

Revised Course / Curriculum / Syllabus in compliance of NEP-2020 (M. Tech.)

M. Tech. in Materials Science and Engineering

Program Learning Objectives:	Program Learning Outcomes:
Program Goal 1: To equip graduates with a comprehensive understanding of the fundamental principles of materials science and engineering, encompassing the relationships between processing, microstructure, properties, and performance of materials.	Program Learning Outcome 1a: At the end of M. Tech program students will be able to apply fundamental principles of materials science and engineering to understand the relationships between processing, microstructure, properties, and performance of various materials. Program Learning Outcome 1b: Students will be able to analyze the structure, properties, and behaviour of different material classes, including metals, ceramics, polymers and composites.
Program Goal 2: To foster the ability to apply scientific and engineering knowledge to design, develop, characterize, and optimize novel materials for diverse applications.	Program Learning Outcome 2: Utilize advanced processing techniques to synthesize and manipulate materials at different scales (macro, micro, and nano). Students will be able to characterize and refine innovative materials for a variety of uses.
Program Goal 3: Demonstrate a deep understanding of the structure, properties, and behaviour of various material classes, including metals, ceramics, polymers, and composites.	Program Learning Outcome 3a: To cultivate critical thinking, problem-solving, and analytical skills to address complex challenges in materials research and development. Program Learning Outcome 3b: Apply fundamental scientific and engineering principles to design and develop materials with tailored properties for specific applications.
Program Goal 4: To gain knowledge of advanced materials concepts, such as nanomaterials, functional materials, and smart materials, and the latest research trends in materials science and engineering.	Program Learning Outcome 4: Graduates will demonstrate professionalism, adhere to ethical principles in research and development activities, and contribute to sustainable development through responsible material design and utilization. Acquire expertise in cutting-edge materials concepts like nanomaterials, functional materials, and smart materials, and to stay abreast of the latest developments in materials science and engineering research.

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	MM5101	Thermodynamics and Phase Transformation	3	1	0	4
3.	MM5102	Concepts in Materials Science	3	0	0	3
4.	MM5103	Mechanical Behavior of Materials	3	0	2	4
5.	MM5104	Nano-structured Materials	3	0	0	3
6.	MM61XX	DE-I	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
TOTAL			19	3	4	24

IDE (Inter Disciplinary electives) in the curriculum aims to create multitasking professionals/scientists with learning opportunities for students across disciplines/apptitude of their choice by opting level (5 or 6) electives, as appropriate, listed in the approved curriculum.

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	MM5201	Advanced Polymer Technology	3	0	2	4
2.	MM5202	Advanced Engineering Materials	3	0	2	4
3.	MM62XX	DE-II	3	0	0	3
4.	MM62XX	DE-III	3	0	0	3
5.	MM62XX	DE-IV	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
TOTAL			21	1	4	24

Sl. No.	Subject Code	SEMESTER III	L	T	P	C
1.	MM6198	Summer Internship/ Mini Project*	0	0	12	3
2.	MM6199	Project I**	0	0	30	15
TOTAL			0	0	42	18

***Note: Summer Internship (Credit based)**

(i) Summer internship (*) period of at least 60 days' (8 weeks) duration begins in the intervening summer vacation between Semester II and III. It may be pursued in industry / R&D / Academic Institutions including IIT Patna. The evaluation would comprise **combined grading based on host supervisor evaluation, project internship report after plagiarism check and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the three components stated herein.

(ii) Further, on return from 60 days internship, students will be evaluated for internship work through combined grading based on host supervisor evaluation, project internship report after plagiarism check, and presentation evaluation by the parent department with equal weightage of each component.

**** Note: M. Tech. Project outside the Institute:** A project-based internship may be permitted in industries/academia (outside IITP) in 3rd or 4th semester in accordance with academic regulations. In the IIIrd Semester, students can opt for a semester long M. Tech. project subject to confirmation from an Institution of repute for research project, on the

assigned topic at any external Institution (Industry / R&D lab / Academic Institutions) based on recommendation of the DAPC provided:

(i.) The project topic is well defined in objective, methodology and expected outcome through an abstract and statement of the student pertaining to expertise with the proposed supervisor of the host institution and consent of the faculty member from the concerned department at IIT Patna as joint supervisor.

(ii.) The consent of both the supervisors (external and institutional) on project topic is obtained a priori and forwarded to the academic section through DAPC for approval by the competent authority for office record in the personal file of the candidate.

(iii.) Confidentiality and Non Disclosure Agreement (NDA) between the two organizations with clarity on intellectual property rights (IPR) must be executed prior to initiating the semester long project assignment and committing the same to external organization and vice versa.

(iv.) The evaluation in each semester at Institute would be mandatory and the report from Industry Supervisor will be given due weightage as defined in the Academic Regulation. Further, the final assessment of the project work on completion will be done with equal weightage for assessment of the host and Institute supervisors, project report after **plagiarism check**. The award of grade would comprise **combined assessment based on host supervisor evaluation, project report quality and seminar presentation at the Department (DAPC to coordinate)** with equal weightage of each of the components stated herein.

(v.) In case of poor progress of work and / or no contribution from external supervisor, the student need to revert back to the Institute essentially to fulfill the completion of M. Tech. project as envisaged at the time of project allotment. However, the recommendation of DAPC based on progress report and presentation would be mandatory for a final decision by the competent authority.

Sl. No.	Subject Code	SEMESTER IV	L	T	P	C
1.	MM6299	Project II	0	0	42	21
		TOTAL	0	0	42	21

Total Credits – 87

ELECTIVE GROUPS

Department Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6101	Processing technology of Metal, Ceramic and Composites	3	0	0	3
2.	MM6102	Surface Engineering	3	0	0	3
3.	MM6103	Nanomaterials: Structure, Property and Applications	3	0	0	3
4.	MM6104	Field-assisted Sintering Techniques	3	0	0	3

Department Elective - II						
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Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6201	Defects and Diffusion in Materials	3	0	0	3
2.	MM6202	Polymer Matrix Composite	3	0	0	3
3.	MM6203	Functional Ceramics	3	0	0	3

Department Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6204	Materials Characterization Techniques	3	0	0	3
2.	MM6205	Selection of Alloys and Heat Treatment	3	0	0	3
3.	MM6206	Thin films - An Engineering Approach	3	0	0	3
4.	MM6207	Joining of Materials	3	0	0	3

Department Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6208	Crystal Symmetry and Tensor properties	3	0	0	3
2.	MM6209	Coating Technology	3	0	0	3
3.	MM6210	Fabrication of Solid-state Devices	3	0	0	3

Interdisciplinary Elective (IDE) Course for M. Tech. (Available to students other than MME)

IDE						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6105	Structural Characterization of Materials	3	0	0	3
2.	MM6106	Composite Science and Technology	3	0	0	3

Sl. No.	Subject Code	SEMESTER I	L	T	P	C
1.	HS5111	Technical Writing and Soft Skill	1	2	2	4
2.	MM5101	Thermodynamics and Phase Transformation	3	1	0	4
3.	MM5102	Concepts in Materials Science	3	0	0	3
4.	MM5103	Mechanical Behavior of Materials	3	0	2	4
5.	MM5104	Nano-structured Materials	3	0	0	3
6.	MM61XX	DE-I	3	0	0	3
7.	XX61PQ	IDE	3	0	0	3
	TOTAL		19	3	4	24

Course Number	MM5101
Course Credit (L-T-P-C)	3-1-0 (4 AIU credits)
Course Title	Thermodynamics and Phase Transformation
Learning Mode	Lecture and Tutorial
Prerequisite	None
Learning Objectives	To understand the laws of thermodynamics and their application to materials science. To learn the phase diagram and Ellingham diagram of materials. To apply the thermodynamics for engineering problem solving.
Course Description	This course explores the fundamental principles governing energy transfer and the behaviour of materials.
Course Content	Thermodynamics basic concepts (state variables, the first law, the enthalpy concept, heat capacity) The second law (reversible and irreversible processes, entropy, Gibbs energy, Helmholtz energy, Gibbs-Duhems equation, Maxwell's relationships) Equilibrium conditions (chemical potential, driving force, the third law, Clausius-Clapeyrons equations, P-T diagram, Ellingham diagrams Thermodynamics of solutions, construction and interpretation of two component phase diagrams, Gibbs's Phase rule, Interpretation of mass fractions using Lever's rule, Hume Rothery rules, Binary Isomorphous, Eutectic alloy, Peritectic alloy system, Invariant reactions, Iron-Iron carbide phase diagram, ceramic phase diagram, ternary phase diagram, phase separation, spinodal decomposition, Thermodynamics and kinetics of Nucleation and growth, JMAK equation. Temperature-Time-Transformation (TTT) and Continuous Cooling Transformation (CCT) Diagrams.
Learning Outcome	Upon completion of this course, the student will be able to: Understand the laws of thermodynamics. Understand the importance of phase diagram and Ellingham diagram in the materials processing. Apply thermodynamics for solving numerous engineering problems.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to the Thermodynamics of Materials, David R. Gaskell, 5th ed., CRC Press, 2008.
2. Phase Transformations in Metals and Alloys, Porter, Easterling; 3rd ed, CRC Press, 1991.

