

## **B. Tech. in METALLURGY / METALLURGY & MATERIAL SCIENCE**

### **Syllabus of Paper – 1**

#### **PHYSICAL METALLURGY & MATERIALS ENGINEERING**

Structure of metals: Coordination number, Relationship between lattice parameter and atomic radius, Packing factor and density calculations, Miller indices, Miller – Bravais indices, Allotropy, Stacking sequence and interstitial voids. Phase equilibria, thermodynamics of phase evolution, Solid solutions. Vegard's law, Hume Rothery Rules, Intermediate alloy phases, X-ray diffraction, Imperfections in solids. Construction of equilibrium diagrams, Isomorphous systems, Lever rule, Coring, Miscibility gap, Eutectic system, Congruent melting intermediate phase, Eutectoid, Peritectic, Peritectoid, Monotectic and Syntectic reactions. Phase rule. Study of Fe-Fe<sub>3</sub>C, Cu-Zn, Cu-Sn, Al-Cu and Al-Si ternary phase diagrams. Diffusion laws: Fick's first and second laws, Solution to Fick's second law, Kirkendall effect, Darken's analysis, Atomic theory of diffusion, other diffusion processes. Structure and properties of ceramics, polymers and composites, Physical properties of materials. Construction and Principles of Optical and transmission Electron Microscope. Types of objectives, Eye pieces and common defects of lenses.

#### **MINERAL PROCESSING**

Mineral & ores, resources of different metals in india. Sampling of ores by different methods – hand sampling, mechanical sampling, errors in sampling. Theory of liberation of minerals, primary, secondary and special crushers (jaw, gyratory, cone, rolls and toothed rolls crusher). Grinding, ball mills, theory of ball mill operation, rod mills and tube mills. Theories of comminution – Kick's, Rittinger's and Bond's theories. Sizing - Sizing scales, laboratory sizing and reporting the data in various numerical and graphical forms, sedimentation, and elutriation. Industrial sizing methods, types of screens. Mechanism of passing through a screening surface and effectiveness of a screen. Movement of solids in Fluids, Stoke's and Newton's laws, Terminal velocity and its relation with size, relation between time and velocity, relation between distance traveled and velocity, free and hindered settling ratios. Quantifying concentrating operation, ratio of concentration, recovery, selective index and economic recovery. Classification: Principles, sizing and sorting classifiers. Heavy media separation, processes using heavy liquids, processes using heavy suspensions, coal washing methods. Thickening, filtration and its practice. Jigging - Theory of jigging, jigging machines. Tabling - Theory of flowing film concentration, shaking tables. Flotation - Principles of flotation, physical and chemical aspects. Application of flotation process for concentration of copper, lead and zinc ores. Principles and applications of magnetic and electrostatic separation processes. Details about Indian ore dressing practices. Flowchart for the mineral beneficiation of important metals like aluminium, iron, zinc, copper etc.

#### **METALLURGICAL THERMODYNAMICS AND KINETICS**

Laws of thermodynamics, concepts of reversibility, internal energy, enthalpy, entropy, maximum work, free energy, Maxwell's equations and Gibbs-Helmholtz equation, Clausius-Clapeyron equation, fugacity, activity and equilibrium constant, Sigma function, Concept of chemical potential, homogeneous and heterogeneous equilibria, phase rule, Thermodynamics of solutions,

Concept of partial molal properties, thermodynamics of reversible cells, basic kinetic laws, order of reactions, rate constant, elementary and complex reactions, rate limiting steps, Arrhenius equation, theories of reaction rates – simple collision theory, activated complex theory.

