MATERIALS ENGINEERING

M. Tech in MATERIALS ENGINEERING
(Duration: 2 Years, 64 credits)

Hard core (8 credits)

MT 202	3:0	Thermodynamics and Kinetics
MT 241	3:0	Structure and Characterization of Materials
MT 243	0:2	Laboratory Experiments in Materials Engineering

Soft core (9 credits): At least three out of the following courses

MT 209	3:0	Defects in Materials
MT 213	3:0	Electronic Properties of Materials
MT 220	3:0	Microstructural Engineering of Structural Materials
MT 231	3:0	Interfacial Phenomenon in Materials Processing
MT 253	3:0	Mechanical Behaviour of Materials
MT 260	3:0	Polymer Science and Engineering

Project (32 credits)

MT 299 0:32 Dissertation Project

Electives (15 credits): At least 9 credits must be taken from the courses offered by the Department.

MT 201 (JAN) 3:0
Phase Transformations

Overview of phase transformations, nucleation and growth theories, coarsening, precipitation, spinodal decomposition, eutectoid, massive, disorder-to-order, martensitic transformations. crystal interfaces and microstructure. topics in the theory of phase transformations: linear stability analysis, elastic stress effects, sharp interface and diffuse interface models of microstructural evolution.

Instructor: Chandan Srivastava

Prerequisites: Basic courses on crystallography, thermodynamics, phase diagrams and diffusion.

References: D.A. Porter. and K.E. Easterling: Phase Transformations in Metal and Alloys, Van Nostrand, 1981.
A.K. Jena, and M. Chaturvedi: Phase Transformations in Materials, Prentice-Hall, 1993.
A.G. Khachaturyan: Theory of Structural Transformation in Solids, John Wiley, 1983.
R.E. Reed-Hill and R. Abbaschian: Physical Metallurgy Principles, P.W.S-Kent, 1992.

MT 202 (AUG) 3:0
Thermodynamics and Kinetics
Classical and statistical thermodynamics, Interstitial and substitutional solid solutions, solution models, phase diagrams, stability criteria, critical phenomena, disorder-to-order transformations and ordered alloys, ternary alloys and phase diagrams, Thermodynamics of point defects, surfaces and interfaces. Diffusion, fluid flow and heat transfer.

Instructor: Sai Gautam G

C.H.P. Lupis: Chemical Thermodynamics of Materials, Elsevier Science, 1982
P. Shewmon: Diffusion in Solids, 2nd Edition, Wiley,
1989.~A.W. Adamson and A.P. Gast: Physical Chemistry of Surfaces (Sixth Edition), John Wiley, 1997.

MT 206 (AUG) 3:0
Texture and Grain Boundary Engineering

Concepts of texture in materials. Representation of texture by pole figure and orientation distribution functions. Texture measurement by different techniques. Origin and development of texture during material processing stages: solidification, deformation, annealing, phase transformation, coating processes, and thin film deposition. Influence of texture on mechanical and physical properties. Texture control in Engineering Materials. Introduction to Grain boundaries in polycrystalline materials. Grain boundary engineering and its applications.

Instructor: Satyam Suwas

References: M. Hatherly and W.B. Hutchinson, An Introduction to Texture in Metals (Monograph No. 5), The Institute of Metals, London
V. Randle, and O. Engler, Introduction to Texture Analysis: Macrotexture, Microtexture and Orientation mapping, Gordon and Breach Science Publishers
S. Suwas, and R.K. Ray, Crystallographic Texture of Materials, Springer-Verlag
F. J. Humphreys, and M. Hatherly, Recrystallization and Related Phenomenon, Pergamon Press
P. E. J. Flewitt, and R. K. Wild, Grain Boundaries

MT 208 (JAN) 3:0
Diffusion in Solids

Fick's laws of diffusion, driving forces for diffusion, radiotracer and diffusion couple methods, atomic mechanism of diffusion, diffusion-controlled growth of phases, diffusion-controlled microstructural evolution, Matano-Boltzmann analysis, History, and development of the Kirkendall effect, Darken analysis, lattice and grain boundary diffusion, multicomponent diffusion, diffusion process in various multicomponent materials used in electronic packaging, jet engine turbine blades, A15 intermetallic superconductor, Multi-principal element alloys.

