CURRICULUM & SYLLABI
M. Tech. MATERIALS SCIENCE AND TECHNOLOGY

Effective from AY: 2026-27



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL
WARANGAL, TELANGANA

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Vision and Mission of the Institute
NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating Centre to serve the societal needs.

Vision and Mission of the Centre
CENTRE FOR MATERIALS SCIENCE AND TECHNOLOGY

VISION

To be a global knowledge hub in Materials Science and Technology education, research, entrepreneurship and industry outreach services.

MISSION

- Impart quality education and training to nurture globally competitive engineers in Inter-disciplinary area of research.
- Provide vital state-of-the-art research facilities to create, interpret, apply and disseminate knowledge.
- Engage in quality research in materials science and technology that bridges the gap between theory and application in the semiconductor, automotive, and energy industries, preparing students to become industry-ready pioneers in their respective fields.
- Develop linkages with world class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.

CENTRE FOR MATERIALS SCIENCE AND TECHNOLOGY

List of Programmes offered by the CENTER:

Program	Title of the Programme
M.TECH	Materials Science and Technology

Note: Refer to the following weblink for Rules and Regulations of M.Tech. program:
https://nitw.ac.in/page/?url=/RulesandRegulations/list

Program: M.Tech. - Materials Science and Technology

Program Educational Objectives (PEOs)

Program Educational Objectives (PEOs) are broad statements that describe the career and professional accomplishments that the program is preparing graduates to achieve. They are consistent with the mission of the Institution and Department. Department faculty members continuously worked with stakeholders (employers, industry and R&D advisors and the alumni) to review and update them periodically.

PEO1	Apply advanced principles of materials science to analyze and establish structure–processing–property–performance relationships in metallic, ceramic, polymeric, composite, and functional materials.
PEO2	Design, develop, and optimize advanced and emerging materials for engineering, energy, electronic, structural, and societal applications using experimental and computational approaches.
PEO3	Identify, analyze, and solve complex problems in materials engineering using appropriate research methodologies, modeling tools, and modern characterization techniques while adhering to professional ethics.
PEO4	Engage in lifelong learning, innovation, and professional development to adapt to evolving technologies, interdisciplinary research, and global industrial and academic environments.

Program Articulation Matrix

Mission Statement	PEO1	PEO2	PEO3	PEO4
Impart outstanding technical education for analysis, design, and operation of materials systems	3	3	2	2
Provide vital state of the art research facilities to create, interpret, apply and disseminate knowledge.	3	2	3	3
Engage in quality research in materials science and allied interdisciplinary areas	3	3	3	3
Develop linkages with world-class educational institutions and R&D organizations for excellence in teaching, research and consultancy services.	2	2	2	3

1: Slightly **2: Moderately** **3: Substantially**

Program: M.Tech. - Materials Science and Technology

Program Outcomes (POs)

Program Outcomes describe what the students are expected to know and be able to do upon the graduation. They relate the knowledge, skills and behaviour of the students acquire through the programme. The Programme Outcomes (PO) are specific to the programme and facilitate the attainment of PEOs.

PO1	Identify and demonstrate comprehensive knowledge of materials science and technology needed for materials research and innovation demanded by society and environment.
PO2	Apply advanced materials processing, characterization, modeling, simulation, and data-driven tools to evaluate materials performance and reliability.
PO3	Innovate, design and develop advanced materials for multidisciplinary applications including energy, electronics, aerospace, biomedical, and sustainability sectors.
PO4	Conduct independent research to solve complex problems in materials science and engineering.
PO5	Communicate technical findings through quality reports, publications, and presentations, adhering to professional standards.
PO6	Demonstrate professional ethics, teamwork, leadership skills, and commitment to lifelong learning in academic/research/industrial environments.

Program Articulation Matrix

	PO1	PO2	PO3	PO4	PO5	PO6
PEO 1	3	3	3	3	2	3
PEO 2	3	3	3	3	3	3
PEO 3	3	3	3	3	2	3
PEO 4	2	2	2	3	2	3

1: Slightly **2: Moderately** **3: Substantially**

Credits in Each Semester

Category	I Year Sem - I	I Year Sem - II	II Year Sem - I	II Year Sem - II	Total No. of credits to be earned
Core courses	09	06	--	--	**15**
Electives	06	09	--	--	**15**
Lab Courses	04	04	--	--	**08**
Comprehensive Viva-Voce	--	--	02	--	**02**
Summer and internship	--	--	02	--	**02**
Major Project	--	--	08	12	**20**
Minor Project	--	02	--	--	**02**
Seminar and Technical writing	--	--	02	--	**02**
Total	**19**	**21**	**14**	**12**	**66**

CURRICULUM

M. Tech. - MATERIALS SCIENCE AND TECHNOLOGY

I Semester

S. No.	Course Code	Course Title	L- T- P	Credits
1	MM46001	Advanced Physical Metallurgy	3-0-0	3
2	EC26033	Semiconductor Materials and Devices	3-0-0	3
3	ME26045	Artificial Intelligence and Machine Learning in Materials Engineering	3-0-0	3
5		Professional Elective – I	3-0-0	3
6		Professional Elective – II	3-0-0	3
7	MM46003	Manufacturing Processes Laboratory	0-1-2	2
8	MM46005	Computational Methods in Materials Science Laboratory	0-1-2	2
			Total Credits	**19**

II Semester

S. No.	Course Code	Course Title	L-T-P	Credits
1	MM46002	Mechanical Behavior of Materials	3-0-0	3
2	MM46004	Advanced Materials Characterization Techniques	3-0-0	3
3		Professional Elective – III	3-0-0	3
4		Professional Elective – IV	3-0-0	3
5		Professional Elective – V	3-0-0	3
7	MM46006	Advance Materials Characterization Laboratory	0-1-2	2
8	MM46008	Mechanical Behavior of Materials Laboratory	0-1-2	2
9	MM46010	Minor Project	0-0-0	2
			Total Credits	**21**

III Semester

S. No.	Course Code	Course Title	L-T-P	Credits
1	MM46007	Seminar and Technical writing	0-0-0	2
2	MM46009	Summer Internship/Research Experience (SIRE)	0-0-0	2
3	MM46011	Comprehensive Viva-Voce	0-0-0	2
4	MM46013	Dissertation: Part-A	0-0-0	8
			Total Credits	**14**

IV Semester

S. No.	Course Code	Course Title	L-T-P	Credits
1	MM46012	Dissertation: Part-B	0-0-0	12
			Total Credits	**12**

List of Elective Courses

Professional Elective – I		
S. No.	**Course Code**	**Course Title**
1.	MM46015	Light Weight Metals and Alloys
2.	MM46017	Materials for Advanced Nuclear Power Plants
3.	MM46019	Energy Materials: Conversion and Storage
4.	MM46021	High Temperature Materials
5.	MM46023	Materials for Extreme Environments
6.	MM46025	Functional and Smart Materials
7.	MM46027	Advanced Materials Processing
8.	MM46029	Rare Earth Materials

Professional Elective – II		
S. No.	**Course Code**	**Course Title**
1.	MM36007	Nanotechnology
2.	CY16026	Nanochemistry and Smart Materials
3.	MM46031	Bulk Nanostructured Materials
4.	MM46033	Introduction to Biomaterials
5.	ME26043	Microwave Materials Processing: Principles and Applications
6.	MM46035	Nature Inspired Materials Engineering
7.	MM46037	Materials for Quantum Technology
8.	MM46039	Materials Thermodynamics
9.	MM46041	Multiscale Modeling of Materials

Professional Elective – III		
S. No.	**Course Code**	**Course Title**
1.	MM46014	Additive Manufacturing Technologies
2.	MM46016	Materials Joining Processes
3.	MM46018	Design, Selection and Processing of Engineering Alloys
4.	MM46020	Non-Destructive Testing
5.	MM46022	Mechanics of Metal Forming
6.	MM46024	Thermomechanical Processing of Materials
7.	MM46026	Materials Extraction Technology
8.	MM46028	Circular Materials Engineering & Sustainability

Professional Elective – IV		
S. No.	**Course Code**	**Course Title**
1.	MM46030	Ceramics and Composites Technology
2.	MM46032	Advanced Powder Processing
3.	CH16074	Technology of Thermoplastic and Thermoset Polymers
4.	MM46034	Optoelectronic Materials and Devices
5.	MM5213	Environmental Degradation of Materials
6.	EE26042	Advanced Polymeric Materials for Electrical and Energy Applications

Professional Elective – V		
S. No.	**Course Code**	**Course Title**
1.	PH17032	Thin film & Vacuum Technologies
2.	MM46036	Functional Coatings for Engineering Applications
3.	MM46038	Manufacturing Techniques in MEMS
4.	MM46040	Diffraction and Electron Microscopy
5.	MM46042	Texture and Grain Boundary Engineering
6.	ME36004	Industry 4.0 and IIoT
7.	ME36022	Supply Chain Management
8.	ME26028	Design and Analysis of Experiments
9.	MM46044	Engineering Entrepreneurship
10.	MM46046	Process Design & Economics
11.	ME26035	Finite Element Applications in Martials Processing

SYLLABI

M.Tech Materials Science & Technology

Semester I

MM46001 **3-0-0 (3)**

Advanced Physical Metallurgy

Pre-Requisites: None

Course Outcomes:

CO-1	Visualize phase equilibria and phase diagrams using thermodynamic principles.
CO-2	Discuss phase stability and microstructural evolution in alloy systems.
CO-3	Explain phase transformations encompassing diffusional and diffusionless mechanisms
CO-4	Apply advanced physical metallurgy principles for alloy designing

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	1	1	-	-
CO-2	3	3	1	1	-	-
CO-3	3	3	2	1	-	-
CO-4	3	2	2	2	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Thermodynamics and Phase Diagrams: Gibbs free energy and chemical potential; single-component and binary systems; ideal, regular, and real solutions; activity and ordering; binary phase diagrams (eutectic, peritectic, miscibility gap); Gibbs phase rule; effect of temperature on solubility; equilibrium vacancy concentration; ternary equilibrium

Diffusion in Solids: Atomic mechanisms of diffusion; interstitial and substitutional diffusion; types of diffusin; Fick's laws; steady-state and non-steady-state diffusion; tracer diffusion; diffusion in binary and ternary alloys; high-diffusivity paths (grain boundaries, dislocations)

Solidification of Metals and Alloys: Homogeneous and heterogeneous nucleation; nucleation kinetics; growth of pure metals: diffusion-controlled and interface-controlled growth; ingot and casting solidification; segregation; solidification of welds; metallic glasses—thermodynamics and kinetics.

Diffusional Transformations in Solids: Nucleation and growth in solids; grain boundary migration and grain growth kinetics; precipitate: coherent, semi-coherent, and incoherent interfaces, growth and coarsening; TTT and CCT diagrams; precipitation in age-hardening alloys (Al–Cu, Al–Ag); spinodal decomposition; ferrite, pearlite, and bainite transformations; effect of alloying elements.

Diffusionless Transformations: Characteristics of martensitic transformations; crystallography (Bain model); nucleation theories; role of dislocations and strain energy; growth of lath and plate martensite; tempering of martensite; case studies in steels and shape-memory alloys.

Learning Resources:

Text Books:

1. Porter, David A., and Kenneth E. Easterling. Phase transformations in metals and alloys (revised reprint). CRC press, 2009.
2. Laughlin, David E., and Kazuhiro Hono, eds. Physical metallurgy. Newnes, 2014.
3. Schastlivtsev, Vadim M., and Vitaly I. Zel'dovich. Physical Metallurgy: Metals, Alloys, Phase Transformations. Walter de Gruyter GmbH & Co KG, 2022.
4. Abbaschian, Reza, Lara Abbaschian, and Robert E. Reed-Hill. Physical metallurgy principles. Vol. 200. Stamford: Cengage Learning, 2010.

Reference Books:

1. Haidemenopoulos, Gregory N. Physical metallurgy: principles and design. CRC Press, 2018.
2. Christian, John. The theory of transformations in metals and alloys. Newnes, 2002.
3. Fultz, Brent. Phase transitions in materials. Cambridge University Press, 2020.

EC26033 **3-0-0 (3)**

Semiconductor Materials and Device Structures

Pre-Requisites: **None**

Course Outcomes:

CO-1	Describe concepts of semiconductor materials and their behaviour
CO-2	Analyze the structure, operation, and I–V characteristics of basic semiconductor and optoelectronic devices
CO-3	Explain industrial-scale electronic-grade silicon production and electronic device fabrication
CO-4	Evaluate advanced and emerging semiconductor materials and technologies for modern electronic and optoelectronic applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	1	-	-	-
CO-2	2	2	1	-	-	-
CO-3	2	3	2	-	-	-
CO-4	3	2	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Semiconductor fundamentals: energy band theory; conductors, semiconductors, and insulators; band diagrams; Fermi energy and Fermi–Dirac distribution; density of states; effective mass of charge carriers; intrinsic and extrinsic semiconductors; doping mechanisms; carrier concentration; temperature dependence of carrier concentration; carrier mobility; drift and diffusion processes; continuity equation; generation and recombination mechanisms; I–V characteristics.

Semiconductor devices and materials: p–n junction diode formation and characteristics; Zener and Schottky diodes; bipolar junction transistors (BJT); field effect transistors (MOSFETs); elemental and compound semiconductors (Si, Ge, GaAs, GaN); optical properties of semiconductors; fundamentals of optoelectronic devices.

Silicon technology and device fabrication: manufacturing of metallurgical-grade silicon; Siemens process for electronic-grade silicon; single crystal growth by Czochralski technique; crystal defects and impurity control; silicon wafer preparation for electronic devices; lithography; physical vapour deposition (PVD); chemical vapour deposition (CVD); thin film processing.

Solar cells and advanced semiconductor materials: photovoltaic effect; types of silicon solar cells (amorphous, polycrystalline, single crystal); fabrication and functioning of silicon solar cells; multi-junction solar cells; LEDs; wide bandgap semiconductors (SiC, GaN); organic and polymer semiconductors; perovskite materials; thin films and nanostructured materials; low-dimensional systems (quantum wells, wires, and dots); nanoelectronic and optoelectronic devices; recent trends in advanced semiconductor technologies.

Learning Resources:

Text Books:

1. C. Kittel, Introduction to Solid State Physics, Wiley, 2005.
2. S. M. Sze and K. K. Ng, Physics of Semiconductor Devices, Wiley, 2007.
3. B. G. Streetman and S. Banerjee, Solid State Electronic Devices, Pearson, 2015.
4. D. A. Neamen, Semiconductor Physics and Devices, McGraw-Hill Education, 2012.
5. S. O. Kasap, Principles of Electronic Materials and Devices, McGraw-Hill, 2018.

ME26045 **3-0-0 (3)**

Artificial Intelligence and Machine Learning in Materials Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the fundamentals of materials structure, processing, and structure–property relationships relevant to materials design
CO-2	Implement and evaluate machine learning models by applying supervised and unsupervised algorithms
CO-3	Apply statistical and machine learning techniques for materials data analysis and property prediction.
CO-4	Use computer vision and AI methods to establish microstructure–property correlations and support data-driven materials design.

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	3	3	2	-	-
CO-2	1	2	1	2	-	-
CO-3	-	-	2	3	-	-
CO-4	-	-	3	2	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of Materials science and Processing: Introduction to AI/ML in Materials Engineering: motivation and scope, Structure of materials: atomic, crystalline, and defect structures, Microstructure and property relationships, Processing of materials: solidification, deformation, heat treatment, Correlation between processing, structure, and properties

Fundamentals of Machine Learning: Supervised learning – Regression, Support Vector Machine, Random Forest; Cost functions and optimization; Feature engineering, model training and model validation; Classification metrics; Unsupervised learning – Clustering

Machine Learning for Materials Design: Materials databases, Materials datasets, Materials descriptors, Statistical analysis and data handling in materials science, Data generation using simulations and data integration, Machine learning for materials applications – case studies: Materials property prediction, Phase prediction of high entropy alloys

Advanced AI Applications in Materials Engineering: Machine learning for microstructural evolution modeling, ML-based microstructure property correlations, Computer vision techniques for microstructure analysis, Case studies and recent advances in AI-driven materials design

Learning Resources:

Text Books:

1. Materials Informatics: Data-Driven Discovery in Materials Science by Krishna Rajan, Springer, First Edition, 2015.
2. Machine Learning in Materials Science by A. Agrawal and A. Choudhary, Elsevier, First Edition, 2016.
3. Computational Materials Science: An Introduction by June Gunn Lee, CRC Press, Second Edition, 2017.
4. Data-Driven Materials Science and Engineering by Turab Lookman, K. Rajan, and A. Saxena, Elsevier, First Edition, 2016.
5. Artificial Intelligence for Materials Science by Taylor Sparks, Morgan & Claypool Publishers, First Edition, 2020.

Reference Books:

1. Jake VanderPlas, "Python Data Science Handbook: Essential Tools for Working with Data, O'Reilly Media, 1st Edition, 2016
2. Machine Learning: A Probabilistic Perspective by Kevin P. Murphy, MIT Press, First Edition, 2012.
3. Pattern Recognition and Machine Learning by Christopher M. Bishop, Springer, First Edition, 2006.
4. Computational Materials Engineering by Koenraad George Frans Janssens et al., Elsevier, First Edition, 2017.
5. Multiscale Materials Modeling by Z. X. Guo and W. Sha, Woodhead Publishing, First Edition, 2010.
6. Introduction to Computational Materials Science by Richard LeSar, Cambridge University Press, Second Edition, 2013.

Other Suggested Readings:

1. NPTEL Courses: Machine Learning for Engineering and Science Applications By Prof. Balaji Srinivasan and Prof. Ganapathy
2. https://jarvis.nist.gov/

MM46003 **0-1-2 (2)**

Manufacturing Processes Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Demonstrate metal joining operations following standard safety procedures
CO-2	Perform cold working operations on ferrous and non-ferrous metals/alloys
CO-3	Analyze microstructure and hardness variation in welded and cold rolled samples
CO-4	Detect common manufacturing defects using NDT

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	2	-	3	1
CO-2	2	2	-	-	3	1
CO-3	-	2	1	-	3	1
CO-4	-	2	-	-	3	1

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

1. Demonstration of Gas Tungsten Arc Welding (GTAW) on a given sample.
2. Demonstration of Gas Metal Arc Welding (GMAW) on a given sample.
3. Demonstration of Shielded Metal Arc Welding (SMAW) on a given sample.
4. Demonstration and characterization of the Wire Arc Additive Manufacturing (WAAM) process.
5. Metallographic preparation of welded samples and identification of weld metal, HAZ, and base metal.
6. Study of microstructural changes in various zones of welded samples.
7. Hardness testing across the weldment and plotting the hardness profile.
8. Identification of defects using Liquid Penetrant Testing (LPT) and Magnetic Particle Testing (MPT).
9. Cold rolling of Cu/Brass/SS/Plain carbon steel using lab rolling mill, followed by annealing, and observation of microstructural changes.
10. Nano fabrication of materials using PVD.

