformation of aluminum and copper by rolling and its effect on microstructure and mechanical properties.
7. Corrosion testing of different materials
8. Tensile Testing of materials
9. Hardness testing of materials (Rockwell, Vicker hardness)
10. Impact testing (Izod/Charpy Test)

Note: *The concerned Course Coordinator will prepare the actual list of experiments/problems at the start of semester based on above generic list.*

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Demonstrate proficiency in metallography techniques and optical microscopy.
CO2: Apply and analyze heat treatment processes on different types of carbon steels.
CO3: Evaluate the effects of plastic deformation on the microstructure and properties of metals.
CO4: Perform and interpret corrosion, tensile, hardness, and impact tests to assess material properties.

Course Name**: Vacuum Science & Cryogenics** Course Code**: MS-711** Course Type**: Programme Elective-I**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To teach the behavior of gases
- To teach various techniques to create vacuum in chamber and its measurements.
- Measurements of leak using leak detectors and their principles.
- Concept of low temperature, liquefactions of gases and cryogenic thermometery.
- Design of vacuum system and Design of Low temperature systems.

Course Content

Behavior of Gases; Gas Transport Phenomenon, Viscous, molecular and transition flow regimes, Measurement of Pressure, Residual Gas Analyses; Production of Vacuum - Mechanical pumps, Diffusion pump, Getter and Ion pumps, Cryopumps, Materials in Vacuum; High Vacuum, and Ultra High Vacuum Systems; Leak Detection. Properties of engineering materials at low temperatures; Cryogenic Fluids - Hydrogen, Helium 3, Helium 4, Superfluidity, Experimental Methods at Low Temperature: Closed Cycle Refrigerators, Single and Double Cycle He3 refrigerator, He4 refrigerator, He3-He4 dilution refrigerator, Pomeranchuk Cooling, Pulsed Refrigerator System, Magnetic Refrigerators, Thermoelectric coolers; Cryostat Design: Cryogenic level sensors, Handling of cryogenic liquids, Cryogenic thermometry.

Course Outcomes:

Upon successful completion of the course, the students will be able to

CO1: Students will learn about the behavior gasses.

CO2: The concept of low, high and ultra high vacuum and its measurements.

CO3: The concept of Low temperature, liquifications of the gases to create low temperature in different temperature ranges.

CO4: Learn about the design of low temperature systems.

Books and References

1. Vaccum science and technology by Paul A Redhead, American Institute of Physics.
2. Handbook of Vacuum Science and Technology by Dorothy Hoffman, Academic Press
3. Foundations of Vacuum Science and Technology by James M. Lafferty, Wiley-Interscience

Course Name**: Advanced Functional Oxide Materials**
Course Code**: MS-712**
Course Type**: Programme Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To teach the concept of superconductivity and its theory. High Tc superconductors and their applications.
- To teach the concept of dielectric and ferroelectric phenomenon and materials. Their applications.
- Magnetism and magnetic materials and their applications.
- Concept of GMR and CMR materials and their applications in sensors and memory devices.
- Concept of spintronic materials and their applications in electronics and memory devices.
- Coupling of various ferroic materials and their applications.

Course Content

Superconductivity and its basic properties, flux dynamics, high-Tc superconductors and their applications. Ferroelectric and dielectric materials. Their fundamental properties. Types of ferroelectric materials and their applications. Theory of magnetism (diamagnetic, paramagnetic, ferromagnetic, antiferromagnetic and ferrimagnetic materials). Their applications. Magneto-resistance, gaint magneto resistance (GMR) and colossal magneto resistance (CMR) materials. Double exchange and John Tellor distortion mechanism to explain the concept of CMR materials. The applications of CMR materials. Spintronics; the basic theory, spin polarization, dilute magnetic semiconductors (DMS). Materials engineering of spintronics and their applications. Multi-ferroic materials and their applications.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Learn about the applications of High-Tc superconductors.
CO2: Applications of ferroelectric materials.
CO3: Applications of GMR, CMR and spintronics materials.

Books and References

1. Magnetism and Magnetic Materials by J. P. Jakubovics, Institute of Materials, London.
2. High Temperature Superconductivity by J. W. Lynn, Springer- Verlag.
3. Characterization of nanophase materials by Z.L Wang, Wiley- VCH.
4. The Science and Engineering of Microelectronics Fabrication by S. Compbell, Oxford.

Course Name: **Semiconductor Devices and Technology** Course Code: **MS-713** Course Type: **Programme Elective-I**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- Students will be familiar with crystal growth along with some compression of material on the device physics.
- To develop an understanding among students about selected topics within fabrication technology for semiconductor devices.
- To impart the knowledge about various steps/technologies used in the fabrication of IC.