Reference Books:

1. Thermodynamics in Materials Science, Robert DeHoff; 2nd ed, 2006.
2. Physical chemistry of metals, Lawrence S. Darken, Robert W. Gurry, McGraw-Hill, 1953
3. Phase transformation in materials, A. K. Jena, M. C. Chaturvedi, Prentice-Hall, Englewood Cliffs, New Jersey, 1992

	CLO1	CLO2
PLO1		
PLO2		
PLO3		
PLO4		

Course Number	MM5102
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Concepts in Materials Science
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To provide a foundational understanding of structure of materials at different length scales. To understand material's properties and behaviors and how they are influenced by the structure.
Course Description	This course offers an in-depth overview of the fundamentals of materials science, emphasizing the relationships among the structure, properties, and performance of various materials. Students will explore key topics including polymers, ceramics, composites, atomic bonding, crystal structures, phase diagrams, and mechanical properties.
Course Content	Atomic structure: Review of atomic structure, electronic configuration, Characteristic quantum numbers. Electronic distribution in solids, Density of energy states and Fermi energy, band theory of solids. Bonding in solids: Primary and secondary bonding in solids, bond strength and bond energy. Properties of differently bonded solids. Molecular orbital theory. Basic crystallography: crystalline and amorphous materials. Packing of atoms, coordination number, unit cell, Bravais lattice, simple crystal structures. Crystal symmetry, Miller indices. defects in solids. Quasi crystals, amorphous materials. Order and disorder in solids, Defects and impurities. Solid Solutions, Hume Rothery Rules. Classification of materials: engineering materials and their classification, metallic materials, ceramic materials and polymeric materials. Composite materials. Microstructure-property correlation in materials. Materials selection and design: General principles of materials selection and design based on requirements of function and property. Introduction to materials selection charts, Ashby maps, materials performance index, processability and cost. Case studies: (i) Applications of advanced metallic materials in aerospace, automotive, and energy sectors. (ii) Applications of ceramics in electronics, wear resistance, and high-temperature environments.
Learning Outcome	On completion of the course the students will be able to Differentiate between different types of materials and their structures. Understand the structure dependence of properties and design materials for various engineering applications.

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Book:

1. Materials Science and Engineering, an Introduction: William D. Callister, 7th Ed., John Wiley and Sons, 2007
2. Materials Science and Engineering: V. Raghavan, 6th Ed., Prentice Hall India, 2015.

	CLO1	CLO2
PLO1	X	
PLO2	X	
PLO3		

Course Number	MM5103
Course Credit (L-T-P-C)	3-0-2 (4 AIU credits)
Course Title	Mechanical Behavior of Materials
Learning Mode	Lecture and Practical
Prerequisite	
Learning Objectives	To understand how the strength of metals and alloys can be altered. To identify the properties of metals, ceramics, and polymers and their failure mechanisms against a mode of stress applied. To understand the behaviour of the different material systems during their service in terms of fatigue, fracture, and creep.
Course Description	The course explores the mechanical behavior of materials, focusing on stress-strain relationships, various properties, fracture mechanics, fatigue, and the behaviors of ceramics and polymers.
Course Content	Theory Syllabus Elastic modulus – Stress-strain curves - Tensile test of ductile material – properties evaluation, Hardness measurement tests – Plasticity, yield strength, yield criteria, theory of dislocation, dislocation mechanisms, strengthening mechanisms in metals Creep and high-temperature deformation Fracture of materials – Mechanisms of Ductile and Brittle fracture; fracture toughness, Impact testing Fatigue – Endurance limit – Fatigue test, crack growth Fracture behaviour of ceramic materials, The Weibull distribution, Toughening mechanism, and R curve behaviour Mechanical behaviour of polymer and soft matter, Viscoelastic behaviour with models Lab Syllabus Tensile/compression test: Introduction to the Universal Testing Machine (UTM) for conducting tensile and compression tests on materials such as aluminum, copper, steel, and polymers. Plotting engineering and true stress-strain curves and calculating tensile properties like yield strength, ultimate tensile strength, elongation, and modulus of elasticity, as well as examining the effects of strain rate and strain rate sensitivity. Hardness testing: Encompasses micro and macro-hardness methods for metals, alloys, ceramics, and polymers, including fracture toughness, nanoindentation, and the determination of elastic modulus and ductility. Non-destructive testing methods: Liquid Penetrant Testing (LPT), Eddy Current Testing (ECT), Magnetic Particle Inspection (MPI), Ultrasonic Testing (UT), and Radiographic Testing (RT).
Learning Outcome	Upon completion of this course, the student will be able to: Understand the limiting values of loads that a component can withstand without failure. Optimize the stress applied for mechanical applications of different materials. Classify and distinguish different types of mechanical properties and correlate the same with relevant industrial applications.

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.
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Text Books:

2. Mechanical Behaviour of Materials, Thomas H. Courtney; 2nd (ed.), Waveland press Inc., 2000
3. Mechanical Metallurgy, George E. Dieter; MCGRAW-HILL Publications, 1998.

Reference Books:

1. Fatigue of Materials, S. Suresh; 2nd (ed.), Cambridge University Press, 2003.
2. Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg, Richard P. Vinci, Jason L. Hertzberg; Wiley, 2012.

	CLO1	CLO2
PLO1	X	
PLO2	X	
PLO3	X	

Course Number	MM5104
Course Credit (L-T-P-C)	3-0-0 (6 AIU credits)
Course Title	Nano-structured Materials
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the nature and magnitude of the changes in behaviour and properties of nanomaterials. To correlate and decode the underlined reasons due to which such changes in properties are observed at reduced length scales. To learn about different crystallization pathways in nanocrystals and their implications on final properties.
Course Description	This course provides general aspects on the synthesis, nucleation, growth, thermodynamics, properties and applications of a wide variety nanomaterials.
Course Content	Classification: Nanocrystals, thin films & coatings, definitions, Effect on properties and phase stability in lower dimension compared to the bulk state, Materials at Reduced Dimensions: Two-dimensional nanostructures – surfaces and films, One-dimensional nanostructures – nanotubes and wires, Zero dimensional nanostructures – fullerenes, nanoparticles, nanoporous materials, Nanoclays, Graphene, polyhedral oligomeric silsesquioxane (POSS) nanoparticles, Colloidal Monodisperse Nanocrystals, nanocrystals of ferrite, oxide and chalcogenides, core-shell nanoparticles, micelle assisted nanoparticles, surfactant coated nanoparticles, microemulsion synthesis, self-assembly routes, Inorganic-organic hybrid materials, hydrophobic and hydrophilic nanoparticles, water-dispersable nanoparticles. Preparation: Synthesis routes, Sol-gel technique, Nonaqueous Sol–gel route for Metal Oxide nanoparticles, hydrothermal synthesis, co-precipitation, preparation of nanocomposites, Properties and applications at the nanoscale: Electrical, Mechanical, Magnetic, (Electro)Chemical, Optical, Thermal and thermoelectric properties, Health and regulatory issues with Nanomaterials
Learning Outcome	Upon completing of this course, the student will be able to Identify the reasons behind new novel properties emerging at nanoscale for different classes of materials. Classification of properties at different length scales along with their possible market applications. Distinguish between different synthesis and crystallization pathways in nanomaterials and their correlation with the observed novel properties.

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.
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Text Book:

1. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, 2nd ed., Guozhong Cao, Ying Wang; Imperial College Press, 2004.
2. Nanoparticles: From Theory to Application, Günter Schmid, Wiley, 2005.
3. Synthesis, Properties, and Applications of Oxide Nanomaterials, José A. Rodriguez, Marcos Fernández-García, Wiley, 2007
4. Monodispersed Particles, T. Sugimoto, Elsevier.
5. Characterization of Nanophase Materials, Zhong Lin Wang, Wiley
6. Nanomaterials, Nanotechnologies and design: an introduction for engineering and architects, Michael Ashby and Paulo J. Ferreira; Elsevier, 2009.

Reference Books:

1. Nanoscale Materials in Chemistry, Kenneth J. Klabunde, Ryan M. Richards, 2nd Edition, Wiley, 2009
2. Nanoparticulate Materials: Synthesis, Characterization, and Processing, Kathy Lu, Wiley.
3. Nanostructured Materials (Processing, Properties and Applications), Carl C. Koch, Elsevier, 2006
4. Nanoparticles and Nanostructured Films: Preparation, Characterization, and Applications, Janos H. Fendler, Wiley, 2008 Nanostructured Materials and Nanotechnology, Hari Singh Nalwa (ed.); Elsevier, 2001.

