MATERIALS SCIENCE AND METALLURGICAL ENGINEERING DEPARTMENT

M.Tech. MATERIALS SCIENCE AND TECHNOLOGY

Course of Study & Scheme of Examination
2016-17

Maulana Azad National Institute of Technology
Bhopal

SCHEME

M.Tech. in Materials Science and Technology

First Semester

Course Number	Subject	Scheme of Studies Periods per week			Credits
		L	T	P	
MME 511	Thermodynamics of Materials	3	-	-	3
MME 512	Advanced Physical Metallurgy	3	-	-	3
MME 513	Mechanical Behavior of Materials	3	-	-	3
	Elective 1	3	-	-	3
	Elective 2	3	-	-	3
	Open elective 1	3	-	-	3
MME 514	Physical Property Measurement Lab	1	-	4	2
MME 515	Seminar 1	-	-	-	2
				Total credit 22	

Second Semester

Course Number	Subject	Scheme of Studies Periods per week			Total Credits
		L	T	P	
MME 521	Kinetics of Materials	3	-	-	3
MME 522	Materials Characterization	3	-	-	3
MME 523	Phase Equilibria and Phase Transformations	3	-	-	3
	Elective 3	3	-	-	3
	Elective 4	3	-	-	3
	Open elective 2	3	-	-	3
MME 524	Materials Processing and Characterization Lab	-	-	2	2
MME 525	Seminar 2 and mini project	-	2	-	2
				Total credit 22	

List of department electives

MME 531 Functional Materials
MME 532 Polymer Engineering
MME 533 Corrosion Engineering
MME 534 Science and Technology of Magnetic Materials
MME 535 Composite Materials
MME536 Powder metallurgy

List of open electives for the M.Tech students

MME 551 Advanced Mathematics
MME 552 Advanced Ceramic and Composite Materials
MME 553 X-ray diffraction and electron microscopy
MME 554 Advanced Manufacturing Processes

MME511 THERMODYNAMICS OF MATERIALS

Introductory concepts and Definitions, First Law of Thermodynamics, Heat Content or Enthalpy, Heat Capacity, Einstein's theory, Debye's Theory, Thermo-chemistry and its Applications in Metallurgy, Experimental Measurements of Enthalpy Changes, Second law of Thermodynamics: Entropy and Free Energy, Entropy and Quantification of Irreversibility, Entropy changes of reversible, irreversible processes, chemical reactions, Criterion of Spontaneity based on Entropy, Criteria for Maximum Work, Free Energy, Criterion of Spontaneity based on Free Energy, Calculation of Free Energy Change, Maxwell's Relations, Third law of thermodynamics.

The Clausius-Clapeyron Equation and Applications, Trouton's Rule, Fugacity, Activity, Equilibrium Constant, Phase Equilibrium in one component system, Variation of Gibbs Free Energy with Temperature and Pressure, Phase Rule, Graphical Representation of Phase Equilibrium, Ellingham Diagrams, Predominance Area Diagrams. The Behavior of Solutions, Raoult's Law, Hentry's Law, Sievert's Law, Thermodynamic Activity of a Component in a Solution, Gibbs-Duhem Equation, Regular Solutions, Sub-regular Solutions, Interaction Parameter, Free Energy-Composition-Phase diagrams for Isomorphous, Eutectic and Peritectic Systems. Electrochemistry, The relationships between chemical and Electrical Driving Forces, Thermodynamics of Aqueous Solutions, Gibbs Free Energy of Formation of Ions and Std Reduction Potentials, Pourbaix Diagrams, Thermodynamics of Surfaces and Interfaces, Homogeneous Nucleation, Heterogeneous Nucleation, Thermodynamics of Defects in Solids.

References:

1.	Physical Chemistry of Metals	L.S.Darken and R.W. Gurry
2.	Problems in Metallurgical Thermodynamics and Kinetics	G.S.Upadhyaya,R.K.Dubey
3.	Metallurgical Thermodynamics	D.R.Gaskell
4.	Metallurgical Thermodynamics, Kinetics and Numericals	S.K. Dutta, A.B. Lele
5.	Textbook of Materials and Metallurgical Thermodynamics	A. Ghosh