Course Content

Silicon wafer fabrication and oxidation techniques, Growth kinetics, Oxide growth measurements techniques, Defects in silicon, silicon dioxide, Interface defects, Point defect based model for oxidation, Polysilicon, Si3N4 and Silicide formation. UV, Electron, plasma and x-ray lithography techniques, Wet etching and plasma etching techniques. Diffusion and ion implantation, Diffusion in polycrystalline materials, Ion implantation techniques, Modeling and measurement of dopant profiles, Overview of process flow for IC technology.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Familiar with the state-of-the-art semiconductor materials and the basic semiconductor devices and circuit applications.

CO2: The student will have an understanding of semiconductor physics, bipolar devices and unipolar devices, and related device operations.

CO3: Understand the importance of doping to change carrier density

CO4: Understand the band diagram and depletion layer in PN junctions

CO5: Understand the fundamental operation of a bipolar transistor.

Books and References

1. Semiconductor Devices: Physics and Technology by Simon M. Sze, John Wiley and Sons.
2. The Science and Engineering of Microelectronics Fabrication by S. Campbell, Oxford.
3. Principle of Microelectronics Technology by D. Nag Chaudary, Wheeler Publishing.

Course Name: **Recycling and utilization of industrial Waste**
Course Code: **MS-714**
Course Type: **Programme Elective-I**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide an understanding of the types and sources of industrial waste.
- To examine the environmental and economic impacts of industrial waste.
- To explore various methods and technologies for recycling and utilizing industrial waste.
- To develop skills in designing and implementing waste management systems for industries.

Course Content

Introduction to Industrial Waste: Definition and types of industrial waste, Sources of industrial waste, Characterization of industrial waste, Environmental impact of industrial waste. Waste Management Principles: Waste hierarchy: Reduce, Reuse, Recycle, Recover, and Dispose, Waste management strategies, Life cycle assessment of industrial waste, Economic aspects of waste management Technologies for Waste Recycling: Physical recycling methods (e.g., sorting, shredding, crushing), Chemical recycling methods (e.g., pyrolysis, gasification, chemical treatment), Biological recycling methods (e.g., composting, anaerobic digestion), Case studies of successful recycling technologies. Utilization of Industrial Waste: Industrial symbiosis and by-product exchange, Utilization of waste in construction materials, Energy recovery from waste (waste-to-energy technologies), Case studies of waste utilization in various industries. Regulatory and Policy Framework: National and international regulations on industrial waste management, Policies promoting recycling and utilization of waste, Extended producer responsibility (EPR), Compliance and enforcement mechanisms. Designing Waste Management Systems: Integrated waste management systems, Designing for waste minimization and recycling, Waste audit and material flow analysis, Case studies on industrial waste management systems. Advanced Topics and Innovations: Emerging technologies in waste recycling and utilization, Circular economy principles in industrial waste management, Digital solutions and Industry 4.0 in waste, management, Research trends and future directions.

Course Outcomes:

By the end of this course, students will be able to:

CO1: Identify and classify different types of industrial waste.
CO2: Assess the environmental and economic impacts of industrial waste.
CO3: Apply principles and techniques of recycling and waste utilization.
CO4: Design effective waste management systems for various industries.
CO5: Develop innovative solutions for minimizing waste and maximizing resource recovery.

Books and References

1. Waste Management: Principles and Practice by Rajkumar Joshi and Rajesh Kumar, I.K. International Publishing House Pvt. Ltd.
2. Waste Management and Resource Recovery by Dr. B. B. Dhar and D. N. Thakur, Scientific Publishers
3. Industrial Waste Treatment Handbook, Frank Woodard, Butterworth-Heinemann
4. Solid Waste Technology and Management by Thomas Christensen (Editor), Wiley-Blackwell

Course Name: **Extractive Metallurgy**
Course Code: **MS-715**
Course Type: **Programme Elective-I**

Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To provide an in-depth understanding of the principles and techniques involved in the extraction of metals from their ores.
- Familiarize students with the various processes used in pyrometallurgy, hydrometallurgy, and electrometallurgy.
- Enable students to apply thermodynamic and kinetic principles to the extraction and refining of metals.
- To develop the ability to analyze and solve complex problems in extractive metallurgy.
- To understand the environmental and economic aspects of metal extraction processes.

Course Content

Introduction to Extractive Metallurgy: Overview of extractive metallurgy, Classification of metallurgical processes, Historical development and significance of metal extraction. Mineral Processing: Comminution: crushing and grinding, Screening and classification, Gravity concentration, magnetic and electrostatic separation, Froth flotation: principles and applications. Pyrometallurgy: Principles of pyrometallurgy, Calcination, roasting, and smelting, Matte smelting and converting, Refining: fire and electrolytic methods, Case studies: Iron, copper, and lead extraction. Hydrometallurgy: Principles of hydrometallurgy, Leaching: types and mechanisms, Solution purification and concentration, Metal recovery: precipitation, cementation, solvent extraction, ion exchange, and electro-winning, Case studies: Gold, zinc, and uranium extraction. Electrometallurgy: Fundamentals of electrochemistry, Electrolytic refining and electro-winning, Cell design and operation, Case studies: Aluminum and copper electro-winning. Thermodynamics and Kinetics in Metallurgy: Thermodynamic principles: Gibbs free energy, Ellingham diagrams, Kinetic principles: reaction rates, diffusion, and mass transfer, Applications to metallurgical processes. Environmental Aspects of Extractive Metallurgy: Environmental impact of mining and metal extraction, Waste management and recycling in metallurgy, Pollution control and mitigation measures, Sustainability in extractive metallurgy. Advances Extractive Metallurgy: Emerging technologies in metal extraction, Biohydrometallurgy and biotechnology applications, Nanotechnology in metallurgy, Metal extraction from secondary sources (urban mining).