### **TRANSPORT PHENOMENA**

Introduction to Transport phenomena, Units and Dimensional Analysis. Fluid Flow, Properties of fluids, Types of fluid flow, Control volume, Reynolds experiments, concept of velocity boundary layer, Newton's law of viscosity, Molecular theory of viscosity of liquid, Molecular theory of viscosity of gas, Momentum transfer in fluid, Equation of continuity and motion, Law of conservation of energy, Navier stroke equation, Energy and momentum relationships, Friction factor, Fourier's law conduction in solids, conduction in liquids and gases, steady state and unsteady state conduction in solids, Natural convection, Forced convection, concept of heat transfer coefficient and thermal boundary layer, Radiation heat transfer, Gurney-Lurie, Haisler, Hottel and allied charts. Heat transfer with change of phase. Introduction to solidification heat transfer and ablation, Heat transfer in packed and fluid beds. Diffusivity and steady state diffusion, Unsteady state mass transfer, concept of mass transfer coefficient concentration boundary layer, Inter-phase mass transfer– theories, introduction to simultaneous mass and heat transfer. Classification of diffusional operations and conduction of diffusional operations, introduction to stage operations. Similarity criteria and introduction to model and pilot plant studies Similarities of momentum, mass and energy transfer. Applications of Navier - Stoke's equation.

### **PHASE TRANSFORMATIONS AND HEAT TREATMENT**

Theory of Nucleation, Homogeneous and Heterogeneous Nucleation, Nucleation Kinetics, Growth Kinetics, Different types of Diffusion Growth. Nucleation and Grain size, Super Cooling, Directional Solidifications, and Segregations. Study of Fe-Fe<sub>3</sub>C Phase Diagram, Phase Transformation in Steel on heating and cooling, Austenitic Grain Growth on heating, Determination of Grain Size, Isothermal Transformation Diagrams, Pearlite, Bainite and Martensitic Transformations. Annealing, Normalizing, Hardening and Tempering of steel, Hardenability, Mechanism of Heat removal during Quenching, Quenching media, Residual stresses and Quench Cracks, Martempering and Austempering, Purpose of alloying, Effect of alloying on Fe-Fe<sub>3</sub>C Phase Diagram, Temperature Time Transformation (TTT) and Continuous Cooling Transformation (CCT) Plots. Secondary Hardening, Temper embrittlement. Classification of alloys steel, high strength low alloys steel, corrosion resistant steel, tool steel, Hadfield Mn steel, Different types of cast irons, White cast iron, grey cast iron, malleable cast iron, S.G iron and alloy cast iron. Flame and Induction Hardening, Laser beam Hardening (LBM), Carburizing (solid, liquid their heat treatments and gas), Nitriding, Cyaniding, Boronizing. Solution Treatment, Ageing treatment, Nucleation of Precipitates, Theory of Precipitation Hardening, Effect of variables on Precipitation Hardening.

### **UNIT PROCESSES IN EXTRACTIVE METALLURGY**

Principles of Unit processes: Calcination, Sintering, Pelletising and Briquetting. Principles and types of roasting (Oxidising roasting, Sulphating roasting, Chloridising roasting), Roasting equipment and methods (Multiple hearth, Flash, Fluidized bed and blast roasting), Predominance area diagrams. Principles of reduction and Matte Smelting. Industrial methods of smelting such as reverberatory, Flash smelting. Principles of converting of matte. Generalised flow sheets for the extraction of metals by pyro and hydro metallurgical routes. Pyro-metallurgical processes using, reduction of halide by another element carbothermic metallothermic reduction. Principles of

refining processes: Fire refining, Liquation, Distillation, Electro refining and zone refining. Principles of electro-winning from fused salts. Processing steps in the extraction of metals from sulphide and oxide ores. Slags and their properties. Ellingham diagrams for oxides and sulphides, criteria for reduction. Principles and types of leaching, purification of leach liquors by solvent extraction and ion exchange, Metal recovery from leach solutions. Comparison of pyro, hydro and electro metallurgical methods of extraction in respect to some metals like aluminium, copper, zinc etc.