Learning Resources:

Text Books:

1. Serope Kalpakjian & Steven R. Schmid, Manufacturing Engineering and Technology, Pearson.
2. Howard B. Cary & Scott C. Helzer, Modern Welding Technology, Pearson.

Reference Books:

1. ASM International, ASM Handbook, Volume 6A: Welding Fundamentals and Processes, ASM International.

Other Suggested Readings:

1. ASNT, Nondestructive Testing Handbook, Volume 1: Leak Testing / Liquid Penetrant Testing (ASNT).

MM46005 **3-0-0 (3)**

Computational Methods in Materials Science Laboratory

Pre-Requisites: **Physical Metallurgy**

Course Outcomes:

CO-1	Apply fundamental concepts of crystallography, solid-state physics, and thermodynamics to construct and analyze atomic-scale models of materials
CO-2	Perform first-principles calculations and classical Molecular Dynamics (MD) simulations
CO-3	Calculate phase equilibria using computational tools
CO-4	Develop data-driven models using machine learning techniques

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	1	1	-	-
CO-2	2	3	2	-	-	-
CO-3	3	3	1	-	-	-
CO-4	3	2	3	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

List of Experiments:

1. Introduction to Linux and High-Performance Computing (HPC)
2. Crystal Structure Visualization and Symmetry Analysis
3. Generation of Crystal Structures and Supercells
4. Convergence Testing in DFT Calculations
5. Structural Optimization and Equation of State
6. Electronic Structure Calculations
7. Calculation of Elastic Constants
8. Defect Formation Energy Calculations
9. Classical MD Simulation of Metals
10. Thermal Properties from MD
11. CALPHAD-Based Phase Diagram Calculation
12. Short-Range Order and Enthalpy of Mixing
13. Machine Learning for Materials Properties

Learning Resources:

Text Books:

1. LeSar, R. – Introduction to Computational Materials Science
2. H. Lukas, S. G. Fries, B. Sundman – Computational Thermodynamics: The CALPHAD Method
3. Martin, R. M. – Electronic Structure: Basic Theory and Practical Methods
4. Frenkel & Smit – Understanding Molecular Simulation
5. Kittel, C. – Introduction to Solid State Physics

Reference Books:

1. Hohenberg & Kohn (1964), Kohn & Sham (1965) papers
2. Giustino, F. – Materials Modelling Using Density Functional Theory
3. N. Saunders & A. P. Miodownik – *CALPHAD:* Calculation of Phase Diagrams
4. Butler et al. – Machine learning for molecular and materials science (Nature)
5. Schmidt et al. – Recent advances and applications of machine learning in solid-state materials science

Other Suggested Readings:

1. Giustino, F. – Materials Modelling Using Density Functional Theory
2. Frenkel & Smit – Understanding Molecular Simulation
3. Plimpton, S. – LAMMPS Documentation & Tutorials
4. MIT OpenCourseWare – Computational Materials Science
5. nanoHUB.org (DFT, MD, phase-field tutorials)
6. Materials Project Workshops

Semester II

MM46002 **3-0-0 (3)**

Mechanical Behavior of Materials

Pre-Requisites: **Physical Metallurgy**

Course Outcomes:

CO1	Identify importance of relationship between structure and mechanical properties
CO2	Apply the knowledge of plastic deformation of metals to design efficient metal working operations
CO3	Apply the fracture mechanics principles to determine the fracture toughness of brittle and ductile materials
CO4	Apply the knowledge of fatigue, creep and superplasticity phenomena to design processes for improved microstructure and properties

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	-	-	-
CO2	3	2	3	-	-	-
CO3	2	2	2	-	-	-
CO4	3	2	3	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Fundamentals of Stress and Strains: Concept of stresses and strains, engineering stresses and strains, Different types of loading and temperature encountered in applications, Tensile Test - stress - strain response for metal, ceramic and polymer, elastic region, yield point, plastic deformation, necking and fracture, Bonding and Material Behaviour, theoretical estimates of yield strength, Physical origin of elastic moduli, Generalized Hooke's law and its application to crystals, Designing for modulus and Composites.

Yielding and Plastic Deformation: Hydrostatic and Deviatoric stress, Octahedral stress, yield criteria and yield surface, texture and distortion of yield surface, Limitation of engineering strain at large deformation, true stress and true strain, Necking and Considere's Criterion, effective stress, effective strain, flow rules, strain hardening, stress - strain relation in plasticity.

Microscopic view of plastic deformation: crystals and defects, classification of defects, geometry of dislocations, slip and glide, dislocation generation - Frank Read and grain boundary sources, stress and strain field around dislocations, force on dislocation - self-stress, dislocation interactions, partial dislocations, twinning, dislocation movement and strain rate, deformation behavior of single crystal, critical resolved shear stress (CRSS), deformation of poly-crystals - Hall-Petch and other hardening mechanisms, grain size effect - source limited plasticity, Hall-Petch breakdown.

Fracture: Fracture, Fracture Mechanics, Griffith Fracture Theory, LEFM -K_{IC}, EPFM - J_{IC}, CTOD; Fatigue: HCF and LCF, Fatigue crack inhibition, Fatigue crack growth, Paris law; Creep: Time dependent deformation - creep, different stages of creep, creep and stress rupture, creep mechanisms.

Learning Resources:

1. R. W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Edition, John Wiley & Sons Inc., 2012.
2. M.A. Meyers and K.K. Chawla: Mechanical Behavior of Materials, Prentice Hall Inc., New Delhi, 1999.
3. T. L. Anderson: Fracture Mechanics- Fundamentals and Applications, 3rd Edition, CRC Press, 2011.
4. G. E. Dieter: Mechanical Metallurgy, McGraw-Hill, 2002

MM46004 **3-0-0 (3)**

Advanced Materials Characterization Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Distinguish various characterisation techniques for microstructural analysis
CO-2	Appraise principles, instrumentation and applications of advanced characterization techniques.
CO-3	Describe specimen preparation techniques for various characterization techniques
CO-4	Choose the appropriate technique for microstructure and chemical composition analysis

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	1	-	-
CO-2	3	3	3	-	-	-
CO-3	2	3	2	-	-	-
CO-4	2	3	2	3	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Optical Microscopy: Basic principles, illumination modes (brightfield, darkfield, phase contrast, polarized light), specimen prep.

Electron Microscopy (SEM/TEM/STEM): Principles, interaction of electrons with matter, imaging modes, specimen prep, EDX/WDS, HRTEM, STEM-EELS.

Scanning Probe Microscopy (AFM/STM/MFM): Principles, modes (contact, tapping, non-contact) and applications.

X-ray Diffraction (XRD): Principles, powder XRD, single crystal, thin film analysis. Small-Angle X-ray/Neutron Scattering. XPS (X-ray Photoelectron Spectroscopy), AES (Auger Electron Spectroscopy), FTIR (Fourier Transform Infrared), Raman Spectroscopy, UV-Vis Absorption & Emission Spectroscopy, Electron Energy Loss Spectroscopy (EELS).

Advanced/Specialized Techniques-Atom Probe Tomography (APT): Electron Beam Techniques, EBSD (Electron Backscatter Diffraction), Laser Confocal Microscopy. Thermal Analysis-TGA (Thermogravimetric Analysis), DTA (Differential Thermal Analysis), DSC (Differential Scanning Calorimetry)

Learning Resources:

Text Books:

1. ASM Handbook: Materials Characterization, ASM International, 2008.
2. C. Suryanarayana, M. Grant Norton: X-Ray Diffraction-A Practical Approach, Plenum Publishing Corporation, 1998)
3. Transmission Electron Microscopy; D.B. Williams and C.B. Carter, Plenum Press (2004)
4. Modern ESCA The Principles and Practice of X-Ray Photoelectron Spectroscopy, Terry L.Barr, CRC press, (1994)

5. Scanning Electron Microscopy and X-ray Microanalysis by Joseph Goldstein, Dale E. Newbury, David C. Joy, and Charles E.; Springer Science (2003)
6. Advanced Techniques for Materials Characterization, Materials Science Foundations (monograph series) A. K. Tyagi, Mainak Roy, S. K. Kulshreshtha and S. Banerjee;, Volumes 49 – 51 (2009)

Reference Books:

1. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.
2. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House,1967.
3. S.J.B. Reed: Electron Microprobe Analysis, Cambridge University Press, London, 1975.

Other Suggested Readings:

1. http://digimat.in/nptel/courses/video/113104004/L22.html

MM46006 **0-1-2 (2)**

Advanced Materials Characterization Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Recognize various characterisation techniques for microstructural, compositional and thermal analysis
CO-2	Appraise principles, instrumentation, specimen preparation and observation of materials using advanced characterisation techniques
CO-3	Analysis and quantification of data obtained from different characterisation techniques
CO-4	Choose suitable characterisation techniques for appropriate analysis of advanced materials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	2	2	3	2
CO-2	2	3	3	3	3	3
CO-3	1	3	2	3	3	3
CO-4	3	3	3	2	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

1. Microstructural characterisation of a given sample using Optical Microscopy (OM) and Scanning Electron Microscopy (SEM)
2. Quantification of phases using image j software
3. Fractographic characterisation of a given sample using Scanning Electron Microscopy (SEM).
4. Chemical composition analysis of a given sample using SEM coupled with Energy Dispersive Spectroscopy (EDS).
5. Identification of phases, lattice parameter measurement, and crystal structure determination using X-Ray Diffraction (XRD).
6. Assessment of lattice strain and crystallite size utilizing X-Ray Diffraction (XRD).
7. Measurement of thermal properties using Differential Scanning Calorimetry (DSC).
8. Evaluation of oxidation kinetics through Thermogravimetric Analysis (TGA) or Differential Thermal Analysis (DTA).
9. Chemical composition analysis of a given sample using Inductively coupled plasma mass spectroscopy

Learning Resources:

Text Books:

1. S Zhang, L. Li and Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.
2. David B. Williams, C.Barry Carter, Transmission Electron Microscopy, Textbook for Materials Science, Springer, 2009, 2nd Edition

Reference Books:

1. Materials Characterization Techniques Laboratory Manual

Other Suggested Readings:

1. ASM Handbook: Materials Characterization, ASM International, 2008

MM46008 **0-1-2 (2)**

Mechanical Behaviour of Materials Laboratory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Operate mechanical testing equipment for measuring materials properties
CO-2	Analyze the data obtained from mechanical testing
CO-3	Determine the fracture toughness of materials
CO-4	Assess high-temperature mechanical properties of alloys

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	3	3	2
CO-2	2	2	2	3	3	2
CO-3	2	2	2	3	3	3
CO-4	2	2	2	3	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Hardness test, Tensile test, Compression test, Impact test, Wear and erosion test, Microhardness and indentation fracture toughness test, Fracture toughness test, Fatigue testing, Creep and stress rupture tests. NDT techniques- Ultrasonic, magnetic particle, die penetrant test.

Learning Resources:

Text Books:

1. R. W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Edition, John Wiley & Sons Inc., 2012.
2. M.A. Meyers and K.K. Chawla: Mechanical Behavior of Materials, Prentice Hall Inc., New Delhi, 1999.
3. T. L. Anderson: Fracture Mechanics- Fundamentals and Applications, 3rd Edition, CRC Press, 2011.
4. G. E. Dieter: Mechanical Metallurgy, McGraw-Hill, 2002
5. Laboratory Manual

MM46010 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	3	3	3
CO-2	2	2	2	3	3	3
CO-3	2	2	2	3	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	
II	Study of Existing Systems and establishing clear objectives	
III	Planning of project and work distribution within the team	
IV	Proper Documentation and Technical Writing	
V	Presentation and Response to questions	

Semester III

MM46007 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	-	2	2	2	3	3
CO-2	-	-	2	2	3	3
CO-3	-	2	-	2	3	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	**Description**	**Weightages**
I	Clarity on the topic	Weightage for each criterion will be determined by the panel and will be informed to the students.
II	List of lectures attended	
III	Report	
IV	Presentation	
V	Response to questions	

Evaluation Criteria-CO Mapping

CO / **Criteria**	**CO1**	**CO2**	**CO3**
I	X		
II	X		
III		X	
IV			X
V			X

MM46009 **0-0-0 (2)**

Summer Internship/Research Experience (SIRE)

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	2	3	3	3	3
CO-2	2	-	2	3	3	3
CO-3	-	2	-	2	3	3
CO-4	-	-	-	2	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Every student has to undergo either a Summer Internship / EPICS / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The EPICS/research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	**Description**	**Weightages**
I	Relevance of the area of work	Weightage for each criterion will be determined by the panel and will be informed to the students.
II	Performance of the Task	
III	Crucial learnings from the work	
IV	Report Preparation	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

CO / **Criteria**	**CO1**	**CO2**	**CO3**	**CO4**
I	X			
II		X		
III			X	
IV				X
V				X

MM46011 **0-0-0 (2)**

Comprehensive Viva-Voce

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	2	-	-
CO-2	3	3	3	2	-	-
CO-3	2	2	-	2	3	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

MM46013 **0-0-0 (8)**

Dissertation: Part-A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of Materials and Manufacturing Engineering.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	3	3
CO-2	3	2	2	3	3	3
CO-3	3	2	3	3	3	3
CO-4	2	2	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	Weightage
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

The midterm review and the end semester viva-voce examination will be conducted by a committee constituted by the Head of the Department.

iv. The marks may be distributed among various components like selection of topic, problem statement, literature review, methodology, oral and written presentation of the work done and performance in viva- voce examination.
v. If the performance of the student in Dissertation Part-A is not satisfactory, he/ she will be awarded ‘F’ grade. The student has to repeat the dissertation work by registering in the next semester. Such students may be given an option either to continue with the same topic and with the same guide or change the guide and the topic of his/ her dissertation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	Weightage for each criterion will be determined by the panel and will be informed to the students.
II	Literature Survey	
III	Defining the Objectives and Solution Methodology	
IV	Performance of the Task	

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

Semester IV

MM46012 **0-0-0 (12)**

Dissertation: Part-B

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference without plagiarism

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	3	3	3	3
CO-2	3	2	2	3	3	3
CO-3	3	2	3	3	3	3
CO-4	2	2	3	3	3	3
CO-5	2	2	2	2	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	**Description**	**Weightages**
IV	Performance of the Task	Weightage for each criterion will be determined by the panel and will be informed to the students.
V	Dissertation Preparation	
VI	Review (Presentation & Understanding)	
VII	Viva-Voce	

VIII	Publications /Possibility of publication	

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	X	X			
V				X	
VI			X		
VII				X	
VIII					X

Refer to the M.Tech. – "Refer to M.Tech. – Regulations for any further information regarding Mid-term review, End Sem evaluation, Template for report preparation and plagiarism"

PROFESSIONAL ELECTIVES – I

MM46015 **3-0-0 (3)**

Light Weight Metals and Alloys

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the relationship between Processing, Microstructure and Properties
CO-2	Design and develop Al - alloys for automotive applications
CO-3	Apply the concepts of microstructure design for high strength Mg- alloy development
CO-4	Apply the concepts of processing for controlling the properties of Ti- alloys

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	2	-	-	-
CO-2	3	3	3	-	-	-
CO-3	3	3	2	-	-	-
CO-4	3	3	2	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

General introduction - strengthening by solid solution, precipitation, dispersion, grain refining and work hardening. Production of aluminum, magnesium, titanium by various methods. Aluminum alloys - Designation, temper and characteristics of cast and wrought aluminum alloys. Magnesium alloys - Alloy designation and tempers, casting alloys, wrought alloys, latest trends in applications of Mg alloys. Titanium alloys - alpha alloys, alpha - beta alloys, beta alloys, fabrication, heat treatments. Metal matrix composites - principles, processing, properties and applications.

Learning Resources:

Text Books:

1. I.J. Polmear, Light Alloys - From Traditional Alloys to Nanocrystals, Fourth Edition, Butterworth Heinemann, 2005
2. R.W. Heine, C.R. Loper, P.C. Rosenthal, Principles of Metal Casting, Tata McGraw Hill, 1976.
3. D.H. Kirkwood, M. Surey, P. Kapranos, H.V. Atkinson, K.P. Young, Semisolid Processing of Alloys, Springer Series in materials Science, 2010.
4. M. Gupta, N.M.L. Sharon, Magnesium, Magnesium Alloys, and Magnesium Composites, Wiley, 2011
5. G. Lutjering, J.C. Williams, Titanium, Springer, 2007
6. T.W. Clyne, P.J. Withers, An introduction to metal-matrix composites, Cambridge University Press, 1993.

MM46017 **3-0-0 (3)**

Materials for Advanced Nuclear Power Plants

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain nuclear basics for materials: binding energy, fission, fusion, neutron interactions, moderation, and spectrum.
CO-2	Choose materials for key components in fission and fusion systems, with clear justification.
CO-3	Correlate irradiation damage (dpa, transmutation, He/H) with microstructure and property changes (organic and inorganic).
CO-4	Evaluate degradation mechanisms, shielding logic, and waste/waste-form material aspects for safe operation.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	-	-	-
CO-2	2	3	3	-	-	-
CO-3	3	2	2	-	-	-
CO-4	2	3	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Elementary concepts of nuclear reactors: structure of the nucleus, binding energy and nuclear stability, radioactivity and decay, fission reactions and energy release, neutron interactions and cross sections, moderation, neutron spectrum (thermal/fast), and qualitative criticality through multiplication factor.

Reactor components and materials for fission systems: classification of reactors and material requirements for performance, safety, and reliability. Materials used for fuels, cladding, moderators, control rods, coolants, reflectors, and structural components; key fabrication/microstructure considerations for fuel and cladding; compatibility challenges with water, sodium, lead/LBE, helium, and molten-salt environments.

Radiation effects and degradation: interaction of radiation with materials, displacement damage and transmutation, swelling, irradiation hardening/embrittlement, irradiation creep, thermal property changes, and corrosion/oxidation and stress-corrosion mechanisms under reactor service. Radiation hazards, fundamentals of shielding, and safe handling/containment considerations relevant to nuclear facilities.

Fusion energy materials: materials needs for plasma-facing components (first wall/divertor), breeding blankets and tritium-related materials issues (permeation/retention), structural and heat-sink materials under high heat flux, and superconducting magnet material constraints. Low-activation material philosophy, activation/waste considerations, and an overview of Indian nuclear power programme and reactor context from a materials perspective.

Learning Resources:

Text Books:

1. S. Glasstone and A. Sesonke, Nuclear Reactor Engineering, Van Nostrand, 1994.
2. John R. Lamarsh and Anthony J. Baratta, Introduction to Nuclear Engineering, Prentice Hall, 2001.
3. J. Kenneth Shultis and Richard E. Faw, Fundamentals of Nuclear Science and Engineering, Marcel Dekkar, 2002.