Course Outcomes:

By the end of this course, students will be able to:

CO1: Gain comprehensive knowledge of the fundamental principles and techniques of extractive metallurgy.
CO2: Demonstrate proficiency in applying thermodynamic and kinetic principles to metallurgical processes.
CO3: Analyze and design extraction processes for various metals.
CO4: Understand and address the environmental impacts of metallurgical operations.
CO5: Develop problem-solving skills specific to extractive metallurgy and implement sustainable practices.

Books and References

1. Principles of Extractive Metallurgy" by Fathi Habashi, CRC Press.
2. Extractive Metallurgy of Non-Ferrous Metals" by H.S. Ray, R. Sridhar, and K.P. Abraham, Affiliated East-West Press.
3. Principles of Extractive Metallurgy" by Terkel Rosenqvist and H.S. Ray, New Age International Publishers.
4. Hydrometallurgy: Principles and Applications" by T.R. Mankhand, Prentice Hall.

Course Name: **Polymer Science & Technology**
Course Code: **MS-721**
Course Type: **Programme Elective-II**

Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To understand various types of polymers; Natural and Synthetic
- To understand the polymer synthesis; Different polymerization techniques.
- To understand the processing of polymer to get the different products; Compounding and mixing
- To understand the different behavior of polymers; Thermal, Optical, Mechanical and Chemical
- To understand the properties of different special kind of polymers; conducting, magnetic, biodegradable etc.
- To understand the different problems associated with polymer such as Degradation fire hazards, toxicity etc.

Course Content

Basic Materials Science; Basic concepts; polymer raw materials; polymerization principles and processes (step, chain and other polymerizations, polymer kinetics, polymerization techniques).Polymer manufacture (unit operations, polymer reactors, polymer isolation, handling and storage); polymer structure and property; polymer characterization; polymer modification, multicomponent polymeric materials (polymer miscibility, polymer blends and alloys, filled plastics, polymer composites).Polymer compounding and fabrication (polymer additives, compounding processes, fabrication techniques, post fabrication operations); polymer testing (sample preparation, testing standards and methods, analysis of polymer and additives) ; polymer product design; Polymer applications; frontiers of polymer materials (biogradable polymers, biomedicalpolymers, conducting polymers, magnetic polymers, polymers for space, nonlinear optical polymers);
problems of polymer (thermoxidative degradation, fire hazards, toxicity, effluent disposal, feedstock scarcity).

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: List some synthetic and natural polymers with their characteristics

CO2: Have knowledge about the synthesis of polymeric material; Different Polymerization Techniques

CO3: Have knowledge about the polymer processing; Extrusion, Compression, molding, Calendaring etc.

CO4: Have knowledge about the polymer testings; Mechanical, Thermal, Tribological

CO5: Have knowledge about the Frontiers of polymer materials; Biodegradable, Conducting and Magnetic Polymers

Books and References

1. Fundamentals of Polymer Engineering by Arie Ram, Springer.
2. Polymer Science by V.R. Gowariker, N.V. Viswanathan and J. Sreedhar, Wiley-Eastern.

Course Name: **Electronic Ceramics**	
Course Code: **MS-722**	
Course Type: **Programme Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To provide students with a basic understanding of electronic ceramic materials
- To demonstrate structure-property relationships in electronic ceramics
- To provide students and appreciation of recent developments in electronic ceramic industry

Course Content

Review of Bonding Characteristics of Ceramics: Madelung Constant, Born-Haber Cycle, Non-Bonding Electron Effects, Crystal Field Effect, Jahn-Teller Distortion; Crystal Structure of Ceramics: Pauling Rules, Silicate Structure, Structure of Covalent Ceramics, Structure of Glasses, Zachariasen's Rules; Phase Diagrams, Phase Stability and Phase Transformations in Ceramics; Defects in Ceramics and Defect Chemistry; Diffusion, Electrical and Electronic Transport in Ceramics; Sintering and Grain Growth; Dielectric Properties; Magnetic and Nonlinear Dielectric Properties; Optical Properties; Preparation Methods (Bulk and Thin Films); Applications of Electronic Ceramics in Various Devices: Sensors for Gases, Temperature, Pressure and Voltage; Optical Communications; Magnetic and Oxide Electronics; Electric Power and Energy Storage Devices.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Apply the principles of physical sciences and engineering to electronic ceramic systems

