M.Tech.

IN

MATERIALS SCIENCE AND TECHNOLOGY

CURRICULUM AND SYLLABI

(Applicable from 2023 admission onwards)

तमसो मा ज्योतिर्गमय

Department of Mechanical Engineering
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT
Kozhikode - 673601, KERALA, INDIA

The Program Educational Objectives (PEOs) of M.Tech. in Materials Science and Technology

PEO1	Graduates apply their in-depth and advanced knowledge for fostering skills of analysing, formulating, defining and solving complex materials related challenges for productive and successful careers.
PEO2	Graduates demonstrate innovative and independent research work in academia/industry/R&D to enhance the knowledge base in materials science and technology and to disseminate the knowledge.
PEO3	Graduates exhibit a high level of professionalism, integrity, social responsibility and life-long independent learning ability.

Programme Outcomes (POs) of M.Tech. in Materials Science and Technology

PO1	Independently carry out research/investigation and development work to solve practical problems.
PO2	Write and present a substantial technical report/document.
PO3	Demonstrate mastery in materials science and technology at a level higher than the requirements in the appropriate bachelor program.
PO4	Acquire and share in-depth knowledge in the area of materials science and technology.
PO5	Analyse complex problems critically in the field of materials science and technology and arrive at optimal solutions.
PO6	Use modern computer/software tools to model and analyse problems related to materials science and technology.

CURRICULUM

Total credits for completing M.Tech. in Materials Science and Technology is 75.

COURSE CATEGORIES AND CREDIT REQUIREMENTS:

The structure of M.Tech. programme shall have the following Course Categories:

Sl. No.	Course Category	Minimum Credits
1.	Program Core (PC)	26
2.	Program Electives (PE)	12
3.	Institute Elective (IE)	2
4.	Projects	35

The effort to be put in by the student is indicated in the tables below as follows:
L: Lecture (One unit is of 50 minute duration)
T: Tutorial (One unit is of 50 minute duration)
P: Practical (One unit is of one hour duration)
O: Outside the class effort / self-study (One unit is of one hour duration)

PROGRAMME STRUCTURE

Semester I

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	MA6001E	Advanced Engineering Mathematics	3	1	0	8	4	PC
2.	ME6501E	Mechanical Behaviour of Materials	3	0	0	6	3	PC
3.	ME6502E	Structure and Characterisation of Materials	3	0	0	6	3	PC
4.		Elective 1	3	0	0	6	3	E
5.		Elective 2	3	0	0	6	3	E
6.	ME6591E	Materials Science Laboratory - I	0	0	3	3	2	PC
7.		Institute Elective	2	0	0	4	2	E
		Total	17	1	3	39	20	--

Semester II

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME6511E	Thermodynamics and Kinetics of Materials	3	0	0	6	3	PC
2.	ME6512E	Composite Materials Technology	3	0	0	6	3	PC
3.	ME6513E	Ceramics Science and Technology	3	0	0	6	3	PC
4.	ME6313E	Advanced Materials Processing Technologies	3	0	0	6	3	PC
5.		Elective 3	3	0	0	6	3	E
6.		Elective 4	3	0	0	6	3	E
7.	ME6592E	Materials Science Laboratory - II	0	0	3	3	2	PC
8.	ME6593E	Project Phase I	0	0	0	6	2	PC
		Total	18	0	3	45	22	**--**

Semester III

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME7594E	Project Phase II	0	0	0	9*	3	PC
2.	ME7595E	Project Phase III	0	0	0	45	15	PC
		Total	0	0	0	54	18	--

* To be completed during semester break. The number of hours is indicative only, and corresponds to a regular semester. Since the duration of the semester break is shorter, students are expected to devote more time per week. Furthermore, if Project Phase II is done as an internship, the working hours will be governed by the organization in which the internship is done.

Semester IV

Sl. No.	Course Code	Course Title	L	T	P	O	Credits	Category
1.	ME7596E	Project Phase IV	0	0	0	45	15	PC
		Total	0	0	0	45	15	--

List of Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	ME6521E	Numerical and Computational Methods in Material Science	3	0	0	6	3
2.	ME6522E	Materials for Energy and Sustainability	3	0	0	6	3
3.	ME6523E	Ferrous and Non-Ferrous Metallurgy	3	0	0	6	3
4.	ME6524E	Corrosion Science and Technology	3	0	0	6	3
5.	ME6525E	Science of Solidification Process	3	0	0	6	3
6.	ME6526E	Surface Science and Engineering	3	0	0	6	3
7.	ME6527E	Powder Technology	3	0	0	6	3

List of Institute Electives

Sl. No.	Course Code	Course Title	L	T	P	O	Credits
1.	IE6001E	Entrepreneurship Development	2	0	0	4	2
2.	ZZ6002E	Research Methodology	2	0	0	4	2
3.	MS6174E	Technical Communication and Writing	2	1	0	3	2

MA6001E ADVANCED ENGINEERING MATHEMATICS

Prerequisite: NIL

L	T	P	O	C
3	1	0	8	4

Total Sessions: 52

Course Outcomes:

CO1: Apply the concepts of matrix theory and vector calculus.
CO2: Develop the analytic approach for solving differential equations.
CO3: Apply the finite difference and finite volume methods for differential equations.
CO4: Implement the analytical and computational techniques in engineering problems.

Mathematical operations with matrices system of linear equations, consistency – vector spaces, linear dependence and independence, basis and dimension – linear transformation – projections – orthogonal matrices, positive definite matrices, eigenvalues and eigenvectors, similarity of matrices, diagonalisation, singular value decomposition.

Vector fields, line integrals, surface integrals – change of variables, green's theorem, stokes theorem, and divergence theorem.

The ordinary differential equation (ODE), Initial value problems and their solution techniques, general solutions of second-order ordinary differential equations, homogeneous and non-homogenous cases, boundary value problem, Sturm-Liouville problem, and system of ODEs – Partial differential equations (PDEs), Cauchy problem, method of characteristics, second-order PDE and classifications, type of boundary conditions, formulation and solution of the heat, wave, and Laplace equations.

Numerical implementation of ODE and PDE with MATLAB/python – ODE: initial value problem: first order and higher order methods, boundary value problem, shooting method, data-fitting, least-squares – first and higher order numerical methods for scalar transport equation, finite difference methods for heat, wave, and Laplace equations.

Case studies relevant to the program: The acoustic model for seismic waves, diffusion in heterogeneous media, development of flow between two flat plates, welding problem, heat conduction in a solid material, phase field solution to diffusion (Allen Cahn 1D solution), solution to the interaction of two or more molecules with Lennard-Jones Potentials, etc.

References:

[1] Lay, D., C., Lay, S., R., and McDonald, J., J., 2016, *Linear Algebra and its Applications*, Pearson, USA.
[2] Kreyszig, E., 2011, *Advanced Engineering Mathematics*, Wiley, India.
[3] Simmons, G., F., 2011, *Differential Equations with Applications and Historical Notes*, McGraw Hill, USA.
[4] Sneddon, I., N., 2006, *Elements of Partial Differential Equations*, Dover, Inda.
[5] Rao, K., S., 2010, *Introduction to Partial Differential Equations*, Prentice-Hall, India.
[6] Butcher, J., C., 2003, *Numerical methods for Ordinary Differential Equations*, Wiley, USA.
[7] Thomas, J., W.,2013, *Numerical Partial Differential Equations: Finite Difference Methods*, Springer, Switzerland.
[8] Versteeg, H., K., and Malalasekera, W., 2007, *An Introduction to Computational Fluid Dynamics: The Finite Volume Method*, Pearson, USA.