MME512 ADVANCED PHYSICAL METALLURGY

Phase rule, lever rule and Free energy of phase mixtures; Binary isomorphous systems - Equilibrium solidification, non-equilibrium, Cu-Ni alloys and Zone refining; Thermodynamic order of transformations; Theory of nucleation -Kinetics of homogeneous, transient and heterogeneous nucleation; Theory of Thermally Activated Growth: Interface controlled growth, Diffusion controlled growth, Interface instability and Widmanstatten growth, Solidification -Nature and growth of solid-liquid interfaces, Rapid solidification, Glass transition, metallic glasses; Precipitation and Particle Coarsening; Binary Eutectic and Peritectic Systems -solidification of eutectic, hypo-eutectic, and hyper- eutectic alloys; solidification of peritectic, hypo-peritectic, and hyper-peritectic alloys; morphologies of eutectic systems, Binary Monotectic and Syntectic Systems; Stability of regular solution and miscibility gap, intrinsic stability of solution and spinodal; Hume-Rothery rules and intermediate phases e.g., lave, sigma, electron compounds; Iron-carbon phase diagram and

microstructures of plain carbon steel and cast iron: non-equilibrium structures; Ternary phase diagrams -Gibbs triangle, isothermal and vertical sections, polythermal projections, two-phase equilibrium, concept of tie lines, rules for construction of tie lines, three phase equilibrium, concept of tie-triangle, four phase equilibria; Eutectoid growth, Discontinuous precipitation, Massive transformation; Transformation Kinetics -Johnson-Mehl equation, Avrami model, Transformation kinetics in diffusion-controlled transformations, Isothermal and continuous cooling transformation diagrams; Kinetics of recrystallization, Theory of grain growth, Effect of second phase particles; Martensitic transformation - Nature of martensitic transformations, Bain distortion, Nucleation, and growth of martensite, Athermal, isothermal and burst transformations, Thermoeleastic martensitie; Spinodal Decomposition - Diffusion equation in spinodal region, Effect of gradient energy and elastic strain energy; Example of ferrous and non-ferrous alloys system.order and disorder Transformation: example of ordered structure, long and short-range order, detection of super lattice, influence of ordering on properties

References:

1. Fundamentals of Material Science and Engineering — William D. Callister
2. Introduction to Physical Metallurgy — S. H. Avnor
3. Physical Metallurgy (Vol. I & II) — Dr. P. R. Khangaonkar
4. The Science and Engineering of Materials — D.R. Askeland,P.P. Phule

MME513 MECHANICAL BEHAVIOUR OF MATERIALS

Stiffness, Strength, and Toughness, Types of mechanical behavior, Relevance, Measurement, data, Macroscopic, continuum behavior, Physical mechanisms controlling behaviour Elasticity: Introduction, Stress, strain, compliance and stiffness tensors, Physical origin of elastic moduli, Generalized Hooke's law and its application to crystals. Continuum Plasticity:True stress-true strain, Necking and Considère's Criterion, strain rate and temperature dependence of flow curve, Yield Criteria and yield locus, Normality, Isotropic and kinematic hardening, Plastic stress-strain relations .Microstructural Aspects of Plasticity and residual stresses. Theoretical shear strength, Dislocations and Burger's vector, Elastic properties and energy of dislocations, Forces between dislocations, Partial dislocation and stackingfaults, Dislocation-dislocation interactions, The Peierls-Nabarro Stress, Origin and multiplication of dislocations, Crystallography of Slip and Independent Slip systems, Slip plane rotation, Twinning and twin geometry, Twinning in HCP crystals Strengthening Mechanisms:Work hardening, Solid solution strengthening, Point defect–dislocation interaction energy, Yield point phenomenon, Precipitation hardening, Dislocation-precipitate interactions Fracture:Importance of Fracture Mechanics, Griffith Fracture Theory, Crack Driving Force & Energy Release Rate, Modes of fracture, Stress intensity factors, Similitude, Role of Crack-tip Plasticity--Plastic Zone Size & Shape, K-dominance, Fracture Toughness-Microstructural Issues programming.

References:

1. Mechanical Metallurgy — George E. Dieter
2. Mechanical Behavior of Materials — William F. Hosford
3. Mechanical Metallurgy: Principles and Applications — Marc A. Meyers, K K Chawla
4. Dislocations and Mechanical Behaviour of Materials — M. N. Shetty
5. Mechanical Behavior of Materials: Engineering Methods — Norman E. Dowling

MME514 PHYSICAL PROPERTY MEASUREMENT LAB

MSM 515 SEMINAR I

The student has to select a project work based on topic of interest and carryout literature survey in the selected area. Periodically the implementation will be evaluated by the project guide. The end of each semester student will be evaluated by departmental committee formed by HOD**.**

