प्रतिष्ठित संस्थान
INSTITUTION OF EMINENCE
राष्ट्रीय अपेक्षाएँ, वैश्विक मानक
National Needs, Global Standards
हैदराबाद विश्वविद्यालय
UNIVERSITY OF HYDERABAD

Outcome Based Education (OBE) Document

M.Tech. (Materials Engineering)

School of Engineering Sciences and Technology

हैदराबाद विश्वविद्यालय
University of Hyderabad

Vision Statement

To be a centre of excellence for learning, training, research and development and entrepreneurial attitude in engineering sciences and technology.

Mission Statements (MS)

- To produce scientists, engineers and technologists through training programs in Materials Engineering, Nano Science and Technology, Manufacturing Science and Technology and other current areas of Engineering Sciences and Technology.

- To create a culture of addressing and solving the short-term and long-term pertinent problems in the society through engineering interventions.

- To encourage inter-disciplinary and collaborative research both at national and international levels.

- To carry out sponsored research and consultancy projects funded by national and international agencies and industries.

Program Educational Objectives (PEOs)

PEO1. To attain world-class quality in learning (theory and practical) and research related to engineering sciences and technology.
PEO2. To provide comprehensive and interdisciplinary knowledge on analyses, design, and creation of novel and environmentally benign engineering solutions for short-term and long-term pertinent problems in the society.
PEO3. To give a comprehensive hands-on training in the theory and experiments related to processing, characterization, testing of advanced materials and engineering components.
PEO4. To produce high quality and industrially relevant human resource for possible employment in industries, and academic and research organizations.

Mapping Program Educational Objectives (PEOs) with MS

	MS-1	MS-2	MS-3	MS-4
PEO-1	3	3	3	2
PEO-2	3	3	3	2
PEO-3	2	3	2	2
PEO-4	3	2	2	2

‘3’ – ‘high-level’ mapping; ‘2’ – ‘Medium-level’ mapping; ‘1’ – ‘Low-level’ mapping;

Program Outcomes (POs)

On completion of the M.Tech. (Materials Engineering) program at School of Engineering Sciences and Technology, the students will be able to:

PO-1. apply the basic science and engineering knowledge and course-specific engineering fundamentals to solve the problems in the society

PO-2. identify or formulate complex engineering problems and design specific and generic solutions for the same

PO-3. analyze the identified (or formulated) problems and conduct systematic and interdisciplinary research to solve them and/or to provide valid conclusions

PO-4. select and apply appropriate resources, and contemporary techniques and tools while solving the identified (or formulated) problems with a complete understanding of the limitations

PO-5. illustrate the complete cognizance of public health and safety, environmental safety, and cultural, societal and legal implications while solving the identified (or formulated) problems

PO-6. evaluate the sustainability, impact and implications of their work on solving the identified (or formulated) problems

PO-7. summarize effectively and explain the identified (or formulated) problems and their solutions and the methodology followed to solve the problems to the appropriate professional community as well as to the general public

PO-8. perform effectively as an individual and as a member (or a leader) of a team under inter-disciplinary national and international contexts.

PO-9. apply the project management skills under inter-disciplinary scenarios

PO-10. demonstrate professional responsibility and ethics

PO-11. recognize the need to develop interest in life-long learning to keep-up with the contemporary science and engineering

PO-12. To impart approaches in general problem solving, professional and ethical values, principles of team work and written and oral communication skills

PO-13. To provide an environment that fosters the culture of life-long learning

Course Structure

Semester I

Subject Type	Subject Code	Subject Name	L-T-P	Credits
Core	MT401	Thermodynamics and Phase Equilibria of Materials	3-0-0	3
Core	MT402	Material Characterization Methods-I	3-0-0	3
Core	MT403	Processing of Engineering Materials	3-0-0	3
Core	MT 404	Mechanical Behavior of Materials	3-0-0	3
Core	MT405	Functional Behavior of Materials	3-0-0	3
Core	MT406	Materials Processing & Characterization: Laboratory-I	0-0-4	4
Core	MT407	Advanced Engineering Mathematics	3-0-0	3
		Total		**22**

L-Lecture; T-Tutorial; P-Practical;

Semester II

Subject Type	Subject Code	Subject Name	L-T-P	Credits
Core	MT451	Diffusion, Phase Transformation and Kinetics	3-0-0	3
Core	MT452	Materials Modeling	3-0-0	3
Core	MT453	Material Characterization Methods-II	3-0-0	3
Core	MT454	Selection and Manufacturing of Engineering Materials	3-0-0	3
Core	MT455	Materials Processing & Characterization: Laboratory-II	0-0-4	4
Core	MT495	Seminar I and Comprehensive Viva	0-0-2	2
Elective	MT65X	Elective I	3-0-0	3
Elective	MT65X	Elective II	3-0-0	3
		Total		**24**

L-Lecture; T-Tutorial; P-Practical;

Semester III

Subject Code	Subject Name	L	T	P	Credits
MT498	Project Part-I	0	0	12	12
MT496	Project Seminar-I	0	0	8	8
	Total				**20**

L-Lecture; T-Tutorial; P-Practical;

Semester-IV

Subject Code	Subject Name	L	T	P	Credits
MT499	Project Part-II	0	0	12	12
MT497	Project Seminar-II	0	0	8	8
	Total				**20**

L-Lecture; T-Tutorial; P-Practical;

Total Credits (I+II+III+IV semesters) = 22+24+20+20 = **86**

List of Electives (Semester II)

{Any two (2) from the following list of subjects and those (relevant and) offered in other MTech courses}

MT651 Powder Metallurgy
MT652 Corrosion Engineering
MT653 Crystallography and Texture Analysis
MT654 Introduction to Microelectromechanical Systems
MT655 Surface Engineering
MT656 Advanced Ceramics
MT657 Composites

Program Specific Outcomes (PSOs)

PSO-1 demonstrate comprehensive knowledge on engineering materials processing, characterization and testing
PSO-2 apply knowledge on modelling and designing new engineering materials
PSO-3 conduct systematic experimentation to produce new engineering materials and products
PSO-4 select appropriate technologies leading to new engineering products and processes for different applications