	CLO1	CLO2
PLO1		X
PLO2		X
PLO3		
PLO4	X	

Department Elective - I						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6101	Processing technology of Metal, Ceramic and Composites	3	0	0	3
2.	MM6102	Surface Engineering	3	0	0	3
3.	MM6103	Nanomaterials: Structure, Property and Applications	3	0	0	3
4.	MM6104	Field-assisted Sintering Techniques	3	0	0	3

Course Number	MM6101
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Processing technology of metal, ceramic and composites
Learning Mode	Lecture
Prerequisite	
Learning Objectives	To introduce students to the different processing technology. To understand the connection between material properties and characteristics with the processing technologies involved.
Course Description	The course covers metal forming processes, solidification, and ceramic processing, focusing on microstructure development and material applications in engineering.
Course Content	Metal Forming: Introduction to rolling, forging, extrusion, drawing and its engineering aspects, Development of microstructures with different processing technologies and its effects on forging, extrusion, rolling, and drawing on metallic alloy components. Effect of alloying additions. Solidification: Thermodynamics of solidification, Nucleation and growth, Pure metal solidification, Gibbs Thomson effect, Alloy Solidification, Constitutional undercooling, Dendritic growth, Casting Pattern and Mould, Melting and Pouring, Heat transfer, Design of riser and gating Ceramic Processing: Overview of different ceramic processing techniques, Colloidal processing of ceramics, DLVO theory, porous ceramics and ceramic fibres, Co-precipitation method, Sol-Gel process, technology for ceramic powder preparations, solid state reactions, science of sintering, Types of sintering, sintering mechanisms, products for engineering applications, powder metallurgy
Learning Outcome	Upon completion of this course, the student will be able to: Will gain knowledge in metal processing, ceramic processing, and polymer processing. Understand the challenges involved in the processing of different materials.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Recommended text books:

1. Hosford, W. F., and Cadell, R. M., 2007, Metal Forming: Mechanics and Metallurgy, Cambride University Press, Cambridge.
2. George Dieter, 1986, Mechanical Metallurgy, Mc-Graw Hill
3. Solidification Processing; Fleming, M.C., McGraw-Hill, N.Y., 1974
4. Science and Engineering of Casting Solidification; Stefanescu, D.M., Kluwar Publications, 2002
5. Ceramic Materials: Science and Engineering, C. Barry Carter, M. Grant Norton; Springer, 2nd ed. 2013.
6. Fundamentals of Ceramics, M.W Barsoum; McGraw Hill, 1997.
7. Introduction to Ceramics, 2nd Ed, W. David Kingery, H. K. Bowen, Donald R. Uhlmann, Wiley, 1976.

	CLO1	CLO2
PLO1		
PLO2		X
PLO3	X	X
PLO4		

Course Number	MM6102
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Surface Engineering
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To make them understand the significance of surfaces and bulk property. To familiarize the students with a different kind of degradation of surfaces such as wear, corrosion. To impart knowledge on different types of coatings techniques and their characterizations.
Course Description	To make them understand the significance of surfaces and bulk property. To familiarize the students with a different kind of degradation of surfaces such as wear, corrosion. To impart knowledge on different types of coatings techniques and their characterizations.
Course Content	Syllabus Introduction: Introduction to surface Engineering, Differences between surface and bulk, Properties of surfaces, surface energy concepts Modification of surface: Changing the surface metallurgy: Localized surface hardening (flame, induction, laser, electron-beam hardening, Laser melting, shot peening), Changing the surface chemistry: Phosphating, Chromating, Anodizing (electrochemical conversion coating), Carburizing, Nitriding, Ion implantation, Laser alloying, boriding, Organic coatings (paints and polymeric or elastomeric coatings and linings), Hot-dip galvanizing (zinc coatings), Ceramic coatings (glass linings, cement linings, and porcelain enamels), Advanced surface coating methods: Gaseous State (CVD, PVD etc), Solution State (Chemical solution deposition, Electrochemical deposition, Sol gel, electroplating), Molten or semimolten State (Laser cladding and Thermal spraying) Characterization of surface and coatings: Surface Characterization (physical and chemical methods, XPS, AES, RAMAN, FTIR etc), Structural Characterization, Mechanical Characterization (Adhesion, Hardness, Elastic Properties, Toughness, Scratch and Indentation etc.), Tribological Characterization, Corrosion tests. Applications of the altered surface: Degradation of surfaces, wear and its type, Adhesive, Abrasive, Fretting, Erosion wear, Surface fatigue, Different types of Corrosion and its prevention, Galvanic corrosion, Passivation, Pitting, Crevice, Microbial, High-temperature corrosion, Corrosion in nonmetals, polymers and glasses, Protection from corrosion through surface modifications, bio mimicking.
Learning Outcome	Upon completion of this course, the student will be able to:

	Students understand the differences between the surface and bulk property. Students acquire fundamental knowledge about the different kind of degradation mechanism. Students will have the better clarity on the thin film and thick coating techniques as well as its characterization techniques.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to Surface Engineering and Functionally Engineered Materials, Peter Martin; Wiley, 2011.
2. Materials and Surface Engineering: Research and Development, J. Paulo Davim; Woodhead Publishing review, 2012.

Reference Books:

1. Surface Engineering: Processes and Applications, Chinnia Subramanian, K.N. Strafford, R. St. Smart, I.R. Sare; Technomic Publishing Company, 1995.
2. Surface Engineering for Corrosion and Wear Resistance, J. R. Davis; ASM International, 2001.

	CLO1	CLO2
PLO1	X	
PLO2		
PLO3		

Course Number	MM6103
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Nanomaterials: Structure, Property and Applications
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To comprehend how materials' behavior and properties change when examined at smaller scales. To establish connections and decipher the underlying reasons for the observed changes in properties as length scales decrease. To understand various crystallization pathways in nanocrystals and their impact on final properties.
Course Description	The course is designed for post graduate students to provide holistic understanding of nanomaterials from synthesis to application and future challenges.
Course Content	Nanomaterials: Definition, history, and brief background, Synthesis: Top-down and bottom-up techniques, Hybrid assembly of nanomaterials, micelle, surfactant, self-assembly, nanopatterning, surfactant assisted growth in nanocrystals. Thermodynamics at nanoscale: Size effects on equilibrium vapor pressure, surface energy, Young-Laplace equation, Kelvin equation, Size Dependent Physical Properties in nanomaterials: melting point, sintering temperature, shape dependence on melting, size-dependent phase transformations at nanoscale, Surface properties of nanomaterials, surface energy for solids, broken bond theory, calculations of surface energy involving cubic structures, Wulff construction. Nucleation and growth of Nanocrystals: different types, growth of nanocrystals via diffusion and surface process, contribution of surface energy on free energy for nanomaterials, size effects in nucleation, Ostwald ripening, Burst nucleation in nanomaterials, Classical (La Mer theory) and Non-classical crystallization, Oriented attachment in nanocrystals, Mesocrystallisation. Size dependent Properties at nanoscale and their application: Chemical, Mechanical, Adhesion, Electrical, Magnetic, Optical, Applications of nanomaterials, shape memory polymer, Nanomaterials in Nature (Nacre, Gecko, Teeth), Biomimetic nanocomposites, Hydrogel, Nanotechnology in marketplace, ferro-fluids, Biomedical applications etc.
Learning Outcome	Upon completing this course, the student will be able to Able to investigate the origins of novel properties emerging at the nanoscale across different material classes. Understand the categorization of properties depending on the length scales. Understand the crystallization pathways in nanomaterials and their correlation with the observed novel properties.

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.
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Text Book:

1. Nanoparticles: From Theory to Application, Günter Schmid (Editor), ISBN: 978-3-527-60404-3, 2006
2. Nanoparticles: From Theory to Application, Günter Schmid, Wiley, 2005. Synthesis, Properties, and Applications of Oxide Nanomaterials, José A. Rodriguez, Marcos Fernández-García, Wiley, 2007
3. Monodispersed Particles, T. Sugimoto, Elsevier.
4. Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, 2nd ed., Guozhong Cao, Ying Wang; Imperial College Press, 2004.