CO2: Describe crystal structures of a wide range of electronic ceramic materials

CO3: Explain the defect chemistry of ceramics

CO4: Discuss electric, dielectric, magnetic and optical properties of ceramics

CO5: Relate important developments in the past with the future needs of the electronic ceramic industry

Books and References

1. Ceramic Science and Technology by W. D. Kingery, H. K. Bowen and D. R. Uhlman, John Wiley and Sons, Singapore
2. Ceramic Materials for Electronics by R. C. Buchanan, Marcel Dekker.
3. Ceramic Fabrication Processes by F. F. Y. Wang, Academic Press.
4. Principles of Electronic Ceramics by L. L. Hench and J. K. West, John Wiley and Sons, New York.
5. Better Ceramics through Chemistry by C. J. Brinker, D. E. Clark and D. R. Ulrich, North Holland.

Course Name: **Green chemistry**
Course Code: **MS-723**
Course Type: **Programme Elective-II**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- The primary goal of this course is to make students aware of how chemical processes can be designed, developed and run in a sustainable way.
- Students acquire the competence to think of chemistry as a sustainable activity.

Course Content

Introduction: Definition, the twelve basic principles of green chemistry. Green synthetic methods: Microwave synthesis, electro-organic synthesis, The design and development of environmentally friendly chemical pathways: challenges and opportunities. High-yield and zero-waste chemical processes. Representative processes. Materials for green chemistry and technology: Catalysis, environmental friendly catalysts, Bio-catalysis, biodegradable polymers, alternative solvents, ionic liquids Bio-energy: Thermo-chemical conversion: direct combustion, gasification, pyrolysis and liquefaction; Biochemical conversion: anaerobic digestion, alcohol production from biomass; Chemical conversion process: hydrolysis and hydrogenation; Biophotolysis: Hydrogen generation from algae biological pathways; Storage and transportation;
Applications.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Students learn the basic principles of green and sustainable chemistry.
CO2: They must be able to do and understand stoichiometric calculations and relate them to green process metrics.
CO3: They learn alternative solvent media and energy sources for chemical processes.
CO4: They learn about renewable feedstocks for the chemical industry, present and under development.
CO5: An understanding of several real world examples where organizations used green chemistry to improve the sustainability performance of their products.
CO6: An appreciation of how the practice of green chemistry enhances competitiveness, innovation and faster time to market.

Books and References

1. Green Reaction Media in Organic Synthesis by Mikami Koichi, Wiley-Blackwell
2. Solvent-free Organic Synthesis Green chemistry by Koichi Tanaka, Wiley-VCH
3. Methods and Reagents for Green Chemistry: An Introduction by Alvise Perosa, Fulvio Zecchini, and Pietro Tundo Wiley Interscience.
4. Green Chemistry by M. Lancaster, RSC.
5. Green Chemistry and the Ten Commandments of Sustainability by Stanley E. Manahan, ChemChar.

Course Name: **Corrosion Science** Course Code: **MS-724** Course Type: **Programme Elective-II**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To understand the fundamental principles and mechanisms of corrosion.
- To identify and analyze different forms of corrosion and their causes.
- To explore methods and techniques for corrosion prevention and control.
- To comprehend the impact of corrosion on materials and structures in various industries.
- To develop skills in designing and implementing corrosion management systems.

Course Content

Introduction to Corrosion: Definition and importance of corrosion, Historical perspective, Economic impact of corrosion, Basic principles and terminology. Electrochemical Principles of Corrosion: Electrochemical cells and reactions, Thermodynamics of corrosion, Kinetics of corrosion processes. Types of Corrosion: Uniform corrosion, Galvanic corrosion, Crevice corrosion, Pitting corrosion, Intergranular corrosion, Stress corrosion cracking, Erosion corrosion, Hydrogen damage. Corrosion Testing and Monitoring: Laboratory corrosion testing methods, Electrochemical techniques, Non-destructive testing (NDT) methods, Corrosion monitoring techniques. Corrosion Prevention and Control: Material selection and design considerations, Protective coatings and linings, Cathodic protection, Anodic protection, Corrosion inhibitors, Environmental control. Corrosion in Specific Environments: Atmospheric corrosion, Soil corrosion, Corrosion in water and seawater, High-temperature corrosion, Microbiologically influenced corrosion (MIC). Corrosion in Industries: Oil and gas industry, Chemical processing industry, Power generation industry, Marine and offshore industry, Automotive and aerospace industry. Advances and Innovations: Corrosion in advanced materials (e.g., composites, nanomaterials), Smart coatings and self-healing materials, Corrosion modeling and simulation, Research trends and future directions

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Explain the fundamental principles and mechanisms of corrosion.
CO2: Identify and classify different types of corrosion.
CO3: Assess the impact of corrosion on materials and structures.
CO4: Apply techniques for corrosion prevention and control.