Mapping of POs and PSOs with PEOs

	PEO-1	PEO-2	PEO-3	PEO-4
PO-1	3	3	3	3
PO-2	3	3	3	3
PO-3	3	3	3	3
PO-4	3	3	3	3
PO-5	2	2	2	1
PO-6	2	2	2	1
PO-7	3	2	2	2
PO-8	2	2	2	2
PO-9	2	2	2	2
PO-10	2	2	2	1
PO-11	2	2	2	1
PO-12	2	2	2	2
PO-13	3	2	2	2
PSO-1	3	3	3	3
PSO-2	3	3	2	2
PSO-3	3	3	3	3
PSO-4	3	3	3	2

‘3’ – ‘high-level’ mapping; ‘2’ – ‘Medium-level’ mapping; ‘1’ – ‘Low-level’ mapping;

Course Outcomes (COs)

Subject Code: **MT401**
Title of the Course: **Thermodynamics and Phase Equilibria of Materials**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): Basic concepts of thermodynamics such as temperature, pressure, system, properties, process, state, cycles and equilibrium

After completion of this subject successfully, the students will be able to:

CO-1: illustrate the metallurgical thermodynamic concepts and equations for understanding phase diagrams, phase transformations and theory of solutions
CO-2: compute thermodynamic properties like enthalpy, entropy, free energy of metallurgical reactions
CO-3: analyze the phase equilibria, unary and binary phase diagrams of any complexity
CO-4: explain thermodynamics of nucleation, oxidation and reduction and electrolysis

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	3	3	3	3	2	2	2	2	2	1	1	3	2	2	1
CO2	2	2	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1
CO3	2	2	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1
CO4	2	2	3	1	1	2	2	2	2	2	2	1	1	2	2	2	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Introduction & definition of thermodynamic terms (system, extensive/intensive properties, variables, state, isothermal/adiabatic processes, component, phase equilibrium, internal energy, heat capacity, enthalpy, entropy, free energy);

Unit 2: Laws of Thermodynamics; Equation of state; Homogeneous systems; Reversibility and irreversibility; Maxwell's relationships; Gibbs-Helmoltz equation;

Unit 3: Single Component Systems; Variation of G with P and T; Triple point; Phase equilibria; Critical point; Impure substances; Solubility; Ideal and non-ideal solutions; Activity; Chemical Potential; Solution models; Gibbs’ phase rule; Phase diagrams;

Unit 4: Behavior of gases; P-V-T relationships in gases; Thermodynamics of non-ideal gases;

Unit 5: Analysis & synthesis of phase diagrams; Construction of phase diagrams from thermodynamic data; extraction of thermodynamic data from phase diagrams; Current status of phase diagrams;

Unit 6: Thermodynamics of: Nucleation; Reactions involving gases; Oxidation & reduction; Electrolysis (and some specific processes);

Suggested Books:

1. Introduction to the Thermodynamics of Materials, D. R. Gaskell and D. E. Laughlin.
2. Thermodynamics of Solids, R. A. Swalin.
3. Engineering in Process Metallurgy, R. I. Guthrie.

Subject Code: **MT402**
Title of the Course: **Material Characterization Methods-I**
L-T-P: 3-0-0   Credits: 3
Prerequisite Course/Knowledge (If any): Basic knowledge of physics, chemistry and materials science at bachelor level

After completion of this subject successfully, the students will be able to:

CO-1: explain the fundamentals of microscopy and spectroscopy
CO-2: apply the knowledge of various diffraction techniques to characterize materials
CO-3: apply the knowledge of various spectroscopic techniques to characterize materials
CO-4: apply the knowledge of various microscopic and spectroscopic techniques to characterize materials at different length scales

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	2	1	1	1	1	1	1	1	1	1	3	2	3	1
CO2	3	1	2	2	1	1	2	1	1	1	1	1	1	3	3	2	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	3	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	3	2	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Fundamentals: Resolution; magnification; contrast; scattering; interference; diffraction etc.;

Unit 2: Microscopy/diffraction techniques: Light microscopy; scanning electron microscopy (SEM) ; transmission electron microscopy/diffraction (TEM) ; x-ray diffraction (XRD); neutron diffraction; scanning probe microscopy;

Unit 3: Spectroscopic techniques: Electron induced x-ray emission (EDS) in SEM and TEM; Electron energy loss spectroscopy (EELS) in TEM; x-ray photoelectron spectroscopy (XPS);

Unit 4: Characterization of materials at the micrometer, nanometer and atomic scale using various microscopy/diffraction methods;

Suggested Books:

1. Materials Characterization Techniques, Sam Zhang, Lin Li, Ashok Kumar.
2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Y. Leng.
3. Practical Materials Characterization, M. R. Sardela
4. Lecture notes and handouts

Subject Code: **MT403**
Title of the Course: **Processing of Engineering Materials**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1: determine the total solidification time required for the casting and designing riser size
CO-2: analyze the advantages and limitations associated with particulate processing of metals
CO-3: analyze the advantages and limitations associated with processing of ceramics
CO-4: identify the factors that affect the performance in metal forming (Analyze)
CO-5: analyze the advantages and limitations associated with materials joining processes
CO-6: analyze the advantages and limitations associated with variety of plastic moulding techniques
CO-7: analyze the advantages and limitations associated with variety of composite materials
CO-8: select best suited method for processing any given material

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	1	1	1	1	1	1	1	1	1	1	3	3	1	1
CO2	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO3	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO4	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO5	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO6	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO7	3	3	1	3	1	1	1	1	1	1	1	1	1	3	3	1	1
CO8	3	3	1	3	1	3	1	1	1	1	1	1	1	3	3	3	3

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Solidification Process: fundamentals of metal casting; metal casting processes;

Unit 2: Particulate processing of metals: Characterization of engineering powders; production of metallic powders; conventional pressing and sintering; alternative pressing and sintering techniques, materials and products, design considerations;

Unit 3: Processing of ceramics and cermet: processing of traditional and new ceramics, processing of cermets, product design considerations;

Unit 4: Metal forming: fundamentals in metal forming, bulk deformation processes- rolling, forging, extrusion, drawing;

Unit 5: Materials joining: Fundamentals of welding, gas flame and arc processes, resistance and solid-state welding processes, other welding processes- brazing and soldering, adhesive bonding, mechanical fastening and joining of non-metals;

Unit 6: Plastic materials: extrusion, plastic moulding, different types of plastic moulding, processing of elastomers

Unit 7: Composite materials: processing of polymers–matrix composites, metal-matrix and ceramic-matrix composites, design considerations

Suggested Books:

1. Fundamentals of Modern Manufacturing, M.P. Groover.
2. DeGramo’s Materials and Processing in Manufacturing, J.T. Black and R. A. Kohser.
3. Manufacturing Engineering and Technology, S. Kalpakjian, S.R. Schmid.