Reference Books:

1. The Chemistry of Nanomaterials: Synthesis, Properties and Applications, Editors: C. N. R. Rao, Achim Müller, Anthony K. Cheetham, ISBN: 978-3-527-30686-2, March 2004
2. Nanoscale Materials in Chemistry, Kenneth J. Klabunde, Ryan M. Richards, 2nd Edition, Wiley, 2009
3. Nanostructured Materials (Processing, Properties and Applications), Carl C. Koch, Elsevier, 2006
4. Nanoparticles and Nanostructured Films: Preparation, Characterization, and Applications, Janos H. Fendler, Wiley, 2008

	CLO1	CLO2
PLO1		
PLO2	X	X
PLO3		
PLO4	X	X

Course Number	MM6104
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Field-assisted Sintering Techniques
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the influence of electric field on the sintering behavior of materials. To understand the technology and theoretical concepts of major field-assisted sintering techniques. To understand the relation between processing parameters and properties of sintered materials.
Course Description	This course provides a comprehensive overview of various field-assisted powder consolidation methods covering the interplay of thermal and athermal factors driving mass transport.
Course Content	Introduction: Historical overview of field-assisted powder consolidation methods. Categorization of field-assisted sintering technologies. Underlying physical mechanism: Thermal and athermal factors influencing mass transport Spark plasma sintering: Characteristic features, sintering equipment. Issue of spark and plasma in SPS. Effect of heating rate and applied pressure, sinter-forging. Temperature gradients and temperature measurements, electromigration Flash sintering: Characteristic features of flash sintering, experimental setup. Influence of electrical parameters on densification. Power dissipation in samples, temperature measurements and luminescence. Mechanism of flash sintering. Reactive flash sintering. Microwave sintering: Principles and mechanism of microwave heating and sintering, effective medium approximation, influence of ponderomotive forces. Microwave non-thermal effects. Other field assisted sintering techniques: Magnetic pulse compaction, resistance sintering, sintering in noncontact mode and sintering in a magnetic field. Electromagnetic radiation (IR, visible and UV) for sintering, Laser assisted sintering.
Learning Outcome	Upon completion of this course the student will be able to: Understand how electric field can affect the sintering of materials. Understand the fundamental principle, hardware and applications of various field-assisted sintering techniques. Correlate the lower processing temperature and/or sintering time to obtain unique properties in materials compared to conventional sintering techniques .
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Textbook:

1. Field-Assisted Sintering: Science and Applications, Eugene A Olevsky and Dina V Dudina, Springer, 2018.
2. Spark Plasma Sintering Current Status, New Developments and Challenges, Giacomo Cao, Claude Estournes, Javier Garay, Roberto Orru. 1st Ed., Elsevier, 2019.

Reference book:

1. Review articles on various field assisted sintering techniques

	CLO1	CLO2
PLO1	X	X
PLO2	X	
PLO3		
PLO4	X	X

Sl. No.	Subject Code	SEMESTER II	L	T	P	C
1.	MM5201	Advanced Polymer Technology	3	0	2	4
2.	MM5202	Advanced Engineering Materials	3	0	2	4
3.	MM62XX	DE-II	3	0	0	3
4.	MM62XX	DE-III	3	0	0	3
5.	MM62XX	DE-IV	3	0	0	3
6.	RM6201	Research Methodology	3	1	0	4
7.	IK6201	IKS	3	0	0	3
	TOTAL		21	1	4	24

Course Number	MM5201
Course Credit (L-T-P-C)	3-0-2 (4 AIU credits)
Course Title	Advanced Polymer Technology
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To explain the basic and advanced concepts of macromolecules. To gain knowledge of the mechanics underlying various polymerization techniques and polymer reactions. To disseminate information on the variables controlling the physical characteristics of polymers. To gain knowledge about the processing of different polymers
Course Description	The course aims to provide an integrated advanced view of polymer science and technology, including synthesis of polymers, testing / characterization of polymers, processing of polymers and structure-property relationship in polymers. This course will also cover essential details about the different classes of polymers such as commodity polymers, industrial polymers and smart polymers.
Course Content	Introduction Basic definitions, molecular weight, degree of polymerization, polymerization and functionality, copolymers, molecular architecture and classification of polymers Polymerization Step growth polymerization, free radical polymerization, copolymerization, dispersion and emulsion polymerization and ionic and coordination polymerization, metathesis polymerization, controlled polymerization methods, viz, NMD, ATRP, GTP, and RAFT Characterization Polymer solutions, molecular weight and size measurements, polymer testing and analysis, and polymer crystallinity Structure and properties Polymer structure and morphology, rheological characteristics, viscoelastic characteristics, mechanical characteristics, and polymer structure and physical properties. Industrial polymers Thermosetting polymers, heterochain thermoplastics, hydrocarbon polymers, and other carbon-chain polymers Smart polymers Explanation of smart polymers with physical shapes, pH sensitive polymers, magnetic field sensitive polymers and ionic intensity sensitive polymers Polymer processing Mixing and compounding, molding, calendaring, spinning, coating and extrusion processes

	Lab Syllabus Polymer processing: injection, compression, and extrusion molding of polymer. Impact of fillers and additives. Effect of processing conditions, 3D printing of selected designs in polymer. Demonstration of basic polymerization techniques
Learning Outcome	Upon completion of this course, the student will be able to: Recognize how polymers' structures and properties relate to one another and. Select appropriate polymerization processes for the synthesis of polymer. Select proper characterization techniques for the analysis of the polymers. Select right molding techniques for the processing of polymers.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text books:

1. F.W. Billmeyer, "Textbook of Polymer Science", Wiley international publishers, 1984.
2. Alfred Rudin, "The Elements of Polymer Science and Engineering", Academic Press, 1999.

Reference books:

1. Premamoy Ghosh, "Polymer Science and Technology of Plastics and Rubbers", Tata McGraw - Hill, New Delhi, 1990.
2. V. R. Gowariker, N. V. Viswanathan, Jayadev Sreedhar, "Polymer Science", New age international publishers, 2015.
3. R.J. Young and P. Lovell, "Introduction to Polymers", 2nd Ed., Chapman & Hall, 1991.
4. George Odian, "Principles of Polymerization", 4th Edition., A John Wiley & Sons, Inc., Publication, 2004.
5. J A Brydson, "Plastics Materials", 7th Edition, Elsevier, 1999.
6. Joel R. Fried, "Polymer Science and Technology", Prentice Hall, NJ, 1995.

	CLO1	CLO2
PLO1		
PLO2		
PLO3	X	

Course Number	MM5202
Course Credit (L-T-P-C)	3-0-2 (4 AIU credits)
Course Title	Advanced Engineering Materials
Learning Mode	Lecture and Practical
Prerequisite	None
Learning Objectives	To introduce the basic concepts of different categories of engineering materials that are being used in day-to-day life. To develop an understanding of electronic materials, engineering ceramics, and metals. To develop an understanding of the properties of engineering materials and characterize different engineering materials.
Course Description	The course deals with the important engineering materials that find applications in our day-to-day life and the niche applications. The application includes electronic gadgets components, structural materials and tools, etc
Course Content	Electronic materials: structure of semiconductors and insulators, Diamond structure, packing fraction, nature of bonding, allotropes of carbon, the structure of graphite, characterization of diamond, graphite, and graphene via Raman spectroscopy, Zinc blende/sphalerite structure, examples of II-VI, III-V, and IV-IV group semiconductors, the concept of the band gap, direct, indirect semiconductors, Applications of Semiconductors Engineering ceramics: crystal structure and polymorphism Al_2O_3, the concept of hexagonal close packing, c/a ratio, the structure of fully and partially stabilized zirconia structures and polymorphs, transformation toughening, theories behind zirconia stabilization, Basics of Perovskite BaTiO_3 and PZT structure, Goldschmidt tolerance factor, Applications of BaTiO_3 and PZT in functional devices Abrasives & cutting tools: crystal structure of abrasives like silicon carbide, tungsten carbide, diamond and boron nitride, structure-property correlations, origin of high hardness, bulk modulus, Steel and superalloy: Structure of Metals (Al, Cu, Zn, Fe, etc), key phases in Iron-Carbon phase diagram and their crystal structures, martensite, close-packed metallic structures, Application & behaviour of crystalline metals in rolling, stretching, heat treatment, Development of superalloys, uses and properties, Alloy composition and crystal structure, Origins of strength Smart materials: Piezoceramic actuators, Magnetostriction, magnetostrictive materials, Shape memory effect (SME), alloys with SME, Mechanical and thermal characterization of shape memory alloys Lab Syllabus Practical aspects of X-ray diffraction analysis will be emphasized; hands-on experience in qualitative and quantitative analysis techniques, use of electronic databases, and phase analysis using XRD data. Thermal properties of materials, identification of materials based on their TG, DSC, and DMA characteristic responses.

	Hands-on experience in the applications of metallography and optical microscopy, phase analysis using microscopic information, hands-on experience in the area of microstructures of metal, ceramic, and polymer materials using optical microscopy and SEM. Standard laboratory practices including safety, report writing, and error analysis are also emphasized.
Learning Outcome	Upon completing this course, the student will be able to Understand the structure-property relationship of advanced engineering materials. Will be able to select suitable material for critical industrial application. Will be able to analyze phases, structures and microstructure of different engineering materials.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text books:

1. Electronic Materials: Science and Technology: Shyam P. Murarka, Martin C. Peckerar, Academic Press, 1989.
2. Ceramic Materials: Science and Engineering: C. Barry Carter, M. Norton, Springer, 2nd Ed., 2013.
3. Steels: Structure, Properties, and Design, H.K.D.H. Bhadeshia, R.W.K. Honeycombe, Elsevier
4. Brian Culshaw, Smart Structures and Materials, Artech House, 2000
5. Electronic Materials Science: Eugene A. Irene, Wiley, 2005.