SEMINAR 1

MME 521 KINETICS OF MATERIALS

Theory of nucleation-Kinetics of homogeneous, transient and heterogeneous nucleation, Theory of thermally activated growth, Interface controlled growth, Diffusion controlled growth, Interface instability and Widmanstatten growth, Eutectoid growth, Discontinuous precipitation, Massive transformation, Transformation Kinetics- Johnson-Mehl equation, Avrami model, Transformation kinetics in diffusion-controlled transformations, Isothermal and continuous cooling transformation diagrams, Precipitation and particle coarsening, Kinetics of recrystallization, Theory of grain growth, Effect of second phase particles, Martiensitic transformations- nature of martensitic transformations, Bain distortion, Nucleation and growth of martensite, Athermal, isothermal and burst transformations, Thermoelestic transformations, Spinodal Decomposition- diffusion equation in spinodal region, Effect of gradient energy and elastic strain energy, Solidification- Nature and growth of solid-liquid interfaces, Rapid solidification, Glass transition, metallic glasses Adsorption – physical adsorption vs. chemisorption, adsorption isotherms; Langmuir, BET , rate limiting step.

References:

1. Kinetic Processes: Crystal Growth, Diffusion, and Phase Transitions in Materials, Kenneth A. Jackson

MME 522 MATERIALS CHARACTERIZATION

Advance microscopic techniques: Phase contrast, interference and polarized light microscopy, and High temperature microscopy, X Ray diffraction: working principle, counters, filters and cameras, Calculations for SC, BCC, FCC and HCP structures,. Indexing patterns, Precise lattice parameter determination Chemical analysis, Particle size and strain, Electron microscopes: Construction and working principles of TEM, Image formation, resolving power, magnification, depth of focus, elementary treatment of image contrasts, important lens defects and their correction, Bright field and dark field images, Stereographic projection, Formation of SAD patterns, reciprocal lattice and Ewald sphere construction, indexing of diffraction patterns, sample preparation techniques, Scanning electron microscope; construction, interaction of electrons with matter, modes of operation, Chemical analysis using EDX, EPMA Atomic force microscopy, working principles of XRF,, Augur spectroscopy, TG-DTA and DSC.

References:

1. Elements of X Ray Diffraction — B. D. Cullity
2. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods — Yang Leng
3. A Guide to Materials Characterization and Chemical Analysis — Y John P. Sibilia
4. Experimental Techniques in Materials and Mechanics — C. Suryanarayana

MME 523 PHASE EQUILIBRIA AND PHASE TRANSFORMATIONS

Application of Physical metallurgy: Strengthening mechanism, strength vs. toughness (ductility), thermo mechanical processing, micro alloyed steel, ultra high strength steel, superalloy, control of texture

Thermodynamics order of transformations, Theory of nucleation-Kinetics of homogeneous, transient and heterogeneous nucleation, Theory of thermally activated growth, Interface controlled growth, Diffusion controlled growth, Interface instability and Widmanstatten growth, Eutectoid growth, Discontinuous precipitation, Massive transformation, Transformation Kinetics- Johnson-Mehl equation, Avrami model, Transformation kinetics in diffusion-controlled transformations, Isothermal and continuous cooling transformation diagrams, Precipitation and particle coarsening, Kinetics of recrystallization, Theory of grain growth, Effect of second phase particles, Martiensitic transformations- nature of martensitic transformations, Bain distortion, Nucleation and growth of martensite, Athermal, isothermal and burst transformations, Thermoelestic transformations, Spinodal Decomposition- diffusion equation in spinodal region, Effect of gradient energy and elastic strain energy, Solidification- Nature and growth of solid-liquid interfaces, Rapid solidification, Glass transition, metallic glasses, Heat treatment – IT and ICT diagrams in steels, quench hardening and tempering of martensity, hardenablity of steels, surface hardening processes, tool steels and their heat treatments, heat treatment of cast irons, heat treatment of Ni-base superalloys and Ti alloys, Thermo-mechanical treatments

References:

1. Physical Metallurgy Principles — Robert E Reed-Hill and Reza
2. Phase Transformation in Metals & Alloys — D A Porter & K Easterling
3. Fundamentals of Physical Metallurgy — John D Verhoeven
4. Theory of Structural Transformations in Solids — G. Khachaturyan

MME 524 MATERIAL PROCESSING AND CHARECTERIZATION LAB

Raw Material Preparation, Particle Size Analysis, Dry Pressing, Particle Dispersion and Slip Casting, Sintering of Ceramics, Thin Film Production Study of X-Ray Diffractometer, Structure factor calculations, Determination of SC, BCC, FCC and Tetragonal crystal structures, Precise lattice parameter measurements, Construction of phase diagrams, Study of order disorder transformations, Chemical Analysis of phases, Study of TGA / DTA, DSC Study of operation of Atomic Force microscopy and observations of fracture surfaces.