Reference Books:

1. H. S. Ray, R. Sridhar and K. P. Abraham, Extraction of Non-Ferrous Metals.
2. Geoffrey F. Hewitt and John G. Collier, Introduction to Nuclear Power, Taylor and Francis, 1997.
3. K. Almenas and R. Lee, Nuclear Engineering: An Introduction, Springer Verlag, 1992.

Other Suggested Readings:

1. Kenneth D. Kok, Nuclear Engineering Hand Book, CRC Press, 2009.

MM46019 **3-0-0 (3)**

Energy Materials: Conversion and Storage

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the need for electrochemical energy conversion and storage.
CO-2	Discuss the principle and materials used in electrochemical conversion devices.
CO-3	Describe the principle and materials used in batteries for energy storage.
CO-4	Describe the principle and materials used in supercapacitors and hybrid electrochemical storage devices.
CO-5	Understand future electrochemical energy devices: beyond conventional batteries and fuel cells.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	-	-
CO-2	2	3	3	-	-	-
CO-3	3	3	3	-	-	-
CO-4	3	3	3	-	-	-
CO-5	2	2	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Electrochemical energy and environment: role of electrochemical technologies in modern energy systems, world energy use and transport electrification context, gap between energy production and energy needs, current energy conversion/storage technologies and their limitations, challenges in energy-efficient material technology for electrochemical devices.

Basics of electrochemical conversion devices: definition and brief history of fuel cells and electrolyzers, principle of operation, thermodynamics and efficiency, electrochemical kinetics and polarization losses, mass transport concepts, types of fuel cells and electrolyzers, their chemistries, advantages/disadvantages.

Basics of electrochemical storage devices: primary and secondary batteries, types of batteries, lithium-ion battery (LIB) and sodium-ion battery (SIB) components, working principle, thermodynamics and efficiency, types of materials used for electrodes, electrolytes and separators, safety aspects; basics of supercapacitors (EDLC and pseudocapacitors), materials for supercapacitors, hybrid devices; concepts of future electrochemical devices beyond conventional LIB technologies (solid-state batteries, metal anodes, Li–S/Na–S, redox flow batteries—introduction), introduction to smart grid and grid-scale electrochemical storage.

Characterization techniques to study electrochemical device characteristics: open-circuit voltage, charge–discharge testing, cyclic voltammetry, electrochemical impedance spectroscopy, rate capability and cycling stability evaluation.

Learning Resources:

Text Books:

1. Introduction to materials for advanced energy systems, Colin Tong, Springer, 2019.
2. Korthauer, R. ed., 2018. Lithium-ion batteries: basics and applications. Springer.

Reference Books:

1. Liao, C., 2021. Fundamentals of rechargeable lithium ion and beyond lithium ion batteries. In Batteries: Materials principles and characterization methods (pp. 1-1).

Other Suggested Readings:

1. https://www.doitpoms.ac.uk/tlplib/batteries/index.php

MM46021 **3-0-0 (3)**

High Temperature Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the principles of high temperature oxidation and corrosion of materials
CO-2	Understand materials degradation and its mechanisms
CO-3	Explain mechanisms of creep, thermal fatigue, oxidation
CO-4	Select materials for high temperature applications

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	-	-
CO-2	2	3	3	-	-	-
CO-3	3	3	3	-	-	-
CO-4	3	3	3	-	-	-
CO-5	2	2	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

High Temperature Oxidation and Environmental Degradation: Mechanisms of oxidation; oxidation of pure metals and alloys; Wagner's theory; selective and internal oxidation; oxidation in mixed environments; hot corrosion; effect of alloying elements; oxide scale formation, growth, and failure; strategies for improving oxidation and corrosion resistance.

Creep and High Temperature Mechanical Behavior: Creep phenomena and stages of creep; diffusion and dislocation creep mechanisms; metallurgical factors influencing creep; stress rupture testing and life prediction parameters; activation energy for creep; microstructural evolution during creep; creep–fatigue interaction; effects of stress, temperature, strain rate, and environment; representation and extrapolation of engineering creep data; principles of creep-resistant alloy design.

Materials Systems and Applications: Heat-resistant and stainless steels; superalloys; titanium alloys; intermetallics; ceramics and ultra-high temperature ceramics; refractory metals and alloys; high-temperature polymers; composites; coatings and surface engineering (thermal and environmental barrier coatings); applications in aerospace, power generation, automotive, nuclear, and space systems.

Learning Resources:

Text Books:

1. G.W. Meetham, M.H. Van de Voorde, Materials for High Temperature Engineering Applications, Springer, 2000.
2. Michael E. KassnerMarı´a-Teresa Pe´rez-Prado, Fundamentals of Creep in Metals and Alloys, Elsevier, 2004.

Reference Books:

1. R.W. Evans, B Wilshire, Introduction to creep, Institute of Materials, 1993.
2. David young, High Temperature Oxidation and Corrosion of Metals, Elsevier Publications, 2016,2nd Edition.
3. Roger C. Reed, The Super alloys: Fundamentals and Applications, Cambridge university press,2006.

Other Suggested Readings:

1. https://archive.nptel.ac.in/courses/113/106/113106088/
2. https://archive.nptel.ac.in/content/storage2/courses/112108150/pdf/PPTs/MTS_08_m.pdf

MM46023 **3-0-0 (3)**

Materials for Extreme Environments

Pre-Requisites: None

Course Outcomes:

CO-1	Understand thermodynamic and kinetic principles governing materials in extreme environments.
CO-2	Analyze degradation mechanisms of materials under thermal, radiation, mechanical and chemical extremes
CO-3	Apply experimental and computational techniques to study materials under extreme conditions
CO-4	Select appropriate materials for aerospace, nuclear and energy-related extreme environments
CO-5	Interpret material behavior under energetic flux and electromagnetic extremes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	-	-
CO-2	3	3	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	3	3	-	-	-
CO-5	2	2	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to extreme environments and their relevance in modern engineering applications: Review of fundamental concepts of thermodynamics and kinetics with emphasis on phase stability, diffusion, defect transport and non-equilibrium processes under extreme conditions. Experimental and computational techniques for extreme environments including diamond anvil cell, cryogenic and spin-cooling methods, ultrafast spectroscopy, dynamic transmission electron microscopy, quantum mechanical calculations and molecular dynamics simulations.

Engineering materials applied in extreme environments: Structural materials for high-temperature applications including superalloys, intermetallics and refractory materials, creep, oxidation, thermal fatigue and phase stability. Radiation-resistant materials for nuclear and space applications, radiation-induced defects, swelling and embrittlement.

Engineering materials: for spacecraft and aerospace environments subjected to vacuum, thermal cycling, radiation and micrometeoroid impacts, lightweight alloys, composites, thermal protection systems and ablative materials.

Materials under thermomechanical extremes: including static and dynamic loading, high-pressure phase transformations, shock, detonation, cavitation and behavior of supercooled liquids and metallic glasses. Materials under chemical extremes including aggressive environments, interfaces in fuel cells, protective coatings and novel synthesis routes.

Materials under energetic flux and electromagnetic extremes: including interaction with photons, electrons and ions, focused ion beam fabrication, metastable phase formation, dielectric breakdown, field-induced phase transformations and material synthesis under extreme electric and magnetic fields.

Learning Resources:

Text Books:

1. George Dieter, Mechanical Metallurgy;
2. Neil Bourne, Materials response under mechanical extreme;
3. Gary was, Fundamentals of Radiation Materials Science
4. Advanced Materials and structures for extreme operating conditions, Dr. Jacek J Skrzypek, Dr. Arthur W. Ganczarski, Haling Egner, Dr. Franco Rustichelli, Springer, 2008, 1st Edition.

Reference Books:

1. Ultra-high temperature ceramics: Materials for extreme environment applications (I, II & III), William G. Fahrenholtz, Eric J. Wuchina, Wiley, 2014

MM46025 **3-0-0 (3)**

Functional and Smart Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify materials for functional applications
CO-2	Suggest materials for energy harvesting applications
CO-3	Evaluate shape memory behaviour of materials
CO-4	Comprehend operational principles of optical fibres, magneto/electro rheological fluids
CO-5	Select materials for sensor/actuator applications in smart structures

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	3	3	-	-	-
CO-2	2	3	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	2	2	-	-	-
CO-5	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Functional materials: Magnetic materials, Electronic Materials, Electric Contact Materials, Conducting Thermoplastics and polymer composites, Surface coatings for functional applications, Biomaterials, Shape memory metals, Materials for energy harvesting, Reflective and anti-reflective layers, material properties of ceramic-metal FMs.

Smart materials: Smart responses from nature, Classification of smart materials, Sensing and actuation, Examples and applications.

Piezoelectric and Magnetostrictive Materials: Piezoelectric effect, Structure of piezoelectric ceramics, Polarization, Processing of piezoelectric ceramics, Polymer piezoelectrics, Composites, Electrostrictive materials, Magnetostrictive materials, Magnetostrictive effects for sensing and actuation, Hybrid sensors.

Shape memory materials: Shape memory alloys (SMAs), Shape memory effect and phase changes, Phase transformation in SMAs, Types of SMAs, Superelasticity, SMA properties and Processing, Applications - aerospace, automotive, medical and construction, Challenges in SMAs, Smart memory ceramics, Mechanisms of smart recovery in ceramics.

Magneto/electro rheological fluids and optical fibers: Magneto rheological (MR) fluids, MR vs ferro fluids, Applications of MR fluids – damping and dissipation, Electro rheological (ER) fluids, Giant electro rheological (GER) fluid and its applications, Optical fibers, Fiber optic total internal reflection, Fiber optic sensors, Intrinsic and extrinsic fiber optic sensors, Applications and advantages.

Smart Structures: Need for smart structures, Concept of smart structure, Integration of functions, sensor / actuator and control mechanisms, Smart structure classifications, Applications – aerospace, defence, automotive, industrial, medical, civil/construction.

Learning Resources:

Text Books:

1. Engineering Materials for Technological Needs, Vol. 2- Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications, D.D.L. Chung, World Scientific Publishing,2010.

2. Smart Materials and Structures, M.V. Gandhi, B.S. Thompson, Chapman & Hall, 1992.
3. Shape Memory Materials, D.I. Arun, P. Chakravarthy, R. Arockia Kumar, B. Santhosh, CRC Press, 2018.

Reference Books:

1. Composite Materials - Functional Materials for Modern Technologies, D.D.L. Chung, Springer, 2002.
2. Smart Materials: Proceedings of the 1st Caesarium, Hoffmann, Karl-Heinz (Ed.), Springer, 1999.
3. Smart Materials – An Industrial Perspective, P. Nikhil Chandra, Mothi Krishna Mohan, Notion Press, 2021.
4. Smart Structures Theory, I Chopra and J. Sirohi, Cambridge University Press, 2013.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113/105/113105081/
2. https://nptel.ac.in/courses/112/104/112104251/
3. https://nptel.ac.in/courses/113/105/113105081/

MM46027 **3-0-0 (3)**

Advanced Materials Processing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the classification of engineering materials and relate structure–property requirements to processing routes.
CO-2	Describe fundamentals of casting, powder/particulate processing, and forming methods used for producing engineering components.
CO-3	Explain joining and surface engineering processes, including typical process selection criteria, defects, and applications.
CO-4	Analyze the influence of processing parameters on microstructure, properties, quality, and manufacturing defects in processed components.

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	2	2	-	-	-
CO-2	3	3	3	-	-	-
CO-3	3	3	2	-	-	-
CO-4	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Engineering Materials: Metals and alloys; ceramics—structure and properties, traditional ceramics, advanced ceramics, glass ceramics; polymers—fundamentals of polymers, thermoplastics, thermosets, elastomers; composite materials—classification and basic processing relevance.
Foundry Technology and Advanced Casting: Overview of casting technology; sand casting and mold materials; expendable-mold casting processes; permanent-mold casting processes; solidification basics (conceptual), casting quality, common casting defects and inspection concepts.
Particulate Processing of Materials: Powder metallurgy—characterization of engineering powders, powder production methods, blending/compaction; conventional sintering; alternative processing and sintering techniques; particulate processing routes for ceramics, polymers, and composites (overview).
Metal Forming and Shaping: Mechanics of plastic deformation (basic concepts); rolling, forging, extrusion, drawing; deep drawing and sheet metal forming; forming limits and typical defects (earing, wrinkling, cracking) with process selection overview.
Materials Joining: Need for joining and selection of joining methods; welding processes—TIG, MIG, SAW, SMAW, resistance spot welding; solid-state joining—friction welding and friction-stir welding; advanced welding—laser beam welding; brazing, soldering, adhesive bonding; welding defects and quality considerations.
Surface Engineering: Importance of surface engineering; classification of surface modification processes; introduction to thermal (coatings), thermo-chemical (carburizing/nitriding), and electro-chemical surface engineering processes; advantages, limitations, and typical industrial applications.

Learning Resources:

Text Books:

1. Kalpakjian and Schmid, Manufacturing Engineering and Technology, Prentice Hall, New Jersey, 2013.
2. Mikell P. Groover, Fundamentals of Modern Manufacturing, John Wiley & Sons, Inc, New Jersey, 2010.
3. R. S. Parmar, Welding Processes and Technology, Khanna Publishers, 2010.
4. H.S. Bawa, Manufacturing Technology-I, Tata McGraw Hill, New Delhi, 2007.

Reference Books:

1. DeGarmo, Black, and Kohser, Materials and Processes in Manufacturing, John Wiley & Sons, New York, 2011.
2. Serope Kalpakjian, Manufacturing Processes for Engineering Materials, Addison Wesley, 2001.

Other Suggested Readings:

1. NPTEL course: https://onlinecourses.nptel.ac.in/noc20_mm29/preview

MM46029 **3-0-0 (3)**

Rare Earth Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Discuss various rare earth materials and their strategic importance
CO-2	Explain the geology, mineralogy, and mineral processing of rare earth minerals
CO-3	Describe the extraction and refining of metals from rare earth minerals
CO-4	Discuss the applications of rare earth materials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	-	-	-
CO-2	2	2	2	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Rare Earth Materials: Definition and classification of Rare Earth Materials. Basic properties about the Rare Earth Elements like Scandium, Yttrium and other 14 Lanthanides, their occurrence and strategic importance.

Extraction of Rare Earth Elements: Geology and mineralogy of rare-earth-bearing minerals; the mineral processing techniques; metal extraction through routes such as hydrometallurgy followed by solvent extraction; and production of rare-earth metals via metallothermic reduction and molten-salt electrolysis, including subsequent purification.

Application of Rare Earth Materials: Use of rare earth materials in permanent magnets such as Nd based magnets, catalysts and refining, electronic devices, ceramics and polishing, batteries, fuel cells and hydrogen storage, fluorescent lamps, displays and lasers, use in the nuclear industry.

Learning Resources:

Text Books:

1. Science and Technology of Rare Earth Materials by E. C. Subbarao and W. E. Wallace
2. Rare Earth Elements: Fundamentals and Applications by David A. Atwood
3. Rare-earth Elements: Solid State Materials: Chemical, Optical and Magnetic Properties by De Gruyter
4. Hydrometallurgy of Rare Earths Extraction and Separation by Dezhi Qi

Reference Books:

1. Extractive Metallurgy of Rare Earths by Nagaiyar Krishnamurthy and Chiranjib Kumar Gupta
2. Rare Earth Materials: Properties and Applications by A. R. Jha.

PROFESSIONAL ELECTIVES – II

MM36007 **3-0-0 (3)**

Nanotechnology

Pre-Requisites: **None**

Course Outcomes:

CO1	Discuss the significance, properties and applications of nanomaterials
CO2	Distinguish various synthesis techniques for the preparation of nanomaterials
CO3	Appraise the effect of size reduction on functional properties of materials
CO4	Select suitable nanomaterials for advanced applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	-	-
CO2	2	3	3	-	-	-
CO3	2	3	3	-	-	-
CO4	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Significance, properties and applications nanomaterials, carbon nano structures, nano indentation, super plastic behaviour of nanomaterials, Ceramic nanosystems, quantum confinement, effect of size reduction on optical, electrical, electronic, mechanical, magnetic and thermal properties of materials, nano electronics, Nano fluidics, NEMS, photonic crystals, biomimetic nano structures.

Learning Resources:

Text Books:

1. B S Murty et. al.: Textbook of Nanoscience and Nanotechnology, Universities Press (India) Private Limited 2013.
2. Sulabha K. Kulkarni: Nanotechnology Principles and Practices, Capital Publishing Company, 2007.
3. Massimilano Di Ventra, S. Evoy, James R. Heflin Jr: Introduction to Nanoscale Science and Technology, Springer, 2009.
4. Charles P. Poole Jr., Frank J. Owens: Introduction to Nanotechnology, Wiley India, New Delhi, 2010.

Reference Books:

1. Jack Uldrich, Deb Newberry: Next Big Thing Is Really Small: How Nanotechnology Will Change the Future of Your Business.
2. H. Hosono, Y. Mishima, H. Takezoe, K.J.D Mackenzie: Nanomaterials- From Research to Applications, Elsevier, 2008.

Other Suggested Readings:

1. www.nano.gov
2. www.science.doe.gov/nano
3. www.nnin.org

CY16026 **3-0-0 (3)**

Nanochemistry and Smart Materials

Pre-Requisites: None

Course Outcomes:

CO1	Understand the fundamental principles of nanochemistry and nanoscale phenomena.
CO2	Explain the synthesis, functionalization, and self-assembly of nanomaterials for diverse applications.
CO3	Correlate structure - property relationships in nanostructured and smart materials.
CO4	Evaluate nanomaterials using advanced physicochemical and spectroscopic characterization techniques.
CO5	Design and apply nanomaterials for smart technologies in catalysis, energy, sensing, and biomedicine.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	-	-
CO-2	2	2	2	-	-	-
CO-3	3	3	3	-	-	-
CO-4	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Fundamentals of Nanochemistry: Quantum size effects; surface energy and surface plasmon resonance; top-down vs bottom-up synthesis; sol-gel, hydrothermal, and microemulsion methods; supramolecular and subcomponent self-assembly; green synthesis approaches.

Functional Nanomaterials: Metal, metal oxide, semiconductor, and carbon-based nanomaterials (graphene, CNTs, fullerenes); hybrid and composite nanostructures; polymer nanocomposites; nanoclusters and quantum dots.

Smart and Responsive Materials: Stimuli-responsive polymers, hydrogels, and soft materials; shape-memory materials; self-healing systems; piezoelectric, thermochromic, and magnetoresponsive materials; bioinspired smart materials.

Characterization Techniques: SC-XRD, PXRD, SAXS, ToF-SIMS, ITC, SEM, TEM, AFM, DLS, UV–Vis, CD, FTIR, Raman, XPS, TGA/DSC, and NMR; mass spectrometry, electron diffraction and EDS; BET surface area and porosity analysis; correlation of nanostructure with optical, electrical, and mechanical properties.