Reference Books:

1. Introduction to Ceramics: W.D. Kingery, H.K. Bowen, D.R. Uhlmann, 2 nd Ed., Wiley, 1976.
2. Introduction to the Electronic Properties of Materials: David C. Jiles, 2nd Ed., CRC Press, 2001.
3. Antonio Concilio, Vincenza Antonucci, Ferdinando Auricchio, Leonardo Lecce, Elio Sacco., Shape memory alloy engineering for aerospace, structural, and bio-medical applications, Second edition, 2021.
4. Structure of Metals: Crystallographic Methods, Principles and Data, 3rd Edition, by C. S. Barrett, T. B. Massalski.
5. Cullity, B. D., & Stock, S. R. (2001). Elements of X-ray Diffraction, Third Edition. Prentice-Hall.
6. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Yang Leng; 2nd ed., Wiley, 2013
7. Scanning Electron Microscopy and X-Ray Microanalysis, Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy and Patrick Echlin; 3rd ed., Springer, 2003

	CLO1	CLO2
PLO1	X	X
PLO2	X	
PLO3		

Department Elective - II						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6201	Defects and Diffusion in Materials	3	0	0	3
2.	MM6202	Polymer Matrix Composite	3	0	0	3
3.	MM6203	Functional Ceramics	3	0	0	3

Course Number	MM6201
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Defects and Diffusion in Materials
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the structure of crystalline materials and defects present at various dimensions in materials and their influence on properties. To understand various methods to control and quantify the amount of defects in various materials. To understand how material transport is fundamental to understand the materials processing including phase transformation.
Course Description	The course deals with understanding defect types, their generation, and interactions during material processing. The focus is on enhancing knowledge, particularly regarding dislocations and the diffusion.
Course Content	Bonding and structure in crystalline solids: Bonding in solids- primary and secondary, unit cells, crystal systems, indexing planes and direction Defects in crystalline materials: Point, linear, planar and volume defects. Equilibrium concentration of vacancies, doping in semiconductors. Point defects in ionic crystals, Frenkel and Schottky defects, Kröger-Vink notation. Edge and screw dislocations, Burger vector. Concept of slip, dislocation structures in fcc and bcc crystal systems. Slip systems, dislocation locks, Kear-Wilsdorf lock, partial dislocations, stacking faults, Orowan looping. Atomic structure and nature of grain boundaries, Energy of grain boundaries. Twin boundaries. Observation of defects. Role of defects on the properties of materials. Diffusion: Atomistic mechanisms of diffusion, substitutional and interstitial diffusion. Fick's first and second law. Diffusion kinetics. Chemical potential gradient – Uphill diffusion, Surface, lattice, grain boundary and pipe diffusion. Kirkendall effect. Tracer diffusion. Case studies: (i) Role of microstructure in transparency of alumina (ii) Electromigration in integrated circuits (iii) Ionic conductivity in cubic zirconia (iv) Carburization and decarburization in steel (v) Role of Kirkendall voids on weld joints
Learning Outcome	At the end of the course, the student will be able to Understand how defects impact numerous properties of materials - from the conductivity of semiconductors to the strength of structural materials. Understand and quantify the equilibrium and non-equilibrium defects that are present in crystals. Correlate diffusion process and kinetics with temperature, concentration and time.

Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.
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Text Book:

1. Introduction to dislocation theory: D. Hull and D.J. Bacon, Butterworth-Heinemann, Elsevier, 2011.
2. Diffusion in Solids: Paul Shewmon, 2nd Ed., Springer, 2016.

Reference Book:

1. Defects in Solids, R. J. D. Tilley, JW Wiley Press, 2008.
2. Fundamentals of Materials Science, the microstructure – property relationship using metals as model systems: Eric J. Mittemeijer, Springer, 2011.
3. Phase Transformation in Metals and Alloys: D.A. Porter, K.E. Easterling and M.Y. Sherif, 3rd Ed., CRC Press, 2009.

	CLO1	CLO2
PLO1	X	X
PLO2		
PLO3		

Course Number	MM6202
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Polymer Matrix Composite
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To educate the knowledge about the fundamentals of polymer composites and structures. To comprehend the manufacturing, properties, and applications of various polymer matrix composites.
Course Description	The course covers the introduction to polymer composites, details of different polymer matrices and reinforcements, processing of polymer composites, testing and characterization of polymer composites, mechanics of polymers composites, structure-property relationship of polymer composites and application of polymer composites.
Course Content	Syllabus: Introduction: Fundamental definitions, classification, and outline of composite materials, together with its constituents (interface, matrix, and reinforcements/fibers) Matrices: Rubber matrices, Thermoplastic matrices, Thermoset matrices–polyesters, epoxides, phenolics, vinyl esters, polyimides and cyanate esters. Fibers: Natural fibers, glass, carbon, kevlar, and surface treatment—sizing and coupling agents, Interfaces: optimal interfacial bond strength, forms of bonding at the interface, wettability, and crystallographic nature of interfaces. Processing: Sheet molding compounds, bulk molding compounds, hand layup process, spray layup process, resin transfer molding, pressure bag molding, vacuum bag molding, autoclave molding, filament winding and pultrusion. Post processing techniques – Electroplating, vacuum metallization, joining, welding, bonding of polymers, hot foil stamping process, in mold decoration and recycling. Mechanics of Composite: Macromechanics of Composites- elastic constants of laminate, elastic constants of an isotropic material, relationship between engineering constants and reduced stiffness and compliances. Micromechanics of Composites- Iso-strain and iso-stress models, Halpin-Tsai equation, longitudinal tensile strength prediction and transverse tensile strength prediction. Failure criteria - maximum strain theory, maximum stress theory, and Tsai-Wu failure criteria. Testing of Composite: Degree of cure, viscosity, gel time, void content, density, shrinkage, flexural, shear, fatigue, tensile, compression, creep and impact properties. Non-destructive testing – Ultrasonic, acoustography, radiography, shearography, acoustic emission/ultrasonics, thermography, X-rays, tap test and visual test.

Learning Outcome	Upon completion of this course, the student will be able to: Choose the suitable materials to fabricate novel polymer composites materials. Recognize the principles involved in choosing reinforcing agents and incorporating them into polymer matrices.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text books:

1. F. R. Jones (Ed.), Handbook of Polymer-Fibre Composites, Longman Group (1994).
2. K. Friedrich, S. Fakirov, Z. Zhang (Eds.), Polymer Composites – from Nano to Macro scale, Springer (2005).

Reference books:

1. P. K. Mallick, Composites Engineering Handbook Part-1&2, CRC Press (2016).
2. Bhagwan D. Agarwal, Lawrence J. Broutman, K. Chandrashekhara, Analysis and Performance of Fiber Composites, 4th Edition, Wiley India (2017).
3. Ever J. Barbero, Introduction to Composite Materials Design, 2nd Edition., CRC Press (2011).

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM6203
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Functional Ceramics
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the physics and chemistry of the ceramic material. To understand the structure-property correlation in ceramic. To learn about state of the art regarding the application of functional ceramic materials.
Course Description	This course provides general overview on the origins of functional properties of ceramics, their wide varieties and their usability in different advanced technological applications.
Course Content	Bonding in ceramic, Structure of ceramic, Pauling's rule Defects in ceramics, Defect Classes, Point Defects, Kröger-Vink Notation, Point Defect Formation, Thermodynamics of Intrinsic Defects, and Defect Reactions. Introduction to electronic properties; Drude model, its success and failure; energy bands in crystals; density of states; electronic conduction in ceramics; ceramic semiconductors; Ionic conduction in ceramics. Ceramic insulators, dielectric strength, dielectric constant, ferroelectricity; piezoelectricity, polarization theories; Magnetic properties, hysteresis, microscopic origin, exchange interaction, types of magnetism; Optical properties, atomic-electronic interaction, refraction, reflection, Absorption Transmission, Luminescence, Lasers, optical fibers
Learning Outcome	Upon completing this course, the student will be able to Identify the reasons behind new novel properties emerging for ceramic materials. Classification of properties along with their possible market applications. Distinguish between different functional ceramic materials.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Electronic Properties of Materials, R. E. Hummel, Springer-Verlag New York Inc.; 4th ed. CBS Publishers, 2011.
2. An Introduction to Electronic Materials for Engineers, Zhengwei Li, Nigel M. Sammes; World Scientific Publishing Co. Pte. Ltd., 2011.