ME6501E MECHANICAL BEHAVIOUR OF MATERIALS

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the relationships which exist between structure of materials and its mechanical properties/behaviour.
CO2: Solve engineering problems involving plastic deformation.
CO3: Explain the mechanisms of fatigue, fracture and creep.
CO4: Evaluate the mechanical properties via various mechanical testing procedures.

Concepts of crystals, plastic deformation by slip and twinning, slip systems in FCC, BCC and HCP lattices, critical resolved shear stress for slip, theoretical shear strength of solids, stacking faults and deformation bands – observation of dislocations, climb and cross slip, dislocations in FCC and HCP lattice, interaction of dislocations, dislocation sources and their multiplications – strengthening from grain boundaries, grain size measurements, yield point phenomenon, strain aging, solid solution strengthening – strengthening from fine particles – fiber strengthening, cold working and strain hardening, annealing of cold worked metal – Mechanical properties of metals, ceramics and polymers.

Fracture in metals: Griffith theory of brittle fracture, metallographic aspects of fracture, fractography, dislocation theories of brittle fracture, ductile fracture, notch effects, strain energy release rate in fracture, fracture toughness and design – fatigue of metals: the S-N curve, low cycle fatigue, fatigue crack propagation, effect of stress concentration on fatigue, size effect, surface effects and fatigue, fatigue under combined stresses, effects of metallurgical variables and fatigue, corrosion fatigue, design for fatigue, effect of temperature on fatigue – creep and stress rupture: creep curve, stress rupture test, mechanism of creep deformation, activation energy for steady state creep, super plasticity, fracture at elevated temperature, creep resistant alloys, creep under combined stresses.

Tension test: stress-strain curves, instability in tension, ductility measurement, effect of strain rate, temperature and testing machine on flow properties, stress relaxation testing, notch tensile test, anisotropy of tensile properties – compression test – flow curve analysis – hardness test: Brinnel, Rockwell and Vickers hardness, flow of metal under the indenter, relationship between hardness and flow curve, micro hardness testing, hardness at elevated temperatures.

References:

[1] Dieter, M., G., 2017, *Mechanical Metallurgy*, McGraw Hill, USA.
[2] Callister, W., D., 2013, *Materials Science and Engineering an Introduction*, Wiley, USA
[3] Norman, E., D., 2013, *Mechanical Behaviour of Materials*, Pearson Education, UK.
[4] Thomas, H., C., 2017, *Mechanical Behavior of Materials*, McGraw Hill, USA.
[5] Richard, W., H., 2012, *Deformation and fracture mechanics*, Wiley, USA
[6] Reed, H., and Robert, E., 2008, *Physical Metallurgy Principles*, East West Press, Inda.
[7] Hyden, W., M., 1965, *Structure and properties of Materials*, Vol. 3, Wiley, USA
[8] Honeycombe, R., W., K., 1984, *Plastic deformation of Metals*, Hodder Arnold, UK.
[9] Avner, S., H., 2017, *Introduction to Physical Metallurgy*, McGraw Hill, USA.

ME6502E STRUCTURE AND CHARACTERISATION OF MATERIALS

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the X-ray diffraction and compare it with neutron and electron diffraction techniques.
CO2: Apply the principles of optical, scanning, and transmission techniques on material characterisation.
CO3: Evaluate physical behaviour of materials when subjected to specific heating rate.
CO4: Describe the principles, operation, and applications of FTIR (Fourier Transform Infrared Spectroscopy), Raman spectroscopy and Atomic Absorption Spectroscopy Techniques.

Diffraction Techniques

X-ray Diffraction: fundamentals of crystal structure, Bragg's condition, Laue treatment, reciprocal lattice, intensity of diffracted beam, crystal structure determination, atomic scattering factor, geometrical structure factor for SC, FCC, and BCC, structures, experimental methods, Laue, rotating crystal and powder photograph methods, estimation of stress, crystallographic textures – electron diffraction, neutron diffraction.

Optical and Electron Microscopy

Macro and micro examination of metals – specimen preparation – qualitative and quantitative examination – optical microscopy – scanning electron microscopy (SEM): Secondary and backscattered electron imaging, Electron Backscatter Diffraction (EBSD) – transmission electron microscopy (TEM), Selected Area Electron Diffraction (SAED) – atomic force microscopy (AFM).

Thermal analysis and Spectroscopy techniques

Thermal characterisation techniques: Thermogravimetric analysis (TGA), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Thermo mechanical (TMA) and Dynamic mechanical analyses (DMA) – Spectroscopy Techniques: Energy/Wavelength dispersive spectroscopy (EDS/WDS), Fourier transform infrared spectroscopy (FTIR), Raman Spectroscopy, Atomic absorption spectroscopy.

References:

[1] Cullity, B., D., and Stock, S.,R., 2013, *Elements of X-ray Diffraction*, Pearson Education, UK.
[2] Peter, J., G., John, H., and Richard B., 2000, *Electron Microscopy and Analysis*, Routledge, UK.
[3] Douglas, B., M., and Michael, W., D., 2012, *Fundamentals of Light Microscopy and Electronic Imaging,* Wiley, USA.
[4] Michael, E., B., 2015, *Introduction to Thermal Analysis: Techniques and Applications,* Springer, USA.
[5] Ewen, S., and Geoffrey, D., 2019, *Modern Raman Spectroscopy– A Practical Approach*, Wiley–Blackwell, USA.
[6] Walker, H. S., and Straw, H., 1967, *Spectroscopy: Ultra Violet, Visible, Infra-Red and Raman Spectroscopy - Volume Two*, Chapman & Hall, UK.
[7] Engler, O., and Randle, V., 2009, *Introduction to Texture Analysis, Macrotexture, Microtexture, and Orientation Mapping,* CRC Press, USA.
[8] Singhal, R., L., and Alvi, P., A., 2001, *Solid State Physics*, 7th ed., Kedar Nath Ram Nath& Co., Meerut, India.
[9] Srivastava, C., M., and Srinivasan, C., 2010, *Science of Engineering Materials and Carbon Nanotubes,* New Age Science, India.
[10] Agrawal, B., K., 2006, *Introduction to Engineering Materials*, Mc Graw Hill India.

ME6591E MATERIALS SCIENCE LABORATORY - I

Pre-requisite: NIL

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Analyse microstructure of ferrous and non-ferrous materials.
CO2: Assess the mechanical properties of metals and alloys.
CO3: Develop alloys and composites using casting method.
CO4: Inspect using advanced materials testing facilities.
CO5: Analyse structural and thermal properties of materials using computational techniques.

Clear understanding and hands-on practice on sample preparations for microstructural analysis using optical microscope: analysis of grain boundaries, precipitates and phase fractions – understanding of various process monitoring and testing equipment – understanding of flaw detection techniques – ability to perform various heat treatment processes – hands-on practice of alloy development though casting and powder metallurgy route – sample preparation for mechanical testing – ability to perform various mechanical testing of materials based on standards.

List of experiments:

1. Polishing, etching and microstructure analysis of mild steel, aluminium and copper.
2. Study of variation in microstructure of ferrous and non-ferrous metals before and after heat treatment.
3. Hardness analysis of polymer, aluminium and mild steel (before and after heat treatment).
4. Die-casting of aluminium composite materials.
5. Monitoring of metallurgical processes using temperature data acquisition system.
6. Mechanical testing of aluminium composite materials.
7. Electrochemical corrosion analysis of ferrous and non-ferrous materials.
8. Preparation of micro and nano-sized metal and ceramic reinforcements using planetary ball mill.
9. Development of aluminium metal matrix composite by powder metallurgy method
10. T6 heat treatment of aluminium composite prepared by powder metallurgy method.
11. FEM simulation of mechanical deformation.