Applications of Nanochemistry and Smart Materials: Catalysis and photocatalysis; energy storage and conversion (batteries, supercapacitors, fuel cells); sensors and actuators; nanomedicine and drug delivery; water purification and environmental remediation.

Recent Advances and Case Studies: Emerging 2D materials, metal–organic frameworks (MOFs), covalent organic frameworks (COFs), and perovskite nanomaterials; sustainable and bioinspired nanochemistry; ethical and safety aspects of nanotechnology.

Learning Resources:

Text Books:

1. G. Cao and Y. Wang, Nanostructures and Nanomaterials: Synthesis, Properties and Applications, World Scientific, 2016.
2. C.N.R. Rao, A. Müller, and A.K. Cheetham (Eds.), The Chemistry of Nanomaterials: Synthesis, Properties and Applications, Wiley-VCH, 2006.
3. T. Pradeep, Nano: The Essentials – Understanding Nanoscience and Nanotechnology, McGraw-Hill, 2007.

Reference Books:

1. M. Ratner and D. Ratner, Nanotechnology: A Gentle Introduction to the Next Big Idea, Pearson, 2003.
2. M. Ashby, P. Ferreira, and D. Schodek, Nanomaterials, Nanotechnologies and Design, Butterworth-Heinemann, 2009.
3. Recent review papers from Advanced Materials, Nature Nanotechnology, and ACS Nano.

MM46031 **3-0-0 (3)**

Bulk Nanostructured Materials

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the fundamentals of bulk nanostructured materials
CO-2	Acquire knowledge of various severe plastic deformation (SPD) methods and other processing techniques
CO-3	Identify appropriate characterization tools for nanostructured materials
CO-4	Analyze the relationship between structural characteristics and mechanical properties

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	-	-
CO-2	2	2	2	-	-	-
CO-3	3	3	3	-	-	-
CO-4	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to nanostructured materials: Classification of nanostructured materials, Dimensionality – one, two- and three-dimensional materials

Bulk nanostructured materials: Definition, Historical perspective, and distinguishing them from nanoparticles.

Processing techniques: Top-down and bottom-up approaches, Mechanical milling/alloying, Consolidation techniques – Spark plasma sintering, etc, Severe plastic deformation techniques.

Structural and mechanical characterization: Recent advances in understanding the microstructure evolution and understanding deformation mechanisms, mechanical behavior at small length scales – nanoindentation

Properties and applications: Mechanical Properties: Hall-Petch relationship, strengthening mechanisms, superplasticity; Functional Properties: Magnetic properties (e.g., in nanocomposites), electrical conductivity, thermoelectric properties; Applications: High-strength structural alloys, biomedical implants, wear-resistant materials.

Learning Resources:

Text Books:

1. R. Z. Valiev, A. P. Zhilyaev, T. G. Langdon, Bulk Nanostructured Materials: Fundamentals and Applications; 2014, Wiley
2. I. Sabirov, N.A. Enikeev, M.Yu. Murashkin, R.Z. Valiev; Bulk Nanostructured Materials with Multifunctional Properties, Springer

Reference Books:

1. Michael J. Zehetbauer (Editor), Yuntian Theodore Zhu (Editor), Bulk Nanostructured Materials 2009

MM46033 **3-0-0 (3)**

Introduction to Biomaterials

Pre-Requisites: **None**

Course Outcomes:

CO1	Discuss the materials science principles for bio-applications
CO2	Design the processing methods for biomaterials
CO3	Apply different characterization techniques to assess biomaterials properties
CO4	Select materials for different bio-applications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	-	-	-
CO2	3	3	3	-	-	-
CO3	3	3	3	-	-	-
CO4	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Overview: Historical development; Materials in Medical Applications; Materials Properties for Bio-applications

Biomaterials Classification and Processing: Metallic materials; Ceramic and glass implant materials; Polymeric implant materials; Collagen; Thin films; Grafts and coatings; Biological functional materials

Advanced Biomaterials: Bionic materials, bio-hybrid material, bio-inspired materials, prosthetic materials, surgical materials, implants, materials for pacemakers

Cell Structure: Bone structure; Bone properties; Proteins; Bacteria structure; Antibacterial assay

Cell-material Interaction: In vivo testing; Cell-material interaction; Cell-signalling; in vitro testing; Cytotoxicity; Clinical trials

Tissue Engineering: Scaffolds, cellular materials, stem cells, regeneration engineering

Learning Resources:

Text Books:

1. Buddy D. Ratner: Bio Material Science- An introduction to Materials in Medicine, Elsevier, 2013.
2. B. Basu, D. Katti and Ashok Kumar; Advanced Biomaterials: Fundamentals, Processing and Applications; John Wiley & Sons, Inc., USA, 2009.
3. B. Basu; Biomaterials Science and Tissue Engineering: Principles and Methods, Cambridge IISc Press, 2017.
4. Lisa A. Pruitt and Ayyana M. Chakravartula: Mechanics of Biomaterials- Fundamental Principles for Implant Design, Cambridge University Press, 2011,

Reference Books:

1. S. V. Bhat, Biomaterials; 2nd Ed., Narosa Publishing House, 2006.
2. J. Park, R.S. Lakes, Biomaterials an introduction; 3rd Ed., Springer, 2007

Online Resources:

https://nptel.ac.in/courses/113/108/113108071

ME26043 **3-0-0 (3)**

Microwave Materials Processing: Principles and Applications

Pre-Requisites: Basic Physics (Electromagnetism, Heat Transfer), Engineering Materials, and Thermodynamics

Course Outcomes:

CO1	Explain the principles of microwave generation, propagation, and interaction with different classes of materials.
CO2	Analyze the thermal, electromagnetic, and dielectric behavior of materials under microwave fields.
CO3	Design and evaluate microwave-assisted systems and processes for applications such as sintering, curing, drying, and synthesis.
CO4	Integrate interdisciplinary knowledge from electrical, mechanical, civil, chemical, and materials engineering to develop innovative and sustainable processing solutions.
CO5	Assess the efficiency, environmental impact, and industrial relevance of microwave processing compared to conventional techniques.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	-	-	-
CO2	2	3	3	-	-	-
CO3	3	3	3	-	-	-
CO4	3	3	3	-	-	-
CO5	3	2	3	-	-	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Microwave Processing: Overview of electromagnetic energy and microwave spectrum, Fundamentals of microwave heating, Conventional vs microwave heating: energy and kinetics comparison, Interaction of microwaves with materials, Dielectric properties and their significance. Multidisciplinary applications overview: Civil: microwave curing of concrete, asphalt drying, Mechanical: Microwave Heating, Microwave Drying, Microwave Welding, Microwave Sintering / Metallurgy, Microwave Cladding / Coating, Microwave-Assisted Machining, Microwave-Assisted Chemical Processing, Electrical: dielectric heating, electronic materials, Chemical/Materials: synthesis, waste processing

Fundamentals of Microwave Generation & Propagation: Sources: magnetrons, solid-state generators, Transmission: waveguides, cavities, resonant modes, Electric and magnetic field distribution, Instrumentation and power measurement, Electrical and electronics design perspective: impedance matching, power control

Interaction of Microwaves with Materials: Dielectric properties: permittivity, loss tangent, penetration depth, safety/shielding, hybrid heating, and frequency selection., Factors affecting microwave absorption (temperature, composition, moisture), Measurement methods for dielectric properties, interaction with polymers, interaction with ceramics, interaction with metals and non-metals.

Thermo-Mechanical Aspects of Microwave Heating: Coupled electromagnetic–thermal behaviour, Nonuniform heating, hot spots, and thermal stresses, Modelling of heat transfer and stress using FEA tools (COMSOL/ANSYS), Application examples: Microwave drying of cement and wood, Rapid sintering of metal and ceramic components

Learning Resources

Textbooks & References:

1. Advances in Microwave Processing for Engineering Materials, Edited By Amit Bansal, Hitesh Vasudev(1st Edition),CRC Press, Taylor & Francis Group
2. Microwave Chemical and Materials Processing, A Tutorial. Authors: Satoshi Horikoshi, José M. Catalá-Civera, Robert F. Schiffmann, Jun Fukushima,Tomohiko Mitani, Nick Serpone
3. Microwaves and Metals by M. Gupta, Manoj Gupta, and Eugene Wong Wai Leong
4. Microwave Engineering of Nanomaterials from Mesoscale to Nanoscale ,Edited By Erwann Guenin
5. Microwave Materials and Applications, 2 Volume Set, Sebastian, Mailadil T. / Ubic, Rick / Jantunen, Heli (Editor)
6. Advances in Microwave Engineering from Novel Materials to Novel Microwave Applications, Edited By Ankan Bhattacharya, Bappadittya Roy, Arnab De, Ujjal Chakraborty, Anup Kumar Bhattacharjee
7. Microwave Applications in Chemical Engineering.Edited byKama Huang, Junwu Tao, Huacheng Zhu.
8. Microwave Assisted Synthesis of Materials author: Charu Lata Dube

Online Resources:

1. https://www.youtube.com/watch?time_continue=31&v=dd5BlyCwpt0&embeds_referring_euri=https%3A%2F%2Fwww.bing.com%2F&embeds_referring_origin=https%3A%2F%2Fwww.bing.com&source_ve_path=Mjg2NjY
2. Applications and new trends in Microwave Material Processing
3. https://www.youtube.com/watch?v=IES-Ik8x3E0
4. https://www.youtube.com/watch?v=ppHSqhX9e_Q
5. https://www.comsol.com/support/learning-center/article/Getting-Started-with-Electro-Thermal-Mechanical-Modeling-10561/82

MM46035 **3-0-0 (3)**

Nature Inspired Materials Engineering

Pre-Requisites: **None**

Course Outcomes:

CO1	Identify and explain natural material architectures and the mechanisms responsible for their properties.
CO2	Apply biomimetic design principles to propose engineering material solutions for targeted functions.
CO3	Choose appropriate processing routes to create bioinspired structures (bulk/surface/coatings).
CO4	Use characterization tools (SEM/AFM, contact angle, nanoindentation, tribology, mechanical tests) to interpret structure–property relations.
CO5	Critically assess feasibility: cost, scale-up, durability, safety, and sustainability.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	-	-	-
CO-2	3	3	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	3	2	-	-	-
CO-5	2	2	3	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Biomimicry and Bioinspired Design, Biomimicry vs bioinspiration vs bio-utilization, lightweight structures, protective shells, water-repellent surfaces, Hierarchical Structures in Natural Materials, Levels of hierarchy (nano, micro and macro), Interfaces, gradients, and toughening mechanisms, Mechanics of Nature's Materials, Strength vs toughness synergy; crack deflection/bridging, pull-out, viscoelastic damping, Composite concepts: fiber–matrix, brick-and-mortar, helicoidal (Bouligand) structures, Nature-Inspired Surfaces and Coatings, Superhydrophobicity and self-cleaning, Dry adhesion and reversible attachment, Surface texturing, wettability maps, contact angle hysteresis, Responsive and Self-Healing Materials, Capsule-based, vascular networks, intrinsic healing polymers, Processing Routes for Bioinspired Materials: templating and replication (soft lithography, nanoimprint), self-assembly and directed assembly, biomineralization-inspired routes; sol–gel and hybrid materials, electrospinning for fibrous architectures, additive manufacturing for gradients/lattices and bioinspired geometries, scale-up challenges and reliability considerations. Characterization and Performance Evaluation: microstructure: optical/SEM, AFM, profilometry, nanoindentation, fracture tests, DMA, fatigue basics, contact angle, tribology (friction/wear), corrosion screening, mapping and failure analysis.

Learning Resources

Text Books

1. Bhushan, B. Biomimetics: Bioinspired Hierarchical-Structured Surfaces for Green Science and Technology, Springer.
2. Vincent, J.F.V. et al. Biomimetics: Its Practice and Theory, RSC / relevant editions

Reference Books

1. Meyers, M.A., Chen, P.-Y. Biological Materials Science: Biological Materials, Bioinspired Materials, and Biomaterials, Cambridge University Press.
2. Fratzl, P., Weinkamer, R. (eds./selected readings) on hierarchical biological materials (book chapters/reviews).
3. Aizenberg, J., Wegst, U.G.K. (edited volumes / key review collections on bioinspired materials and surfaces).

Other Suggested Readings (Journals & Reviews)

1. Nature Materials, Advanced Materials, Materials Today, Progress in Materials Science
2. Bioinspiration & Biomimetics
3. ACS Applied Materials & Interfaces
4. Surface & Coatings Technology (for bioinspired coatings and surface texturing)

MM46037 **3-0-0 (3)**

Materials for Quantum Technology

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the fundamental quantum mechanical principles underlying the behavior of quantum materials.
CO-2	Identify and classify common quantum materials and relate their structure to their quantum functionalities.
CO-3	Discuss synthesis and characterization techniques relevant to quantum materials and their device applications.
CO-4	Analyze the role of defects, interfaces, and disorder in determining quantum coherence and device performance.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	-	-	-
CO-2	3	2	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	3	2	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Quantum mechanical foundations, superposition, entanglement; Classification of Quantum Materials: superconductors, topological insulators, spin qubit materials, and photonic systems.

Superconducting Quantum Materials: Josephson junctions, niobium/aluminum systems, thin films, and loss mechanisms; Semiconducting Qubit Materials: Si/SiGe quantum dots, GaAs heterostructures, isotopic purification, and fabrication methods. Color Centers and Quantum Defects: NV centers in diamond, optical readout, implantation, and annealing processes. 2D Quantum Materials: Graphene, TMDCs, moiré systems, and their role in quantum transport.

Synthesis of Quantum Materials: MBE, PLD, sputtering, CVD, and controlled defect incorporation. Defects, Interfaces, and Disorder: Role of structural, chemical, and magnetic defects on coherence and device reliability. Characterization Techniques: FIB, S/TEM, XPS, ARPES, SQUID, PL/ODMR, and microwave measurements for quantum materials.

Device Integration and Scalability: Cryogenic packaging, interconnects, coherence preservation, and noise mitigation, miniaturization and power efficient models.

Current Challenges and Future Prospects: Material bottlenecks, reproducibility, hybrid quantum systems, and materials discovery via quantum simulation.

Learning Resources:

Text Books:

1. G Scappucci, PJ Taylor, JR Williams, T Ginley, S Law, Crystalline materials for quantum computing: Semiconductor heterostructures and topological insulators exemplars, MRS Bulletin, 46 (2021) 596-606
2. N. W. Ashcroft and N. D. Mermin, Solid State Physics.
3. M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information.
4. Hasan, M. Z., and Kane, C. L., “Colloquium: Topological Insulators,” Rev. Mod. Phys. 82 (2010).

MM46039 **3-0-0 (3)**

Materials Thermodynamics

Pre-Requisites: **Basic Thermodynamics / Physical Chemistry**

Course Outcomes:

CO-1	Explain and apply the fundamental laws of thermodynamics to analyze energy, entropy, and free energy changes in materials systems.
CO-2	Interpret phase equilibria and phase diagrams using concepts of chemical potential, activity, and Gibbs phase rule.
CO-3	Evaluate thermodynamic driving forces for phase transformations, defect formation, and interfacial phenomena in materials.
CO-4	Apply thermodynamic principles to solve practical materials problems related to alloy design, oxidation–reduction reactions, and high-temperature materials stability.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	-	-	-
CO-2	3	2	2	-	-	-
CO-3	2	3	3	-	-	-
CO-4	3	3	3	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Foundations of Thermodynamics - Introduction: Thermodynamic systems and state functions, Zeroth and First Laws of Thermodynamics, Internal energy, work, heat, and specific heats, Enthalpy and energy balances, Extensive and intensive properties, Thermodynamic equilibrium, Heat capacity, state functions, path independence

Second Law and Entropy - Limitations of the First Law, Carnot cycle and thermodynamic temperature scale, Entropy: definition and physical meaning, Entropy change for ideal gases and pure substances, Reversible and irreversible processes, Spontaneity and criteria for equilibrium, Applications: Entropy in phase transformations

Gibbs and Helmholtz Free Energies - Mathematical formulation and physical interpretation, Criteria for equilibrium under constant T, P, V. Free energy change and work of expansion, Maxwell relations, Temperature and pressure dependence of free energies, Industrial Context: Predicting phase stability.

Phase Equilibria - Chemical potential and partial molar quantities, Gibbs–Duhem equation, Ideal and non-ideal solutions, Activity, activity coefficients, Phase diagrams and rules (Gibbs phase rule), Binary phase diagrams fundamentals, Case Studies: Cu-Ni, Fe-C systems

Thermodynamics of Defects and Interfaces - Point defects in solids (vacancies, interstitials), Defect formation energy and concentration, Thermodynamics of surfaces and interfaces, Grain boundary energy and segregation.

Phase Transformations - Driving force for transformations, Nucleation and growth thermodynamics, Free energy curves and spinodal decomposition, Order-disorder transitions, Application: Heat treatment of steels

Chemical Thermodynamics in Materials - Thermochemistry of reactions in materials, Ellingham and predominance diagrams, Oxidation, corrosion, and reduction equilibria, Thermodynamics of ceramic formation, Use-Case: High-temperature stability.

Learning Resources:

Text Books:

1. Robert DeHoff, Thermodynamics in Materials Science, Second Edition, CRC Press (Taylor & Francis Group), 2006.
2. J.M. Smith, H.C. Van Ness & M.M. Abbott, Introduction to Chemical Engineering Thermodynamics, 7th or 8th Edition, McGraw-Hill Education (India) Private Limited / McGraw-Hill Education.

3. D. R. Gaskell and David E. Laughlin, Introduction to Thermodynamics of Materials, 6th Ed., CRC Press, 2018.
4. D.A. Porter, K.E. Easterling & M.Y. Sherif, Phase Transformations in Metals and Alloys, Fourth Edition, CRC Press (Taylor & Francis Group), 2021.