Reference books:

1. Solid State Chemistry and Its Applications, Anthony R. West; John Wiley & Sons, 1985.

2. Ceramic Materials: Science and Engineering, C. Barry Carter, M. Grant Norton; Springer, 2nd ed. 2013.
3. Fundamentals of Ceramics, M.W Barsoum; McGraw Hill, 1997

	CLO1	CLO2
PLO1	X	X
PLO2		
PLO3	X	

Department Elective - III						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6204	Materials Characterization Techniques	3	0	0	3
2.	MM6205	Selection of Alloys and Heat Treatment	3	0	0	3
3.	MM6206	Thin films - An Engineering Approach	3	0	0	3
4.	MM6207	Joining of Materials	3	0	0	3

Course Number	MM6204
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Materials Characterization Techniques
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To enlighten students with the fundamental arrangement of atoms in materials and characterization of material's structure. To understand how characterization of phases, composition and grain morphology is performed. To understand the strength and weaknesses of different characterization techniques.
Course Description	Materials Characterization course explores the fundamental techniques and methodologies used in materials characterization, focusing on the analysis of structure, properties, and performance of various materials.
Course Content	Theory Syllabus Introduction: Importance and the need for materials characterization, highlights of various characterization techniques, Crystal structure, miller indices, Bravias lattice. Diffraction: Basics of diffraction and interference of light, Young's double slit experiment, interpretation of diffraction from the single slit and multiple slits X-ray diffraction: Generation of X-ray, X-ray diffraction (XRD), Bragg's Law, Atomic scattering factor, structure factor, indexing of diffraction, selection rules, estimation of peak intensity, phase identification and analysis by XRD, stress calculation, crystallite size measurements through XRD. Principles of optical microscopy-resolution, magnification, depth of focus; electron diffraction, imaging, construction of SEM, SE/BSE mode, EDS, EBSD, TEM, BF/DF imaging, contrast in TEM, crystal structure identification through Selected area diffraction pattern (SADP), Sample preparation for TEM Instrumentation and principles of techniques used for thermal analysis (DSC, DTA, TG) and a combined method of thermal analysis and their applications in materials characterization.
Learning Outcome	Upon completion of this course, the student will be able to: Able to understand different structures in materials and identify the phases and structure of materials through XRD. Analyze the phase and grain morphology through SEM and elemental composition through EDS. Understand the which characterization technique will be suitable for a given material.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Cullity, B. D., & Stock, S. R. (2001). Elements of X-ray Diffraction, Third Edition. Prentice-Hall.
2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Yang Leng; 2nd ed., Wiley, 2013
3. Scanning Electron Microscopy and X-Ray Microanalysis, Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy and Patrick Echlin; 3rd ed., Springer, 2003

Reference Books:

1. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry, Marc De Graef, Michael E. McHenry; 2nd (ed.), Cambridge University Press, 2012.
2. Crystal Structure Determination, Werner Massa; 2nd (ed.), Springer, 2010.
3. Crystal Structure Analysis: Principles and Practice, Peter Main, William Clegg (ed.), Alexander J. Blake, Robert O. Gould , Vol 6, Oxford Science Publication, 2001.

	CLO1	CLO2
PLO1		
PLO2	X	X
PLO3	X	

Course Number	MM6205
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Selection of alloys and heat treatment
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the basic concept/design of adopting different engineering alloys (ferrous and non-ferrous) and their processing based on their applications. To understand heat treatment's basic concept and effect on the relationship between processing, microstructure, properties, and applications for different engineering alloys.
Course Description	This course delves into the selection, microstructures, and properties of engineering alloys, including steels, cast irons, and superalloys. It also covers heat treatment principles, techniques, and applications to achieve desired metallurgical properties.
Course Content	Syllabus: Selection of engineering alloys, including steels (carbon, alloy, stainless, dual phase, TRIP/TWIP), cast irons, aluminium, magnesium, titanium, nickel and cobalt-based superalloys and zirconium alloys. In depth understanding of the microstructures and their development for the most common classes of engineering alloys. Overview of microstructures, processing and properties in engineering alloys. State-of-the-art approaches to the design and development of new alloys for the 21st century. Principles of heat treatment, heat treatment of steels; Use of heat treatment to produce required metallurgical properties. Cooling curves and equilibrium diagrams. Hardenability, Strength, and Toughness; Case hardening, Carburizing, Nitriding, De-carburizing Re-heat treatment, Re-tempering, Annealing, and Normalizing. Heat treatment of Aluminum alloys, Annealing, Solution treatment, Natural ageing, Artificial ageing, Over ageing explanation of the heat treatment of Aluminum alloys, Control testing. Theory of Heat Treatment, Heat Treatment Environment, Different Heat Treatment Techniques, Fundamentals and Properties; Annealing, Tempering, Hardening, Thermomechanical treatment; Economy of Heat Treatment Processes.
Learning Outcome	After completion of this course, the student will be able to Understand the processing for the development of different alloys along with suitable heat treatment process. Able to obtain required microstructure and properties for their respective applications in industrial practice.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Principles of Heat Treatment of Steels, R.C. Sharma; New Age International (P) Ltd, 2003.
2. The Heat Treating Source Book, ASM International, 1986.

Reference Books:

1. Physical Metallurgy, Vijendra Singh, Standard Publishers Distributors, Delhi, 2015.
2. Engineering Physical Metallurgy and Heat Treatment; Y. Lakhstein, Mir Publisher, 1979.
3. Materials and Design, M.F. Ashby and Kara Johnson; Butterworth-Heinemann Ltd, 2002.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	

Course Number	MM6206
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Thin films- an engineering approach
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand the various physical and chemical deposition methods. To understand and analyze the characteristics of thin films using different instrumentation techniques. To understand different types of nucleation theories, growth mechanisms of thin films.
Course Description	This course provides fundamentals of synthesis, nucleation, growth of thin films along with their suitability of applications in diverse technological fields.
Course Content	Syllabus Thin films and Surfaces, thermodynamics and reactivity of Surfaces, Surface crystallography and reconstruction, Atomic models for crystalline surfaces, Nucleation and Growth in thin films: Capillarity theory, atomistic and kinetic models of nucleation, basic modes of thin film growth (Volmer - Weber, Frank van der Merwe, Stranski-Krastanov), Microstructural development in epitaxial, polycrystalline, and amorphous films Thin film deposition (Vapour based), Hertz Knudsen equation; mass evaporation rate; Directional distribution of evaporating species Evaporation of elements, compounds, alloys. Raoult's Law: E-beam, pulsed laser and ion beam evaporation, Sputtering, ion beam assisted deposition. Chemical Vapor Deposition (CVD) Methods, sputtering, epitaxial films, Laser ablation, lattice misfit and imperfections Solution-based chemical Techniques: Spray pyrolysis, Electrodeposition, electroless deposition and plating for large area industrial coating, chemical bath deposition (CBD), successive ionic layer adsorption and reaction (SILAR) method, Sol-gel (spin coating and dip coating) and Langmuir Blodgett techniques for polymer and soft molecules Thin film and surface characterization techniques Application and devices: thin films in MEMS, NEMS, sensors, actuators, transducers and other relevant fields involving surface engineering applications.
Learning Outcome	Upon completing this course, the student will be able to: Identify various techniques of thin film depositions. Classify and distinguish different thin film properties and correlate the same with relevant industrial applications. Understand the fundamentals of nucleation and growth of various thin films.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Milton Ohring, The Materials Science of Thin Films, Academic Press-Sanden, 1992
2. Reference Books:
3. Thin Film Materials: Stress, Defect Formation and Surface Evolution, L. B. Freund, S. Suresh, Cambridge University Press, 2004
4. Thin Film Processes II, Werner Kern, editor: John Vossen, Academic Press, 2012
5. Thin-Film Deposition: Principles and Practice, Donald L. Smith, McGraw Hill Professional, 1995

	CLO1	CLO2
PLO1		
PLO2		X
PLO3	X	
PLO4	X	

Course Number	MM6207
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Joining of Materials
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To know about the relevance of joining materials and the methods involved. To understand the challenges in joining dissimilar materials. To understand the different strategies employed in the joining of metals, ceramic, and polymer.
Course Description	This course teaches welding and joining techniques for metals, polymers, ceramics, and semiconductors, with emphasis on weld evaluation and material weldability.
Course Content	Syllabus Welding, theory, and classification of welding, submerged arc welding, gas metal arc welding or MIG/MAG welding, TIG welding, resistance welding. Other joining processes, soldering, brazing, diffusion bonding, and adhesive bonding of metallic materials; adhesive bonding, solvent bonding, and welding of polymer materials; brazing, frit sealing, diffusion bonding, and welding of ceramic materials and composite materials; wire bonding, flip-chip bonding, and wafer bonding of semiconductor materials; nanofoils based bonding Solid state welding technique: friction welding, friction stir welding, welding defects, characterization of weld: weld microstructure, compositional analysis, tensile test, bend test, hardness test, toughness test and non-destructive test, HAZ, weldability.
Learning Outcome	Upon completing this course, the student will be able to Understand different ways of joining of metal, ceramic, and polymer. Understand the difficulties of joining materials and come up with solutions. Understand the advancements in joining technology from research and industrial perspectives.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Metallurgy of Welding, Lancaster, Allen, Unwin; Springer, 1980.
2. Welding and Welding Technology, Little R.L; McGraw-Hill Companies, 1973.
3. Advanced Welding processes, Norrish, J., Woodhead, Woodhead Publishing, 2006.