Subject Code: **MT404**
Title of the Course: **Mechanical Behavior of Materials**
L-T-P: 3-0-0   Credits: 3
Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1: analyze the stress state at any point of the component knowing the load acting on it
CO-2: analyze the yield strength, ultimate tensile strength, toughness and fracture strength of any given material subjected to tests
CO-3: apply the fundamentals of mechanical behavior of materials and predict safe range of operation of a given material
CO-4: compare the microstructure and fractograph of a material in the presence and absence of defects subjected to different forms of loading
CO-5: select an appropriate forming method from the fundamental knowledge of the deformation behavior of a material

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO2	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1
CO3	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1
CO5	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	1

'3'–'high-level' mapping; '2'–'Medium-level' mapping; '1'–'Low-level' mapping;

Detailed Syllabus:

Unit1: Strength of Materials: Basic assumptions, elastic and plastic behavior, stress- strain relationship for elastic behavior, elements of plastic deformation of metallic materials, Mohr's circle, yielding theories;

Unit 2: Theory of plasticity: Dislocation theory, properties of dislocations, stress fields around dislocations, application of dislocation theory to work hardening, solid solution strengthening, grain boundary strengthening, dispersion hardening;

Unit 3: Ductile and brittle fracture: Charpy and Izod testing, Significance of DBTT, Elements of fractography;

Unit 4: Fatigue failure: Initiation and propagation of Fatigue cracks, factor affecting fatigue strength and methods of improving fatigue behaviour, testing analysis of fatigue data, mechanism of fatigue crack propagation, Corrosion fatigue;

Unit 5: Creep failure: Creep mechanism, creep curve, variables affecting creep, accelerated creep testing, development of creep resisting alloys, Larsen- Miller parameter, Manson Hafred parameter;

Unit 6: Mechanical behaviour of thin films : Residual/intrinsic stress, strength - a size effect, epitaxy and stress, composite thin films, bending of beam, different structure mechanical behavior at micro-nano scale, applications in MEMS;

Unit 7: Mechanical behaviour of materials at nanoscale : Depth-sensing nanoindentation, micro beam bending, micro tensile testing, substrate curvature testing for elastic, plastic, fracture toughness and interfacial toughness.

Suggested Books:

1. Mechanical Metallurgy, G. E. Dieter.
2. Deformation and Fracture Mechanics of Engineering Materials, R.W. Hertzberg
3. Introductions to Dislocations, D. Hull.
4. Fundamentals of Creep and Creep Rupture in Metals, F. Garofalo.
5. Mechanical Behavior of Materials, M. A. Meyers, K. K. Chawla.

Subject Code: **MT405**
Title of the Course: **Functional Behavior of Materials**
L-T-P: 3-0-0   Credits: 3
Prerequisite Course/Knowledge (If any): Basic knowledge of physics, chemistry and materials science at bachelor level

After completion of this subject successfully, the students will be able to:

CO-1: explain the fundamentals of atomic structure, bonding, energy bands in crystals, density of states, behavior of electrons in solids, consequence of band model
CO-2: explain the mechanism of electrical conduction in solids, origin of various types of magnetism and magnetic properties, dielectric properties, mechanical, thermal and optical properties
CO-3: correlate the structures with electrical, magnetic, thermal, mechanical and optical properties of metals, ceramics and polymers
CO-4: interpret the results of P-E loop, M-H loop, M-T curve, frequency dependence of dielectric constant of any given material
CO-5: establish structure property correlation in any given material

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	2	1	1	1	1	1	1	1	1	1	3	2	3	1
CO2	3	1	2	2	1	1	2	1	1	1	1	1	1	3	3	2	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	3	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	3	2	1	1
CO5	3	2	1	2	1	2	1	1	1	1	1	1	1	3	2	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Introduction: Atomic structure, electronic configuration, periodic table, bonding forces and energies, ionic bonding, covalent bonding, metallic bonding, van der waals bonding, hydrogen bonding, dipole bonding;

Unit 2: Fundamentals of Electron Theory: Energy bands in crystals, electrons in a crystal, Fermi energy and surface, Fermi distribution function, density of states, population density, density of states function within a band, consequence of band model;

Unit 3: Electrical and Dielectric Properties: Electrical conduction, electronic and ionic conduction, band structure in solids, conduction in terms of band structure and atomic bonding model, electrical resistivity of metals, intrinsic and extrinsic semiconduction, electrical conduction in ionic ceramics and polymers, dielectric behavior – capacitance, types of polarization, frequency dependence of dielectric constant, dielectric strength, ferroelectricity, piezoelectricity;

Unit 4: Magnetic Properties: Basic concepts, diamagnetism and paramagnetism, ferromagnetism, antiferro- and ferrimagnetism, influence of temperature on magnetic behavior, domains and hysteresis, magnetic anisotropy, soft magnetic materials, hard magnetic materials, magnetic storage, superconductivity;

Unit 5: Thermal Properties: Heat capacity, thermal expansion, thermal conductivity, thermal stress/shock;

Unit 6: Optical Properties: Basic concepts, electromagnetic radiation, light interaction with solids, atomic and electronic interactions, refraction, reflection, absorption, transmission, optical birefringence, color, opacity and translucency in insulators, luminescence, photoconductivity, lasers;

Suggested Books:

1. Materials Science and Engineering, William D Callister, Jr.
2. Electronic Properties of Material, Rolf E. Hummel.
3. Materials Science for Engineers, James F. Shackelford.
4. Science and Engineering of Materials, Askeland.
5. Introduction to Solid State Physics, C. Kittel.
6. Elements of Materials Science and Engineering, Van Vlack and H. Lawrence.