Reference Books:

1. Yunus A. Çengel, Michael A. Boles, Mehmet Kanoglu, Thermodynamics: An Engineering Approach, 10th Edition, McGraw-Hill Education (2025)
2. Y. Austin Chang & W. Robert Powell, Materials Thermodynamics, First Edition, John Wiley & Sons (Wiley Series on Processing of Engineering Materials), 2009–2010
3. Hae-Geon-Lee, Chemical Thermodynamics for Metals and Materials, Imperial College Press, 2000

Other Suggested Readings:

1. NPTEL courses on Thermodynamics & Phase Transformations
2. ASM Handbook (Thermodynamics sections)

MM46041 **3-0-0 (3)**

Multiscale Modeling of Materials

Pre-Requisites:

- Fundamentals of Materials Science and Engineering
- Basic Thermodynamics and Statistical Mechanics
- Elementary Solid State Physics concepts
- Fundamentals of Mechanics of Materials
- Basic knowledge of Differential Equations and Numerical Methods
- Introductory programming exposure (Python / C / MATLAB preferred)

Course Outcomes:

CO-1	Explain the theoretical foundations of Molecular Dynamics and its role in materials engineering
CO-2	Apply Density Functional Theory (DFT) and electronic structure concepts to understand bonding, stability, and energetics of materials
CO-3	Perform Molecular Dynamics simulations to evaluate structural, thermodynamic, and mechanical properties
CO-4	Utilize Monte Carlo methods to study ordering, phase stability, and defect processes
CO-5	Interpret microstructure evolution using mesoscale modeling approaches such as Phase Field and Kinetic Monte Carlo

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	3	3	-	-	-
CO-2	3	3	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	3	2	-	-	-
CO-5	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Foundations of Computational Materials Science: Length and time scales in materials modeling,Continuum vs atomistic descriptions, Deterministic and stochastic simulation approaches, Integrated Computational Materials Engineering (ICME) framework, Overview of multiscale methods: DFT → MD → MC → Mesoscale, Applications in structural, functional, and energy materials

Electronic Structure Methods: Density Functional Theory: Schrödinger equation and many body problem, Born–Oppenheimer approximation, Fundamentals of Density Functional Theory (DFT), Hohenberg–Kohn theorems, Kohn–Sham equations, Exchange–correlation functionals (LDA, GGA – overview), Cohesive energy and lattice parameter prediction, Elastic properties from first principles calculations, Defect formation energies, Role of DFT in development and validation of interatomic potentials

Interatomic Potentials and Force Fields: Need for interatomic potentials, Pair potentials: Lennard Jones, Morse, Many body potentials: Embedded Atom Method (EAM), MEAM, Bond order potentials: Tersoff, Stillinger–Weber, Reactive force fields (ReaxFF – overview), Angular dependent potentials, Selection criteria and limitations

Molecular Dynamics Simulation: Newton's equations of motion, Numerical integration algorithms: Velocity Verlet, Leapfrog, Time step selection and numerical stability, Boundary conditions and periodic simulation cells, Minimum image convention and cut-off radius, Energy conservation and trajectory analysis

Statistical Mechanics & Ensembles: Microcanonical (NVE), Canonical (NVT), Isothermal–Isobaric

(NPT), Thermodynamic foundations of ensembles, Thermostats: Berendsen, Nose–Hoover, Langevin, Barostats and pressure control, Equilibration vs production simulations
Property Evaluation via Atomistic Simulations: Structural, Thermodynamic, Mechanical, and Transport Properties
Monte Carlo Methods: Statistical basis of Monte Carlo simulations, Metropolis algorithm, Canonical Monte Carlo, Order–disorder transformations, Short range ordering in alloys, Phase stability and configurational thermodynamics
Kinetic Monte Carlo: Time evolution in materials systems, Event selection algorithms, Vacancy diffusion and defect migration, Precipitation kinetics, Grain boundary processes (overview)
Mesoscale Modeling - Phase Field Methods: Introduction to mesoscale simulations, Order parameters and free energy functionals, Cahn–Hilliard equation, Allen–Cahn equation, Spinodal decomposition, Grain growth and microstructure evolution, Applications in alloys and functional materials

Learning Resources

Text Books

1. Frenkel, D. and Smit, B., *Understanding Molecular Simulation*, Academic Press

Reference Books

1. Rapaport, D. C., *The Art of Molecular Dynamics Simulation*, Cambridge University Press
2. Leach, A. R., *Molecular Modelling: Principles and Applications*, Pearson

Other Suggested Readings

1. Review articles from *Acta Materialia*, *Physical Review B*, *Computational Materials Science*
2. MD software manuals (LAMMPS – user guide)
3. Selected recent journal papers discussed in class

PROFESSIONAL ELECTIVES – III

MM46014 **3-0-0 (3)**

Additive Manufacturing Technologies

Pre-Requisites: None

Course Outcomes:

CO1	Explain the basic concepts and importance of additive manufacturing
CO2	Describe the principles, processes and advantages of additive manufacturing systems
CO3	Apply the knowledge of additive manufacturing for various real-life applications
CO4	Suggest mitigation techniques for additive manufacturing defects

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	2	-	-	-
CO-2	2	3	3	-	-	-
CO-3	3	3	3	-	-	-
CO-4	2	2	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Overview, basic principles and advantages of additive manufacturing, procedure of product development in additive manufacturing, classification of additive manufacturing processes, materials used in additive manufacturing, challenges in additive manufacturing.
Generic AM process: CAD, conversion of STL, transfer to AM machine and STL file manipulation, machine setup, build, removal, distinction between AM and CNC machining, reverse engineering
Additive Manufacturing Processes: Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modeling (FDM), Laminated Object Manufacturing (LOM), Selective deposition lamination (SDL), Ultrasonic consolidation, Material Jetting, Binder jetting
Powder bed fusion processes: Selective laser sintering (SLS), Laser engineered net shaping (LENS), Selective laser melting (SLM), Electron beam melting (EBM), materials, powder fusion mechanisms (Solid-state sintering, chemically induced sintering, liquid phase sintering, Full melting), powder handling challenges, powder recycling, defects
Direct energy deposition processes: DED process description, powder feeding, wire feeding, laser andelectron-based deposition processes
Post-Processing in Additive Manufacturing: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancementsusing non-thermal and thermal techniques
Future scope in Additive Manufacturing: Evaluation of additive manufactured structures/ components, scope of AM in various fields. Its importance and applications.

Learning Resources:

Textbooks:

1. C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.
2. Gibson, I, Rosen D W., and Stucker B., Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010
3. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: Fourth Edition of Rapid Prototyping, World Scientific Publishers, 2014
4. A. Gebhardt: Rapid prototyping, Hanser Gardener Publications, 2003.

Reference Books:

1. Additive Manufacturing Processes, Editor: David L. Bourell, William Frazier, Howard Kuhn, and Mohsen Seifi, ASM Handbook, Volume 24, ASM International, 2020Title of the Textbook, Author(s), Publisher, Year and Edition.
2. L.W. Liou, F.W. Liou: Rapid Prototyping and Engineering applications: A toolbox for prototype development, CRC Press, 2007.
3. A.K. Kamrani, E.A. Nasr: Rapid Prototyping- Theory and Practice, Springer, 2006.
4. P.D. Hilton, P.F. Jacobs: Rapid Tooling- Technologies and Industrial Applications, CRC Press, 2000.
5. Ian Gibson, David W Rosen, Brent Stucker: Additive Manufacturing Technologies- Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010

Online Resources:

1. https://additivemanufacturing.com/basics/
2. https://www.additivemanufacturing.media/

MM46016 **3-0-0 (3)**

Metal Joining Processes

Pre-Requisites: None

Course Outcomes:

CO1	Compare the working principles of traditional and modern welding processes
CO2	Relate welding process parameters with weld quality.
CO3	Identify various welding defects and remedial measures
CO4	Select a suitable welding process for a given application.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	-	-	-
CO2	2	3	3	-	-	-
CO3	2	3	3	-	-	-
CO4	2	2	2	-	-	-

1 – Slightly; 2 – Moderately; 3 – Substantially

Syllabus:

Fundamentals of welding, soldering and brazing, classification of welding processes, types of weld joints, welding positions, welding arc characteristics, arc initiation, power source characteristics
Manual metal arc welding: principles of operation, electrode designation, types of electrodes, and their applications, Gas tungsten arc welding (GTAW): principles of operation, polarities in GTAW, tungsten electrodes, shielding gases, filler wire, applications, variations in GTAW (pulsed and hot wire), plasma arc welding (PAW): principles of operation, modes of PAW (Micro- mode, low current melt-in mode, and key-hole mode), applications, gas metal arc welding (GMAW): principles of operation, modes of metal transfer (Spray, globular, short-circuit and pulsed spray), self-regulating arc, applications. Fluxed core arc welding (FCAW): principles of operation, variants in FCAW (self-shielded and gas shielded), types of electrodes, applications, submerged arc welding (SAW): principles of operation, classification of flux and electrodes in SAW, applications.
Gas welding processes: fuel gases, oxy acetylene welding, principles of operation, types of flames, applications, other welding processes: resistance welding (RW): principles of operation, types of RW, spot welding, resistance spot welding cycle, seam welding, projection, flash butt and percussion
Electron beam welding (EBW): concepts, types and applications. Laser beam welding (LBW): physics of lasers, types of lasers, operation of laser welding setup, advantages and limitations, applications
Solid-state welding: need for solid-state welding, types of solid-state welding, Friction welding: variations, steps in friction welding, types and applications. Friction stir welding: principles of operation, metal flow phenomena, tools, process variables and applications, explosive, diffusion and ultrasonic welding, principles of operation, process characteristics and applications.
Welding defects: discontinuity vs defects, incomplete fusion, insufficient penetration, weld undercut, weld cracks, weld porosity, slag inclusions, tungsten inclusion, reinforcement, overlap, burn through, crater cracks, spatter, arc strike.

Learning Resources:

Text Books:

1. Cary, Howard B. and Scott C. Helzer, Modern Welding Technology. Upper Saddle River, New Jersey: Pearson Education, USA, 2005.
2. Sindo Kou, Welding metallurgy, John Willey, 2003, 2nd edition, USA.
3. J.F. Lancaster, Metallurgy of Welding, Abington Publishing, 6th edition, England. 1999.
4. Richard Little, Welding and Welding Technology, McGraw Hill, 1st edition, 2001.
5. Metals Handbook-Welding, Brazing and Soldering, American Society for Metals, 10th edition,

Vol. 6, 1993.
6. Inspection and testing of weld joints Welding handbook, American Welding Society, 7th edition, USA, 1983.

Reference Books:

1. Metals Handbook-mechanical testing and evaluation, American Society for Metals, Volume 8, USA, 1993.
2. Welding handbook, American Welding Society, 8th edition, vol.1 & 2, USA, 1987.

Online Resources:

1. https://www.twi-global.com/technical-knowledge/faqs/what-is-welding
2. https://nptel.ac.in/courses/113/106/113106087/

MM46018 **3-0-0 (3)**

Design, Selection and Processing of Engineering Alloys

Pre-Requisites: None

Course Outcomes:

CO-1	To understand the principles governing alloy design and selection.
CO-2	To correlate composition, processing, microstructure, and properties.
CO-3	To introduce modern alloy systems and advanced processing routes.
CO-4	To develop the ability to select appropriate alloys for engineering applications.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	3	-	-	-
CO-2	2	3	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	3	3	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Fundamentals of Alloy Design (Role of alloying in engineering materials, Thermodynamics of alloy systems: Gibbs free energy, mixing enthalpy, entropy, Hume–Rothery rules and phase stability, Strengthening mechanisms in alloys, Structure–property–processing relationships)

Phase Diagrams and Alloy Selection (Binary and ternary phase diagrams, Lever rule and phase fraction calculations, Metastable phases and non-equilibrium solidification, Use of phase diagrams in alloy design, Introduction to CALPHAD-based alloy design)

Aluminium and Magnesium Alloys (Classification of aluminium alloys (wrought vs cast), Heat-treatable and non-heat-treatable aluminium alloys, Ageing and precipitation hardening, Magnesium alloys: alloying, processing, and applications, Lightweight alloy selection for automotive and aerospace sectors)

Ferrous Alloys (Plain carbon steels and alloy steels, Heat treatment of steels: annealing, quenching, tempering, Stainless steels: types, corrosion resistance, and applications, Tool steels and high-strength steels, Case studies in steel selection)

Processing of Engineering Alloys (Solidification and casting processes, Thermomechanical processing, Powder metallurgy and additive manufacturing, Heat treatment and surface engineering, Effect of processing routes on microstructure and properties)

Advanced Alloy Design Concepts (High entropy alloys and complex concentrated alloys, Computational alloy design and ICME, Machine learning in alloy design, Sustainability and recyclability in alloy selection)

Learning Resources:

Text Books:

1. Ashby, M.F. – Materials Selection in Mechanical Design
2. Reed-Hill & Abbaschian – Physical Metallurgy Principles
3. Porter, Easterling & Sherif – Phase Transformations in Metals and Alloys
4. Totten – Handbook of Aluminium

Reference Books:

1. ASM Handbook Volumes (Alloy Systems & Heat Treatment)
2. Callister & Rethwisch – Materials Science and Engineering

Other Suggested Readings:

1. Introduction to ICME concepts**.**
2. Kaufman & Bernstein Computer Calculation of Phase Diagrams

MM46020 **3-0-0 (3)**

Non-Destructive Testing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic principles of different NDT processes
CO-2	Differentiate NDT processes
CO-3	Select an NDT technique to identify a defect
CO-4	Apply precautions against radiation and other hazards in NDT processes

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	-	-	-
CO-2	2	2	2	-	-	-
CO-3	2	3	2	-	-	-
CO-4	2	3	-	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to NDT: Advantages and classification of NDT processes; Visual inspection, principles of inspection equipment used.
Eddy Current Testing: Principle, influencing factors, Advantages, limitations and applications.
Liquid Penetrant and Magnetic Particle testing: Principle, Characteristics, precautions, advantages, limitations and applications. methods to generate magnetic fields, Method of De-Magnetization.
Radiographic Testing: Principle, equipment & methodology, influencing factors, Radiograph Interpretation, Precautions against radiation hazards.
Ultrasonic Testing: Principle, Testing Techniques Ultrasonic Propagation, probes, Transducers, applications, advantages and limitations. Reference and calibration blocks for various NDT methods, codes, standards and specifications (ASME, ASTM, AWS etc.) of NDT testing.

Learning Resources:

Text Books:

1. Non-Destructive Examination and Quality Control, ASM International, Vol.17, 9th edition (1989).
2. J. Prasad and C. G. K. Nair, Non-Destructive Test and Evaluation of Materials, Tata McGra Hill Education, 2nd edition (2011).
3. B. Raj, T. Jayakumar and M. Thavasimuthu, Practical Non Destructive Testing, Alpha Science International Limited, 3rd edition (2002).
4. T. Tangachari, J. Prasad and B.N.S. Murthy, Treatise on non-destructive testing and evaluation, Navbharath Enterprises, Vol.3, (1983).

Reference Books:

1. C. Hellier, Handbook of NonDestructive Evluation, McGraw-Hill Professional, 1st edition (2001).
2. J. Thomas Schmidt, K. Skeie and P. MacIntire, ASNT Non-Destructive Testing Handbook: Magnetic Particle Testing, American Society for Nondestructive Testing, American Society for Metals, 2nd edition (1989).

3. V. S. Cecco, G. V. Drunen and F. L. Sharp, Eddy current Manual: Test method, Vol.1, Chalk River Nuclear Laboratories (1983).
4. B.P.C. Rao, Practical Eddy Current Testing, Alpha Science International Limited (2006).
5. N. A. Tracy, P. O. Moore, Non-Destructive Testing Handbook: Liquid Penetrant Testing, Vol. 2, American Society for Nondestructive Testing, 3rd edition (1999).

Other Suggested Readings:

1. https://nptel.ac.in/courses/113106070
2. https://www.nde-ed.org

MM46022 **3-0-0 (3)**

Mechanics of Metal Forming

Pre-Requisites: **None**

Course Outcomes:

CO1	Solve for strain rates, temperatures and metallurgical states in forming problems
CO2	Develop process maps for metal forming processes using plasticity principles
CO3	Estimate formability limits for sheets and bulk metals
CO4	Evaluate workability of different ductile materials
CO5	Apply FE principles to simulate metal forming processes

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	-	-	-
CO2	3	3	3	-	-	-
CO3	3	3	3	-	-	-
CO4	2	3	3	-	-	-
CO5	2	3	3	-	-	-

1: Slightly 2: Moderately 3: Substantially

Syllabus:

Introduction: Metal forming as a manufacturing process and its relationship with other processes – Classification based on type of stresses - Examples.

Description of Material properties: Tensile test, effect of properties on forming. Sheet deformation processes: Uni-axial tension, general sheet forming processes, Yield criteria, Flow rule, Yield criterion and flow rule for Anisotropic material, work of plastic deformation, isotropic and anisotropic yield functions, Bauschinger effect modelling, effective stress and strain. Sheet deformation in plane stress: strain distributions, strain diagram, deformation modes, effective stress-strain laws, principal tensions

Rolling Processes: Analysis of longitudinal strip or sheet rolling process (calculation of roll separating force, torque & power, angle of bite, maximum reduction in rolling), rolling defects

Forging processes: Metal flow in forging, Analysis of plane strain compression, Analysis of compression of circular disc

Extrusion Processes: Calculation of extrusion load, advances in extrusion, Defects in extrusion. Direct & indirect extrusion, impact and hydrostatic extrusion

Wire Drawing Processes: Introduction, wire drawing load calculation

Deep Drawing Processes: Introduction, determination of drawing force and power in deep drawing

Sheet forming: Mechanics – Flow Rules – Anisotropy - Formability of sheet, Formability tests, forming limit diagrams, strain path diagrams, Case studies

Pressing and Sintering: Workability Studies – Densification

Recent advances: Hydroforming, formability of tailor welded blanks, formability of friction stir welding sheets, incremental sheet forming, and electric assisted forming

Modelling and Simulation in Metal Forming: The plane strain compression test, FEM Model and Input Data to the Model - process simulation for deep drawing, Effective Strain and Strain-Rate, Distributions in Deformed Zones, modelling to predict the strains and formability

Case studies: Case studies on the manufacturing aspects of products using the lessons learnt and practical applications of metal forming

Learning Resources:

Textbooks:

1. Surender Kumar, Technology of Metal Forming Processes, Prentice - Hall, Inc., 2008.
2. Henry S. Valberg, Applied Metal Forming - Including FEM Analysis, Cambridge University Press, 2010.
3. Metal Forming: Mechanics and Metallurgy by William F. Hosford and Robert M. Caddell, Prentice-Hall (USA) – 2012

MM46024 **3-0-0 (3)**

Thermomechanical Processing of Metals

Pre-Requisites: Physical Metallurgy

Course Outcomes:

CO1	Build strong fundamentals of deformation and microstructure evolution during metal working.
CO2	Understand temperature–strain–strain rate effects on flow behaviour and workability.
CO3	Apply Thermomechanical Processing of Metals (TMP) principles to design industrial processing schedules for targeted properties.
CO4	Introduce modelling/tools: constitutive equations, processing maps, recrystallization kinetics, and basic FE/analytical concepts.
CO5	Interpret microstructural evidence (EBSD/SEM/TEM) to validate TMP outcomes.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	-	-
CO2	2	3	3	-	-	-
CO3	3	3	3	-	-	-
CO4	2	3	3	-	-	-
CO5	2	3	2	-	-	-

1: Slightly 2: Moderately 3: Substantially

Syllabus:

Fundamentals of Plastic Deformation & Flow Stress; Stress–strain response; true stress/true strain; strain hardening, Yield criteria (von Mises/Tresca), work hardening laws (Hollomon, Ludwik, Voce), Temperature & strain-rate sensitivity; Zener–Hollomon parameter (Z), Constitutive modelling for hot deformation, Hot, Warm and Cold Working – Process Physics,
Workability concepts; friction, redundant deformation, adiabatic heating, Defects: cracking, laps, shear bands, edge cracking, centreline cracking, Role of lubrication, die design, reduction schedules, Recovery, Recrystallization and Grain Growth, Stored energy, dislocation density evolution, Static vs dynamic recovery; polygonization, Texture and Anisotropy in Deformed Metals, Thermo-Mechanical Processing of Steels (TMCP), TMP of Non-Ferrous Alloys (Al, Mg, Ti, Ni), Severe Plastic Deformation & Advanced TMP, SPD routes: ECAP, HPT, ARB, MDF; grain refinement to UFG/nano regimes, Strength–ductility synergy; stability of refined grains, Gradient structures and heterogeneous lamella structures, Industrial relevance and scaling limitations, Process Design Tools and Modelling.