## **ELECTRONIC AND MAGNETIC MATERIALS**

Types of magnetic materials, ferrites and garnets, Weiss theory of ferromagnetism, soft and hard magnetic materials, magnetic tapes and films. Classification of Semiconductors, Direct and indirect band gap semiconductors, Hall effect and its applications. High temperature Superconductors, Types of Superconductors, Applications. Dielectric materials, Ferro electricity and Piezo electric effect. Growth of thin films by M B E, C V D, Sputtering and other techniques. Growth of single crystals by CZ and Bridgmann techniques, and applications. Silicon wafer preparation for electronic devices. Different techniques involved for the preparation of electron chip. Photovoltaic effect, Fabrication of single crystal solar cell and its applications.

## **Syllabus of Paper - 2**

### **MECHANICAL BEHAVIOUR OF MATERIALS**

Hardness Testing: Methods of hardness testing: Brinell hardness testing. Vickers and Rockwell hardness testing. Shore scleroscope & Poldi hardness testing. Micro hardness Testing. Relation between hardness and other mechanical properties. Hot hardness testing. Introduction to dislocations: Slip, slip planes and directions, slip systems. Resolved shear stress. Theoretical strength of crystals. Imperfections in Crystalline materials. The concept of dislocations – Edge, screw and mixed dislocations. Burgers circuit, burgers vector, movement of dislocations, Glide, climb, cross-slip and velocity of dislocations. Tension Testing: Mechanism of elasticity, linear elastic properties, plasticity in metals. Engineering stress-strain and true stress-true strain curves. Tensile properties, conditions for necking. Effect of temperature and strain rate on tensile properties and strain hardening. Strengthening strain again, cold working, dispersion strengthening, mechanisms, Hall-Petch relation. Static compression: Elasticity and plasticity action in compression, elastic and in-elastic properties in compression. The Compression Test. Impact Testing: The brittle failure problem and notch sensitivity, notched bar impact test. Significance and Specialized test for transition temperature. Metallurgical factors affecting transition temperature. Temper Embrittlement. Fracture: Elementary theories of fracture. Griffith's theory of brittle fracture, ductile fracture. Fatigue Testing: Fatigue testing and its significance, Stress cycles, S-N curve, Goodman diagram, fatigue limit. Mechanism of fatigue failure, effect of stress concentration, size, surface condition and environments on fatigue. Effect of metallurgical variables on fatigue properties. High cycle and low cycle fatigue thermal fatigue. Creep Testing: Creep Test. The creep curve, creep properties of metals. Stress-rupture test, deformation and fracture at elevated temperature. Theories of creep, prediction of long time properties. Creep resistant materials. Effect of metallurgical variables on creep.

### **POWDER METALLURGY**

Introduction and History of PM. Why PM? And Future Trends of PM. Different Powder Production Techniques. Analysis of Performance of Different Production Techniques. Importance of Powder Characterization, Particles Size, Distribution, Surface Analysis Interparticle friction and Powder Compressibility Microstructure control of Powder Tailoring of Powder for Shaping and Consolidation, Lubricants and Binders Powder Compaction and Process variables. Cold pressing and hot isostatic pressing powder injection molding. Density distribution of compact and Isostatic Pressing Powder extrusion, Injection molding, Slip Casting Analysis of defects in Powder Compact. Theory of sintering :Mixed Powder and Alloy powder Sintering, Liquid Phase and Reactive Sintering, Defect analysis of sintered components, Recent Development in Sintering. Structure-Properties Evaluation of Sintered samples PM of Filter, Friction Parts, W filament, Biomaterials etc.

### **WELDING TECHNOLOGY**

Classification of welding processes, welding symbols, weld joint design, edge preparation, Oxyacetylene gas welding- Types of flames, process description and application, solid state welding, Ultrasonic, Explosion and Friction welding, Arc welding- Arc characteristics, duty cycle, arc welding processes, welding metallurgy, testing and inspection.

