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): Any three out of the following six courses

MT 203	3:0	Materials Design and Selection
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 252	3:0	Science of Materials Processing
MT 253	3:0	Mechanical Behaviour of Materials

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.

C Srivastava

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

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.

T A Abinandanan

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 203 (AUG) 3:0
Materials Design and Selection

After an overview of microstructures, processing and properties in engineering materials, the students will focus on procedures for materials selection and design. The students will explore materials selection charts, and the course will involve case studies, projects as well as software packages for materials design and selection over a wide range of conditions.

A H Chokshi

M.F. Ashby: Materials Selection in Mechanical Design, 3rd edition (2005).
M.F. Ashby and D. Johnson: Materials and Design (2002).

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

Concepts of texture in materials, their representation 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 aluminum industry, automotive grade and electrical steels, magnetic and electronic materials. Introduction to grain boundary engineering and its applications.

S. Suwas

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
F. J. Humphreys and M. Hatherly, Recrystallization and Related Phenomenon, Pergamon Press
P. E. J. Flewitt, R. K. Wild, Grain Boundaries

MT 208 (JAN) 3:0
Diffusion in Solids

Fick's first and second law, Interdiffusion, Intrinsic diffusion and Integrated diffusion coeffiecient, Relation with tracer diffusion coefficient, Growth Kinetics, Matano-Boltzmann analysis, History and development of the Kirkendall effect, Darken analysis, Stable, unstable and multiple Kirkendall planes. Concept of velocity diagram construction, Role of the Kirkendall effect on morphogenesis, Physico-chemical approach.

A Paul

P. Shewmon: Diffusion in Solids

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

S Karthikeyan

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.

S. Dasgupta

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.

A N Choudhury

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

Role of microstructure on properties; Elements of microstructure (geometric, texture, composition, order, topology); Review of crystal defects; Methods of controlling microstructures: materials processing routes, heat treatments and phase transformations; Survey of phase transformation mechanisms; Control of grain size and orientation in single phase microstructures with case studies in Al and Ti alloys, oxide systems for sensors, electrical steels, epitaxial microstructures, ferromagnetic materials, processing of nanostructured materials, processing of single crystals; Control of multiphase microstructures with case studies in precipitate strengthened alloys (Al alloys, Ni-base superalloys),hierarchical microstructures (alpha-beta Ti alloys), composites; adaptive microstructures (shape memory alloys, zirconia, TRIP steels).

S Karthikeyan, A N Choudhury, D Banerjee

David A. Porter, K.E. Easterling, Phase transformations in metals and alloys, Chapman & Hall, 2nd edition, 1992

MT 235 (AUG) 3:0
Corrosion Technology

Basic electrochemical principles governing corrosion. Types and mechanisms of corrosion. Advances in corrosion engineering and control. Anodic and Cathodic control-Biocorrosion, mechanisms and microbiological aspects. Corrosion under sub-soil and sea water conditions- Marine biofouling and biocorrosion with respect to industrial conditions. Methods of abatement.

K A Natarajan

M.G. Fontana: Corrosion Engineering, 3rd Edition, McGraw-Hill, N.Y., 1978.
Borenstein: Microbiologically Influenced Corrosion Handbook.

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.

R Ranjan

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.

Govind S Gupta

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.

Govind S Gupta

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; 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.

Subodh Kumar

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

MT 252 / PD 214 (JAN) 3:0
Science of Materials Processing

Fundamentals of Materials Processing: Deformation processing. Fundamentals and applications of plasticity, yielding, flow instability, drawability, anisotropy. Temperature and strain rate dependence. Thermally activated deformation, dynamic recovery and recrystallization. Modeling of materials processing-processing maps. Applications of deformation processing. Casting and Joining, Powder processing.

Satyam Suwas and Satish Vasu Kailas

W.A. Backofen: Deformation processing: Addision Wesley.
R.W. Cahn and P. Haasan (Editors): Processing of Metals and Alloys: Materials Science and Technology series, Wiley VCH.
B.H. Amstead, P.F. Oswald. and M. Begeman: Manufacturing Processes, John Wiley, 1987.

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

Theory of Elasticity. Theory of Plasticity. Review of elementary dislocation theory. Deformation of single and polycrystals. Temperature and Strain rate effects in plastic flow. Strain hardening, grain size strengthening, solid solution strengthening, precipitation strengthening, dispersion strengthening. martensitic strengthening. Creep, fatigue and fracture.

Subodh Kumar

Thomas H. Courtney, Mechanical Behaviour of Materials, Waveland Press.
George E. Dieter, Mechanical Metallurgy, McGraw-Hill Book Company.

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.

A N Choudhury

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. Indentation failure. Environmental aspects of failure. Cyclic Fatigue. Methods to measure toughness. Fracture in thin films and interfaces. Toughening in hierarchical structures

V Jayaram

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 258 (JAN) 3:0
Mechanical Behavior of Thin Films

Short description of common thin film deposition techniques; Origin of residual stresses; Determination of stress state in thin films deposited on substrate; Stress relaxation processes, including hillocking and whiskering, grain boundary sliding, and interface governed phenomenon, such as dewetting, buckling, interfacial fracture, interfacial sliding, etc.; Size effects; Mechanical testing of thin films, including nanoindentation.

Praveen Kumar

Materials Science of Thin Films by M. Ohring,Academic Press,Thin film materials: stress,defect formation and surface evolution. L. B. Freund,S. Suresh

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.

P C Ramamurthy

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

S Bose

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.

K Chatterjee

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.

FACULTY