Subject Code: **MT406**
Title of the Course: **Material Processing & Characterization: Laboratory- I**
L-T-P: 0-0-4 Credits: 4
Prerequisite Course/Knowledge (If any): Basic concepts of materials processing and characterization

After completion of this subject successfully, the students will be able to:

CO-1: preparation of materials by casting process
CO-2: preparation of powders (metallic, alloy, ceramics) by ball milling
CO-3: preparation of specimens for optical and electron microscopy
CO-4: record and analyze X-ray diffractogram of any material
CO-5: record and analyze optical and electron micrograph data of any material
CO-6: communicate the results of all experiments in the form of a written technical report

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO2	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO3	2	2	2	3	1	1	1	2	2	2	2	2	2	2	3	2	1
CO4	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1
CO5	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1
CO6	2	2	2	2	1	2	3	3	3	2	2	2	2	1	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

1. Solidification casting
2. Powder processing by mechanical milling
3. Metallographic analysis
4. Microscopic analysis by scanning electron microscopy
5. Crystal structure analysis by X-ray diffraction

Subject Code: **MT407**
Title of the Course: **Advanced Engineering Mathematics**
L-T-P: 3-0-0   Credits: 3
Prerequisite Course/Knowledge (If any): BE/BTech level mathematics knowledge

After completion of this subject successfully, the students will be able to:

CO-1: solve the problems using the principles of linear vector spaces and matrices
CO-2: solve ordinary and partial differential equations analytically with relevant examples in Materials Engineering
CO-3: practice integral transforms and apply to differential equations
CO-4: assess statistical fits
CO-5: solve differential, integral, approximation, interpolation and optimization problems numerically

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO2	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO3	2	2	2	2	1	1	1	1	1	1	1	1	1	2	3	3	2
CO4	3	3	3	3	1	1	1	1	1	1	1	1	1	3	3	3	3
CO5	3	3	3	3	1	1	1	1	1	1	1	1	1	3	3	3	3

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Linear vector spaces and matrices: Functions as elements of a linear vector space; Basis sets and expansion; Operators and matrix representations; Eigen value problem and diagonalization;

Unit 2: Differential calculus: Solutions to ordinary differential equations; Variational calculus; Applications of partial derivatives – Lagrange multipliers;

Unit 3: Integral transforms: Fourier and Laplace transforms; Their properties; Equivalence of conjugate Fourier spaces; Application to differential equations with examples;

Unit 4: Probability and statistics: Random variables and joint distributions; Functions of random variables; Basic statistical estimators; Method of linear least squares; Random processes;

Unit 5: Numerical methods: Numerical differentiation and integration; Interpolation and polynomial approximations; Numerical optimization; Introduction to MATLAB commands;

Suggested Books:

1. Advanced Engineering Mathematics, M. D. Greenberg.
2. Mathematical Methods for Physics and Engineering, K. F. Riley and M. P. Hobson.
3. Mathematical Physics - A Modern Introduction to its Foundations, Sadri Hassani.
4. Mastering MATLAB 7, D. Hanselman and B. Littlefield.

Subject Code: **MT451**

Title of the Course: **Diffusion, Phase Transformation and Kinetics**

L-T-P: 3-0-0 Credits: 3

Prerequisite Course/Knowledge (If any): BE/BTech level Metallurgy, Materials, Mechanical engineering, Nano Science and Technology; Some knowledge of materials science; prior exposure to thermodynamics and kinetics.

After completion of this subject successfully, the students will be able to:

CO-1: explain the basics of diffusion phenomenon in solids

CO-2: demonstrate diffusion mechanism and its applications in metals and alloys

CO-3: illustrate the principles underlying liquid-to solid and solid-state phase transformations in a range of materials

CO-4: apply the phase transformation mechanism to develop the desired microstructures

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO3	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	3	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Phenomenological Laws of Diffusion: Fick’s Laws, Chemical Potential Gradient & Driving Force for Diffusion, Relationship between Mobility and Diffusion Solution to Diffusion Equations: Semi Infinite & Infinite Diffusion Couples, Finite Diffusion couples;

Unit 2: Mechanisms of Diffusion: Lattice Defects & Diffusion, Random Walk Problem & Einstein Equation, Interstitial and Substitutional Diffusion Mechanisms, Activation Energy for Diffusion, Crystal boundary & Surface Diffusion, Diffusion Data base;

Unit 3: Single Component Systems; Variation of G with P and T; Triple point; Phase equilibria; Critical point; Impure substances; Solubility; Ideal and non-ideal solutions; Activity; Chemical Potential; Solution models; Gibbs’ phase rule; Phase diagrams;

Unit 4: Diffusional Transformations: Solidification & Solid – Liquid Transformations: Solid – Solid Transformations: Nucleation & Growth; Particle Coarsening, Grain Growth, Sintering; Diffusion Controlled Gas – Solid Reactions: Oxidation Reactions, Carburization/Decarburization, Diffusion of Hydrogen;

Unit 5: Diffusion Controlled Deformation: Creep Diffusion Controlled Phenomena in Systems Several topics related to Kinetics;

Suggested Books:

1. Diffusion in Solids, P.G. Shewman.
2. The Mathematics of Diffusion, J. Crank.
3. Transport Phenomena, R. B. Bird, W. E. Stewart, E. N. Lightfoot.
4. Diffusion: Mass Transfer in Fluid Systems, E. L. Cussler.
5. Conduction of Heat in Solids, H. S. Carslaw, J. C. Jaeger.
6. Diffusion in solids: field theory, solid-state principles, and applications, M. E. Glicksman.
7. Kinetics of Materials, R.W. Ballubi, S.M. Allen and W.C. Carter.

Subject Code: **MT452**
Title of the Course: **Materials Modelling**
L-T-P: 3-0-0   Credits: 3
Prerequisite Course / Knowledge (If any): BE/BTech level knowledge in materials science and mathematics

After completion of this subject successfully, the students will be able to:

CO-1. describe the input and output parameters in density functional theory calculations
CO-2. explain the elements of computational materials thermodynamics
CO-3. explain the Monte-Carlo methods for modeling of materials
CO-4. discuss the molecular dynamics methods of modelling of materials
CO-5. calculate the material properties by applying the learnt modeling and simulation tools

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO2	3	3	3	2	1	1	1	1	1	1	1	1	1	2	3	3	2
CO3	2	2	2	2	1	1	1	1	1	1	1	1	1	2	2	3	2
CO4	2	2	2	2	1	1	1	1	1	1	1	1	1	3	2	3	2
CO5	3	3	3	3	1	1	1	1	1	1	1	1	1	3	3	3	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Density functional theory: Introduction to density functional theory; Thermodynamic quantities; Density of states; Software packages;