References:

[1] Dieter, G., E., 2007, *Mechanical Metallurgy*, McGraw Hill, USA
[2] Callister, W., D., and Rethwisch, D., G, 2018, *Materials Science and Engineering*, Wiley, USA.
[3] Douglas, B., M., and Michael, W., D., 2012, *Fundamentals of Light Microscopy and Electronic Imaging*, Wiley, USA.
[4] Abbaschian, R., and Reed-Hill, R., E., 2009, *Physical Metallurgy Principles*, East-West Press, India.
[5] Avner, S. H., 1982, *Introduction to Physical Metallurgy*, McGraw Hill, USA.
[6] Meyers, M., A., and Chawla, K., K., 2009, *Mechanical Behavior of Materials*, Cambridge University Press, UK.
[7] Porter, D., A., Easterling, K., E, and Sherif, M., Y., 2009, *Phase Transformations in Metals and Alloys*, CRC Press, USA.
[8] Perez, N., 2004, *Electrochemistry and Corrosion Science*, Springer, USA.
[9] ASM, 1973, *Metals Handbook. - Vol. 8 Metallography, Structures and Phase Diagrams,* American Society for Metals, USA.
[10] Cook, R., D., Malkus, D., S., Plesha, M. E., and Witt, R., J., 2007, *Concepts and Applications of Finite Element Analysis*, Wiley, USA.

ME6511E THERMODYNAMICS AND KINETICS OF MATERIALS

Pre-requisite: NIL

L	T	P	O	C
3	0	3	6	3

Total Lecture Sessions: 39

Course outcomes:

CO1: Describe basic laws and principles of thermodynamics.
CO2: Interpret phase diagrams to understand the phase evolutions and processing conditions of materials.
CO3: Apply the principles of thermodynamics to understand the phase transformations in materials.
CO4: Apply the knowledge of diffusion kinetics to understand the materials behavior.

Basic laws and principles of thermodynamics

First law of thermodynamics, heat, work, heat capacity, enthalpy and internal energy – Hess's law and second law of thermodynamics, entropy and criterion for equilibrium, statistical interpretation of entropy, Boltzmann equation, auxiliary functions, thermodynamic relations, Maxwell's equations, Clausius Clapeyron equation, Gibbs Helmholtz equation, examples, heat capacity, enthalpy – entropy and the third law of thermodynamics.

Phase diagrams and phase transformations

Concept of equilibrium, free energy as criterion for equilibrium and its applications to processing of materials, unary, binary and multicomponent systems, evolution of phase diagrams, Gibbs free energy composition diagrams, metastable phase diagrams, calculation of phase diagrams – thermodynamics of phase transformation, melting and solidification, spinodal, martensitic, order-disorder transformations and glass transitions, first and second order transitions – thermodynamics of defects, point defects in crystals, defects stability.

Diffusion kinetics

Grain growth kinetics, precipitate nucleation and growth kinetics, concepts of fields, fluxes and gradients – Fick's laws of diffusion, steady state and non-steady state, solutions to the diffusion equation – diffusion in crystals, interstitial and substitutional diffusion, diffusion mechanisms, diffusion along crystal imperfections, interdiffusion, Kirkendall effect, diffusion in multicomponent systems.

References:

[1] Gaskell, D., R., and Laughlin, D., E., 2017, *Introduction to the Thermodynamics of Materials*, CRC Press, USA.
[2] Hae-Geon, L., 2012, *Materials thermodynamic: With emphasis on chemical approach*, World Scientific Publishing Company, Singapore.
[3] Balluffi, R., W., Samuel, M., A., and Carter, W., C., 2005, *Kinetics of Materials*, Wiley, USA.
[4] Porter, D., A., Easterling, K., E, and Sherif, M., Y., 2009, *Phase Transformations in Metals and Alloys*, CRC Press, USA.
[5] Ragone, D., V., 1995, *Thermodynamics of Materials, Volume I*, Wiley, USA.

ME6512E COMPOSITE MATERIALS TECHNOLOGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the different fabrication method of composite material.
CO2: Analyse the basic mechanical behaviour of composite materials.
CO3: Evaluate the behaviour of unidirectional composite lamina.
CO4: Analyse the macromechanical properties of fibre reinforced composites.
CO5: Apply failure theories to design safe composite material for various loading condition.
CO6: Demonstrate a practical understanding of multifunctional properties of composites for advanced applications.

Classification and fabrication of composite materials

Introduction, classifications, terminologies – introduction to fibrous composites, fibre, matrix–materials, properties and fabrication processes – manufacturing, hand and prepreg layup–bag molding, autoclave processing, compression molding, resin transfer molding, pultrusion – metal-matrix composites, solid state and liquid state processing – ceramic-matrix composites, solid state.

Analysis of fiber composites

Analysis of continuous fiber composites: derivation for density, mass of composite, critical fiber volume fraction, minimum fiber volume fraction – theoretical evaluation of UD composite properties (elastic modulus, shear modulus, poison's ration, etc.), fraction of load carried by fibers, longitudinal tensile strength.

Mechanical analysis of lamina

Hooke's law for anisotropic, monoclinic, orthotropic, transversely isotropic and isotropic materials – 2D unidirectional and angle ply lamina – stress-strain relations for general orthotropic lamina, compliance matrix and stiffness matrix.

Macromechanical analysis of laminates

Analysis of laminated composites: types of laminates and lamination code, lamination theory, laminate geometry, laminate strains and curvatures, laminate forces and moments, elements in the stiffness matrices, extensional stiffness matrix, coupling stiffness matrix, bending stiffness matrix – analysis of laminates subjected to thermal stresses and hygroscopic stresses.

Failure Theories

Failure mode: failure mode under tensile–compressive–shear loading – criteria of failure for isotropic material von mises criterion for metals – criteria for failure in orthotropic material: maximum stress theory, maximum strain theory, Tsai Hill theory or maximum work theory.

Designing of composite products

Development of multifunctional properties in composite materials: thermal, electrical, mechanical and optical properties – fracture processes in composites – toughening mechanisms in fibre reinforced plastics and ceramic-matrix composites – composite material testing methods and standard.

References:

[1] Agarwal, B. D., Broutman, L. J., and Chandrashekhara, K., 2017, *Analysis and Performance of Fiber Composites*, Wiley, USA.
[2] Mallick, P.K., 2008, *Fiber Reinforced Composites: Materials Manufacturing and Design*, CRC Press, USA.
[3] Autar, K., K., 2005, *Mechanics of Composite Materials*, CRC Press, USA.
[4] Daniel, G., and Suong, V., H., 2007, *Composite Materials, Design and Applications*, CRC Press, USA.
[5] Reddy, J. N., 2003, *Mechanics of Laminated Composite Plates*, CRC Press, USA.
[6] Balasubramanian, M., 2013, *Composite Materials and Processing*, 1st ed., CRC Press, USA.

ME6513E CERAMIC SCIENCE AND TECHNOLOGY

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the structure-property correlation of ceramics.
CO2: Identify and use different methods for ceramics components fabrication.
CO3: Evaluate the properties and performance of ceramics.
CO4: Appraise the advanced forms of ceramics and composites and their applications.

Structure-property correlation

Properties, classification and applications of ceramics: traditional and advanced ceramics – Crystal structure of ceramics: type of bonds, structural rules – common ceramic structures: rocksalt structure, zinc blend structure, corundum, silicate structures, etc. – glass & glass ceramics – defects in ceramics: defect reactions, effect of impurities.