## **X-RAY DIFFRACTION AND ELECTRON MICROSCOPY**

Introduction to crystallography, Symmetry – point group and space group, Reading of the space group tables, X-ray diffraction – Generation of X-rays, characteristic X-ray spectrum, Bragg's Law, Diffraction methods – Laue method, rotating crystal method, powder method, Principle, equipment and applications, structure factor, derivation of diffraction conditions for SC, BCC and FCC Bravais lattice, X-ray diffractometer, filters and counters/detectors, texture, importance of texture, measurement of texture, pole figures (stereographic projections), orientation distribution function, sample symmetry, and its importance, applications of X-ray diffraction in materials characterization – determination of crystal structure, lattice parameter, examples of textures in cubic materials, Introduction of GIXRD, instrumental configuration for texture measurement and GIXRD. Electrons as source, properties of electron beam, elastic and inelastic scattering of electrons, importance in electron microscopy, resolution.

## **MECHANICAL WORKING OF MATERIALS**

Forming processes, effect of metallurgical structure & strain-rate, cold working, recovery, recrystallisation and grain growth, hot working, Stress, Strain fields, strain energy & line tension of a dislocation, Forces on and between dislocations, Dislocation reactions in FCC, BCC and HCP crystals, Dislocation intersections, Origin, multiplication and observation of dislocations, plasticity of single crystal of FCC, BCC and HCP structures, Twinning, deformation mechanisms of poly-crystalline metals, effect of grain boundary, solute atoms and second phase particles, Yield point phenomena and strain ageing, Forging processes, forging equipment, Forging in plane strain, Open and closed die forging, Forging defects, Rolling processes, Rolling mills, Rolling of bars and shapes, Forces and geometrical relationships in rolling, Simplified analysis of rolling load, rolling variables, problems and defects in rolled products, Theories of cold and hot rolling, torque and horsepower, Extrusion processes, extrusion equipment, Deformation and defects in extrusion, analysis of the extrusion process, Extrusion of tubing and production of seamless pipes and tubes, Rod, wire and tube drawing, Deep drawing and redrawing, Common defects in sheet metal formed products.

## **NON FERROUS EXTRACTIVE METALLURGY**

Copper: Principal ore minerals, traditional bath smelting processes viz., Blast furnace, Reverberatory furnace, Electric furnace. Autogenous smelting – Outokumpu flash smelting, INCO flash smelting. Converting. Continuous smelting and converting- Noranda process and Mitsubishi process, other processes. Hydro-metallurgical extraction - principles, leaching processes. Recovery of copper from leach solutions- cementation and electro-winning. Refining - fire refining, electrolytic refining. Zinc: General principles, roasting. Retort processes- horizontal and vertical retort processes. Electro-thermal production. Production in shaft furnace- Imperial Smelting Process. Hydro-metallurgical zinc production - leaching practice, solution purification; Electrolytic production. New developments in zinc production. Refining of crude zinc- liquation and fractional distillation. Lead: Ore concentration. Smelting- sintering reduction process, reduction in the blast furnace. Roast reaction processes. Direct smelting reduction processes- air flash smelting, oxygen flash smelting, oxygen - slag bath smelting, QSL Process. Refining of lead bullion – pyro-metallurgical and electrolytic refining. Aluminum: Raw materials, Production of pure alumina- Bayer process; Deville-Pechiney process; Hall-Heroult cell- electrolyte, electrode reactions, current efficiency, cell voltage, anode effect. Refining of aluminum. Alternate processes for the production of aluminum. Simplified flow sheets for the extraction of Nickel, Magnesium, Uranium and Titanium. Non-ferrous metal industry in India.

## **CHARACTERIZATION TECHNIQUES**

Optical metallography, image analysis, quantitative phase estimation. Analytical transmission electron microscopy (TEM), Selected area of Diffraction bright and dark field imaging. Specimen preparation techniques. Scanning Electron Microscopy (SEM), electron beam specimen interaction, image formation in SEM, Energy Dispersive analysis X-ray analysis, Electron Probe Micro- Analysis (EPMA) to solid samples and biological materials, XRD, STM, SPM, AFM, ICP, Thermal Analysis, Differential Thermal Analysis, Differential Scanning Calorimetry, Thermo Gravimetric Analyzer. Chromotography, mass Chromotography.

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