Unit 2: Computational Thermodynamics: Generation of thermochemical and phase equilibria information; Models for Gibbs energy; Thermodynamic assessment; Gibbs energy database creation; Diffusion modelling; Software packages;

Unit 3: Monte Carlo Methods: Random variables, Generation of different distributions, Metropolis algorithm, Phase transitions (magnetic systems as example);

Unit 4: Molecular Dynamics: Newtonian dynamics, Finite-difference methods, Molecular dynamics of hard spheres, phase transitions (solid-liquid transformation as example). Stochastic processes, Markov chains, Diffusion models based on random walks, Transport phenomena (heat conduction as an example);

Unit 5: Laboratory component: Phase diagram calculation o Thermodynamic property diagram calculation of Random number generation and testing for randomness o Construction of ensembles of different standard distributions o Monte Carlo simulations based on Metropolis algorithm;

Suggested Books:

1. Sidney Yip (ed), Handbook of Materials Modeling, Volumes A and B, (Springer, 2005).
2. Fong C Y, Topics in Computational Materials Science (Singapore: World Scienti_c, 1999).
3. Landau R H, Paez M J, and Bordeianu C C, A Survey of Computational Physics (Prince-ton: Princeton University Press, 2008).
4. Martin R M, Electronic Structure (Cambridge: Cambridge University Press, 2004).
5. Hoover WG, Computational Statistical Mechanics (Elsevier, 1991).
6. Allen M P and Tildesley D J, Computer Simulation of Liquids (Oxford: Oxford University Press, 1989).
7. Haile J M, Molecular Dynamics Simulation: Elementary Methods (New York: Wiley, 1992).

8. Rapaport DC, The Art of Molecular Dynamics Simulations, Second Edition, (Cambridge University Press, 2004).
9. Landau and Binder, A Guide to Monte Carlo Simulations in Statistical Physics, 2nd.ed. (CUP, 2005).
10. Kalos M H and Whitlock P A, Monte Carlo Methods Volume I: Basics (Wiley, 1996).
11. Saunders N and Miodownik A P, CALPHAD (Calculation of Phase Diagrams): A Comprehensive Guide, (Oxford, Pergamon, 1998).

Subject Code: **MT 453**
Title of the Course: **Material Characterization Methods-II**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): Basic knowledge of physics, chemistry and materials science at bachelor level

After successful completion of this subject successfully, the students should be able to,

CO-1: apply the knowledge of various physical methods to characterize materials
CO-2: apply the knowledge of various spectroscopic techniques to characterize materials
CO-3: characterize the material based on electrical, electronic and dielectric properties
CO-4: determine ferroelectric and dielectric properties of materials
CO-5: apply different methods of thermal analysis to characterize materials

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	2	1	1	1	1	1	1	1	1	1	3	2	3	1
CO2	3	1	2	2	1	1	2	1	1	1	1	1	1	3	3	2	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	3	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	3	2	1	1
CO5	3	2	1	2	1	2	1	1	1	1	1	1	1	3	1	2	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Physical Characterizations – Particle size/shape/distribution, Surface area, Porosity, Density, Flow property

Unit 2: Chemical Characterizations – Elemental analysis (EDS/WDS/EPMA), Raman, IR/FTIR, UV-Vis, SIMS, XPS

Unit 3: Electrical, Electronic and Dielectric Characterizations – I-V, C-V, carrier type and concentration, Dielectric constant and its temp dependence, capacitance and loss factor, Impedance spectroscopy

Unit 4: Ferroelectric and Magnetic Characterizations – Electric field dependence of Polarization (P-E loop), piezoelectric coefficients, M vs H, M vs T, Magnetic permeability/susceptibility, energy product etc

Unit 5: Thermal and Optical Characterizations – DTA, TGA, DSC, Thermal conductivity, Thermal expansion, PL, Ellipsometry etc

Suggested Books:

1. “Materials Characterization Techniques” by Sam Zhang, Lin Li, and Ashok Kumar CRC Press, Taylor and Francis Group
2. “Physical Methods for Materials Characterization” by Peter E. J. Flewitt and Robert K Wild, CRC Press, Taylor and Francis Group
3. “Concise Encyclopedia of Materials Characterization”, ed. Robert W Cahn and Eric Lifshin, Pergamon Press
4. Lecture notes and handouts

Subject Code: **MT454**
Title of the Course: **Selection and Manufacturing of Engineering Materials**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): Basics in materials/mechanical engineering, engineering physics/chemistry at bachelors level

After completion of this subject successfully, the students will be able to:

CO-1. Explain the classification of engineering materials and design-limiting materials' properties
CO-2. apply the materials selection criteria for different engineering applications
CO-3. apply the materials selection criteria in fabrication of micro and nano scale systems
CO-4. compare different materials based on selection criteria for a given application

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	2	1	1	1	1	1	1	1	1	1	2	3	1	1
CO2	3	1	2	2	1	1	2	1	1	1	1	1	1	3	2	1	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1

'3'–'high-level' mapping; '2'–'Medium-level' mapping; '1'–'Low-level' mapping;

Detailed Syllabus:

Unit 1: Basics of metals, ceramics, polymers, glasses, quasicrystals, amorphous solids, composites, hybrid materials, graphite, diamond, graphene, nanotubes. The evolution of engineering materials, design limiting properties such as density, cost, mechanical, thermal, wear, corrosion/oxidation etc.

Unit 2: Selection criteria for different engineering applications: automotive, aerospace, marine etc. Data driven selection approach using the Ashby charts for various engineering applications. Casting processes, forming processes such as rolling, extrusion, forging, sheet metal forming, formability, powder based manufacturing processes, single crystal development etc.

Unit 3: Various joining processes (fusion as well as solid state methods), advanced machining processes, fabrication of micro and nano scale systems. Principles of subtractive manufacturing and additive manufacturing, opportunities, limitations.