Powder preparation, component fabrication and testing

Ceramics powder synthesis processes: Bayer process, solid state route, solution route (sol-gel, precipitation, hydrothermal, microwave etc.) – processing techniques: slip casting, extrusion, injection molding, tape casting, dry pressing, hot pressing, iso-static pressing – Sintering: sintering kinetics, sintering mechanisms & methods – Finishing process for ceramics.

Testing and property evaluation of ceramics: flexural strength, compressive strength, ultrasonic pulse method – Hardness: Rockwell, microhardness – Creep: high temperature property evaluation.

Advanced ceramics and composites

Ceramic composites: toughening of ceramics: transformation toughening, mechanisms of crack deflection – Processing: preform processing, yarn infiltration, preform infiltration, sol-gel infiltration, chemical vapour route, polymer pyrolysis, liquid infiltration techniques, Lanxide process.

Introduction to structural and functional ceramics: refractories, abrasives, cements, cutting tools, high-temperature ceramics, electro-ceramics, bio-ceramics, etc.

References:

[1] Kingery, W. D., Bowen, H. K., and Uhlmann, D. R., 2016, *Introduction to Ceramics*, Wiley, USA.
[2] Reed, J. S., 1995, *Principles of Ceramics Processing*, Wiley, USA.
[3] Barsoum, M., W., 2020, *Fundamentals of Ceramics*, CRC Press, USA.
[4] Barry Carter, C., and Grant, N., M., 2013, *Ceramic Materials: Science & Engineering*, Springer, USA.
[5] Buchanan, R. C., 2019, *Ceramic Materials for Electronics*, CRC press, USA.
[6] Joon, P., 2008, *Bioceramics: Properties, Characterisations, and Applications*, Springer, USA.

ME6313E ADVANCED MATERIAL PROCESSING TECHNOLOGIES

Pre-requisites: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain advances in manufacturing techniques (i.e., in casting, forming, welding and additive manufacturing) for industrial production.
CO2: Explain the methods, materials, and equipment related to casting.
CO3: Analyse material behaviour mechanisms during forming.
CO4: Evaluate heat effects on structure-property correlations during joining process.
CO5: Identify capabilities and limitations of additive manufacturing processes based on component application and criticality.
CO6: Evaluate the quality and integrity of materials produced using advanced manufacturing techniques.

Casting processes and steps involved: design of patterns, moulds, cores, and gating system, solidification and cooling, shrinkage and machining allowance – overview of traditional casting methods – advances in casting: die-casting, centrifugal casting, investment casting, high-pressure die casting, vacuum casting and lost foam casting, additive manufacturing integrated casting – advanced casting materials – process simulation and optimisation – defects and quality control in casting processes – economics of casting and moulding – sustainable metals and green metallurgy.

Theory of metal forming: plasticity, yield criteria, strain rate sensitivity, effect of temperature and friction in forming – mechanics of sheet deformation processes: Bauschinger effect modelling, sheet formability and forming limit curve – classification of forming processes: advances in metal forming, superplastic forming, electroforming, hydroforming, laser forming, open and close die forging, non-conventional drawing techniques, Incremental forming etc. – evaluation of defects after metal forming – sustainability in metal forming – numerical modelling in metal forming, FEA simulations.

Joining processes: classification; physics, arc characteristics: analysis of metal transfer, welding power sources, high energy density welding processes, solid state welding, friction stir welding – metallurgy of welding, heat flow in welding, residual stresses, temperature distribution; cooling rate; metallurgical transformation in and around weldment, gas metal reactions – design of weld joints – weld quality and testing – welding automation – advances and challenges.

Introduction to Additive Manufacturing (AM) – AM process chain, benefits and comparison with conventional manufacturing – classification of AM processes, AM technologies: vat polymerisation, powder bed fusion, material extrusion, material jetting binder jetting, sheet lamination, direct energy deposition, direct write technologies, hybrid AM technologies, key strengths, process, applications, case studies, research and development – materials for AM, powder production and characteristics – issues challenges and defects of AM parts – AM qualification and certification.

References:

[1] Ghosh, A., and Mallik, A.K., 2010, *Manufacturing Science*, Affiliated East-West Press Pvt. Ltd, India.
[2] Heine, R. and Rosenthal, P., 2017, *Principles of Metal Casting*, Tata McGraw Hill, India.
[3] Valberg, H, 2010, *Applied Metal Forming Including FEM Analysis*, Cambridge University Press, UK.
[4] Robert W Messler, 2004, *Principles of Welding*, WILEY-VCH Verlag GmbH & Co., Germany.
[5] Lancaster, J.F., 1999, *Metallurgy of Welding*, Woodhead Publishing, UK.
[6] Little, Richard L., 2017, *Welding and Welding Technology*, Tata McGraw Hill, India.
[7] Gibson Ian, Rosen David, Stucker Brent, and Khorasani Mahyar, 2021, *Additive Manufacturing Technologies*, Springer, Germany.
[8] Dixit, U.S., and Narayanan, R.G., 2013, *Metal Forming: Technology and Process Modelling*, McGraw-Hill Education, New Delhi.
[9] Dixit, P.M., and Dixit, U.S., 2008, *Modeling of Metal Forming and Machining Processes: by Finite Element and Soft Computing Methods*, Springer, Science and Business Media, London.

ME6592E MATERIALS SCIENCE LABORATORY - II

Pre-requisite: NIL

L	T	P	O	C
0	0	3	3	2

Total Practical Sessions: 39

Course Outcomes:

CO1: Develop ceramic components using solid-state and solution synthesis techniques.
CO2: Analyse phase evolution and microstructure of sintered components.
CO3: Assess the characteristics and mechanical properties of sintered components.
CO4: Prepare polymer composites and assess the characteristics.
CO5: Design aluminium metal matrix composites using powder metallurgy method.

Hands-on experience with materials synthesis and consolidation techniques – understand the analysis and quantification of phases using X-ray diffraction technique – experience with analysing surface characteristics and elemental composition using scanning electron microscope (SEM) attached with Energy dispersive spectroscope (EDS) – hands-on experience with testing various mechanical properties relevant to ceramics and composites – structural analysis of mechanical components and process modelling using computational techniques.

List of experiments:

1. Synthesis of oxide ceramic powders using solid-state and solution synthesis routes
2. Preparation of ceramics using granulation, compaction and sintering.
3. Phase analysis and crystallite size measurement using X-ray diffraction technique.
4. Study of microstructural and elemental analysis using SEM/EDS.
5. Determination of surface area and pore size using BET technique.
6. Hardness measurement using nano-indentation technique.
7. Preparation of polymer-ceramic composites using compression moulding technique.
8. Tensile, hardness and fracture toughness measurement of polymer-ceramic composites.
9. Calculation of thermodynamic parameters using DSC analysis.
10. Study of material defects using ultrasonic flaw detector.
11. Study of surface and subsurface defects in materials using Eddy current flaw detector.

References:

[1] Dieter, G. E., 2007, *Mechanical Metallurgy*, McGraw Hill, USA.
[2] Callister, W. D., and Rethwisch D. G, 2018, *Materials Science and Engineering*, Wiley, USA.
[3] Kingery, W. D., Bowen, H. K., and Uhlmann, D. R., 2016, *Introduction to Ceramics*, Wiley, USA.
[4] Reed, J. S., 1995, *Principles of Ceramics Processing*, Wiley, USA.
[5] Peter, J., G., John, H., and Richard, B., 2000, *Electron Microscopy and Analysis*, Routledge, UK.
[6] Cullity, B. D., and Stock, S.R., 2013, *Elements of X-ray Diffraction*, Pearson Education, UK.
[7] Autar, K., K., 2005, Mechanics of Composite Materials, CRC Press, USA.
[8] Michael, E., B., 2015, *Introduction to Thermal Analysis: Techniques and Applications*, Springer, USA.

