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

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours/week	Credit
			L	T	P		
1	MS-611	Introduction to Materials Science and Engineering	4	0	0	4	4
2	MS-612	Material Characterization Techniques	4	0	0	4	4
3	MS-613	Thermodynamics of Materials	4	0	0	4	4
4	MS-7MN	Programme Elective-I	4	0	0	4	4
5	MS-7MN	Programme Elective-II	4	0	0	4	4
6	MS-614	Materials Science Lab 1	0	0	4	4	2
	Total		**20**	**0**	**4**	**24**	**22**

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

SEMESTER-II

Sr. No.	Course No.	Course Name	Teaching Schedule			Hours/week	Credit
			L	T	P		
1	MS-621	Science & Technology of Thin Films	4	0	0	4	4
2	MS-622	Electrical and Electronic Properties of Materials	4	0	0	4	4
3	MS-623	Phase Transformations in Materials	4	0	0	4	4
4	MS-7MN	Programme Elective-III	4	0	0	4	4
5	MS-7MN	Programme Elective-IV	4	0	0	4	4
6	MS-624	Materials Science Lab 2	0	0	4	4	2
	Total		**20**	**0**	**4**	**24**	**22**

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

SEMESTER-III

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	MS-800	M. Tech. Dissertation	--	20
	Total			**20**

SEMESTER-IV

Sr. No.	Course No.	Course Name	Hours/week	Credit
1	MS-800	M. Tech. Dissertation	--	20
	Total		**--**	**20**

Total Credit of the Programme = 84

Annexure
List of Programme Electives

Programme Elective - I

MS-701 Vacuum Science & Cryogenics
MS-702 Advanced Functional Oxide Materials

Programme Elective - II

MS-703 Polymer Science & Technology
MS-704 Electronics Ceramics

Programme Elective - III

MS-705 Magnetism & Superconductivity
MS-706 Nano-Structure & Technology

Programme Elective - IV

MS-707 Green Chemistry
MS-708 Semiconductor Devices & Technology

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, miller indices, 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.

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: **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 Ellingham diagrams
- 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 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 with non-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, equilibrium constant, 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 intensive properties, 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
CO5: Explain the Ellingham diagrams
CO6: Describe the thermodynamic aspects of electrochemistry
CO7: Discuss the thermodynamics of surfaces and interfaces

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

- To know the importance of the synthesis method addressed in the material properties and give practical experience of nanomaterials synthesis.
- To provide a sound understanding of the various concepts involved in synthesis of nanoparticles.

List of Experiments

1. To synthesize nanoparticles of gold and silver.
2. To synthesize CdS nanoparticles.
3. Synthesis of ZnO nanoparticles.
4. Synthesis of TiO_2 nanoparticles.
5. Synthesis of Fe_2O_3 nanoparticles

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: Prepare the nanoparticles of different materials using co-precipitation method.
CO2: Explain the behaviour 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.

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, heat treatment of Ni-base superalloys and Ti alloys, Thermo-mechanical treatments.

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

- To know the importance of the synthesis method addressed in the material properties and give practical experience of nanomaterials synthesis/properties and characterization; investigations into the various factors influence the properties of nanomaterials, optimizing the procedures, and implementations to the new designs
- To introduce the basic working principles of different characterizing techniques used in nanotechnology

List of Experiments

1. Calculate the crystallite size of nanoparticles using XRD technique
2. Calculate the crystallite size of nanoparticles using Zeta-Sizer
3. FTIR studies of prepared nanoparticles
4. Optical studies of prepared nanoparticles using UV-Visible spectroscopy
5. Raman studies of prepared nanoparticles
6. PL studies of prepared nanoparticles
7. 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: Handle the various characterization tools required for analysis of nanoparticles.

CO2: Analysis the data generated during above mentioned machines.

Course Name**: Vacuum Science & Cryogenics**
Course Code**: MS-701**
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-702**
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: **Polymer Science & Technology**
Course Code: **MS-703**
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, biomedical polymers, 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-704**
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: **Magnetism and Superconductivity**
Course Code: **MS-705**
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-706** 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, one dimension 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, Ion beam 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, Noyes Publications, 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: **Green chemistry** Course Code: **MS-707** Course Type: **Programme Elective-IV**	
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: **Semiconductor Devices and Technology** Course Code: **MS-708** Course Type: **Programme Elective-IV**	
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.