Unit 4: Considerations w.r.t technology development based on application, economics and deployment. Selective case studies

Suggested Books:

1. Materials selection in mechanical design, M. F. Ashby, fourth edition, Elsevier, 2011.
2. Manufacturing Engineering and Technology, S. Kalpakjian, S. R. Schmid, Pearson, 2002
3. Several recent journal articles and handouts will be given to the students in class

Subject Code: **MT455**
Title of the Course: **Materials Processing & Characterization: Laboratory-II**
L-T-P: 0-0-4   Credits: 4
Prerequisite Course/Knowledge (If any): Basic concepts of materials processing and characterization

After completion of this subject successfully, the students will be able to:

CO-1: manufacture a small object and report observations during forging operation
CO-2: prepare a butt joint by arc welding technique
CO-3: prepare a oxide ceramic tape by tape casting technique
CO-4: record and analyze thermal characteristics of a given material
CO-5: record and analyze spectroscopic data of carbon
CO-6: communicate the results of all experiments in the form of a written technical report

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO2	3	3	3	3	2	2	3	3	2	2	3	2	2	3	3	2	3
CO3	2	2	2	3	1	1	1	2	2	2	2	2	2	2	3	2	1
CO4	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1
CO5	2	2	3	3	1	2	3	2	2	2	2	2	2	2	3	1	1
CO6	2	2	2	2	1	2	3	3	3	2	2	2	2	1	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

Demonstration and practice of forging operation
Demonstration and practice of welding operation
Ceramic processing by colloidal technique
Determination of thermal characteristics of a given material by TG/DTA and DSC analysis
Determination of vibrational modes of carbon by Raman Spectroscopy

Subject Code: **MT495**
Title of the Course: **Seminar I and Comprehensive Viva**
L-T-P: 0-0-2   Credits: 2
Prerequisite Course/Knowledge (If any): -

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills to prepare scientific/technical presentation
CO-2: demonstrate skills in orally delivering scientific and technical presentations
CO-3: demonstrate skills in answering logical questions in Materials Engineering
CO-4: demonstrate skills in answering scientific/technical questions in Materials Engineering

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	2	2	2	2	2	2	2	1	1	3	3	3	3
CO2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO3	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	3	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

Handouts will be given to the students in class

Electives

Subject Code: **MT651**
Title of the Course: **Powder Metallurgy**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): Basics in materials engineering, engineering physics/chemistry at bachelors level

After completion of this subject successfully, the students will be able to:

CO-1. explain the nuances of powder metallurgy (processing, characterization and applications)
CO-2. determine various characteristics of powders
CO-3. apply different powder metallurgy techniques for a given application
CO-4. compare different powder metallurgy techniques for a given application

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	2	1	1	1	1	1	1	1	1	1	2	3	1	1
CO2	3	3	2	2	1	1	2	1	1	1	1	1	1	3	2	1	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Introduction – What is powder metallurgy, Need for powder metallurgy;

Unit 2: Powder Processing and Characterization – Synthesis of powders: Mechanical methods, thermal decomposition and pyrolysis, chemical precipitation and sol gel techniques, electrolytic methods, atomization and other spray forming techniques, etc.; Particle size, shape and size distribution, flow, apparent density and tap density, granulation.;
.;

Unit 3: Shape Fabrication – compaction behavior, uniaxial and isostatic compaction, powder processing with Laser Engineered Net Shaping (LENS), Extrusion and forging, Roll compaction, Injection moulding, Tape casting, Slip casting, Sol-gel casting;

Unit 4: Sintering and Densification – Solid state sintering, Liquid phase sintering, Reaction sintering, Hot pressing, Hot isostatic pressing, self-propagating combustion sintering; Advanced Sintering Techniques – Spark plasma sintering, Microwave sintering;

Unit 5: Ceramic PM Materials – Al_2O_3, ZrO_2, SiC, Si_3N_4, Cermets, Ceramic-ceramic composites, Soft and hard magnetic materials: ferrites, garnets;

Unit 6: Application of P/M Materials – Structural components, porous components, electrical and magnetic components, friction materials, hard and wear resistant components, high temperature high strength components and components for special applications;

Suggested Books:

1. “Powder Metallurgy & Particulate Materials Processing” by Randall M. German, Metal Powder Industries Federation

2. “Powder Metallurgy Science Technology and Materials” by Upadhyaya and Upadhyaya, University Press
3. “Introduction to Ceramics” by W. D. Kingery, H. K. Bowen and D. R. Uhlmann, John Wiley & Sons.
4. “Ceramic Processing and Sintering” by M. N. Rahaman, Marcel Dekker.
5. “Modern Ceramic Engineering: Properties, Processing, and Use in Design” by D. W. Richerdson, CRC Press.

Subject Code: **MT652**
Title of the Course: **Corrosion Engineering**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): Basics in materials engineering, engineering physics/chemistry at bachelors level

After completion of this subject successfully, the students will be able to:

CO-1: apply the fundamental principles of different forms of corrosion to diagnose the problem of corrosion in any context
CO-2: apply corrosion measurement techniques to determine corrosion rates of different engineering materials in any given application
CO-3: analyze the role of chemical composition, microstructure, and service stresses/residual stresses on the susceptibility of a material to corrosion
CO-4: discuss different methods of corrosion prevention of metals and alloys
CO-5: identify the precursors of corrosion and suggest strategies for corrosion prevention in any given context

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	1	2	1	1	1	1	1	1	1	1	1	2	3	1	1
CO2	3	1	2	2	1	1	2	1	1	1	1	1	1	3	2	1	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
CO5	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Introduction, Importance of corrosion, Economics of corrosion;

Unit 2: Corrosion of Materials: Oxidation, Corrosion and wear. Basics of Thermodynamics and Kinetics of oxidation and corrosion. Pourbaix diagram, Polarization, Mixed potential theory. Passivity, Characteristics of passivation, degradation of composites;

Unit 3: Corrosion: Fundamental of corrosion studies, types of corrosion, atmospheric, galvanic, pitting, crevice corrosion, intergranular corrosion and dealloying. Stress corrosion cracking, Season cracking, Corrosion rate measurement, Tafel extrapolation;

Unit 4: Hydrogen damage and radiation damage, hydrogen embrittlement;

Unit 5: Weld decay and knife line attack, oxidation and hot corrosion of materials; Kinetics of oxidation, Pilling- Bed Worth ratio;

Unit 6: Prevention of degradation: Alloying environment, environment conditioning, design modification, Cathodic and anodic protection, organic and inorganic coating, inhibitors and passivators, Wear resistant coating;

Suggested Books:

1. An Introduction to Electrochemistry, S. Glasstone
2. Corrosion Engineering, M. C. Fontana.
3. The fundamentals of Corrosion, J. C. Scully.
4. Electrochemical Engineering, C. L. Mantell.

Subject Code: **MT653**
Title of the Course: **Crystallography and Texture Analysis**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): BTech level metallurgy, materials, mechanical engineering, nano science and technology.