Books and References

1. Corrosion Engineering: Principles and Practice by Pierre R. Roberge, McGraw-Hill Education.
2. Corrosion Science and Technology by David E.J. Talbot and James D.R. Talbot, CRC Press.
3. Corrosion Engineering by Mars G. Fontana, McGraw-Hill Education.
4. Corrosion Science and Engineering by K. R. Trehan, New Age International Publishers.

Course Name: **Quantum Materials Technology** Course Code: **MS-725** Course Type: **Programme Elective-II**

Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To provide an in-depth understanding of the principles and properties of quantum materials.
- To familiarize students with the synthesis, characterization, and applications of various quantum materials.
- To enable students to analyze the electronic, magnetic, and optical properties of quantum materials.
- To develop skills in designing and utilizing quantum materials for advanced technological applications.
- To cultivate the ability to conduct research and contribute to advancements in quantum materials technology.

Course Content

Introduction to Quantum Materials: Overview of quantum materials, Historical development and significance, Applications in various fields. Fundamental Principles of Quantum Materials: Quantum mechanics basics relevant to quantum materials, Band theory of solids, Electron correlation and quantum entanglement in materials, Topological phases of matter. Synthesis of Quantum Materials: Chemical vapor deposition (CVD), Molecular beam epitaxy (MBE), Sol-gel synthesis, Hydrothermal synthesis, Other advanced synthesis techniques. Electronic Properties of Quantum Materials: Quantum Hall effect, Quantum spin Hall effect, Dirac and Weyl semimetals, Superconductivity in quantum materials, Electronic band structure analysis Magnetic Properties of Quantum Materials: Magnetic ordering and spintronics, Quantum magnets and spin liquids, Skyrmions and magnetic domain walls, Magnetic resonance techniques. Optical Properties of Quantum Materials: Photonic crystals and metamaterials, Plasmonics and excitonics, Quantum dots and quantum wells, Nonlinear optical properties. Topological Quantum Materials: Topological insulators, Topological superconductors, Majorana fermions, Experimental realizations and applications, Two-Dimensional Quantum Materials: Graphene and its derivatives, Transition metal dichalcogenides (TMDs), Layered van der Waals heterostructures, Electronic and optical properties of 2D materials. Quantum Materials for Energy Applications: Quantum materials in photovoltaics, Thermoelectric materials, Energy storage applications (batteries and supercapacitors), Catalysis and photocatalysis. Advances in Quantum Materials: Quantum phase transitions, Quantum simulations and computations with materials, Hybrid quantum materials systems, Future trends and emerging materials.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Gain comprehensive knowledge of the fundamental principles and properties of quantum materials.
CO2: Demonstrate proficiency in the synthesis and characterization techniques of quantum materials.
CO3: Analyze and interpret the electronic, magnetic, and optical properties of quantum materials.
CO4: Understand and design quantum materials for specific technological applications.
CO5: Develop research skills and contribute to advancements in the field of quantum materials technology.

Books and References

1. Quantum Mechanics and Materials Science" by A.K. Rai, I.K. International Publishing house.
2. Quantum Mechanics: Theory and Applications" by Ajoy Ghatak and S. Lokanathan, Springer.
3. Quantum Dot: Properties and Applications" by Madhuri Sharon and Maheshwar Sharon, Springer.
4. Quantum Chemistry: A Unified Approach" by R.K. Prasad, New Age International Publishers.

Course Name: **Magnetism and Superconductivity**	
Course Code: **MS-731**	
Course Type: **Programme Elective-III**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- Students will be introduced to magnetism and superconductivity that are collective phenomena which cannot be described by a one-electron model.
- Standard models for the description of magnetism and superconductivity will be taught.
- The developments in magnetism research and magnetic materials associated with spin-based electronics or "spintronics" will be presented.

Course Content

Demagnetisation factor, Antiferromagnetism, Neutron diffraction, Magnetism in Rare Earths and Antiferromagnetic Alloys, Helimagnetism, Ferrimagnetism, Spin Glasses, Magnetotstriction, Domains and magnetization process, Single Domain Particles, Coercivity in fine particles, Superparamagnetism, Spintronics, Magnetoresistance, ApplicationsType -I Superconductivity, London theory, Specific Heat and Thermal Conductivity, Intermediate State, Measurements of Critical currents and Magnetic Properties, Critical State Models, Ginzberg-Landau and BCS Theory, Josephson effects, SQUIDs, Type-II Superconductivity; Pinning of Vortices, High Temperature Superconductors, Flux Flow, Flux Creep, Fluctuation effects, Levitation and Electrical Power Applications of HTSC.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Students will acquire knowledge about the physics of magnets and superconductors and an appreciation of the physics due to correlated electrons.