	CLO1	CLO2
PLO1	X	X
PLO2		
PLO3	X	

Department Elective - IV						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6208	Crystal Symmetry and Tensor properties	3	0	0	3
2.	MM6209	Coating Technology	3	0	0	3
3.	MM6210	Fabrication of Solid-state Devices	3	0	0	3

Course Number	MM6208
Course Credit (L-T-P-C)	3-0-0 (6 AIU credits)
Course Title	Crystal Symmetry and Tensor properties
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To enlighten students with the fundamental arrangement of atoms in materials. To visualize the illustration of crystal structure with the mathematical theory of crystallography.
Course Description	The course involves the study of the crystal structure of solids. How the atoms are arranged in a systematic manner following definite symmetry operations. It also deals with the correlation of the internal crystal symmetry to the property of a material.
Course Content	Crystal structure: Direct and Reciprocal lattice (2D, 3D), Stereographic projection, Symmetry, Point groups, Space groups, and Systematic absences due to symmetry elements. Wyckoff Notation, Bravais lattices, and Crystal systems. Tensors and Physical Properties: Tensor and scalar notation, ranks, transformations, effect of crystal symmetry on properties, transformation of axes, paramagnetic and diamagnetic susceptibility, electric polarization, stress tensor, strain tensor, thermal expansion, piezoelectricity- third rank tensor, elasticity- fourth rank tensor.
Learning Outcome	Upon completion of this course, the student will be able to: Connect the properties of the material with the atomic arrangement. Connect the physical properties of a material with crystal symmetry.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Crystals and crystal structure by Richard Tilley.
2. M.J. Buerger, Elementary Crystallography.
3. J. F. Nye, Physical Properties of Crystals (1995), Oxford Science Publications

Reference Books:

1. Robert E. Newnham, "Properties of Materials: Anisotropy, Symmetry, Structure", Oxford Pr.
2. International Tables of Crystallography A, International Union of Crystallography
3. D.R. Lovett, Tensor Properties of Crystals (1999), Institute of Physics Publishing
4. Fundamental of powder diffraction and structural characterization of Materials by Vitalij K. Pencharsky and Peter Y. Zavalij

	CLO1	CLO2
PLO1	X	X
PLO2		
PLO3	X	

Course Number	MM6209
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Coating Technology
Learning Mode	Lecture
Prerequisite	
Learning Objectives	To understand the nature and magnitude of the changes in behaviour of materials at the interfaces. To understand different methods for processing of coatings. To learn about different mechanical and functional properties of coatings.
Course Description	This course explores advanced coating technologies, focusing on deposition methods, material selection, and applications to enhance surface properties like wear, corrosion resistance, and thermal stability in diverse industrial sectors.
Course Content	Introduction to coatings for different temperature applications, Properties of surfaces-wear, corrosion, optical, roughness, electrical and thermal properties, wettability Concepts of coating, Thin film coating, Physical Vapour Deposition: Thermal Evaporation, E-Beam Deposition, Sputtering. Chemical Vapour Deposition: Thermal Assisted CVD, Plasma Enhanced CVD, Photo Assisted CVD, Metal-Organic CVD, Sol-gel deposition, Thick Coating: Thermal spray Types of thermals spray and their advantages and disadvantages. Flame Spray, HVOF, Plasma spray- conventional vs. nanostructured coatings, Process parameters, thermal and kinetic history of inflight particle, microstructural features of plasma sprayed coatings, single splat studies, process-structure property relationship-challenges in preparation, plasma spraying of nanopowders - its microstructure – properties –Liquid precursor plasma spray- Thermal barrier coatings and materials including yttria stabilized zirconia Characterization of film and thick coatings, Coatings –thickness-porosity-hardness, fracture toughness, elastic modulus – adhesion-bending strength-fracture strength- tensile strength, coating tribology, corrosion measurement, phase analysis and microstructure, Surface characterization techniques. Applications of coatings: wear resistance, corrosion, thermal barrier, Anti scratch, Biomedical, near net shape, embedded sensors, Energy applications like Solid oxide fuel cell, Dye sensitized solar cell
Learning Outcome	Upon completing of this course, the student will be able to Identify the reasons behind new novel properties emerging at the interface for different classes of materials. Distinguish between different processing technologies for coatings . Understand the mechanical and functional of properties of coatings along with their possible market applications.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Introduction to Surface Engineering and Functionally Engineered Materials, Peter Martin; Wiley, 2011.
2. Materials and Surface Engineering: Research and Development, J. Paulo Davim; Woodhead Publishing Ltd., 2012.
3. The Science and Engineering of Thermal Spray Coatings, Lech Pawlowski; Wiley, 2008. The Cold Spray Materials Deposition Process: Fundamentals and Applications, Victor K. Champagne; Woodhead Publishing Ltd, Maney publishing Ltd., 2007

Reference books:

1. Quo Vadis Thermal Spraying? P. Fauchais, A. Vardelle, B. Dussoubs; Journal of Thermal Spray Technology, Vol. 10, 2001. Thermal Spray Coatings, Kurt H Sien (ed); Chapman and Hall, 1996.

	CLO1	CLO2
PLO1	X	X
PLO2		
PLO3		
PLO4	X	

Course Number	MM6210
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Fabrication of solid-state devices
Learning Mode	Lecture
Prerequisite	
Learning Objectives	Course learning objectives (Comply with PLOs 1 and 2) • To understand the structure of crystalline materials and defects present at various dimensions in materials and their influence on properties • To understand various methods to control and quantify the amount of defects in various materials • To understand how material transport is fundamental to understand the materials processing including phase transformation
Course Description	
Course Content	Bonding and structure in crystalline solids: Bonding in solids- primary and secondary, unit cells, crystal systems, indexing planes and direction Defects in crystalline materials: Point, linear, planar and volume defects. Equilibrium concentration of vacancies, doping in semiconductors. Point defects in ionic crystals, Frenkel and Schottky defects, Kröger-Vink notation. Edge and screw dislocations, Burger vector. Concept of slip, dislocation structures in fcc and bcc crystal systems. Slip systems, dislocation locks, Kear-Wiltsdorf lock, partial dislocations, stacking faults, Orowan looping. Atomic structure and nature of grain boundaries, Energy of grain boundaries. Twin boundaries. Observation of defects. Role of defects on the properties of materials. Diffusion: Atomistic mechanisms of diffusion, substitutional and interstitial diffusion. Fick's first and second law. Diffusion kinetics. Chemical potential gradient – Uphill diffusion, Surface, lattice, grain boundary and pipe diffusion. Kirkendall effect. Tracer diffusion. Case studies: (i) Role of microstructure in transparency of alumina (ii) Electromigration in integrated circuits (iii) Ionic conductivity in cubic zirconia (iv) Carburization and decarburization in steel (v) Role of Kirkendall voids on weld joints
Learning Outcome	Course learning outcomes At the end of the course, the student will be able to

	• Understand how defects impact numerous properties of materials - from the conductivity of semiconductors to the strength of structural materials • Understand and quantify the equilibrium and non-equilibrium defects that are present in crystals • Correlate diffusion process and kinetics with temperature, concentration and time
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Book:

3. Introduction to dislocation theory: D. Hull and D.J. Bacon, Butterworth-Heinemann, Elsevier, 2011.
4. Diffusion in Solids: Paul Shewmon, 2nd Ed., Springer, 2016.

Reference Book:

1. Defects in Solids, R. J. D. Tilley, JW Wiley Press, 2008.
2. Fundamentals of Materials Science, the microstructure – property relationship using metals as model systems: Eric J. Mittemeijer, Springer, 2011.
3. Phase Transformation in Metals and Alloys: D.A. Porter, K.E. Easterling and M.Y. Sherif, 3rd Ed., CRC Press, 2009.