ME6593E PROJECT PHASE I

Pre-requisite: NIL

L	T	P	O	C
0	0	0	6	2

Course Outcomes:

CO1: Understand the process of reviewing and recording the literature.
CO2: Understand the process of identification of the project problem.
CO3: Apply the learning to define the problem and problem environment/boundary conditions.
CO4: Develop a focused research learning, presentation and communication.

Project Phase I is normally an initiation into the project.

Each student shall identify a topic of interest related to the core/elective courses undergone in the first semester of the M. Tech. programme. He/she shall get the topic approved by the project guide in the concerned area of specialisation. The student is expected to conduct a literature survey. A mid semester evaluation shall be done by the guide. At the end of the semester the student shall present the project problem and the related literature in the presence of the duly constituted evaluation committee. Grade will be awarded on the basis of the student's work and presentation.

ME7594E PROJECT PHASE II

Pre-requisite: NIL

L	T	P	O	C
0	0	0	9	3

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem.
CO2: Analyse and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop algorithms and solve the problem.
CO4: Analyse and interpret the results using tables and figures for visualisation.
CO5: Compile and construct a report by employing the techniques of academic writing critical analysis and defend the thesis.
CO6: Publish the findings in reputed journals, conferences or apply for patents.

Project Phase II can be an extension of Phase I or internship outside during the summer semester break.
Students shall continue to work on the problem identified in the project phase I or undergo internship outside. Students shall identify the methodology, apply for a preliminary work. The work should be suitable for communicating to a conference. The student shall submit a report. All the projects will be evaluated by a duly constituted committee.

ME7595E PROJECT PHASE III

Pre-requisite: NIL

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem.
CO2: Analyse and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop algorithms and solve the problem.
CO4: Analyse and interpret the results using tables and figures for visualisation.
CO5: Compile and construct a report by employing the techniques of academic writing critical analysis and defend the thesis.
CO6: Publish the findings in reputed journals, conferences or apply for patents.

The project work can be carried out at the institute or in an industry/research organisation. Students desirous of carrying out project work in an industry or in other organisations have to fulfill the requirements as specified in the "Ordinances and Regulations for M. Tech." The student is expected to complete the pilot study, redefine the project based on pilot study, decide on the appropriate research design, generate data/collect data, develop the algorithm and code, and obtain preliminary results in the third semester. There shall be evaluations of the project work during and at the end of the third semester by a committee constituted by the department.

ME7596E PROJECT PHASE IV

Pre-requisite: NIL

L	T	P	O	C
0	0	0	45	15

Course Outcomes:

CO1: Develop a systematic procedure to solve the identified research/industrial problem.
CO2: Analyse and Identify a suitable research methodology for solving the problem identified.
CO3: Apply the methods/tools learned to develop algorithms and solve the problem.
CO4: Analyse and interpret the results using tables and figures for visualisation.
CO5: Compile and construct a report by employing the techniques of academic writing critical analysis and defend the thesis.
CO6: Publish the findings in reputed journals, conferences or apply for patents.

The project work will be extended to the end of the fourth semester. There shall be evaluations of the project work by a committee constituted by the department during the fourth semester. The student shall submit the thesis based on the recommendation of the departmental evaluation committee. There shall be viva-voce examination conducted by an evaluationcommittee with an external examiner.

"The project work/thesis will be considered for awarding Grade 'S' only if a paper, based on the project work is published/accepted for presentation at least in a Scopus indexed conference or a software copyright is granted. However, in exceptional cases, where the student and the guide want to submit a journal/conference publication at a later stage and if the student is able to submit the draft version of the journal/conference paper to the evaluation committee at the time of final presentation of the project work, the student may be considered for awarding 'S' grade if the committee finds the work to be excellent and guide ensures the submission of the work for journal/conference publication"

Program Specific Electives

ME6521E NUMERICAL AND COMPUTATIONAL METHODS IN MATERIAL SCIENCE

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain fundamental numerical methods used in computational material science.
CO2: Evaluate the deformation behaviour using finite element / finite different methods.
CO3: Analyse the material behaviour using mesoscale modelling techniques.
CO4: Solve complex material science problems via atomistic modelling techniques.

Partial differential equations: review of basic numerical methods (root finding, numerical integration, solving systems of equations, spectral methods), numerical optimisation techniques, constitutive equations describing behaviour of materials – initial and boundary value problems, introduction to finite element (FEM) and finite difference methods – software implementation of FEM.

Overview of mesoscale modelling – phase-field models, governing equations (Cahn Hilliard, Allen- Cahn relations etc.), boundary conditions for phase field simulations, mathematical and computational aspects, determining material parameters for phase field models, numerical simulation of grain growth and phase transformations – cellular automata: Neighborhood Definitions (Moore, Von Neumann) and state transitions, governing equations, microstructure synthesis – dislocation dynamics – crystal plasticity simulation: crystal plasticity constitutive models, numerical methods, deformation simulation using crystal plasticity models (VPSC, CPFEM, etc.).

Models of molecular interactions: Van der Waals interaction potentials, Lennard-Jones potential etc. – introduction to molecular dynamics – simulation of diffusion using LAMMPS – introduction to Monte-Carlo-Metropolis algorithm: numerical implementation – first principles, Hartree-Fock and density functional theory.

References:

[1] Steven, C., C., 2017, *Applied Numerical Methods for Engineers and Scientists*, McGraw Hill, USA.
[2] Richard, L., 2016, *Introduction to Computational Materials Science: Fundamentals to Applications*, Cambridge English; First South Asian Edition.
[3] Dierk, R., Franz, R., Frederic, B., and Long-Qing, C., 2004, *Continuum Scale Simulation of Engineering Materials, Fundamentals, Microstructures and Process Applications*, Wiley-VCH, Germany.
[4] Bulent, B., S., 2017, *Programming Phase-Field Modeling*, Springer, USA.
[5] June, G., L., 2011, *Computational Materials Science: An Introduction*, CRC Press, USA.
[6] Cook, R. D., Malkus, D. S., Plesha, M. E. and Witt, R.J., 2007, *Concepts and Applications of Finite Element Analysis*, Wiley, USA.
[7] Andreoni, W., and Yip, S., 2020, *Handbook of Materials Modeling: Methods: Theory and Modeling*, Springer, USA.

ME6522E MATERIALS FOR ENERGY AND SUSTAINABILITY

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course outcomes:

CO1: Identify the structural elements and the origin of various functional properties of materials.
CO2: Apply materials design principles to select materials for functional applications.
CO3: Explain the principles and characteristics of materials used in energy storage technologies.
CO4: Demonstrate proficiency in identifying materials for sustainable practices.

Materials structure and origin of functional properties

Atomic and molecular arrangement – quantum behavior of electrons – Fermi energy and work function – density of states – reciprocal lattice – Brillouin zones – energy band formation – origin of electronic, magnetic and optical properties of materials – nature of bonding in functional ceramics and elemental semiconductors – correlations between bonding and physico-chemical (thermal, mechanical, electrical, chemical) properties – theory of dielectrics – dielectric constant and polarisation – polarisation in static/alternating electric fields – ferro, piezo and pyroelectric materials. – elements of materials selection for functional requirements.

Materials for energy storage

Defects in elemental solids and ionic compounds – thermodynamics of Intrinsic defects and defect reactions – Kröger-Vink notation – defect association – ionic space charge – Electrical conductivity in materials: theory of ionic conductivity, solid electrolytes and fast ion conductors – material selection for the energy storage devices – device principles and components: batteries, fuel cells, and supercapacitors – electrode reactions – charge transfer – material synthesis methods: sol-gel, hydrothermal, solvothermal, combustion, solid-state synthesis, etc. – introduction to computational methods/machine learning approach for materials discovery and design.