CO2: The lectures might appear useful for engineers and researchers in material sciences who wish to advance their knowledge in phenomenon of superconductivity and its applications.

CO3: Students will acquire the knowledge about the magnetic phenomenon which are occurring at nano level.

Books and References

1. Introduction to Magnetic Materials by B. D. Cullity, Addison-Wesley Publications, California, London
2. Magnetism and Magnetic Materials by J. P. Jakubovics, Institute of Materials, London.te
3. Introduction to Magnetism and Magnetic Materials by D. Jiles, Chapman & Hall.
4. Introduction to Superconductivity by C. Rose-Innes and E. H. Rhoderick, Pergamon Press Oxford
5. Superconductivity by P. Pool, Jr., H. A. Farach and R. J. Creswick, Academic Press.
6. High Temperature Superconductivity by J. W. Lynn, Springer-Verlag.

Course Name: **Nano-Structure & Technology**
Course Code: **MS-732**
Course Type: **Programme Elective-III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives:

- To understand the concept of Nanotechnology
- To inspire from the natural nanotechnology around us
- Application of natural nanotechnology concept to fabricate the artificial nanomaterial
- To study the different types of nanomaterials and their fabrication methods
- Different characterization techniques to confirm the size and properties of synthesized nanomaterials
- Knowledge of some advanced carbon based nanomaterials

Course Content

Introduction to Nanomaterials: Amorphous, Crystalline, microcrystalline, quasicrystalline and nanocrystalline materials- historical development of nanomaterials – Nanomaterials classification (Gleiter‟s Classification), Bottom up and Top Down approach, Properties of Nanomaterials, Quantum Confinement, Density of State, Zero dimension, onedimension and two dimensional nanostructures. Physical Methods: Inert gas condensation, Arc discharge, RF-plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapor deposition method and other variants, Electrodeposition. Chemical Methods: Metal nanocrystals by reduction, Solvothermal synthesis, Photochemical synthesis, Electrochemical synthesis,Nanocrystals of semiconductors and other materials by arrested precipitation, Thermolysis routes, Sonochemical routes, , Liquidliquid interface, Hybrid methods, Solvated metal atom dispersion, Post-synthetic size selective processing. Sol-gel, Micelles and microemulsions, Cluster compounds. Lithographic Techniques: AFM based nanolithography and nanomanipulation, E beam lithography, Ionbeam lithography, oxidation and metallization. Mask and its application.Deep UV lithography, X-ray based lithography. Groups of Carbon: Fullerenes, Carbon Nanotubes, Types of Carbon Nanotubes, Functionalization of Carbon nanotubes, Properties and Synthesis of Carbon nanotubes. Thin Films: Electro plating, Electroless plating, Langmuir-Blodget films, Thermal growth, Chemical vapour deposition, sputtering deposition, molecular beam epitaxy atomistic nucleation process, cluster coalescence and deposition, grain structure of films and coatings, amorphous thin films.

Course Outcomes

By the end of the lesson, students will be able to:

CO1: Know the concept , history and future of nanotechnology

CO2: To have idea about the nanomaterial, their fabrication technique and various characterizations.

CO3: To understand the interdisciplinary application of nanomaterials.

Books and References

1. Nanostructured materials, Processing, Properties and Potential Applications by Carl C. Koch, NoyesPublications, Norwich, New York, U.S.A.
2. Springer Handbook of Nanotechnology by Bhusan, Bharat
3. Nano Technology by Mark Ratner and Daniel Ratner, Pearson Education, New Delhi.
4. Introduction to Nanotechnology by Charles P. Poole Jr., Frank J. Ownes, Wiley Interscience.

Course Name: **Near- net Shape Processing**
Course Code: **MS-733**
Course Type: **Programme Elective - III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- This course is intended to impart knowledge about processing methodology of materials into specific shape of the component.
- The course also provides a valuable insight into manufacturing processes

Course Content

Introduction: Major benefits of near-net shape processing: Fundamentals of manufacturing of performs with citations from steel technology. Castings methodology Rheo-casting, thixo-casting and squeeze-casting processes. rheological behavior and microstructural evolution during semi-solid processing, component shape control. Powder Metallurgy techniques Special consolidation processes, hot pressing and hot isostatic pressing, mechanisms of sintering. Injection molding and liquid infiltration processes. Spray forming Gas-melt interaction during melt atomization, droplet dynamics and their non-equilibrium solidification processes. Control of component shape by substrate maneuvering. Industrial applications of spray formed components. Sheet metal forming processes A brief review of high precision forming, superplastic forming, shaping induced materials properties. Isoforming, ausforming, hot stamping and hydroforming processes.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the concepts of near net shape processing

CO2: Identify the different routes of near net shape processing

CO3: Understand the advantages of near net shape processing

TEXTBOOKS:

1. M.C. Flemings, Solidification Processing, McGraw-Hills, NY
2. Y. Wu and E.J. Laverina, Spray Atomization and Deposition, John Wiley and Sons, NY
3. V.S. Arunnachalam and O.V. Raman (eds.): Powder Metallurgy; Recent Advances; Oxford and IBM Publis.