MME 525 SEMINAR 2 AND MINI PROJECT

The student has to select a project work based on topic of interest and carryout literature survey in the selected area. Periodically the implementation will be evaluated by the project guide. The work starts in second semester and continues through third and fourth semester. The end of each semester student will be evaluated by departmental committee formed by HOD**.**

DEPARTMENTAL ELECTIVES

MME531 FUNCTIONAL MATERIALS

Properties of Materials, Materials in Medical Applications, Stainless steel alloys, Cobalt based alloys, titanium based alloys, polymers, Bioresorbable and Bio erodible materials, bioceramics, porous ceramics, bioactive glasses, calcium phosphates, collagen, thin films, grafts and coatings, biological functional materials Latex products.

MME532 POLYMER ENGINEERING

Basic concepts on polymers, Classification of polymers; Polymer structure: Copolymers, Tacticity, Geometric Isomerism, Nomenclature. Polymerization principles and processes Structure and properties of polymers: Amorphous state, crystalline state, Thermal transitions; Glass transition; Crystalline melting temperature; Structure property relationships, Effect of weight, composition and pressure on Tg, Mechanical properties of polymers, Viscoelastic properties of polymer solutions and melts; Dielectric analysis; Dynamic calorimetry, Additives, Blends and Composites: Plasticizers, Fillers and reinforcements, polymer blends; Polymer processing: Extrusion, Molding; Calendering; Coating, Polymer Rheology, Biopolymers, Natural polymers; Fibres; Engineering and Specialty polymers: Polyamides; Polycarbonates; Engineering polyesters etc; Ionic polymers; Liquid crystal polymers; Conductive polymers; High performance fibres; Dendritic polymers, environmental Problems with polymers.

References:

1. Polymer Science — W.Billmerycr
2. Structure & Properties of Polymeic materials — D.W. Clegg & A. A. Collyer
3. Engineering Materials Vol. I and II — Jones
4. Polymer Science & Technology — J.R.Fried

MME 533 CORROSION ENGINEERING

Unit1: Advanced theory of electro-chemical kinetics and corrosion, theory of electro deposition and allied processes, stress corrosion behavior of materials (important- metals, alloys etc.) in various environments, corrosion testing: Metal-gas reaction at high temperatures, corrosion by liquid metals. Polymer degradation

Unit2: Introduction experimental techniques: Oxide and defect structure: Thermodynamics, Ellingham diagrams, vapor species diagrams, isothermal stability diagrams: kinetics, rate laws, Wagner's theory of parabolic rate laws, mechanism of oxidation: Oxidation of pure metals, multiple scale formation, scale cracking, oxygen dissolution: Oxidation of alloys, internal oxidation, catastrophic oxidation, stresses in oxides:

Unit3: Hot corrosion, acid fluxing, basic, fluxing, High temperature materials, superalloys, intermetallic: Protection against oxidation, coatings, atmospheric control: Conclusions.

MME 534 SCIENCE AND TECHNOLOGY OF MAGNETIC MATERIALS

Optical properties of semiconductors: absorption & emission processes; Kramers-Kronig andVan Roosbroeck-Shockley relations; radiative & non-radiative transitions, Photoluminescence and UV-VIS-NIR Spectroscopy. Photoconducting and non-photoconducting materials. Growth of III-V, II-VI and IV-VI semiconductors and nanostructures for optoelectronic applications--- MOVPE and MBE technology. Photo-detectors: photoconducting, photovoltaic, PIN, APD, gain band width criteria. Optical emission from semiconductors: LED physics and technology, conditions for laser action, DH, DFB & DBR lasers. Quantum Confinement: 2-D, 1-D and O-D systems, Quantum well and quantum dot lasers, Quantum Cascade Laser (QCL), Quantum Well Infrared Photodetectors (QWIP). Photonic crystals. Non-linear optic materials and their plications, fibre-optic systems, IR focal plane arrays and remote sensing. Solar cell: Device physics, p-n junction, polycrystalline and amorphous Si, CdS/CdTe, CIGS, Ge/GaAs/InGaP tandem structure, multi-exciton generation, quantum dot solar cell, anti-reflection coating. Organic optoelectronic materials and devices.
Structure of oxides: Ionic diffusion in oxides: Defect structure of non-stoichiometric compounds:Conductivity dependence on partial pressure of oxygen: Macroscopic characterization of dielectric materials: Electronic, atomic dipole, space charge polarization: Relaxation phenomenoa-Debye equations: Ferroelectrics: Diamagnetism, paramagnetism and ferromagnetism, exchange ferromagnetic domain: Structure and properties of ferrites