Materials for sustainable technologies

Physics of semiconductor devices and basics of solar cells – direct and indirect band semiconductor – high efficiency solar cells – device fabrication technologies: diffusion, oxidation, photolithography, physical vapor deposition (PVD), chemical vapor deposition (CVD), etc., environmental and sustainable materials – concept of green hydrogen – hydrogen separation and purification – materials for hydrogen storage: metal hydrides, high surface area materials, complex and chemical hydrides, etc. – materials for pollution control and remediation: water and air purification – adsorption, separation and photocatalysis.

References:

[1] Barsoum, M., 2020, *Fundamentals of Ceramics*, CRC Press, USA.
[2] Haridoss, P., 2016, *Physics of Materials: Essential Concepts of Solid-State Physics*, Wiley India.
[3] Kasap, S.O., 2018, *Principles of Electronic Materials and Devices*, McGraw-Hill, USA
[4] Huggins, R. A., 2016, *Energy Storage Fundamentals, Materials and Applications*, Springer, USA.
[5] Dekker, A.J., 1969, *Solid State Physics*, Springer, USA.
[6] Solymar, L., Walsh, D., and Syms, R. R. A., 2018, *Electrical Properties of Materials*, Oxford University Press, UK.
[7] Srinivasan, M. R., 2015, *Applied Solid State Physics: A Textbook on Materials Science*, New Academic Science, UK.
[8] Viswanathan, B., 2016, *Energy Sources: Fundamentals of Chemical Conversion Processes and Applications*, Elsevier, USA.

ME6523E FERROUS AND NON-FERROUS METALLURGY

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the fundamental principles underlying the process of solidification in metals and alloys.
CO2: Analyse and interpret solidification diagrams and cooling curves of metals and alloys to understand the relationship between cooling rates and microstructure formation.
CO3: Classify non-ferrous materials based on their composition, and explain their heat treatment procedures, mechanical properties, and industrial applications.
CO4: Evaluate the composition, properties, applications, and appropriate heat treatment procedures for different types of steels.
CO5: Apply principles of thermodynamics and kinetics to calculate the stability and phase transformations in various metallic systems.

Solidification and casting

Solidification of metals: general thermodynamic and kinetic considerations, rate of reaction, Arrhenius equation, thermodynamical theory and nucleation, thermodynamics of solidification, solidification diagrams and cooling curves of metals and alloys, numerical modelling of solidification, recent trends – Fundamentals of casting, classification (investment casting, die casting, centrifugal casting, full mould casting, vacuum sealed casting), evaluation of casting defects. advanced casting materials, economics of casting and moulding, sustainable metals and green metallurgy.

Ferrous metallurgy

Steel: types, composition, structure – Fe-FeC diagram – heat treatment – influence of alloying elements on transformation behaviour – different types of phase transformations in steel, and its applications – phase stability calculation using thermodynamic and kinetic considerations – new trends in steel developments and challenges – Cast iron: types, composition, structure.

Non-ferrous metallurgy

Non-ferrous metals: classification, heat treatment, properties and applications: aluminium alloys, titanium alloys, copper base alloys, superalloys, shape memory alloys, functionally graded materials (FGMs), smart materials, high-entropy alloys and alloys for medical applications – additive manufacturing and recent trends.

References:

[1] Flemings, M.C., 1974, *Solidification process*, McGraw-Hill, USA.
[2] Koenraad, J., Dierk, R., Ernest, K., Mark, M., and Britta, N., 2007, *Computational materials Engineering – An Introduction to microstructure evolution*, Academic Press, UK.
[3] Mahi, S., and Sam, S., 2014, *Principles of Metal Casting*, McGraw-Hill, USA.
[4] Jose Antonio, P.E., Maria Jose, Q.H., and Luis Felipe, V.G., 2017, *Solidification and Solid-State Transformations of Metals and Alloys*, Elsevier, USA.
[5] Ray, H. S., Sridhar, R, and Abraham, K. P., 2018, *Extraction of Nonferrous Metals*, East-west Press, India.
[6] Dennis, W. H., 1966, *Metallurgy of the Non-Ferrous Metals*, the University of Michigan, USA/
[7] Ahindra, G., and Amit, C., 2008, *Ironmaking and Steelmaking: Theory and Practice*, PHI, India.
[8] Reed, H., and Robert, E., 2008, *Physical Metallurgy Principles*, East West Press, India.

ME6524E CORROSION SCIENCE AND TECHNOLOGY

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Evaluate the general characteristics of electrochemical corrosion and the electrochemical heterogeneity of metallic materials.
CO2: Apply important relations and techniques to evaluate corrosion behaviour in materials.
CO3: Identify and classify different types of corrosion, along with their causes and propagation mechanisms.
CO4: Analyse the impact of composition and structure on the environmental degradation of materials and prevention strategies.

Corrosion: electrochemical principles, electrode potential, Nernst equation. oxy-reduction potentials – general characteristics of electrochemical corrosion, electrochemical heterogeneity of metallic materials – models of corrosion cell – corrosion thermodynamics, Pourbaix diagrams – polarisation of the corrosion cell: activation controlled kinetics and concentration polarisation, polarisation curves (potentiodynamic polarisation, linear polarisation) – electrochemical impedance, spectroscopy, electrochemical noise, mixed potential theory, passivity – methods of testing in corrosion – effect of mass transfer – partial corrosion reactions: anodic dissolution of metals, cathodic reactions: oxygen reduction and hydrogen evolution – important relations and techniques (Tafel's equation, Butler Volmer equation, Stern Geary equation, techniques linear polarisation, Tafel extrapolation, EIS, Mott Schottky technique).

Types, causes and propagation of corrosion – metallurgical, mechanical, microbiological and environmental factors – quantitative estimation of corrosion rates – mechanisms of corrosion and material structure – corrosion of materials in natural environments: atmospheric corrosion, general characteristics, mechanism and prevention – soil corrosion: general characteristics, mechanism and prevention – localised corrosion damages and materials failure: passivity and transpassivity of metals, breakdown of passivity and pitting corrosion – stress corrosion cracking of materials – inter-granular corrosion failure – hydrogen embrittlement – corrosion failure of ceramic materials, mechanisms of corrosion of ceramics, effect of chemical, phase composition and structure on corrosion resistance – corrosion degradation of concrete.

Environmental degradation and corrosion of polymer materials: destruction of polymers, types and mechanism, effect of composition and structure on environmental degradation of polymer materials – methods for protection of materials: overview of corrosion prevention methods, chemical and electrochemical surface treatment of metals. metallic, inorganic and organic protective coatings, application of inhibitors, electrochemical methods for corrosion protection – corrosion control, testing and monitoring, principles of material selection.

References:

[1] Fontana, M. G., and Staettle, R.W., 2012, *Advances in Corrosion Science and Technology*, Springer, USA
[2] Dieter, L., 2007, *Corrosion and Surface Chemistry of Metals,* EPFL Press, France.
[3] Winston, Revie, R., and Herbert, H. Uhlig, 2008, *Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering*, Wiley-Interscience, USA.
[4] Luciano, L., and Pietro, P., 2018, *Corrosion Science and Engineering (Engineering Materials)*, Springer, USA.

ME6525E SCIENCE OF SOLIDIFICATION PROCESS

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Analyse the thermodynamics of solidification to explain various liquid-solid transformations and the formation of macrostructures.
CO2: Apply the principles of thermodynamics and stability of phases to construct and interpretation the phase diagrams.
CO3: Explain macro mass transport in solidification processes and solve the governing equations for steady state and non-steady state solidification.
CO4: Evaluate the role of heat and mass transfer in reaction kinetics and explain the significance of activation energy in reaction kinetics.
CO5: Evaluate phase changes in microstructures using the fundamentals of solid-state transformations.