REFERENCE BOOKS

1. Thermo-mechanical simulation and processing of steels, Viva Books Private Ltd, Delhi
2. Powder Metallurgy: Science, Technology andApplication by Angelo and Subramanian, PHI Publishers, New Delhi.

Course Name: **Advanced Materials Processing**
Course Code: **MS-734**
Course Type: **Programme Elective - III**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide a comprehensive understanding of advanced materials processing techniques.
- To explore the principles and mechanisms underlying various processing methods.
- To examine the influence of processing on the microstructure and properties of materials.
- To develop the ability to select appropriate processing methods for different materials and applications..

Course Content

Introduction to Advanced Materials Processing: Overview of materials processing, Importance of advanced materials processing in modern engineering, Classification of processing techniques. Solidification Processing, Principles of solidification. Casting processes (sand casting, investment casting, die casting), Rapid solidification and its effects on microstructure, Additive manufacturing (3D printing) .Deformation Processing: Fundamentals of plastic deformation, Forging, rolling, extrusion, and drawing processes, High-energy rate forming, Superplastic forming. Powder Metallurgy, Powder production methods, Powder compaction and sintering, Hot isostatic pressing, Applications of powder metallurgy. Advanced Welding and Joining Techniques: Fundamentals of welding, Advanced welding techniques (laser welding, electron beam welding, friction stir welding), Diffusion bonding, Brazing and soldering. Surface Engineering: Surface modification techniques (thermal spraying, chemical vapor deposition, physical vapor deposition), Laser surface processing, Electrochemical techniques (anodizing, electroplating), Surface characterization methods Composite Materials Processing: Fabrication of polymer-matrix composites, Metal-matrix composites processing, Ceramic-matrix composites processing, Characterization of composites Advances and Innovations: Recent advancements in materials processing, Green and sustainable processing techniques, Microstructural characterization techniques, Mechanical testing of processed materials, Analysis of processing-structure-property relationships.

Course Outcomes

By the end of this course, students will be able to:

CO1: Describe various advanced materials processing techniques and their principles.
CO2: Analyze the effects of processing parameters on the microstructure and properties of materials.
CO3: Select suitable processing methods for specific materials and applications.
CO4: Apply knowledge of materials processing to solve engineering problems.
CO5: Evaluate current research and advancements in materials processing.

TEXTBOOKS:

1. M.C. Flemings, Solidification Processing, McGraw-Hills, NY
2. Welding Technology, O. P. Khanna, Dhanpat Rai Publications
3. Manufacturing Technology: Foundry, Forming and Welding, P. N. Rao, McGraw-Hill Education

REFERENCE BOOKS

1. Elements of Manufacturing Processes, B. S. Nagendra Parashar and R. K. Mittal, PHI Learning Pvt. Ltd.
2. Powder Metallurgy: Science, Technology andApplication by Angelo and Subramanian, PHI Publishers, New Delhi.

Course Name: **Material Characterization Techniques**
Course Code: **MS-701**
Course Type: **Institute Elective**

Contact Hours/Week: **4L** Course Credits: **04**

Course Objectives

- To provide a thorough introduction to the principles and working of characterization techniques to study the various properties materials.
- To provide basic description of a range of common characterization methods for the determination of the structure and composition of solids

Course Content

Introduction to Materials: Scope and classification of engineering materials, Types, properties and applications of metals and alloys, Super alloy, Polymers, ceramics, Composites, Piezoelectric materials (PZT), Shape memory alloys (SMA) and Micro-electro-mechanical (MEMS) materials. Spectroscopy Techniques: Optical microscopy: Specimen preparation techniques, Elements of phase identification, Grain size determination, Inclusion analysis, Image analysis. UV-visible, FTIR , Raman and Photo- Luminescence techniques. Scanning Electron Microscopy: Theory and principles, construction, controls and operation of scanning electron microscopy, Electron gun parameters, Imaging parameters, Image contrast (topographic and atomic number contrasts), Environmental scanning electron microscopy, High resolution SEM imaging, EDS/EDAX analysis. Transmission Electron Microscopy: Theory and principles, construction and controls. Electron Micro Probe Analyzer: Theory and principles, Quantitative and qualitative analysis. XRD: Principle, Crystallography and Rietveld analysis, Quantitative and qualitative analysis, Residual stress analysis, Determination of layer thickness, Small angle X-ray scattering (SAXS), Atomic pair distribution function. AFM: Principle, Sample preparation and mounting, Scanning techniques, Image capturing, manipulation and analysis techniques. Thermal analysis: Principles and applications of thermal analysis, Dynamic mechanical analyzer. Mechanical Property Characterization Electron Microscopy: Principles and characterization techniques related to tensile, compressive, hardness, fatigues and fracture toughness properties.