MME 535 COMPOSITE MATERIALS

Unit1: Classification of composite materials, Dispersion strengthened, Particle-reinforced and fiber-reinforced composite structural composite (Laminated composite, Flake Sandwich) Properties of matrix and reinforcement molecular composites, micro-and multilayer composites

Unit 2: Principle of strengthening, elastic properties, stress-strain relations, fracture behavior, and Micromechanics of lamina and laminate composite, elementary idea of bending, bucking and vibration of laminated plate. Mechanical behaviour of composites: stress-strain relationship, strength, fracture, toughness and fatigue.

Unit 3: Properties of fiber reinforcement and matrices. Fabrication methods and structural applications of different types of composite materials.

MME 536 POWDER METALLURGY

Basic powder metallurgy processing, advances in metal powder production, powder characterization, modern powder compaction methods, cold isostatic pressing, powder injection moulding, powder rolling, sintering behaviour of ferrous and non-ferrous materials, case studies, microwave sintering of materials.

OPEN ELECTIVES-

MME 552 ADVANCED CERAMIC AND COMPOSITE MATERIALS

Introduction: oxide and non-oxide ceramics, their chemical formulae, crystal and defect structures, non-stoichiometry and typical properties. Powder Preparation: Physical methods (different techniques of grinding), chemical routes - co-precipitation, sol-gel, hydrothermal, combustion synthesis, high temperature reaction (solid state reaction Basic principles and techniques of consolidation and shaping of ceramics: powder pressing- uniaxial, biaxial and

cold isostatic and hot isostatic, injection moulding, slip casting, tape-casting, calendaring, multilayering. Sintering: different mechanisms and development of microstructure (including microwave sintering) Preparation of single crystal, thick and thin film ceramics Mechanical behaviour: fracture mechanics and tribology Engineering applications: at room and high temperatures (including armour application)

References

1. Fundamental of Ceramics by Michel W. Barsoum, McGraw Hill International edition, 1997
2. Modern Ceramic Engineering by David. W. Richerson, Mercel Dekker, NY 1992
3. Ceramic Processing and Sintering by M. N. Rahman, Mercel Dekker, 2003

MME 553 X-RAY DIFFRACTIONH AND ELECTRON MICROSCOPY

Optical Microscopy, Metallography techniques, X-ray diffraction (XRD), basic principle and application, Crystallography, Planes and directions, Extinction rules, indexing patterns for cubic crystals, X-ray Fluorescence (XRF), Electron Microscopes: Scanning Electron Microscopy (SEM), FESEM, Transmission Electron Microscopy (TEM), Atomic force microscopy (AFM), Electron probe micro analyzer (EPMA), Energy Dispersive X-ray spectroscopy (EDX) , Spectroscopy: UV-Vis Spectroscopy, Infra-red spectroscopy, Fourier Transform Spectroscopy, Raman spectroscopy, Mossbauer spectroscopy, Spectro photometry, Auger electron spectroscopy (AES)

Thermal analysis: Thermo gravimetric analysis (TGA) - Differential thermal analysis (DTA) - Differential Scanning Calorimetry (DSC), particle size analysis, surface area analysis, zeta potential measurement

MME 554 ADVANCED MANUFACTURING PROCESSES

Advanced Casting Processes: Metal mould casting, Continuous casting, Squeeze casting, Vacuum mould casting, Evaporative pattern casting, Ceramic shell casting, Pressure Die Casting, Advanced Welding Processes: electron beam welding (EBW), laser beam welding (LBW), ultrasonic welding (USW), Advanced Metal Forming Processes: high energy rate forming (HERF) process, Electro-magnetic forming, explosive forming, Electro-hydraulic forming, Stretch forming, Contour roll forming, SPD, Advanced Sintering Processes: Microwave Sintering, Spark Plasma Sintering, Self Propagating High Temperature Synthesis Process.

References

1. "Materials and Processes in Manufacturing" (8th Edition), E. P. DeGarmo, J. T Black, R. A. Kohser, Prentice Hall of India, New Delhi (ISBN 0-02-978760).
2. "Manufacturing Science" A. Ghosh, and A. K. Mallik, Affiliated East-West Press Pvt. Ltd. New Delhi.
3. "Nontraditional Manufacturing Processes", G.F. Benedict, Marcel Dekker, Inc. New York (ISBN 0-8247-7352-7).