Learning Resources

Text Books

1. Dieter, G.E. Mechanical Metallurgy, McGraw-Hill (plastic deformation fundamentals).
2. Hosford, W.F., Caddell, R.M. Metal Forming: Mechanics and Metallurgy, Cambridge.
3. Humphreys, F.J., Hatherly, M. Recrystallization and Related Annealing Phenomena, Elsevier.

Reference Books

1. Ghosh, A., Mallik, A.K. Manufacturing Science / Metal forming references (for process aspects).
2. Porter, D.A., Easterling, K.E., Sherif, M. Phase Transformations in Metals and Alloys, CRC.
3. ASM Handbook, Vol. 14A/14B (Forming and Forging), Vol. 4 (Heat Treating), and relevant TMP sections.
4. Sakai et al. / Poliak & Jonas (selected review papers) on dynamic recrystallization and hot working kinetics.

MM46026 **3-0-0 (3)**

Materials Extraction Technology

Pre-Requisites: None

Course Outcomes:

CO-1	Understand basic principles of material extraction processes.
CO-2	Analyze the influence of raw material availability on extraction routes.
CO-3	Assess environmental and safety aspects of extraction operations.
CO-4	Apply fundamental concepts to evaluate feasible extraction methods.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	3	-	-	-
CO-2	3	3	3	-	-	-
CO-3	3	3	3	-	-	2
CO-4	3	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Fundamentals of Material Extraction: Introduction to material extraction and its role in metallurgical and materials engineering, classification of raw material sources including primary ores and secondary or recycled resources, ore mineralogy and chemical composition, basic steps in material extraction such as ore preparation, concentration, and metal recovery, overview of major extraction routes including pyrometallurgy, hydrometallurgy, and electrometallurgy, fundamentals of reaction kinetics and mass transfer in extraction processes, criteria for selection of appropriate extraction methods based on material characteristics and availability.
Sustainability, Environment, and Safety: Thermodynamic principles relevant to extraction processes, energy requirements and efficiency of extraction methods, environmental impacts of mining and extraction such as emissions, effluents, and solid waste generation, pollution control measures and waste management strategies, occupational health and safety practices in extraction industries, regulatory and environmental compliance requirements, concepts of sustainable extraction, resource conservation, and circular economy approaches in material extraction.

Learning Resources:

Text Books:

1. Rosenqvist, T., Principles of Extractive Metallurgy, McGraw-Hill.
2. Gupta, C. K., Chemical Metallurgy: Principles and Practice, Wiley-VCH.
3. Biswas, A. K. and Davenport, W. G., Extractive Metallurgy of Copper, Pergamon Press.
4. Habashi, F., Handbook of Extractive Metallurgy, Wiley-VCH.

Reference Books:

1. Davenport, W. G., King, M., Schlesinger, M., and Biswas, A. K., Extractive Metallurgy of Copper, Elsevier.
2. Habashi, F., Principles of Extractive Metallurgy, Gordon and Breach.
3. Pehlke, R. D., Unit Processes of Extractive Metallurgy, Elsevier.
4. Sohn, H. Y. and Wadsworth, M. E., Rate Processes of Extractive Metallurgy, Springer.

Other Suggested Readings:

1. Rankin, W. J., Minerals, Metals and Sustainability, CRC Press.
2. Davenport, W. G., Extractive Metallurgy of Nickel, Cobalt and Platinum Group Metals, Elsevier.
3. Journal articles from Minerals Engineering and Hydrometallurgy.
4. Review articles on sustainable and environmentally responsible extraction technologies.

MM46028 **3-0-0 (3)**

Circular Materials Engineering & Sustainability

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify types and sources of metallurgical waste.
CO-2	Discuss the impact of metallurgical waste on environment and economics.
CO-3	Suggest methods for conservation of energy in metallurgical processes.
CO-4	Comprehend recycling of metallurgical waste.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	-	-
CO-2	2	3	3	-	-	2
CO-3	2	3	3	-	-	-
CO-4	2	2	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction: Types of Metallurgical waste, Waste characterization, Energy conservation, Environmental issues, recycling, etc.

Metallurgical wastes: Primary and secondary solid wastes in metallurgical and powder industry, Generation of waste during primary processing of ores and beneficiation, Waste from extraction and refining processes, nuclear waste, Gaseous wastes in metallurgical operations, minimization techniques, precautionary measures.

Foundations of Circularity & LCA: Introduction to Circular Economy vs. Linear "Take-Make-Waste" models, Life Cycle Assessment (LCA), Waste Characterization: Advanced analytical techniques for identifying complex waste streams.

Energy Sector & Critical Materials: Battery Circularity: Recycling chemistries for Lithium-ion, Solid-state, and Flow batteries, Photovoltaics: Recovery of Silicon, Silver, and Tellurium from decommissioned solar panels, Rare Earth Elements (REEs): Recovery from permanent magnets used in wind turbines.

Semiconductor & E-Waste Processing: Semiconductor Waste: Treatment of GaAs, InP, and toxic precursor gases from cleanroom operations, E-waste Urban Mining: Hydrometallurgical and pyrometallurgical recovery of Gold, Tantalum, and Copper from PCB boards and computers.

Economics, Policy & Industrial Symbiosis: Economics of Recycling: Market volatility of secondary raw materials, Energy Conservation: Energy-efficient alternative routes for material processing, Regulatory Frameworks: Extended Producer Responsibility (EPR) and global "Right to Repair" movements.

Learning Resources:

Text Books:

1. S. Ramachandra Rao, Resource recovery and recycling from metallurgical wastes, Elsevier, 2006.
2. M. Kutz, Environmentally conscious materials and chemicals processing, John Wiley & Sons, 2007.
3. Ernst Worrell, Markus Reuter (Eds): Handbook of Recycling, Elsevier, 2014.
4. Donald L Stewart, James C Delay, Robert L Stephens: Recycling of Metals and Engineered Materials (Proceedings of the fourth international symposium), TMS Publications, 2000.

Reference Books:

1. F. Woodard, Industrial waste treatment handbook: Butterworth-Heinemann, 2001
2. H.F. Lund, Recycling Handbook, 2nd Edition, McGraw-Hill, 2000.

Other Suggested Readings:

1. https://nptel.ac.in/noc/courses/noc19/SEM1/noc19-ce06/

PROFESSIONAL ELECTIVES – IV

MM46030 **3-0-0 (3)**

Ceramics and Composites Technology

Pre-Requisites: None

Course Outcomes:

CO-1	Differentiate the properties of metals, ceramics, polymers and composite materials
CO-2	Estimate the properties using rule of mixture
CO-3	Understand the different Processing routes of Ceramics, polymers and composites
CO-4	Understand the failure concepts and choose the right method to join composite materials

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	-	-	-
CO-2	2	2	2	-	-	-
CO-3	3	3	2	-	-	-
CO-4	2	2	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Ceramics: Introduction to ceramics, properties of ceramics, crystal structure, defects in ceramics structures, classification – Oxide and Non-Oxide ceramics, Processing of ceramics powder, consolidation and shaping of ceramics, sintering, super plasticity in ceramics, Bio ceramics, ceramic coating, Toughening mechanism in ceramics, engineering applications of ceramics.
Composites: Introduction to Composites, properties, rule of mixtures, classification of composites, various routes of processing of composites, advanced composites, applications of composites, fracture in composites.

Learning Resources:

Text Books:

1. W. David Kingery, H. K. Bowen and Donald R. Uhlmann, Introduction to Ceramics, 2nd Edition, John Wiley & Sons, 2004.
2. S. Somiya, Handbook of Advanced Ceramics, Parts 1 and 2, Aacdemic Press, 2006
3. Deborah D. L. Chung, Composite Materials: Science and Applications, Second Edition, Springer, 2009
4. David. W. Richerson, Mercel Dekker, Modern Ceramic Engineering by, NY 1992.

Reference Books:

1. Krishan Kumar Chawla, Composite Materials- Science and Engineering, Springer, 2012.
2. B. Raymond, Seymour and Charles E. CarraherJr, Polymer Chemistry, An Introduction, 2nd Edition,MarcelDekkar, Inc. New York, 1987.

Other Suggested Readings:

1. https://nptel.ac.in/courses/113105015
2. Mechanics of Composite Materials, Jones, R. M., Mc-Graw Hill.
3. https://nptel.ac.in/courses/112104229

MM46032 **3-0-0 (3)**

Advanced Powder Processing

Pre-Requisites: None

Course Outcomes:

CO1	Explain various powder production, and characterization techniques
CO2	Compare and appraise powder processing techniques
CO3	Appraise the need of powder processing in fabrication of special engineering components
CO4	Evaluate the fabrication processes of special engineering components by powder metallurgy

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	-	-	-
CO2	2	3	3	-	-	-
CO3	2	3	3	-	-	-
CO4	3	3	3	-	-	-

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

General Concepts: Introduction and History of Powder Metallurgy (PM), Present and Future Trends of PM
Powder Production Techniques: Different Mechanical and Chemical methods, Atomisation of Powder, other emerging processes, Performance Evaluation of different Processes, Design & Selection of Process.
Characterization Techniques: Particle Size & Shape Distribution, Electron Microscopy of Powder, Interparticle Friction, Compression ability, Powder Structure, Chemical Characterization.
Microstructure Control in Powder: Importance of Microstructure Study, Microstructures of Powder by Different techniques.
Powder Shaping: Particle Packing Modifications, Lubricants & Binders, Powder Compaction & Process Variables, Pressure & Density Distribution during Compaction, Isostatic Pressing, Injection Molding, Powder Extrusion, Slip Casting, Tape Casting, Analysis of Defects of Powder Compact, Laser Engineering Net Shaping (LENS), 3D Printers for Ceramics etc.
Sintering: Theory of Sintering, Sintering of Single & Mixed Phase Powder, Liquid Phase Sintering, Sintering Variables, Modern Sintering Techniques, Physical & Mechanical Properties Evaluation, Structure-Property Correlation Study, Modern Sintering techniques, Defects Analysis of Sintered Components.
Application of Powder Metallurgy: Filters, Tungsten Filaments, Self-Lubricating Bearings, Porous Materials, Biomaterials etc.

Readings:

1. G. S. Upadhyaya, Powder Metallurgy Technology, Cambridge International Science Publishing, 1998.
2. ASM Handbook, Vol-7, Powder Metallurgy, ASM International, 2010.
3. P. C. Angelo and R. Subramaniam, Powder Metallurgy - Science, Technology and Application, PHI, New Delhi, 2008.
4. R. M. German, Powder Metallurgy- Principles and Applications, MPIF, Princeton, 1994.
5. A. K. Sinha, Powder Metallurgy, Dhanpat Rai Publications, New Delhi, 2009.

CH16074 **3-0-0 (3)**

Technology of Thermoplastic and Thermoset Polymers

Pre-Requisites: **None**

Course Outcomes:

CO1	Classify and Characterize Monomers, Polymers and Polymer Reactions
CO2	Understand Polymerization Mechanisms and Develop Models for Polymerization Kinetics and Polymer Rheology
CO3	Select a Reactor for Polymerization Reactions
CO4	Identify Suitable Processing Method for a Given Polymer
CO5	Characterize Polymers using Different Techniques

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	-	-	-
CO2	2	3	3	-	-	-
CO3	2	2	2	-	-	-
CO4	3	3	3	-	-	-
CO5	2	3	2			

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Introduction to thermoplastic and thermoset polymers: Monomers, Polymers, Classification of Polymers, Monomers used for Polymer Synthesis, Synthesis Procedure for Monomers - Styrene, Ethylene, Vinyl Monomers, Thermoplastics-Linear Branch, Cross Linked Polymers, Thermoset Resins – Unsaturated Polyester, Epoxy, Vinyl Ester and Phenolic Resins

Polymerization Mechanism and Kinetics: Thermoplastics – Types of Polymerization, Mechanisms and Kinetics of Addition, Condensation and Emulsion Polymerizations. Polymerization Techniques and Reactors, Thermoset Resin – Resin Curing Mechanism and Resin Cure Kinetics

Polymer Properties: Thermoplastics **-** Molecular Weights, Polydispersity Index, Different Methods of Determination of Molecular Weight, Effect of Molecular Weight on Engineering Properties of Polymers, Polymer Rheology. Thermoset Resin – Resin Curing Gelation and Exotherm, Resin Cure Viscosity and Rheokinetics

Polymer Processing and Manufacturing: Extrusion Process, Twin and Single Screw Extrusion, Blow Moulding, Injection Moulding, Wet and Dry Spinning Processes, Thermoset Moulding. Flow-Sheet Diagrams, Properties & Applications of Polyethylene, Polypropylene, Polystyrene, Nylons, Polyesters, Epoxies and Vinylesters

Polymer Testing and Characterizations: Characterizations of Physical Properties, Mechanical Properties, Morphological Properties, Thermal Properties, Fire and Toxicity, Manufacturing Defects, Non-Destructive Testing.

Learning Resources:

Text Books:

1. Fried J R, Polymer Science and Technology, Prentice Hall of India Pvt. Ltd., 2000.
2. Premamoy Ghosh, Polymer Science and Technology, Tata McGraw Hill Publishing Company, New Delhi, 3rd Edition, 2010
3. George Odian, Principles of Polymerization, John Wiley & Sons, Inc., 2004.
4. Composites Manufacturing Materials, Product, and Process Engineering by Sanjay Mazumdar, First Edition, CRC Press, 2001
5. Fiber-reinforced Composites by P.K. Mallick, Third Edition, Taylor and Francis, 2008
6. Process Modeling in Composite Manufacturing by S. Advani, Second Edition, CRC Press, 2010

MM46034 **3-0-0 (3)**

Optoelectronic Materials and Devices

Pre-Requisites: **None**

Course Outcomes:

CO1	Explain the fundamental optical properties of semiconductors.
CO2	Analyze and interpret photoluminescence, UV–Vis–NIR spectra, and photoconductivity behavior to correlate optical response with material properties.
CO3	Describe and compare the growth and fabrication routes (MOVPE, MBE) for III–V, II–VI, and related semiconductor nanostructures for optoelectronic applications
CO4	Apply device physics to evaluate and design photodetectors (photoconducting, photovoltaic, PIN, APD) using gain–bandwidth and performance criteria.
CO5	Design/assess optoelectronic solutions using photonic crystals, non-linear optical materials, fiber-optic/IR focal plane systems, and solar cell architectures (Si, CdS/CdTe, CIGS, tandem, QD solar cells, AR coatings, organic optoelectronics)

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	-	-	-	-	-
CO2	2	2	2	-	-	-
CO3	3	3	3	-	-	-
CO4	3	3	3	-	-	-
CO5	2	3	3	-	-	-

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Optical properties of semiconductors: absorption & emission processes; KramersKronig and Van Roosbroeck-Shockley relations; radiative & non-radiative transitions, hotoluminescence and UV-VIS-NIR Spectroscopy. Photoconducting and non-photoconducting materials. Growth of III-V, II-VI and IV-VI semiconductors and nanostructures for optoelectronic applications--- MOVPE and MBE technology.
Photo-detectors: photoconducting, photovoltaic, PIN, APD, gainbandwidth criteria.
Optical emission from semiconductors: LED physics and technology, conditions for laser action, DH, DFB & DBR lasers.
Quantum Confinement: 2-D, 1-D and O-D systems, Quantum well and quantum dot lasers, Quantum Cascade Laser (QCL), Quantum Well Infrared Photodetectors (QWIP). Photonic crystals. Non-linear optic materials and their applications, fibreoptic systems, IR focal plane arrays and remote sensing.
Solar cell: Device physics, p-n junction, polycrystalline and amorphous Si, CdS/CdTe, CIGS, Ge/GaAs/InGaP tandem structure, multi-exciton generation, quantum dot solar cell, anti-reflection coating. Organic optoelectronic materials and devices.

Learning Resources:

Text Books

1. S.O. Kasap, Optoelectronics and Photonics: Principles and Practices (Pearson)
2. B.E.A. Saleh & M.C. Teich, Fundamentals of Photonics (Wiley)
3. J.I. Pankove, Optical Processes in Semiconductors (Dover)

Reference Books

1. E. F. Schubert, Light-Emitting Diodes (Cambridge)
2. G.P. Agrawal & N.K. Dutta, Semiconductor Lasers (Springer)
3. S.M. Sze & K.K. Ng, Physics of Semiconductor Devices (Wiley)
4. P. Bhattacharya, Semiconductor Optoelectronic Devices (Prentice Hall)
5. C. Kittel, Introduction to Solid State Physics (Wiley)

MM5213 **3-0-0 (3)**

Environmental Degradation of Materials

Pre-Requisites: **None**

Course Outcomes:

CO1	Describe degradation of alloys, polymers, ceramics and composites
CO2	Explain the thermodynamic basis of degradation
CO3	Select suitable techniques to assess materials degradation
CO4	Suggest methods to mitigate degradation of materials
CO5	Describe degradation of alloys, polymers, ceramics and composites

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	2	-	-	-
CO2	3	3	3	-	-	-
CO3	2	2	3	-	-	-
CO4	2	3	2	-	-	-
CO5	3	2	2	-	-	-

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Degradation economics, types of degradation: electrochemical, high-temperature corrosion and oxidation, chemical and physical ageing of plastics, degradation of reinforced concrete, biofouling, biodegradation, erosion corrosion – environmental variables, cavitation, fretting corrosion, erosive and corrosive wear, corrosion of ceramics, laboratory assessment of corrosion: linear polarisation techniques, Tafelextrapolation, oxidation,free energy- temperature diagrams, corrosion control: materials selection and design, protective coatings, inhibitors, passivators, electrical methods.

Learning Resources:

Text Books

1. Myer Kutz, Handbook of Environmental Degradation of Materials, William Andrew Publishing, 2005
2. Denny A Jones, Principles and Prevention of Corrosion 2Ed., Pearson, 2014
3. R. D. Angel, Principles and Prevention of Corrosion, Narosa, 2010
4. Mars Guy Fontana: Corrosion Engineering, Tata McGraw-Hill Education, New York, 2005.
5. H.H. Uhlig, R. Winston Revie: An Introduction to Corrosion and Corrosion Engineering, 4th Ed, John Wiley & Sons, 2008.