After completion of this subject successfully, the students will be able to:

CO-1: identify the crystallographic orientation relationships
CO-2: compare the orientation measurement of polycrystalline materials and distribution techniques
CO-3: examine the texture of materials processed by different techniques
CO-4 correlate the properties of materials with texture

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	1	1	1	1	1	1	1	1	1	2	3	2	2
CO2	3	3	2	2	1	1	2	1	1	1	1	1	1	3	2	2	2
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	3	1	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Representation of orientation, Crystal, Sample symmetry;

Unit 2: Concepts of texture in materials, their representation by pole figure and orientation distribution functions. Texture measurement by different techniques;

Unit 3: Origin and development of textures during materials processing stages: solidification, deformation, annealing, phase transformation, coating processes and thin film deposition;

Unit 4: Influence of texture on mechanical and physical properties;

Unit 5: Texture control in Aluminium industry, automotive grade and electrical steels, magnetic and electronic materials;

Unit 6: Introduction to grain boundary engineering and its applications. Texture modelling, Crystal plasticity.

Suggested Books:

1. Introduction to Texture Analysis, O. Engler, V. Randle.
2. Crystallographic Texture of Materials, Satyam Suwas, R. K. Ray.
3. Electron Back Scattered Diffraction in Materials Science, A. J. Schwartz, M. Kumar, B. L. Adams, D. Field.
4. Texture and Anisotropy, U. F. Kocks, H. R. Wenk, C. N. Tome.

Subject Code: **MT654**
Title of the Course: **Introduction to Microelectromechanical Systems**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): Fundamentals of electronic materials

After completion of this subject successfully, the students will be able to:

CO-1: explain the fundamentals of processing of materials at micro level
CO-2: develop new process technology for microfabrication of microstructures and MEMS
CO-3: apply the engineering knowledge to use the state of art clean room facilities for making micron level devices such as actuators or sensors
CO-4: develop materials for application in MEMS devices

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	1	2	1	1	1	1	1	1	1	1	1	1	2	2	2	2
CO2	3	3	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CO3	3	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO4	3	3	3	3	1	1	1	1	1	1	1	1	1	1	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Introduction: Basics of semiconductor materials, doping, P-type and N-type, band gap theory and band gap engineering;

Unit 2: Thin films: Chemical vapour deposition (PECVD, LPCVD), Atomic layer deposition, physical vapour deposition, Sputtering (DC, RF), thermal evaporation;

Unit 3: Lithography: E-beam lithography, thick film lithography, thin film lithography, soft lithography, Photoresist (+ve and –ve), Resist profile, Contrast and lithographic sensitivity, Resolution, MTF, spin coating, soft baking, Pre and post baking, Stripping;

Unit 4: Bulk Micromachining: Dry Etching, Loading effect (uniformity and non-uniformity), DRIE, Wet etching, Mask materials, Etch stop, Under etching and undercutting;

Unit 5: Surface Micromachining: Sacrificial layer, Selection of materials, Lift-off process, Thin films (CVD, PECVD, PVD, Evaporation and sputtering), Oxidation, LIGA process;

Unit 6: Nanofabrication: AAO template based mask less, Metal assisted etching, Novel nanofabrication;

Suggested Books:

1. Fundamentals of Microfabrication, M. J. Madou.
2. Foundations of MEMS, C. Liu.
3. Micromachined Transducers Sourcebook, G. Kovacs.

Subject Code: **MT655**
Title of the Course: **Surface Engineering**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): General materials science and technology at masters level

After completion of this subject successfully, the students will be able to:

CO-1: apply the fundamentals of surface engineering and related matters for functional and protection applications
CO-2: apply the principles of thin film deposition and coating methods
CO-3: analyze the advantages and limitations of different surface engineering approaches for functional and protection applications and repair
CO-4: compare different surface engineering technologies from different applications' perspectives
CO-5. select a suitable surface engineering technology for any given application

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	2	2	2	1	1	1	1	1	1	1	1	1	2	2	2	2
CO2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO3	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO4	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1
CO5	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1

'3'–'high-level' mapping; '2'–'Medium-level' mapping; '1'–'Low-level' mapping;

Detailed Syllabus:

Unit 1: Introduction: Definitions and Application Examples; Surface Cleaning and Surface Degradation;

Unit 2: Vacuum Science and Technology: Gas Kinetics, Gas Pumping and Transport; Thin Film Deposition: Physical Vapor Deposition: Evaporation: Thermal evaporation, Evaporation of alloy and compound films, Reactive evaporation, Activated evaporation and other modern evaporation techniques: Sputtering: Basic principles, sputtering of alloys, reactive sputtering and setting up sputtering units, Ion and ionized cluster assisted deposition; Chemical Vapor Deposition: Basic principles, Conventional CVD methods and Plasma enhanced CVD;

Unit 3: Thin film nucleation and growth: Volmer-Weber, Frank Van der Merwe and SK growth modes; Zone Model; Evolutionary selection principle;

Unit 4: Chemical conversion coatings and plating processes; Thermo chemical surface treatments; Thermal Barrier Coatings; Hardfacing & Cladding, Thermal and Plasma Spray Processes; Post synthesis processing and surface modification/functionalization;

Unit 5: Characterization and Performance evaluation of Coatings;

Suggested Books:

1. Surface Engineering, H. Dimigen.
2. Surface Engineering: An Introduction, J. B. Hudson.
3. Engineering Coatings, S. Grainger, J. Blunt.
4. The Materials Science of Thin Films, M. Ohring.
5. Thin Film Deposition, Principles and Practice, D. L. Smith.
6. ASM Handbook, Volume 5, "Surface Engineering", ASM International.