Instructor: A Paul

References: P. Shewmon: Diffusion in Solids, Springer, 1963
J.S. Kirkaldy, D.J. Young, Diffusion in the Condensed State, The Institute of Metals, London, United Kingdom (1987)
A. Paul, Tomi Laurila, Vesa Vuorinen, S. V. Divinski, Thermodynamics, Diffusion and the Kirkendall Effect in Solids, Springer International Publishing, Switzerland (2014)

MT 209 (AUG) 3:0
Defects in Materials

Review of defect classification and concept of defect equilibrium. Review of point defects in metallic, ionic and covalent crystals. Dislocation theory - continuum and atomistic. Dislocations in different lattices. Role of anisotropy. Dislocation kinetics. Interface thermodynamics and structure. Overview of grain boundaries, interphase boundaries, stacking faults and special boundaries. Interface kinetics: migration and sliding. Defect interactions: point defect-dislocation interaction, dislocation-interface interactions, segregation, etc.. Overview of methods for studying defects including computational techniques

Instructor: S Karthikeyan

References: W.D. Kingery, H.K. Bowen and D.R. Uhlmann: Introduction to Ceramics, 2nd ed., John Wiley and Sons, 1976
D. Hull and D. J. Bacon: Introduction to dislocations, 4th ed., Butterworth-Heinemann, 2001.
D.A. Porter and K.E. Easterling: Phase Transformation in Metals and Alloys, 2nd ed. Chapman and Hall, 1992.
R.W. Balluffi, S.M. Allen, W.C. Carter: Kinetics of Materials, 1st ed. Wiley-Interscience, 2005.
J.P. Hirth and J.L. Lothe: Theory of Dislocations, 2nd ed., Krieger, 1982.
A. P. Sutton and R. W. Balluffi: Interfaces in Crystalline Materials, 1st ed., Oxford Univ. Press, 1995.

MT 213 (JAN) 3:0
Electronic Properties of Materials

Introduction to electronic properties; Drude model, its success and failure; energy bands in crystals; density of states; electrical conduction in metals; semiconductors; semiconductor devices; p-n junctions, LEDs, transistors; electrical properties of polymers, ceramics, metal oxides, amorphous semiconductors; dielectric and ferroelectrics; polarization theories; optical, magnetic and thermal properties of materials; application of electronic materials: microelectronics, optoelectronics and magnetoelectrics.

Instructor: Subho Dasgupta

References: R. E. Hummel, *Electronic Properties of Materials*
S. O. Kasap, *Principles of Electronic Materials and Devices*
S. M. Sze, *Semiconductor devices: Physics and Technology*
D. Jiles, *Introduction to the electronic properties of materials*

MT 218 (AUG) 2:1
Modeling and Simulation in Materials Engineering

Importance of modeling and simulation in Materials Engineering. nd numerical approaches. Numerical solution of ODEs and PDEs, explicit and implicit methods, Concept of diffusion, phase field technique, modelling of diffusive coupled phase transformations, spinodal decomposition. Level Set methods, Celula Automata,: simple models for simulating microstructure,. Finite element modelling,: Examples in 1D, variational approach, interpolation functions for simple geometries, (rectangular and triangular elements); Atomistic modelling techniques,: Molecular and Monte-Carlo Methods.

Instructor: A N Choudhury

References: A.B. Shiflet and G.W. Shiflet: Introduction to Computational Science: Modeling and Simulation for the Sciences, Princeton University Press, 2006.
D.C. Rapaport: The Art of Molecular Dynamics Simulation, Cambridge Univ. Press, 1995.
K. Binder, D. W. Heermann: Monte Carlo Simulation in Statistical Physics, Springer, 1997.
K.G.F Janssens, D. Raabe, E. Kozeschnik, M.A. Miodownik, B. Nestler: Computational Materials Engineering: An Introduction to Microstructure Evolution, Elsevier Academic press, 2007.
David V. Hutton, Fundamentals of Finite Element Analysis

MT 220 (JAN) 3:0
Microstructural Engineering of Structural Materials

Elements of microstructure; Role of microstructure on properties; Review of crystalline defects; Methods of controlling microstructures: materials processing routes, heat treatments, phase transformations and mechanisms; Processing of cast and wrought alloys, Processing of nanostructured materials, processing of single crystals, Introduction to light metal alloys (Al-based, Mg-based and Ti-based), Introduction to high temperature superalloys, Introduction to high entropy alloys, Control of multiphase microstructures with case studies, hierarchical microstructures, composites; adaptive microstructures.