Course Outcomes

Upon successful completion of the course, the students will be able to
CO1: Describe theory and practice of X-ray and electron diffraction
CO2: Identify basic elements of electron microscopy
CO3: Identify basic aspects of optical characterization methods
CO4: Understand stereographic projections and their use in characterization crystalline materials.

Books and References

1. Characterization of Materials by Elton N. Kaufman (Ed.), John Wiley and Sons.
2. Elements of X-Ray Diffraction by B.D. Cullity, Prentice Hall, New Delhi.
3. Friction and Wear of Ceramics by S. Jahanmir, CRC Press.

Course Name: **Introduction to Materials Science and Engineering** Course Code: **MS-702** Course Type: **Institute Elective**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- To impart knowledge about the crystal structures and bonding in the materials
- To introduce various types of materials
- To enable the students to understand the various properties of the different classes of materials

Course Content

Bonding in Crystals – Ionic bond, covalent bond, molecular bond, hydrogen bond, metallic bond & Van der Waals bond. Crystalline and Noncrystalline materials – Crystal structure, space lattice, unit cell, crystal systems, atomic packing factor, Co-ordination numbers, crystal structure for metallic elements, Crystal directions & Planes, millerindices, stacking sequence in HCP & FCC. Defects in Crystalline Materials: Point, line, surface and volume defects. Diffusion: Diffusion Mechanism, laws of diffusion- Fick's I law, II law, inter-diffusion and Kirkendall effect, Metals and Alloys: Solid solutions, solubility limit, phase rule, binary phase diagrams, intermediate phases, intermetallic compounds, iron-iron carbide phase diagram, recovery, recrystallization and grain growth. Ceramics: Structure and properties of ceramics. Polymers: Classification, polymerization, structure and properties. Different properties of materials: Mechanical properties: stress strain curves, elastic modulus, plastic deformation, slip, dislocation motion, critical resolved shear stress, strengthening mechanisms. Introduction to fatigue and creep properties of materials. Electronic Properties: Concept of energy band diagram for materials – conductors, semiconductors and insulators, electrical conductivity effect of temperature on conductivity, intrinsic and extrinsic semiconductors, dielectric properties. Magnetic Properties: Origin of magnetism in metallic and ceramic materials, paramagnetism, diamagnetism, antiferromagnetism, ferromagnetism, ferrimagnetism, magnetic hysterisis.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Describe basic crystal structure and atomic bonding in the different class of materials

CO2: Identify the different class of materials

CO3: Assess the different properties of different classes of materials

Books and References

1. Fundamentals of Materials Science and Engineering by W D Callister Jr., John Wiley and Sons.
2. Essentials of Materials for Science and Engineering by Donald R. Askeland and Pradeep P. Phule, CL Engineering
3. The Science and Engineering of Materials by Donald R. Askeland, Chapman & Hall.
4. Materials Science and Engineering by V. Raghvan, Prentice Hall India Learning Private Limited.

Course Name: **Near- net Shape Processing** Course Code: **MS-703** Course Type: **Institute Elective**	
Contact Hours/Week: **4L**	Course Credits: **04**

Course Objectives

- This course is intended to impart knowledge about processing methodology of materials into specific shape of the component.
- The course also provides a valuable insight into manufacturing processes

Course Content

Introduction: Major benefits of near-net shape processing: Fundamentals of manufacturing of performs with citations from steel technology. Castings methodology Rheo-casting, thixo-casting and squeeze-casting processes. rheological behavior and microstructural evolution during semi-solid processing, component shape control. Powder Metallurgy techniques Special consolidation processes, hot pressing and hot isostatic pressing, mechanisms of sintering. Injection molding and liquid infiltration processes. Spray forming Gas-melt interaction during melt atomization, droplet dynamics and their non-equilibrium solidification processes. Control of component shape by substrate maneuvering. Industrial applications of spray formed components. Sheet metal forming processes A brief review of high precision forming, superplastic forming, shaping induced materials properties. Isoforming, ausforming, hot stamping and hydroforming processes.

Course Outcomes

Upon successful completion of the course, the students will be able to

CO1: Understand the concepts of near net shape processing

CO2: Identify the different routes of near net shape processing

CO3: Understand the advantages of near net shape processing

TEXTBOOKS:

1. M.C. Flemings, Solidification Processing, McGraw-Hills, NY
2. Y. Wu and E.J. Laverina, Spray Atomization and Deposition, John Wiley and Sons, NY
3. V.S. Arunnachalam and O.V. Raman (eds.): Powder Metallurgy; Recent Advances; Oxford and IBM Publis.

REFERENCE BOOKS

1. Thermo-mechanical simulation and processing of steels, Viva Books Private Ltd, Delhi
2. Powder Metallurgy: Science, Technology andApplication by Angelo and Subramanian, PHI Publishers, New Delhi.