Phase equilibrium: introduction, thermodynamics and stability of phases – classification of phase transformations: order of transformation, Gibbs rule and application, phase diagrams construction and interpretation – liquid-solid transformation: nucleation, homogeneous and heterogeneous, growth – alloy solidification: cellular and dendritic, eutectic, off-eutectic, peritectic solidification – length scale, thermodynamics of solidification: equilibrium, undercooling, hierarchy of equilibrium, local interface equilibrium, interface non-equilibrium – macro scale phenomena-formation of macrostructures, relevant transport equations, mathematics of diffusive transport.

Macro mass transport: solute diffusion-controlled segregation, fluid flow-controlled segregation – macro energy transport, governing equations, boundary conditions, analytical solutions – macro modeling of solidification: numerical approximation methods – multi scale phenomena and interface dynamics – role of kinetics, heterogeneous and homogeneous kinetics, role of heat & mass transfer in metallurgical kinetics, rate expression, effect of temperature and concentration on reaction kinetics – kinetics of solid-fluid reaction: kinetic steps, rate controlling step, definition of various resistances in series, shrinking core model, chemical reaction as rate controlling step, product layer diffusion as rate controlling step, mass transfer through external fluid film as rate controlling step, heat transfer as the rate controlling step.

Solid state diffusive transformation: classification, nucleation and growth, age hardening, spinodal decomposition, precipitate coarsening – transformation with start range diffusion, moving boundary transformations, recrystallisation, grain growth, eutectoid transformation, discontinuous reactions – pearlitic and bainitic transformation: factors influencing pearlitic transformation, mechanism of transformation, nucleation and growth, orientation relationship, degenerate pearlite – bainite mechanism of transformation, orientation relationships, surface relief, classical and non-classical morphology, effect of alloying elements.

References:

[1] Stefanescu, D.M., 2016, *Science and Engineering of Casting Solidification*, Springer, USA.
[2] Oystein, G., 1997, *Metallurgical Modelling of Welding (Materials Modelling)*, Springer, USA.
[3] Koenraad, J., Dierk, R., Ernest, K., Mark, M., and Britta, N., 2007, *Computational materials Engineering – An Introduction to microstructure evolution*, Academic Press, UK.
[4] Gaskell, D. R., 2018, *Introduction to the Thermodynamics of Materials*, CRC Press, USA.
[5] Hasse, F., and Ulla A., 2012, *Solidification and Crystallization Processing in Metals and Alloys*, Wiley, USA.

ME6526E SURFACE SCIENCE AND ENGINEERING

Prerequisite: NIL

L	T	P	O	C
3	0	0	6	3

Total Lecture Sessions: 39

Course Outcomes:

CO1: Explain the concepts of surfaces, interfaces and coatings and its failure mechanisms.
CO2: Evaluate various surface modification and coating technologies.
CO3: Identify the functional coatings for various applications.
CO4: Analyse methods for characterisation of engineered surfaces.

Surface-thermodynamics, surface dependent properties: physical, chemical and mechanical, surface and surface energy, structure and types of surface interfaces and relevant surface energy equations – surface dependent degradation and their characteristics: analysis of surface-initiated engineering failures, mechanism of surface degradation, mechanisms of wear: abrasive; adhesive wear, contact fatigue; fretting corrosion – approaches and classifications of surface engineering techniques.

Surface engineering practices: cleaning, pickling, etching, grinding, buffing etc., surface engineering by material addition like weld overlay, hot dipping, electrodeposition / plating / electroless coating – surface modification of ferrous and nonferrous components: pack carburising, aluminising, calorizing, diffusion coatings, cyaniding, nitriding, etc. – solid state surface engineering: friction surfacing, friction stir processing, surface composites.

Surface modification by energy beams: classification and general principles, types and energy/intensity deposition profile, laser assisted microstructural modification: surface melting, hardening etc. – surface alloying of steels and non-ferrous alloys by energy beams, surface cladding, composite surfacing and similar techniques for surface compositional modification, electron beam and Ion beam assisted surface modification (both microstructural and compositional) – surface coating techniques: plasma spray process, HVOF, cold spray, principles and scope of applications – thin film surface coatings: sputter deposition of thin films, DC, RF, magnetron and ion beam, PVD/CVD coating processes and their applications, ion implantation.

Functional coatings and their applications: nano structured coatings, surface passivation of semiconductors and effect on the electrical properties – surface engineering of polymers and composites – thin films for optical and magnetic devices and their applications – surface finishing techniques, characterisation of coatings – techniques for characterisation of surface microstructure and brief operating principles of those techniques, measurement of thickness, porosity, adhesion strength, residual stresses, spectroscopic analysis of modified surfaces etc., quality testing of coating (ASTM)

References:

[1] Paulo Davim, J., 2012, *Materials and Surface Engineering*, Woodhead Publishing, USA.
[2] Peter Martin, 2011, *Introduction to Surface Engineering and Functionally Engineered Materials*, Wiley-Scrivener, USA.
[3] Davis, J. R., 2014, *Surface Engineering for Corrosion and Wear Resistance*, CRC Press, USA.
[4] Pawlowski, L., 2008, *The Science and Engineering of Thermal Spray Coatings*, Wiley, USA.
[5] Martin, P. M., 2009, *Handbook of Deposition Technologies for Films and Coatings*, William Andrew Publisher, UK.
[6] ASM Handbook Surface Engineering, 1994, ASM International, USA.
[7] Tadeusz Burakowski and Tadeusz Wierzchon, 1998, *Surface Engineering of Metals Principles, Equipment, Technologies*, CRC Press, USA.
[8] Zhang, S., 2010, *Nano structured Thin Films and Coatings*, CRC Press, USA.
[9] Cha, S. C., and Ali, E., 2015, *Coating Technology for Vehicle Applications*, Springer, USA.
[10] Jain, V. K., 2016, *Nanofinishing Science and Technology*, CRC Press, USA.

ME6527E POWDER TECHNOLOGY

Pre-requisite: NIL

L	T	P	O	C
3	0	0	6	3

Total lecture sessions:39

Course Outcomes:

CO1: Examine the various powder production techniques.
CO2: Apply the principles of powder compaction to select suitable processing techniques.
CO3: Assess various sintering techniques and sintering atmospheres.
CO4: Identify the application of powder metallurgy process in industrial components.

Introduction: scope of powder metallurgy industries – PM process, comparison of powder metallurgyprocess with alternate near net shape producing technologies (viz.casting, forging and machining), advantages and limitations of powder metallurgy – powder production techniques: mechanical milling, atomisation, chemical reduction and carbonyl and electro-chemical processes – powder for additive manufacturing – powder characterisation: particle size analysis, surface area, density and flowability measurements, microscopy techniques, sampling of powders-sieve analysis, sedimentation analysis – Powder conditioning – relation between characteristics of powders and method of production – pre-compacting processes: mixing, milling, lubricant addition etc.

Powder compaction: classification, stages of compaction, effect of different variables on the density and stress distribution in the green compacts, compacting processes – hot iso-static pressing (HIP), cold iso-static pressing; spark plasma sintering (SPS) – pressing equipment and tooling – defects in compacts – alternate shaping processes: powder rolling, slip casting, injection molding, explosive molding etc. – effect of variables on densification in single component system – powder consolidation in additive manufacturing: energy-material interaction of lasers, electron beams, plasma arcs, effect on microstructure and properties of powder.