EE26042 **3-0-0 (3)**

Advanced Polymeric Materials for Electrical and Energy Applications

Pre-Requisites: None

Course Outcomes:

CO1	Understand the fundamentals of high voltage engineering and insulation requirements in electrical power systems.
CO2	Explain the structure, properties, and processing of polymeric materials used for electrical and high-voltage insulation.
CO3	Correlate material structure, fillers, and interfaces with electrical, thermal, mechanical, and environmental performance.
CO4	Analyze insulation degradation mechanisms such as electrical treeing, tracking, erosion, partial discharge, thermal and environmental ageing
CO5	Select and design suitable polymeric and composite insulation systems for high-voltage AC, DC, and pulsed power applications.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	-	-	-
CO2	3	3	3	-	-	-
CO3	3	3	3	-	-	-
CO4	2	2	2	-	-	-
CO5	3	3	3	-	-	-

1: Slightly; 2: Moderately; 3: Substantially

Syllabus:

Fundamentals of High Voltage Insulation: Fundamentals of High Voltage Insulation Role of insulation in power systems; electric field distribution; dielectric polarization mechanisms; conduction in solids, liquids, and gases; breakdown phenomena; intrinsic and extrinsic breakdown; AC, DC, and impulse stresses; insulation coordination.

Polymeric Materials for Electrical Applications: Basic polymer chemistry; thermoplastics and thermosets; molecular weight and morphology; crystalline and amorphous polymers; polyethylene, XLPE, epoxy resins, silicone rubber, polyimides, and fluoropolymers; processing techniques and structure–property relationships.

Polymeric Composites and Nanodielectrics: Micro- and nano-fillers for insulation; polymer–filler interfaces; dispersion and percolation; surface modification of fillers; ATH, silica, alumina, BN, and rare-earth oxides; polymer nanocomposites and hybrid composites; effect on dielectric strength, permittivity, and thermal conductivity.

Degradation, Ageing, and Failure Mechanisms: Thermal ageing; electrical treeing; tracking and erosion; partial discharge inception and propagation; space charge accumulation under DC stress; environmental ageing (UV, moisture, pollution); oil and chemical ageing; diagnostic indicators of insulation health.

Characterization and Testing of Insulation Materials: Electrical characterization: dielectric spectroscopy, breakdown strength, volume and surface resistivity, PD measurement; thermal analysis (TGA, DSC); mechanical testing; surface and microstructural analysis using SEM, AFM, EDS; tracking and erosion tests (IEC 60587); material qualification standards.

Advanced Applications and Case Studies: Polymeric insulation for HV cables, GIS/GIL, bushings, insulators, transformers, and power electronics; HVDC insulation challenges; eco-friendly and recyclable insulation materials; recent advances in nanodielectrics and smart insulation systems; industrial case studies and failure analysis.

Learning Resources:

Text Books and Reference Books:

1. E. Kuffel, W.S. Zaengl, and J. Kuffel, High Voltage Engineering: Fundamentals
2. T. Tanaka, G.C. Montanari, and R. Mulhaupt, Polymer Nanocomposites as Dielectrics and Electrical Insulation, IEEE Press/Wiley.
3. L.A. Dissado and J.C. Fothergill, Electrical Degradation and Breakdown in Polymers, IET.

PROFESSIONAL ELECTIVES – V

PH17032 **3-0-0 (3)**

Thin Film & Vacuum Technologies

Pre-Requisites: **None**

Course Outcomes:

CO1	Understand generation and monitoring of high vacuum using pumps and gauges.
CO2	Explain the influence of growth process on the properties of thin films.
CO3	Identify vacuum related flaws in standard physical vapour deposition units.
CO4	Select appropriate PVD/CVD technique for the deposition of thin films.
CO5	Determine grain size, texture coefficient, sheet resistance, thickness and band-gap of thin films.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	-	-	-
CO2	2	-	-	-	-	-
CO3	3	2	-	-	-	-
CO4	2	3	3	-	-	-
CO5	2	3	2	-	-	-

1: Slightly 2: Moderately 3: Substantially

Syllabus:

Fundamentals of Vacuum science: Fundamentals of Vacuum-types of flow-Viscous, Lamellar and molecular fluid region, Conductance, Mean-free path, Medium, High and Ultra-high vacuum pumps, (Working principle of Rotary pump, Diffusion pump, Turbo-molecular pump and Ti sublimation pump). Vacuum Measuring Gauges-principle, calibration and electronics read out (Pirani gauge and Penning gauge). Types of O-Rings, valves and clamps – Thermal vacuum bake-out. Introduction to Thin Films: Film Formation - Types of Growth Modes (Volmer - Weber, Frank - van der Merwe, Stranski-Krastanov), Factors influencing film growth and quality, Types of Films – Polycrystalline, Epitaxial growth, textured growth - Substrate cleaning procedure - Thickness measurement techniques (quartz micro-balance, stylus profiler and optical interference techniques). Film adhesion, abrasion and hardness. Thin films **Coating Techniques:** Physical coating techniques-Thermal Evaporation (Working principle and Standard Operational Procedure), e-Beam Evaporation, Sputtering (Ion beam sputtering, RF and DC Magnetron Sputtering), Pulsed Laser Deposition, Clean room and architecture of modern-day coating plants. Chemical coating techniques-Spin coating, Sol-gel dip coating, Spray Pyrolysis-Viguie Spitz mechanism, Electro-deposition, Molecular Beam Epitaxy, CVD and MOCVD processes and systems. **Characterization of Thin films:** Texture coefficient, Standard deviation and grain size (from grazing incidence XRD), Stress and strain in thin films, Sheet resistance measurement of thin films (Four Probe method), Surface composition, morphology and roughness (using SEM and AFM and appropriate software), Optical transmittance, reflectance and Band gap estimation (from UV-Vis data), Electrical transport property by Hall effect measurement.

Learning Resources:

Text Books:

1 Milton Ohring, Materials Science of Thin Films, Academic Press, San Diego, 2002.
2 Krishna Seshan (Ed.) Handbook of Thin-Film Deposition Processes and Techniques, Noyes

Publications-William Andrew Publishing, Norwich, New York, U.S.A., 2002.

Reference Books:

1. Handbook of Thin Film Technology- Leon –Imaissel & Reihard Glang –Mc Graw –Hill Book Company -1970
2. D.M. Hoffman, B. Singh, J.H. Thomas, Handbook of Vacuum Science and Technology, Academic Press 1998.
3. Mironov V. L.: Fundamentals of Scanning Probe Microscopy. Tekhnosfera, Moscow 2004.

Others Suggested Readings:

1.https://www.svc.org/Education/SVC-Education-Program.cfm
2. http://technology.niagarac.on.ca/cours

MM46036 **3-0-0 (3)**

Functional Coatings for Engineering Applications

Pre-Requisites: None

Course Outcomes:

CO-1	Explain surface engineering principles, interface reactions, adhesion, and classify surface modification/coating routes.
CO-2	Select and justify appropriate coating processes (electrochemical, thermal spray, thin films, diffusion/thermo-chemical) with key parameters and limitations.
CO-3	Evaluate coatings using standard performance metrics (thickness, porosity, bond strength, hardness, wear/corrosion) and diagnose defects/failure modes.
CO-4	Design functional coating solutions (multifunctional, nano/graded, smart) for targeted applications considering environment, cost, and reliability.
CO-5	Use computational/data-driven approaches (ICME mindset) to shortlist coating materials/process windows and connect structure–process–property–performance.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	2	-	-	-
CO-2	3	3	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	3	3	-	-	-
CO-5	3	3	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Foundations of Surface Engineering: Importance, classification of surface engineering; interfaces, surface reactions, wetting/adhesion, Surface Dependent Properties, Coating characteristics: thickness, continuity, hardness, adhesion, porosity, bond strength.
Overlay Coatings; Thermally sprayed coatings: principles, process–microstructure, advantages/limitations, applications, Electrochemical coatings: electroplating basics, process variables, throwing power/coverage; Micro-arc oxidation and electro-spark coatings.
Diffusion & Thermo-chemical Surface Engineering: Diffusion coatings/thermo-chemical routes (carburizing, nitriding, boriding and other diffusion coatings), Plasma-assisted diffusion processes.
Thermal/Beam-based Surface Modification: Lasers: surface cleaning, hardening, cladding, alloying; induction/flame hardening.
Thin Film Technologies: PVD/CVD fundamentals; sputtering, e-beam evaporation, magnetron sputtering. ALD and plasma-enhanced CVD (concepts + application windows). Sol–gel coating route; DLC coatings.
Coating Characterization: Performance & Defects, Coating defects (origin, diagnosis, prevention) + industrial case studies.
Functional & Smart Coatings: Functional coatings: thermal barrier, anti-wear, anti-corrosion, anti-fouling, self-lubricating. Smart/special surfaces: self-healing, anti-icing, antimicrobial, superhydrophobic/oleophobic, EMI shielding. ICME/Data-driven Coatings Design: Process–structure–property–performance (PSPP) thinking for coatings. Quick intro to computational screening (thermo/DFT-informed choices, CALPHAD/phase logic, or ML-based ranking)

Learning Resources:

Text Books:

1. Surface Engineering for Corrosion and Wear Resistance by J.R. Davis (Ed.), ASM International

2. Surface Engineering by A. Matthews & B. James (or R. Jones & A. Matthews, depending on edition)

Reference Books:

1. Thermal Spray Fundamentals: From Powder to Part — S. Kamnis & S. Gu (or equivalent thermal spray fundamentals texts)
2. Thermal Spray Technology — H. Herman / ASM Thermal Spray handbooks (ASM Handbook Vol. 5: Surface Engineering)
3. Handbook of Thin Film Deposition — Krishna Seshan (Ed.)

Other Suggested Readings:

1. Key journals (for regular reading & term paper sources): Surface and Coatings Technology, Thin Solid Films, Progress in Organic Coatings, Wear, Corrosion Science, Tribology International, Materials & Design, Acta Materialia (selected papers on thin films/coating microstructures)
2. NPTEL Lectures: Prof. I. Manna and Prof. J.D. Majumdar (IIT Kharagpur)

MM46038 **3-0-0 (3)**

Manufacturing Techniques in MEMS

Pre-Requisites: Basics of Materials Science

Course Outcomes:

CO-1	Explain MEMS process flows and select materials (Si, glass, polymers, piezoelectrics, metals) based on properties and constraints.
CO-2	Compare and choose deposition techniques (PVD/CVD/ALD/electroplating/spin coating) for MEMS layers and justify parameter choices.
CO-3	Analyze etching processes (wet/dry, isotropic/anisotropic, DRIE) and predict profiles, selectivity, and defects.
CO-4	Design complete fabrication routes for typical MEMS devices (cantilever, pressure sensor, accelerometer, microfluidic chip), including release and packaging.
CO-5	Evaluate yield, reliability, packaging, and failure mechanisms, and propose mitigation strategies using process control and metrology.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	2	-	-	-
CO-2	2	3	3	-	-	-
CO-3	2	3	3	-	-	-
CO-4	2	3	3	-	-	-
CO-5	3	2	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

MEMS Overview & Materials for MEMS: MEMS vs IC manufacturing; scaling laws; typical devices (sensors/actuators), Substrates: Si (100)/(111), SOI, glass, polymers; orientation and anisotropy. Functional materials: metals, dielectrics, polymers (SU-8/PDMS), piezoelectric (PZT/AlN), magnetic films, Cleanroom basics: contamination, classes, safety, wafer handling; process integration mindset

Lithography & Pattern Transfer: Photolithography workflow: resist types, spin coating, soft bake, exposure, develop, hard bake, Resolution, depth of focus, alignment/overlay; dose and process windows, Advanced lithography: grayscale, e-beam, nanoimprint (overview), Mask design basics; design rules; layout-to-fabrication constraints

Thin Film Deposition for MEMS: PVD: evaporation, sputtering; stress, step coverage, adhesion layers, CVD: LPCVD/PECVD; SiO_2, Si_3N_4, polysilicon; conformality, ALD: ultra-conformal films; barrier/seed layers, Electroplating/electroless plating for thick metals; seed layers and current distribution, Spin coating & polymer films (SU-8), curing; sol–gel and hybrid routes

Etching & Micromachining: Wet etching: isotropic vs anisotropic (KOH/TMAH); crystal planes; etch stops, Dry etching: RIE/ICP; chemistry, ion energy, selectivity, sidewall passivation, DRIE (Bosch) for high aspect ratio structures; scalloping and profile control, Sacrificial layer etching and release; stiction, capillary forces; supercritical drying (overview), Surface micromachining vs bulk micromachining vs SOI micromachining

Wafer Bonding, Integration & Packaging: Wafer bonding: anodic (Si–glass), fusion, eutectic, adhesive bonding, Through-silicon vias (TSVs) and interconnects (overview), Packaging: wafer-level packaging, hermetic sealing, caps, getters, Interfaces with electronics: monolithic vs hybrid integration; interposer concepts

Microfluidic MEMS & Polymer MEMS Manufacturing: Soft lithography (PDMS), molding/replication, hot embossing, injection molding, Surface modification, bonding, leakage control, Lab-on-chip considerations: materials compatibility, biofouling, sterilization

Process Control, Metrology, Yield & Reliability: Metrology: profilometry, ellipsometry, AFM, SEM, optical inspection, thickness & stress measurement, SPC basics; defect density, yield models; design for manufacturability (DfM)

Reliability & failure: fatigue, creep, fracture, delamination, corrosion, dielectric charging, stiction, electromigration, Accelerated testing; standards overview for MEMS reliability

Learning Resources:

Text Books:

1. Marc J. Madou – *Fundamentals of Microfabrication and Nanotechnology*
2. Stephen D. Senturia – *Microsystem Design*

Reference Books

1. Gregory T. A. Kovacs – *Micromachined Transducers Sourcebook*
2. Nadim Maluf & Kirt Williams – *An Introduction to Microelectromechanical Systems Engineering*
3. Simon Middelhoek & S. A. Audet (eds.) – MEMS/NEMS process and packaging references (selected chapters)

Other Suggested Readings / Tools

1. MIT OpenCourseWare (Microsystems Technology / MEMS-related modules)
2. Stanford/UC Berkeley MEMS notes (process integration case studies)
3. Selected review papers on DRIE, wafer bonding, stiction, and MEMS packaging
4. Cleanroom process manuals (institutional) and vendor application notes (etch/deposition recipes)

MM46040 **3-0-0 (3)**

Diffraction and Electron Microscopy

Pre-Requisites: **None**

Course Outcomes:

CO-1	Explain the properties, generation, filtering and detection of X-rays, and the physical basis of diffraction in crystalline materials
CO-2	Apply Bragg's law, reciprocal lattice/crystallography concepts, and intensity rules to index diffraction peaks and interpret diffraction directions.
CO-3	Determine key crystallographic/material parameters from XRD data.
CO-4	Interpret diffraction-based materials phenomena including phase diagrams, order–disorder transformations, and chemical analysis using diffraction evidence and supporting reasoning.
CO-5	Explain electron–specimen interactions and interpret electron diffraction (SAED/CBED) and TEM/HRTEM micrographs, correlating TEM-derived crystallography with XRD results.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	-	-	-	-
CO-2	3	3	3	-	-	-
CO-3	3	3	3	-	-	-
CO-4	3	3	2	-	-	-
CO-5	2	3	2	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Production and detection of X-rays. Basic crystallography of materials - Symmetry Elements, Point Groups, Space Groups. Reciprocal lattice. Analysis of diffracted beam direction - Bragg approach and Laue approach. Intensities of diffracted beams: Scattering from single electron, atom, unit cell, small crystal â the kinametical theory of x-ray diffraction. Single crystal diffraction methods and their applications. Modern powder diffraction methods. Indexing of powder diffraction patterns. Precise lattice parameter estimation. Determination of crystal structures from symmetry and geometry, and Patterson, direct and Fourier methods. Rietveled method and precise crystal structures. Qualitative and quantitative phase identification. Preferred orientation. Grain size and microstrain, Residual stress. Order-disorder transformations. Diffraction from thin films. Neutron diffraction. Theory of electron diffraction, geometry of electron diffraction and their applications, microdiffraction.

Learning Resources:

Text Books:

1. B.D. Cullity & S.R. Stock, Elements of X-Ray Diffraction (3rd ed., Pearson)
2. E. Warren, X-Ray Diffraction (Dover/Addison-Wesley classic)

Reference Books

1. H.P. Klug & L.E. Alexander, X-Ray Diffraction Procedures (Wiley)
2. C. Hammond, The Basics of Crystallography and Diffraction (Oxford)
3. B.E. Warren, X-Ray Diffraction
4. D.B. Williams & C.B. Carter, Transmission Electron Microscopy (Springer)
5. Goodhew, Humphreys & Beanland, Electron Microscopy and Analysis (Taylor & Francis)

Other Suggested Readings / Tools

1. ICDD PDF database / search–match guides (phase identification workflows).
2. Rietveld refinement introductions: R.A. Young (ed.), The Rietveld Method (Oxford).

MM46042 **3-0-0 (3)**

Texture and Grain Boundary Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand grain boundary structure, character and energetics, and crystallographic texture in materials.
CO-2	Analyze grain boundary structure–property relationships influencing mechanical and physical properties.
CO-3	Explain principles of texture formation and evolution during solidification, deformation and annealing.
CO-4	Apply X-ray diffraction and EBSD techniques for texture and grain boundary characterization.
CO-5	Utilize grain boundary and texture engineering concepts for property optimization in engineering materials.

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	2	2	-	-	-
CO-2	3	3	3	-	-	-
CO-3	3	3	3	-	-	-
CO-4	2	3	2	-	-	-
CO-5	2	2	2	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to grain boundary engineering and crystallographic texture, significance in controlling mechanical and functional properties of materials. Grain boundary structure including geometrical aspects, degrees of freedom, grain shape, size and orientation, special boundaries, coincidence site lattice (CSL) and displacement shift complete (DSC) lattice concepts, grain boundary energy, equilibrium, mobility and solute interactions.

Grain boundary structure–property relationships influencing mechanical strength, wear, creep, electrical and magnetic properties, grain boundary engineering strategies through deformation and thermomechanical processing.

Fundamentals of crystallographic orientation and texture, crystal structures and stereographic projections. Texture characterization using X-ray diffraction, pole figures, inverse pole figures and three-dimensional texture analysis. Microtexture measurement using EBSD in SEM, grain boundary classification, character and energy.

Texture evolution during solidification, phase transformations, deformation and annealing, texture development in FCC, BCC and HCP materials. Applications of texture and grain boundary engineering through selected case studies.