Instructor: Surendra Kumar Makineni

References:
R E Reed-Hill and R Abbaschian: Physical Metallurgy Principles, P.W.S-Kent, 1992.
David A Porter, K E Easterling, Phase transformations in metals and alloys, Chapman & Hall, 2nd edition, 1992
Ian Polmear, Light Alloys, 4th edtion, Butterworth-Heinemann, 2006
Roger C Reed, The Superalloys: Fundamentals and applications, Cambrige university press, 2006
B S Murthy, J W Yeh, S Ranganathan, P P Bhattacharjee, High entropy alloys, 2nd Edition, Elsevier, 2019

MT 225 (Aug) 3:0

Deformation and Failure Mechanisms at Elevated Temperatures

Phenomenology of Creep, Microstructural considerations in metals, alloys, ceramics and composites.
Creep mechanisms, Deformation mechanism maps, Superpasticity in metal alloys, ceramics and

nanophase materials, Commercial applications and considerations, Cavitation failure at elevated temperatures by nucleation, growth and interlinkage of cavities. The course will also include some laboratory demonstrations of the phenomena discussed in the class together with an appropriate analysis of the data.

Instructor: Atul H Chokshi

References: J. P. Polreer, Creep of Crystals, Cambridge University Press, Cambridge, 1984,H. Riedel, .Fracture at High Temperatures, Springer Verlag, Berlin, 1987

MT 231 (Jan) 3:0
Interfacial Phenomenon in Materials Processing

Materials and surfaces, Adsorption from solution, Thermodynamics of adsorption - surface excess and surface free energy, Gibbs equation, adsorption isotherms, wetting, contact angle, Young's equation, Monolayer and interfacial reactions, Electrical phenomena at interfaces, electrochemistry of the double layer, Interaction energies, DLVO theory, electrokinetics, flocculation, coagulation and dispersion, Polymers at interfaces, Emulsions. Applications in Materials Processing.

Instructor: Ashok M Raichur

References: Jacob N. Israelachvili, Intermolecular and Surface Forces, Academic Press, 3rd edition, 2011
A.W. Adamson and A. P. Gast, Physical Chemistry of Surfaces, Wiley Interscience, New York, 1996
Paul Hiemenz and Raj Rajagopalan, Principles of Colloid and Surface Chemistry, CRC Press, 3rd edition, 1997

MT 241 (AUG) 3:0
Structure and Characterization of Materials

Bonding and crystal structures, Direct and Reciprocal lattice, Stereographic projection, Point and Space Group, Point defects in crystals, Diffraction basics, X-ray powder diffraction and its applications, Scanning and Transmission electron microscopy.

Instructor: Rajeev Ranjan

References: A. R. West: Solid State Chemistry and its Applications, John Wiley
B. D. Cullity: Elements of x-ray Diffraction.
A. Kelly and G. W. Groves: Crystallography and Crystal Defects, Longman
M. D. Graef and M. E. Henry: Structures of Materials, Cambridge
R. J. D. Tilley: Defects in Solids, Wiley 2008

MT 243 (JAN) 0:2
Laboratory Experiments in Materials Engineering

Experiments in Metallographic techniques, heat treatment, diffraction mineral beneficiation, chemical and process metallurgy, and mechanical metallurgy.

Faculty

MT 245 (AUG) 3:0
Transport Processes in Process Metallurgy

Basic and advanced idea of fluid flow, heat and mass transfer. Integral mass, momentum and energy balances. The equations of continuity and motion and its solutions. Concepts of laminar and turbulent flows. Concept of packed and fluidized bed. Non-wetting flow, Natural and forced convection. Unit processes in process metallurgy. Application of the above principles in process metallurgy.

Instructor: Govind S Gupta

References: J. Szekely and N.J. Themelis, Rate Phenomena in Process Metallurgy, Wiley, New York, 1971~G.H. Geiger and D R Poirier: Transport Phenomena in Metallurgy, Addison-Wesley, 1980.~D.R. Gaskell: Introduction to Transport Phenomena in Materials Processing, 1991.~R.B. Bird, W.E. Stewart and E.N. Lightfoot: Transport Phenomena, John Wiley International Edition, 1960~F.M. White: Fluid Mechanics, McGraw Hill, 1994
Research papers

MT 248 (JAN) 3:0
Modelling and Computational Methods in Metallurgy

(Prerequisite: Knowledge of transport phenomena, program language) Assignments will be based on developing computer code to solve the given problem.)
Basic principles of physical and mathematical modelling. Similarity criteria and dimensional analysis. Detailed study of modelling of various metallurgical processes such as blast furnace, induction furnace, ladle steelmaking, rolling, carburizing and drying. Finite difference method. Solution of differential equations using various numerical techniques. Convergence and stability criteria.