Sintering-stages, single component, material transport mechanisms, model studies, powder shrinkage experiments, sintering diagrams and sintering anomalies – multi-component sintering: solid phase and liquid phase, infiltration, activated sintering, reaction sintering, hot consolidation ofpowders, sintering in binder jet AM process – post-sintering treatment, evolution of microstructure, sintering atmospheres and equipment – products of PM-automobile components: bearings, cutting tools, HSS and carbides, ceramic components etc.

References:

[1] Thummler, F., and Oberacker, R., 1994, *An introduction to Powder Metallurgy*, the Institute of Materials, The University Press, Cambridge, UK.
[2] ASM Handbook, 1984, *Powder Metal Technologies and Applications* (ASM Handbook, Vol7), USA.
[3] Angelo, P.C., and Subramanian, R., 2015, *Powder Metallurgy*, PHI, India.
[4] German, R. M., 1994, *Powder Metallurgy Science*, Metal Powder Industries Federation, University of Minnesota, USA.
[5] Dutta, B. K., 2014, *Powder Metallurgy: An Advanced Technique of Processing Engineering Materials*, PHI, India.
[6] Eric Hug, and Guy Dirras, 2021, *News Trends in Powder Metallurgy: Microstructures, Properties, Durability*, Mdpi AG, Switzerland.

Institute electives

IE6001E ENTREPRENEURSHIP DEVELOPMENT

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Describe the various strategies and techniques used in business planning and scaling ventures.
CO2: Apply critical thinking and analytical skills to assess the feasibility and viability of business ideas.
CO3: Evaluate and select appropriate business models, financial strategies, marketing approaches, and operational plans for startup ventures.
CO4: Assess the performance and effectiveness of entrepreneurial strategies and actions through the use of relevant metrics and indicators.

Entrepreneurial Mindset and Opportunity Identification

Introduction to Entrepreneurship Development - Evolution of entrepreneurship, Entrepreneurial mindset, Economic development, Opportunity Recognition and Evaluation - Market gaps - Market potential, Feasibility analysis - Innovation and Creativity in Entrepreneurship - Innovation and entrepreneurship, Creativity techniques, Intellectual property management. .

Business Planning and Execution

Business Model Development and Validation - Effective business models, Value proposition testing, Lean startup methodologies - Financial Management and Funding Strategies - Marketing and Sales Strategies - Market analysis, Marketing strategies, Sales techniques - Operations and Resource Management - Operational planning and management, Supply chain and logistics, Stream wise Case studies.

Growth and Scaling Strategies

Growth Strategies and Expansion - Sustainable growth strategies, Market expansion, Franchising and partnerships - Managing Entrepreneurial Risks and Challenges - Risk identification and mitigation, Crisis management, Ethical considerations - Leadership and Team Development - Stream wise Case studies.

References:

[1] Kaplan, J. M., Warren, A. C., & Murthy V. (Indian Adoption), 2022, *Patterns of entrepreneurship management.* John Wiley & Sons.
[2] Kuratko, D. F., 2016, *Entrepreneurship: Theory, process, and practic*e. Cengage learning.
[3] Barringer, B. R. 2015, *Entrepreneurship: Successfully launching new ventures*. Pearson Education India.
[4] Shah Rajiv, Zhijie Gao, Harini Mittal, 2014, *Innovation, Entrepreneurship, and the Economy in the US, China, and India,* Academic Press.
[5] Sundar, K., 2022, *Entrepreneurship Developmen*t, Vijaya Nichkol Imprints, Chennai.
[6] Gordon, E., Natarajan, K., *Entrepreneurship Development*, Himalya Publishers, Delhi.
[7] Biswas Debasish, Dey Chanchal, 2021, *Enterpreneurship Development in India*, Taylor & Francis.

ZZ6002E RESEARCH METHODOLOGY

Pre-requisites: NIL

L	T	P	O	C
2	0	0	4	2

Total Lecture sessions: 26

Course Outcomes

CO1: Explain the basic concepts and types of research.
CO2: Develop research design and techniques of data analysis
CO3: Present research to the scientific community
CO4**:** Develop an understanding of the ethical dimensions of conducting research

Exploring Research Inquisitiveness

Philosophy of Scientific Research, Role of Research Guide, Planning the Research Project, Research Process, Research Problem Identification and Formulation, Variables, Framework development, Research Design, Types of Research, Sampling, Measurement, Validity and Reliability, Survey, Designing Experiments, Research Proposal, Research Communication, Research Publication, Structuring a research paper, structuring thesis/ dissertation.

Data Analysis

Literature review :Tools and Techniques - Collection and presentation of data, processing and analysis of data - Descriptive statistics and inferential statistics- Measures of central tendency, dispersion, skewness, asymmetry- Probability distributions – Single population and two population hypothesis Testing - Parametric and non-parametric tests - Design and analysis of experiments: Analysis of Variance (ANOVA),completely randomized design – Measures of relationship: Correlation and regression, simple regression analysis, multiple regression – interpretation of results - Heuristics and simulation

Research writing and Ethics

Reporting and presenting research, Paper title and keywords, writing an abstract, writing the different sections of a paper, revising a paper, responding to peer reviews.

The codes of ethics, copyright, patents, intellectual property rights, plagiarism, citation, acknowledgement, avoiding the problems of biased survey

References:

[1] Krishnaswamy, K.N., Sivakumar, A.I., and Mathirajan, M., 2006, *Management Research Methodology, Pearson* Education.
[2] Leedy, P, D., 2018, *Practical Research: Planning and Design*, Pearson.
[3] Kothari, C.R., 2004, *Research Methodology – Methods and Techniques*, New Age International Publishers.
[4] Martin Mike, Schinzinger Roland, 2004, *Ethics in Engineering*, Mc Graw Hill Education.
[5] Sople, Vinod V., 2014, *Managing Intellectual Property-The Strategic Imperative*, EDA Prentice of Hall Pvt. Ltd.

MS6174E TECHNICAL COMMUNICATION AND WRITING

Pre-requisites: NIL

L	T	P	O	C
2	1	0	3	2

Total Lecture Sessions: 26

Course Outcomes:

CO1: Apply effective communication strategies for different professional and industry needs.
CO2: Collaborate on various writing projects for academic and technical purposes.
CO3: Combine attributes of critical thinking for improving technical documentation.
CO4: Adapt technical writing styles to different platforms.

Technical Communication

Process(es) and Types of Speaking and Writing for Professional Purposes - Technical Writing: Introduction, Definition, Scope and Characteristics - Audience Analysis - Conciseness and Coherences - Critical Thinking - Accuracy and Reliability - Ethical Consideration in Writing - Presentation Skills - Professional Grooming - Poster Presentations

Grammar, Punctuation and Stylistics

Constituent Structure of Sentences - Functional Roles of Elements in a Sentence - Thematic Structures and Interpretations - Clarity - Verb Tense and Mood - Active and Passive Structures - Reporting Verbs and Reported Tense - Formatting of Technical Documents - Incorporating Visuals Elements - Proofreading

Technical Documentation

Types of Technical Documents: Reports, Proposals, Cover Letters - Manuals and Instructions - Online Documentation - Product Documentation - Collaborative Writing: Tools and Software - Version Control Document Management - Self Editing, Peer Review and Feedback Processes

References:

[1] Foley, M., and Hall, D., 2018, *Longman advanced learner's grammar, a self-study reference & practice book with answers*, Pearson Education Limited.
[2] Gerson, S. J., and Gerson, S. M., 2009, *Technical writing: Process and product*, Pearson.
[3] Kirkwood, H. M. A., and M., M. C. M. I., 2013, *Hallidays introduction to functional grammar,* Hodder Education.
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