Course Number	RM6201
Course Credit (L-T-P-C)	3-1-0-4
Course Title	Research Methodology
Learning Mode	Lectures
Learning Objectives	The objective of the course is to train student about the modelling of scalar and multi-objective nonlinear programming problems and various classical and numerical optimization techniques and algorithms to solve these problems
Course Description	Advanced Optimization Techniques, as a subject for postgraduate and PhD students, provides the knowledge of various models of nonlinear optimization problems and different algorithms to solve such problems with its applications in various problems arising in economics, science and engineering.
Course Content	Module I (6 lecture hours) – Research method fundamentals: Definition, characteristics and types, basic research terminology, an overview of research method concepts, research methods vs. method methodology, role of information and communication technology (ICT) in research, Nature and scope of research, information based decision making and source of knowledge. The research process; basic approaches and terminologies used in research. Defining research problem and hypotheses framing to prepare a research plan. Module II (5 lecture hours) - Research problem visualization and conceptualization: Significance of literature survey in identification of a research problem from reliable sources and critical review, identifying technical gaps and contemporary challenges from literature review and research databases, development of working hypothesis, defining and formulating the research problems, problem selection, necessity of defining the problem and conceiving the solution approach and methods. Module III (5 lecture hours) - Research design and data analysis: Research design – basic principles, need of research design and data classification – primary and secondary, features of good design, important concepts relating to research design, observation and facts, validation methods, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization, analysis, reliability, interpretation and presentation. Module IV (16 lecture hours) - Qualitative and quantitative analysis: Qualitative Research Plan and designs, Meaning and types of Sampling, Tools of qualitative data Collection; observation depth Interview, focus group discussion, Data editing, processing & categorization, qualitative data analysis, Fundamentals of statistical methods, parametric and nonparametric techniques, test of significance, variables, conjecture, hypothesis, measurement, types of data and scales, sample and sampling techniques, probability and distributions, hypothesis testing, level of significance and confidence interval, t-test, ANOVA, correlation, regression analysis, error analysis, research data analysis and evaluation using software tools (e.g.: MS Excel, SPSS, Statistical, R, etc.). Module V (10 lecture hours) – Principled research: Ethics in research and Ethical dilemma, affiliation and conflict of interest; Publishing and

	sharing research, Plagiarism and its fallout (case studies), Internet research ethics, data protection and intellectual property rights (IPR) – patent survey, patentability, patent laws and IPR filing process.
Learning Outcome	On successful completion of the course, students should be able to: 1. Understand the terminology and basic concepts of various kinds of nonlinear optimization problems. 2. Develop the understanding about different solution methods to solve nonlinear Programming problems. 3. Apply and differentiate the need and importance of various algorithms to solve scalar and multi-objective optimization problems. 4. Employ programming languages like MATLAB/Python to solve nonlinear programming problems. 5. Model and solve several problems arising in science and engineering as a nonlinear optimization problem.
Assessment Method	Quiz /Assignment/ Project / MSE / ESE

Textbooks & Reference Books:

1. C. R. Kothari, Research methodology: Methods and Techniques, 3rd Edn., New age International 2014.
2. Mark N K. Saunders, Adrian Thornhill, Phkip Lewis, “Research Methods for Studies, 3/c Pearson Education, 2010.
3. K.N. Krishnaswamy, apa iyer, siva kumar, m. Mathirajan, “Management Research Methodology”, Pearson Education, 2010.
4. Ranjit Kumar; “Research Methodology: A Step by Step Guide for Beginners; 2/e; Pearson Education, 2010.
5. Suresh C. Sinha, Anil K. Dhiman, ess ess, 2006 “Research Methodology” Panner Selvam.R. “Research Methodology”, Prentice Hall of India, New Delhi, 2004.
6. C.G. Thomas, Research methodology and scientific writing, Ane books, Delhi, 2015.
7. H. J. Ader and G. J. Mellenbergh, Research Methodology in the Social, Behavioural and Life Sciences Designs, Models and Methods, 3rd Edn., Sage Publications, London, 2000.

IDE						
Sl. No.	Subject Code	Subject	L	T	P	C
1.	MM6105	Structural Characterization of Materials	3	0	0	3
2.	MM6106	Composite Science and Technology	3	0	0	3

Course Number	MM6105
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Structural characterization of materials
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To understand how material characterization is of paramount importance to the study of materials science. To understand the basics as well as strengths and weaknesses of different characterization techniques.
Course Description	The course involves the i) study of the crystal structure of solids. ii) the structural analysis of solids at different length scales, such as micro, nano and angstrom levels, using different techniques.
Course Content	Introduction: Importance and the need for materials characterization, bonding, crystal structure and system, miller indices, Bravais lattice. Diffraction: Basics of diffraction and interference of light, Young's double slit experiment, interpretation of diffraction from the single slit and multiple slits. X-ray Diffraction: Generation of X-rays, X-ray diffraction (XRD), Bragg's Law, Atomic scattering factor, structure factor, indexing of diffraction patterns, selection rules, estimation of peak intensity, phase identification and analysis by XRD, determination of structure and lattice parameters, strain and crystallite size measurements through XRD, effect of temperature on XRD. Electron diffraction: Wave properties of the electron, electron-matter interactions, ring patterns, spot patterns, and Laue zones. Optical Microscopy: Principles of optical microscopy, magnification, Rayleigh criterion, resolution limitation, Airy disk, depth of focus, and field. Scanning Electron Microscopy: Principle, construction, and operation of Scanning Electron Microscope, SE and BSE imaging modes, Elemental analysis using Energy dispersive analysis of X-rays, Transmission electron microscope: Principle, construction, and working of Transmission Electron Microscope (TEM), the origin of contrast: mass-thickness contrast, electron diffraction pattern, Bright field, and dark field images
Learning Outcome	Upon completion of this course, the student will be able to: Understand the importance of the different characterization techniques. Understand the fundamentals of different characterization techniques and application of it in materials characterization.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Text Books:

1. Elements of X-Ray Diffraction: B.D. Cullity and S.R. Stock, 3rd Ed., Pearson, 2001.
2. Scanning Electron Microscopy and X-Ray Microanalysis: Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy and Patrick Echlin, 3rd Ed., Springer, 2003.

Reference Books:

1. Transmission Electron Microscopy: A Textbook for Materials Science: David B. Williams and C. Barry Carter, Springer, 2009.
2. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry, Marc De Graef, Michael E. McHenry; 2nd Ed., Cambridge University Press, 2012.

	CLO1	CLO2
PLO1	X	X
PLO2	X	X
PLO3		

Course Number	MM6106
Course Credit (L-T-P-C)	3-0-0 (3 AIU credits)
Course Title	Composite Science and Technology
Learning Mode	Lecture
Prerequisite	None
Learning Objectives	To impart knowledge on the fundamentals of polymer/metal/ceramic composites and structures. To know about the manufacture, properties, and applications of various polymer/metal/ceramic composites. To understand the effect of reinforcement in composite materials.
Course Description	The course covers the fundamental concepts related to composites. This course will also cover the in-depth details regarding the fabrication/processing, testing and characterization, mechanics and application of different composites based on metals, ceramics and polymers.
Course Content	Syllabus: Introduction and Overview of Metal-based composites, overviews of key technologies and issues in the area, Fabrication of Metal Matrix Composites: Commonly used Matrices, Basic Requirements in Selection of constituents, solidification processing of composites - XD process, Spray processes - Osprey Process, Rapid solidification processing, Dispersion Processes - Stir-casting & Compo casting, Screw extrusion, Liquid-metal impregnation technique - Squeeze casting, Pressure infiltration, Lanxide process), Principle of molten alloy infiltration, rheological behaviour of melt-particle slurry, Synthesis of In situ Composites Resins- Resins used in polymer composites, Fillers- Fibers, conventional fillers, and nanofillers used in polymer composites. Fabrication- Different processing techniques for polymer composites. Testing and characterization, Structure-property relationship in conventional polymer composites and polymer nanocomposites, Applications. Ceramic matrix composites, mechanical properties of ceramic matrix composites, different processing techniques for ceramic matrix composites, process capability, and applications of various techniques. Structure-property correlation in composite
Learning Outcome	By the end of this course, the students will be able to Use appropriate materials in suitable forms for making polymer/metal/ceramic composites and structures. Design, analysis, manufacture, and test new composite materials. Understand the concepts in selecting reinforcing agents and their incorporation in polymer/metal/ceramic matrices.
Assessment Method	Assignments, Quizzes, Mid-semester examination, End-semester examination.

Textbooks:

1. Composite materials, K.K. Chawala; 2nd ed.,Springer-Verlag, 1987.
2. Nanocomposite Science and Technology, P. M. Ajayan, L. S. Schadler, P. V. Braun; Wiley-VCH Verlag GmbH Co, 2013.

Reference Books:

1. Mechanics and Analysis of Composite Materials, V.V. Vasiliev, E.V. Morozov; Elsevier Science Ltd, 2001.
2. Ceramic matrix composites, K.K. Chawala; 1st ed., Chapman & Hall,1993.
3. Advances in composite materials, G. Piatti; Applied Science Publishers Ltd., 1978.
4. Composite Materials, Mel. M. Schwartz; Vol 1 & 2, Prentice - Hall PTR, 1997.

	CLO1	CLO2
PLO1	X	X
PLO2		X
PLO3	X	