Instructor: Govind S Gupta

References: Govind S Gupta,J.Szekely and N. J. Themelis: Rate Phenomena in Process Metallurgy, Wiley, New York, 1971,
B. Carnahan, H. A. Luther, and J. O. Wikes: Applied Numerical Methods, John Wiley, NY 1969.

MT 250 (JAN) 3:0
Introduction to Materials Science and Engineering

Compulsory for M.E. students who do not have BE Metallurgy, Ceramic or Polymer Engineering; Compulsory for research students without materials background.

Bonding, types of materials, basics of crystal structures and crystallography. Methods of structural characterization. Thermodynamics of solid solutions, phase diagrams, defects, diffusion. Solidification. Solid-solid phase Transformations. Mechanical behaviour: elasticity, plasticity, fracture. Electrochemistry and corrosion.

Instructor: Subodh Kumar

Reference: W.D. Callister, Materials Science & Engineering – An Introduction, John Wiley & Sons, Inc.

MT 253 (AUG) 3:0
Mechanical Behaviour of Materials

Introduction to elastic and plastic deformation; Elementary dislocation theory and twinning; Strengthening mechanisms; Fracture; Fatigue; Creep.

Instructor: Praveen Kumar
Reference: Thomas H. Courtney, Mechanical Behaviour of Materials, Waveland Press.

MT 255 (JAN) 3:0
Solidification Processing

Advantage of solidification route to manufacturing, the basics of solidification including fluid dynamics, solidification dynamics and the influence of mould in the process of casting. Origin of shrinkage, linear contraction and casting defects in the design and manufacturing of casting, continuous casting, Semi-solid processing including pressure casting, stir casting and thixo casting. Welding as a special form of manufacturing process involving solidification. Modern techniques of welding, the classification of different weld zones, their origin and the influence on properties and weld design. Physical and computer modeling of solidification processes and development of expert systems. New developments and their possible impact on the manufacturing technology in the future with particular reference to the processes adaptable to the flexible manufacturing system.

Instructor : Abhik N Choudhury

References: J. Campbell: Casting, Butterworth - Haneman, London, 1993
M.C. Flemings: Solidification Processing , McGraw Hill, 1974.

MT 256 (JAN) 3:0
Fracture

Review of elastic and plastic deformation, Historical development of fracture mechanics, Thermodynamics of fracture including Griffith theory, Linear elastic fracture mechanics, Irwin and Dugdale extensions, Stability of cracks, Crack resistance curves and toughening of brittle materials, Ductile failure, J-integral, Introduction to FEM and its applications to fracture mechanics, Indentation failure, Environmental aspects of failure, Thermal stresses, Cyclic Fatigue, Methods to measure toughness.

Instructor: Vikram Jayaram and Praveen Kumar

References: B.R. Lawn: Fracture of Brittle Solids. Cambridge University Press (1993).
T.H. Courtney: Mechanical Behaviour of Materials. McGraw Hill (1990).
David Broek: Engineering Fracture Mechanics. . Sijthoff and Nordhoff , The Netherlands (1978).
Richard Hertzberg: Deformation & Fracture of Engineering Materials. John Wiley (1996).

MT 257 (JAN) 3:0
Finite Element Analysis for Materials Engineers

Quick recap of relevant mathematical concepts, equations of equilibrium and compatibility conditions (structural problem) and stress (Airy) function; Philosophy of FEM, including concepts of discretization, interpolation functions and assembly of equations; Application of FEM for solving differential equations using Galerkin method and variational equations using Rayleigh - Ritz method; 1-D, 2-D and 3-D example problems in elasticity and heat transfer; Solving linear and non-linear structural, thermal and electrical problems using a commercial FEM software

Instructor: Praveen Kumar

Reference: David V Hutton , Fundamentals of Finite Element Analysis, McGraw Hill

MT 260 (Aug) 3:0
Polymer Science and Engineering

Fundamentals of polymer science: Polymer nomenclature and classification. Current theories for describing molecular weight, molecular weight distributions. Synthesis of monomers and polymers. Mechanisms of polymerization reactions. Introduction to polymer compounding and processing (for thermoplastic/thermosets). Structure, property relationships of polymers: crystalline and amorphous states, the degree of crystallinity, cross-linking, and branching. Stereochemistry of polymers. Instrumental methods for the elucidation of polymer structure and properties such as thermal (DSC, TGA, DMA, TMA, TOA), electrical (conductivity, dielectric), and spectroscopic (IR, Raman, NMR, ESCA, SIMS) analysis GPC, GC-MS.