Subject Code: **MT656**
Title of the Course: **Advanced Ceramics**
L-T-P: 3-0-0   Credits: 3
Prerequisite Course/Knowledge (If any): Basics in materials engineering, engineering physics/chemistry at bachelors level

After completion of this subject successfully, the students will be able to:

CO-1: explain the structure and bonding in various ceramics
CO-2: determine various defects in a given ceramic
CO-3: determine the mass and electrical transport in a given ceramic
CO-4: compare different ceramic processing techniques and associated microstructure evolution
CO-5: explain the functioning of a given electronic ceramic

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	2	1	1	1	1	1	1	1	1	1	2	2	1	1
CO2	3	3	2	2	1	1	2	1	1	1	1	1	1	2	2	1	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
CO4	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CO5	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: Structure of Ceramics: Closed packet lattices, stability of ionic crystals, ceramic crystal structures-FCC based structures, HCP based structures, perovskite, spinel, covalent ceramics, crystalline silicates, glass structure;

Unit 2: Defects in Ceramics: Point defects, Kroger-Vink notation, defect chemical reaction, electronic disorder, simultaneous defect equilibrium, Brouwer diagram, defect association and precipitation, Debye-Huckel correlation, line and planar defects;

Unit 3: Mass and Electrical transport: Continuum diffusion kinetics, atomistic diffusion process, electrical conductivity, electrochemical potential;

Unit 4: Sintering of ceramics: solid state sintering, liquid phase sintering, MWS, SPS, HP, HIP

Unit 5: Microstructure development in ceramics: Capillary action, grain growth and coarsening, single phase sintering, reactive additive sintering, hot pressing, glasses and glass ceramics, strength and toughness, toughening of ceramics, toughening mechanism, microstructural toughening, ZTA, TTZ

Unit 6: Electronic ceramics: piezoelectric and magnetic ceramics, ceramics for sensors, relaxors, and electro-optic applications

Suggested Books:

1. Introduction to Ceramics, Kingery, Browen, Uhlmann
2. Modern Ceramic Engineering, D. W. Richerson
3. Physical Ceramics, Y.-M. Chiang, D. Birnie III, W. D. Kingery
4. Fundamental of Ceramics, M. W. Barsoum
5. Ceramic Materials for Electronics, R. C. Buchanan

Subject Code: **MT657**
Title of the Course: **Composites**
L-T-P: 3-0-0 Credits: 3
Prerequisite Course/Knowledge (If any): BE/BTech level materials engineering

After completion of this subject successfully, the students will be able to:

CO-1. explain the nuances of composites (classification, functions of constituents, selection criteria of the constituents)
CO-2. determine the design and processing strategy of a composite for any given application
CO-3. determine different mechanical properties of composites
CO-4. test and characterize different composites based on standard and codes
CO-5: explain various applications of composites

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	1	2	1	1	1	1	1	1	1	1	1	2	2	1	1
CO2	3	3	2	2	1	1	2	1	1	1	1	1	1	2	2	1	1
CO3	3	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
CO4	2	2	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1
CO5	3	3	2	2	1	1	2	1	1	1	1	1	1	2	2	1	1

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed Syllabus:

Unit 1: General introduction to composites; Basic definitions and classification of composites (both based on reinforcements and matrices); Function/role of the constituents of composites; selection criteria of the constituents;

Unit 2: Designing and processing composites;

Unit 3: Micro- and macro- mechanics of composites; mechanical properties (fracture, fatigue, creep etc.,) of composites;

Unit 4: Characterization and testing of composites;

Unit 5: Unconventional composites; Applications;

Suggested Books:

1. Composite Materials: Production, Properties, Testing and Applications”, K. Srinivasan.
2. Composite Materials: An Introduction, R. P. L. Nijssen.
3. Composite Materials: Science and Engineering, K. Chawla.

Subject Code: **MT498**
Title of the Course: **Project Part-I**
L-T-P: 0-0-12 Credits: 12
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters

After completion of this subject successfully, the students will be able to:

CO-1: explain the problem definition of the project assigned
CO-2: design and explain the experiments and/or theoretical work to be carried out
CO-3: explain about the resources required to conduct the project work
CO-4: demonstrate a part of project work done, if any

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	3	3	2	2	2	2	2	2	2	3	3	3	3
CO2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
CO3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
CO4	3	3	3	3	3	3	2	2	2	2	2	2	2	3	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

A problem will be given and explained by the supervisor;
Experimental and/or theoretical plan shall be given by the supervisor;
Continuous guidance till the end of the project shall be given by the supervisor;

Subject Code: **MT496**
Title of the Course: **Project Seminar-I**
L-T-P: 0-0-8 Credits: 8
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters and seminar subject during the 2nd semester of the course

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills to prepare scientific/technical presentation on the project assigned
CO-2: demonstrate skills in orally delivering scientific/technical presentation on the project assigned
CO-3: demonstrate skills in answering logical questions related to the project assigned
CO-4: demonstrate skills in answering scientific/technical questions related to the project assigned

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO3	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

Continuous guidance till the end of the project shall be given by the supervisor;

Subject Code: **MT499**
Title of the Course: **Project Part-II**
L-T-P: 0-0-12 Credits: 12
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills in systematically carrying out the experiments and/or theoretical work in order to find out specific and/or generic solutions to the problem given
CO-2: demonstrate skills to optimally utilize the resources and finish the project in specified time frame
CO-3: analyze critically the obtained results
CO-4: demonstrate skills to give both specific and generic conclusions

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	3	3	3	3	2	2	2	2	2	2	2	3	3	3	3
CO2	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2	2	2
CO3	3	3	3	3	3	3	2	2	2	2	2	2	2	2	2	2	2
CO4	3	3	3	3	3	3	2	2	2	2	2	2	2	3	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:

Continuous guidance till the end of the project shall be given by the supervisor;

Subject Code: **MT497**
Title of the Course: **Project Seminar-II**
L-T-P: 0-0-8 Credits: 8
Prerequisite Course/Knowledge (If any): Theoretical and practical knowledge gained from the 1st two semesters and seminar subject during the 2nd semester of the course

After completion of this subject successfully, the students will be able to:

CO-1: demonstrate skills to prepare scientific/technical presentation on the project assigned
CO-2: demonstrate skills in orally delivering scientific/technical presentation on the project assigned
CO-3: demonstrate skills in answering logical questions related to the project assigned
CO-4: demonstrate skills in answering scientific/technical questions related to the project assigned

Mapping of COs with POs and PSOs

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PO13	PSO1	PSO2	PSO3	PSO4
CO1	3	3	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO2	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO3	2	2	2	2	2	2	2	2	2	2	2	1	1	2	2	2	2
CO4	3	3	3	3	2	2	2	2	2	2	2	1	1	2	2	2	2

‘3’–‘high-level’ mapping; ‘2’–‘Medium-level’ mapping; ‘1’–‘Low-level’ mapping;

Detailed syllabus:
Continuous guidance till the end of the project shall be given by the supervisor;