Learning Resources:

Text Books:

1. Grain Boundaries: From Theory to Engineering: Springer Series in Materials Science, Louisette Prieste

2. Bunge, H. (1982). Texture Analysis in Materials Science. London, Butterworths. (located in the reference section) Gottstein, G. and L. S. Shvindlerman (1999).
3. Grain Boundary Migration in Metals, CRC Press, Boca Raton, FL, ISBN 0-8493-8222-X. Note: 2nd edition is available.

Reference Books:

1. Ohser, J. and F. Mücklich (2000), Statistical Analysis of Microstructures in Materials Science., Chichester, England: Wiley, 381pp, ISBN 0-471-97486-2. Randle, V. and O. Engler (2000).
2. Texture Analysis: Macrotexture, Microtexture & Orientation Mapping, Gordon & Breach, Amsterdam, Holland, ISBN 90-5699-224-4.

Other Suggested Readings:

1. nptel.ac.in/courses/113105103

MM36004 **3-0-0 (3)**

Industry 4.0 and IIOT

Pre-Requisites: None

Course Outcomes:

CO-1	Explore how Industry 4.0 transforms manufacturing through digitization of the value chain and digital twin technologies.
CO-2	Design, integrate, optimize mechatronic devices, and implement control systems for automation solutions
CO-3	Select sensors/actuators, program, simulate, and innovate for addressing automation challenges effectively
CO-4	Explore IIoT protocols, build simple IIoT systems with Arduino, ESP32, and Raspberry Pi for practical application.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	-	-	3
CO-2	3	-	3	-	-	-
CO-3	3	-	3	-	-	-
CO-4	2	-	2	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Introduction to Industry 4.0: Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Mass Customization, Smart Factories, Digital Twin Technologies, Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis Sensors and Actuators Static characteristics of sensors and actuators, Position, Displacement and Proximity Sensors, Force and torque sensors, Pressure sensors, Flow sensors, Temperature sensors, Acceleration sensors, Level sensors, Light sensors, Smart material sensors, Micro and Nano sensors, Selection criteria for sensors, Actuators: Electrical Actuators (Solenoids, Relays, DC motor, Servo motor, BLDC motor, AC motor, Stepper motors), Hydraulic and Pneumatic actuators, Design of Hydraulic and Pneumatic circuits, Piezoelectric actuators, Shape memory alloys. Modelling, Analysis of Mechatronics Systems

Basics of System Modelling: LTI and LTV systems, Need for modelling, Types of modelling, Steps in modelling, Building blocks of models, Modelling of one and two degrees of freedom systems, Modelling of Electro-mechanical systems, Mechanical Systems, Fluid systems, Thermal systems; Dynamic Responses, System Transfer Functions, State Space Analysis and System Properties, Stability Analysis using Root Locus Method, Stability Analysis using Bode Plots, PID Controllers. Programmable Logic Controllers (PLCs): Architecture, Number Systems Basics of PLC Programming, Logic gates, Timers and Counters, Communication among HMI, PLC, SCADA, Fault diagnostics / troubleshooting. Application on real time industrial automation systems.

Introduction to IIoT: Architectural Overview, Design principles and needed capabilities, IoT Applications, Sensing, Actuation, Basics of Networking, M2M and IoT Technology Fundamentals-Devices and gateways, Data management, Business processes in IoT, Everything as a Service (XaaS), Role of Cloud inIoT, Security aspects in IoT.

Elements of IIoT: Hardware Components- Computing (Arduino, Raspberry Pi), Communication, Sensing, Actuation, I/O interfaces. Software Components- Programming API's (using Python/Node.js/Arduino) for Communication Protocols-MQTT, ZigBee, Bluetooth, CoAP, UDP, TCP.
IIoT & Cloud Application Development: Solution framework for IoT applications- Implementation of Device integration, Data acquisition and integration, Cloud service and platforms: Commercial clouds (such as Amazon elastic compute cloud, Google Compute engine, Windows Azure), Storage services, database services, application services, content delivery services, analytics services.
Case Studies: IIoT & Cloud based case studies and mini projects based on Industrial automation, Transportation, Agriculture, Healthcare, Home Automation.

Learning Resources:

Text Books:

2. Sudip Misra, Chandana Roy, Anandarup Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0 CRC Press, 2020.
3. Gilchrist, Alasdair, Industry 4.0: The Industrial Internet of Things, United States: Apress, 2016.
4. Vijay Madisetti, Arshdeep Bahga, A Hands-on Approach", Internet of Things, University Press, 2020.
5. W. Bolton, Mechatronics, Electronic control systems in mechanical and electrical engineering, Pearson Education, 2023 7th Edition.
6. K P Ramachandran, GK Vijayaraghavan, M S Balasundaram, Mechatronics, Wiley, 2019 4th Edition.
7. Mechatronics Systems Design, Devadas Shetty, Cengage Learning, USA, 2021.

Reference Books:

1. Pethuru Raj,Anupama C. Raman, The Internet of Things: Enabling Technologies, Platforms, and Use Cases", CRC Press, 2012.
2. Adrian McEwen, Designing the Internet of Things, Wiley, 2015.
3. W. de Silva, Mechatronics: A foundation course, Clarence, CRC Press, 2010.
4. Robert H. Bishop. The Mechatronics Handbook, CRC Press, 2007,2nd Edition.
5. David G. Alcaiatore and Michel B. Histand, Introduction to Mechatronics and Measuring Systems, Mc.Graw Hill Int. Edition,2022,6th Edition.

Online Sources:

1. http://video_demos.colostate.edu/mechatronics
2. https://onlinecourses.nptel.ac.in/noc21_me129/preview

ME36022 **3-0-0 (3)**

Supply Chain Management

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the decision phases and apply competitive and supply chain strategies.
CO-2	Understand drivers of supply chain performance.
CO-3	Analyze factors influencing network design.
CO-4	Analyze the role of forecasting in a supply chain
CO-5	Understand the role of aggregate planning, inventory, IT and coordination in a supply chain.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	2	-	-	-
CO-2	3	-	3	-	-	-
CO-3	3	-	3	-	-	-
CO-4	2	-	2	-	-	-
CO-5	2	-	2	-	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Strategic Framework: Introduction to Supply Chain Management, Decision phases in a supply chain, Process views of a supply chain: push/pull and cycle views, Achieving Strategic fit, Expanding strategic scope.
Supply Chain Drivers and Metrics: Drivers of supply chain performance, Framework for structuring Drivers, Obstacles to achieving strategic fit.
Designing Supply Chain Network: Factors influencing Distribution Network Design, Design options for a Distribution network, E-Business and Distribution network, Framework for Network Design Decisions, Models for Facility Location and Capacity Allocation.
Forecasting in SC: Role of forecasting in a supply chain, Components of a forecast and forecasting methods, Risk management in forecasting.
Aggregate Planning and Inventories in SC: Aggregate planning problem in SC, Aggregate Planning Strategies, Planning Supply and Demand in a SC, Managing uncertainty in a SC: Safety Inventory.
Coordination in SC: Modes of Transportation and their performance characteristics, Supply Chain IT framework, Coordination in a SC and Bullwhip Effect.

Learning Resources:

Text Books:

1. Supply Chain Management - Strategy, Planning and Operation, Sunil Chopra and Peter Meindl, Pearson Education Asia, 2010, 4th Edition.
2. Designing and Managing the Supply Chain - Concepts Strategies and Case Studies, David Simchi-Levi, PhilpKamintry and Edith Simchy Levy, Tata-McGraw Hill, 2000, 2nd Edition.
3. Managing Supply Chains A Logistics Approach', John J Coyle, Cengage Learning, 2013, 9th Edition
4. Modeling the Supply Chain', Jeremy F Shapiro, Cengage Learning, 2007, 2nd Edition.

ME26028 **3-0-0 (3)**

Design and Analysis of Experiments

Pre-Requisites: None

Course Outcomes:

CO-1	Identify objectives and key factors in designing experiments.
CO-2	Develop appropriate experimental design to conduct experiments.
CO-3	Analyze experimental data and draw valid conclusions.
CO-4	Develop empirical models using experimental data to optimize process Parameters.
CO-5	Design robust products and processes using parameter design approach.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	-	-	-
CO-2	2	-	3	-	-	-
CO-3	3	-	2	-	-	-
CO-4	3	3	2	-	-	-
CO-5	2	3	3	-	-	-

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Fundamentals of Experimentation: Role of experimentation in rapid scientific progress, Historical perspective of experimental approaches, Steps in experimentation, Principles of experimentation.
Simple Comparative Experiments: Basic concepts of probability and statistics, Comparison of two means and two variances, Comparison of multiple (more than two) means & ANOVA.
Experimental Designs: Factorial designs, fractional factorial designs, orthogonal arrays, standard orthogonal arrays & interaction tables, modifying the orthogonal arrays, selection of suitable orthogonal array design, analysis of experimental data.
Response Surface Methodology: Concept, linear model, steepest ascent, second order model, regression.
Taguchi's Parameter Design: Concept of robustness, noise factors, objective function & S/N ratios, inner-array and outer-array design, data analysis.

Learning Resources:

Text Books:

1. Montgomery DC, Design and Analysis of Experiments, John Wiley & Sons, NY, 2019, 10th Edition.
2. Ross PJ, Taguchi Techniques for Quality Engineering, McGraw-Hill Book Company, NY, 2008.
3. Madhav S. Phadke, Quality Engineering using Robust Design, Prentice Hall, 1989.

Reference Books:

1. Dukkipati, R V, Pradip K Ray, Product and Process Design for Quality, Economy and Reliability, New Age International,2010, 1st Edition.

Online Resources:

1. http://reliawiki.org/index.php/Experiment_Design_and_Analysis_Reference
2. https://ieeexplore.ieee.org/abstract/document/6771276
3. https://link.springer.com/chapter/10.1007/978-1-4684-1472-1_1

MM46044 **3-0-0 (3)**

Engineering Entrepreneurship

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify and evaluate entrepreneurship opportunities in materials/engineering sectors using structured frameworks.
CO-2	Conduct customer discovery and translate needs into measurable product requirements (MVP specs).
CO-3	Develop a business model and go-to-market strategy for a materials-based product/technology.
CO-4	Apply basics of startup finance—costing, pricing, unit economics, funding options, and financial projections.
CO-5	Understand IP (patents/trade secrets), technology transfer, standards, EHS/regulatory and manufacturing scale-up considerations.
CO-6	Prepare and deliver a professional investor/customer pitch supported by validation, roadmap, and risk analysis.

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	3	-	2	-	-	-
CO-2	2	-	-	-	3	-
CO-3	2	-	3	-	3	-
CO-4	3	-	2	-	-	-
CO-5	3	-	3	-	-	-
CO-6	2	-	-	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Entrepreneurship Foundations: Engineering entrepreneurship vs. traditional business entrepreneurship, Startup ecosystem: incubators, accelerators, innovation cells, TTOs, Entrepreneurial mindset, ethics, team roles, founder agreements basics, Opportunity landscapes in materials: coatings, corrosion, batteries, additive manufacturing, biomaterials, recycling/circular economy.

Opportunity Identification & Problem–Solution Fit: Problem framing, value proposition, TAM/SAM/SOM basics; competitive landscape & differentiation, Technology readiness levels (TRL) and market readiness, Early risk mapping: technical, market, regulatory, supply chain

Customer Discovery & Validation: Customer discovery interviews, stakeholder mapping (B2B/B2G/B2C), Hypotheses and experiments; evidence-based entrepreneurship

Business Models & Go-to-Market: Business Model Canvas / Lean Canvas, Revenue models: product sales, subscription, licensing, service, contract manufacturing, GTM strategies: channel partners, OEMs, distributors; pricing strategy, Partnerships: suppliers, testing labs, certification agencies; early adopters

IP, Technology Transfer & Standards: Patents: novelty, prior art, claims basics; freedom-to-operate (FTO) concept, Trade secrets vs patents; publication vs patent timing, Standards, certification, quality systems: ISO/ASTM overview

Manufacturing, Scale-up & Operations: DFM/DFA thinking; pilot scale to production scale challenges, Supply chain, vendor development, documentation and traceability, Reliability, warranties, failure modes; risk management (FMEA overview)

Funding, Financials & Pitching: Funding options: bootstrapping, grants, angels, VC, strategic, debt, Term sheet basics (high-level), valuation intuition, dilution concept, Pitch crafting: story, traction, milestones, ask; demo day

Learning Resources

Text Books

1. Steve Blank & Bob Dorf – The Startup Owner's Manual
2. Eric Ries – The Lean Startup
3. Alexander Osterwalder & Yves Pigneur – Business Model Generation

Reference Books

1. Ash Maurya – Running Lean
2. Peter Thiel – Zero to One (strategy & differentiation)
3. Kathleen Allen – Launching New Ventures
4. Donald G. Reinertsen – The Principles of Product Development Flow (product/process thinking)

Other Suggested Readings / Resources

1. MIT OpenCourseWare – Entrepreneurship / New Enterprises (selected lectures)
2. WIPO Patent resources (patent basics, prior art search guidance)
3. National/Institutional innovation & startup policy docs (incubation, grants, IPR policy of institute)

MM46046 **3-0-0 (3)**

Process Design & Economics

Pre-Requisites: None

Course Outcomes:

CO-1	Create process flowsheets (BFD/PFD) and perform mass/energy balances for materials processes.
CO-2	Select appropriate processing routes using technical, environmental, and economic criteria.
CO-3	Size key unit operations/equipment relevant to materials industries and estimate utilities consumption.
CO-4	Estimate CAPEX/OPEX using standard cost estimation methods and develop cost breakdowns.
CO-5	Incorporate safety, sustainability, and compliance considerations (EHS, waste, emissions) into design decisions and communicate a complete design report.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	2	-	-	-
CO-2	-	3	2	-	-	-
CO-3	2	-	3	-	-	-
CO-4	2	-	2	-	3	-
CO-5	2	2	3	-	2	2

1 - Slightly; 2 - Moderately; 3 - Substantially

Syllabus:

Process Design Framework & Flowsheeting: Process design steps, Process selection in materials: primary vs secondary routes; batch vs continuous, Block Flow Diagram (BFD), Process Flow Diagram (PFD), P&ID overview, Materials industries case contexts: steelmaking, casting, coating lines, powder routes, recycling, batteries

Material & Energy Balances for Materials Processes: Stoichiometry, yields, recycle/purge, by-products, Energy balance: sensible/latent heats, reaction heats, furnace/heat losses, Utilities: steam, cooling water, compressed air, electricity, gases

Process Data, Properties & Scale-up Concepts: Process data needs: kinetics, transport limits, residence time, Scale-up laws and similarity, Material properties for design: viscosity, Cp, thermal conductivity, density; phase diagrams & processing windows, Pilot plant logic, TRL/MRL, scale-up risks.

Equipment Selection & Sizing: Sizing philosophy and design margins; throughput and capacity planning, Key equipment in materials processing (illustrative sizing methods): furnaces/heat exchangers, mixers/reactors, filtration/drying, comminution, classification rolling/extrusion/casting lines (capacity and energy), coating systems (thermal spray/CVD/PVD lines—conceptual sizing), ETP units

Cost Estimation (CAPEX/OPEX): Cost terminology: fixed capital investment, working capital, depreciation, CAPEX estimation methods, OPEX,

Profitability, Project Appraisal & Sensitivity: Revenue models, pricing, contribution margin, break-even, Time value of money; NPV, IRR, payback, discounted cash flow, sensitivity/what-if analysis: yield, energy cost, raw material price, downtime, Risk & uncertainty, Techno-economic assessment (TEA) structure for materials technologies

Learning Resources

Text Books

1. Peters, Timmerhaus & West – Plant Design and Economics for Chemical Engineers
2. Towler & Sinnott – Chemical Engineering Design (Coulson & Richardson)

Reference Books

1. Turton et al. – Analysis, Synthesis, and Design of Chemical Processes
2. Ulrich & Vasudevan – Chemical Engineering Process Design and Economics
3. Himmelblau & Riggs – Basic Principles and Calculations in Chemical Engineering (balances)
4. Coulson & Richardson (Vol. 6) – Chemical Engineering Design (equipment & design methods)

Other Suggested Readings / Tools

1. DOE / NREL style Techno-Economic Analysis (TEA) reports (structure and assumptions)
2. Cost indices overview (conceptual use), vendor datasheets and budgeting quotes
3. Spreadsheet modeling templates for cash-flow/NPV and sensitivity analysis

ME26035 **3-0-0 (3)**

Finite Element Applications in Materials Processing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply finite element method to solve problems in solid mechanics
CO-2	Formulate FE characteristic equations for two dimensional elements and analyze plain stress, plain strain, axi-symmetric and plate bending problems.
CO-3	Solve heat transfer and fluid mechanics problems using the principles of FEM.
CO-4	Analyze deformation processes using finite element principles.

Course Articulation Matrix:

	PO-1	**PO-2**	**PO-3**	**PO-4**	**PO-5**	**PO-6**
CO-1	2	3	2	-	-	-
CO-2	2	3	3	-	-	-
CO-3	3	3	2	-	-	-
CO-4	2	3	3	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to FEA: Stresses and equilibrium, Strain displacement relations, Potential energy and equilibrium, FEA in 1 D problems: Element division, Numbering scheme, coordinates and shape functions - Galerkin Approach, Assembly of the global stiffness matrix and load vector, 1 D Problems, Temperature effects.

FEA in 2 D problems: Interpolation in two dimensions, natural coordinates, Isoparametric representation, Concept of Jacobian. Finite element formulation for plane stress plane strain and axi-symmetric problems; Triangular and Quadrilateral elements, higher order elements, subparametric, Isoparametric and superparametric elements. Formulation of plate bending elements using linear and higher order bending theories, Shell elements. Exercises on structural, flow and heat transfer problems.

Non Linear FEA: Introduction to Non Linear Finite Element Analysis – Nonlinearities – Solution Methods – Newton Raphson – Modified Newton Raphson – Secant Method – Incremental Force Method –Problems

FEA of Elasto Plastic Problems: One and Multidimensional Elastoplasticity – Yield Criteria – Hardening Models – Mathematical Formulations – Problems

FEA in Heat Transfer problems: Finite element solution for one dimensional heat conduction with convective boundaries. Formulation of element characteristics and simple numerical problems. Formulation for 2-D problems with convective boundaries, Problems.

Learning Resources:

Textbooks:

1. Henry S Valberg, Applied Metal Forming: Including FEM Analysis, Cambridge Press. 2010
2. Nam Ho Kim, Introduction to Non-Linear Finite Element Analysis, 2015, Springer.
3. R. Boer· N. Rebelo H. Rydstad . G. Schroder, Process Modelling of Metal Forming and

Reference Books:

1. S S Rao, The Finite Element Method in Engineering, 4th Edition, Elsevier 2007.
2. Reddy, J.N., Finite Element Method in Engineering, Tata McGraw Hill, 200