Instructors: Suryasarthi Bose and Ashok Misra

References: Principles of Polymerization, George G Odian, John Wiley and Sons
Textbook of Polymer Science, F. W. Bilmeyer, John Wiley and Sons
The Elements of Polymer Science and Engineering, A. Rudin and P Choi, Academic Press
Plastic Materials, J. A. Brydson, Elsevier

MT 261 (Aug) 3:0
Organic Electronics

Fundamentals of polymers. Device and materials physics. Polymer electronics materials, processing, and applications. Chemistry of device fabrication, materials characterization. Electroactive polymers. Device physics: Crystal structure, Energy band diagram, Charge carriers, Heterojunctions, Diode characteristics. Device fabrication techniques: Solution, Evaporation, electrospinning. Devices: Organic photovoltaic device, Organic light emitting device, Polymer based sensors.Stability of organic devices.

Instructor: Praveen C Ramamurthy

References: T. A. Skotheim and J. R. Reynolds (Editors): Handbook of Conducting Polymers (Third Edition) Conjugated Polymers: Theory, Synthesis, Properties and Characterization, CRC Press.
T.A. Skotheim and J. R. Reynolds (Editors): Handbook of Conducting Polymers (Third Edition) Conjugated Polymers: Processing and Applications Edited by Terje A. Skotheim and John R. Reynolds, CRC Press.
S-S. Sun and N. S. Sariciftci (Editors): Organic Photovoltaics - Mechanisms, Materials, and Devices, CRC Press.
D.A. Neamen: Semiconductor Physics and Devices Basic Principles, McGraw Hill.

MT 262 (JAN) 3:0
Concepts in Polymer Blends and Nanocomposites

Introduction to polymer blends and composites, nanostructured materials and nanocomposites, Polymer-polymer miscibility, factors governing miscibility, immiscible systems and phase separation, Importance of interface on the property development, compatibilizers and compatibilization, Blends of amorphous & semi-crystalline polymers, rubber toughened polymers, particulate, fiber reinforced composites. Nanostructured materials like nano clay, carbon nanotubes, graphene etc. and polymer nanocomposites. Surface treatment of the reinforcing materials and interface/interphase structures of composites / nanocomposites. Various processing techniques like solution mixing, melt processing. Unique properties of blends, composites/nanocomposites in rheological, mechanical, and physical properties and applications

Instructor: Suryasarathi Bose

References: D.R. Paul and S. Newman: Polymer Blends, Vol 1&2 , Academic Press, 2000
L.A. Utracki: Polymer Alloys and Blends, Hanser, 2000
C. Chung: Introduction to Composites, Technomic, Lancaster, PA. 1998.
J. Summerscales and D. Short: Fiber Reinforced Polymers, Technomic. 1988
T.J. Pinnavia and G.W. Beall (Editors): Polymer-Clay Nanocomposites, Wiley, New York 2000.
P.M. Ajayan, L.S. Schadler and P.V. Braun: Nanocomposite Science &Technology, Wiley-VCH, Weinheim, 2003.

MT 271 (Jan) 3:0
Introduction to Biomaterials Science and Engineering

This course will introduce basic concepts of biomaterials research and development including discussion on different types of materials used for biomedical applications and their relevant properties. Contents: Surface engineering for biocompatibility; Protein adsorption to materials surfaces; Blood compatibility of materials; Immune response to materials; Corrosion and wear of implanted medical devices; Scaffolds for tissue engineering and regenerative medicine; Concepts in drug delivery; Regulatory issues and ethics.

Instructor: Kaushik Chatterjee

References: Ratner et al: Biomaterials science: An introduction to materials in medicine, 2nd edition, Elsevier Academic Press
Current Research Literature

MT 299 0:32
Dissertation Project

The M.E. Project is aimed at training the students to analyse independently any problem posed to them. The project may be a purely analytical piece of work. a completely experimental one or a combination of both. In a few cases. the project can also involve a sophisticated design work. The project report is expected to show clarity of thought and expression. critical appreciation of the existing literature and analytical and/or experimental or design skill.

Instructors: FACULTY, Materials Engineering