UG program in

Metallurgical and Materials Engineering

Indian Institute of Technology Patna

Content of Core Courses

Semester – I

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	CE111	Engineering Drawing	1	0	3	5	
2	EE101	Electrical Sciences	3	1	0	8	
3	HS103	Communicative English for Engineers	2	0.5	1	6	
4	MA101	Mathematics – I	3	1	0	8	
5	ME110	Workshop – I	0	0	3	3	
6	PH103	Physics – I	3	1	0	8	
7	PH110	Physics Laboratory	0	0	3	3	
TOTAL			**12**	**3.5**	**10**	**41**	

Semester – II

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	CB102 and CE102	Biology and Environmental Studies	3	0	0	6	
2	CH103	Introductory Chemistry	3	1	0	8	
3	CH110	Chemistry Laboratory	0	0	3	3	
4	CS101	Programming and Data Structures	3	0	0	6	
5	CS110	Programming and Data Structures Laboratory	0	0	3	3	
6	EE102	Basic Electronics Laboratory	0	0	3	3	
7	MA102	Mathematics-II	3	1	0	8	
8	ME102	Engineering Mechanics	3	1	0	8	
TOTAL			**15**	**3**	**9**	**45**	

Semester - III

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	MA201	Mathematics-III	3	1	0	8	
2	HS2XX	HSS Elective – I	3	0	0	6	
3	MM201	Introduction to Metallurgical and Materials Engineering	3	0	0	6	
4	MM203	Introduction to Mineral Processing and Raw Materials	3	0	3	9	
5	MM205	Metallurgical Thermodynamics and Kinetics	3	1	0	8	
TOTAL			**15**	**2**	**3**	**37**	

Semester - IV

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	HS2XX	HSS Elective – II	3	0	0	6	
2	XX2XX	Open Elective – I	3	0	0	6	
3	MM202	Process Metallurgy	3	1	0	8	
4	MM204	Phase Transformation and Diffusion	3	1	0	8	
5	MM210	Metallography and Heat Treatment Lab	0	0	3	3	
6	MM206	Mechanical Metallurgy	3	1	0	8	
TOTAL			**15**	**3**	**3**	**39**	

Semester – V

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	XX3XX	Open Elective - II	3	0	0	6	
2	MM301	Techniques of Materials Characterization	2	0	2	6	
3	MM303	Iron and Steel Making	3	0	0	6	
4	MM305	Engineering Polymers	3	0	0	6	
5	MM307	Ceramic and Glass	3	0	0	6	
6	MM311	Materials Processing Lab I	0	0	3	3	
TOTAL			**14**	**0**	**5**	**33**	

Semester – VI

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	HS3XX	HSS Elective – III	3	0	0	6	
2	MM302	Thermomechanical Processing of Metallic Materials	3	1	0	8	
3	MM304	Corrosion and Degradation in Materials	3	0	0	6	
4	MM306	Functional Materials	3	0	0	6	
5	MM312	Materials Processing Lab II	0	0	3	3	
6	MM314	Mechanical Metallurgy Lab	0	0	3	3	
TOTAL			**12**	**1**	**6**	**32**	

Semester – VII

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	XX4XX	Open Elective – III	3	0	0	6	
2	MM401	Environmental Sustainability and Industrial Safety	3	0	0	6	
3	MMXXX	Department Elective - I	3	0	0	6	
4	MMXXX	Department Elective - II	3	0	0	6	
5	MM431	B.Tech Project	0	0	6	6	
TOTAL			**12**	**0**	**6**	**30**	

Semester – VIII

S. No.	Subject ID	Subject	L	T	P	C	Remark
1	MMXXX	Departmental Elective-III	3	0	0	6	
2	MMXXX	Departmental Elective-IV	3	0	0	6	
3	MM432	B.Tech Project	0	0	18	18	
TOTAL			**6**	**0**	**18**	**30**	

MM201 Introduction to Metallurgical and Materials Engineering (3-0-0) 6 credit

Atomic structure and bonding: Concept of energy versus interatomic separation for atoms, bonding in solids, primary interatomic bonding, secondary bonding

Structure of crystalline solids: Basic idea of lattice, crystalline and non-crystalline materials, unit cell, crystal systems, indexing planes and directions, Miller indices, coordination number, packing of atoms, symmetry in crystal systems.

Defects and diffusion in solids: Point, linear, planar and volume defects, equilibrium concentration of vacancies, edge and screw dislocations, Burger vector, grain boundaries, twin and stacking faults. Microscopy techniques. Diffusion mechanism, Fick's first and second law.

Phase diagrams and phase transformation: Basic concept of solubility, phase and phase equilibria, Gibbs phase rule, isomorphous and eutectic binary phase diagrams, concept of tie line and lever rule, equilibrium and non-equilibrium cooling, microstructure development in eutectic phase diagram.

Mechanical properties of materials: Concept of stress and strain, Hooks law, elastic and plastic deformation, tensile properties, hardness, fatigue, fracture and creep, structure-property relationship

Ferrous and non-ferrous alloys structure and properties: Introduction to ceramic, polymer and composite – processing, structure, properties and applications.

Specific properties of engineering materials: Electrical, magnetic, thermal and optical properties in terms of band and free electron theory.

Text Book:

1. Materials Science and Engineering, an Introduction: William D. Callister, 7th Ed., John Wiley and Sons, 2007.
2. Fundamentals of Materials Science, the microstructure – property relationship using metals as model systems: Eric J. Mittemeijer, Springer, 2011.
3. Materials Science and Engineering: V. Raghavan, 6th Ed., Prentice Hall India, 2015.

Reference Book:

1. Physical Foundation of Materials Science: Günter Gottstein, Springer, 2004.
2. An Introduction to Metallurgy: Sir Alan Cottrell, 2nd Ed., Universities Press, 2000.

MM203 Introduction to Mineral Processing and Raw Materials (3-0-0) 6 credit

Mineralogy: Physical properties of minerals; Classification of various rock forming minerals, Introduction and preliminary study of principle rock forming mineral groups; quartz, feldspar, mica, pyroxenes, amphibole, garnet, feldspathoids. Mode of occurrence, origin, distribution, association, and industrial uses of important metals (Al, Au, Cu, Cr, Fe, Mn, Sn, Pb and Zn)

Comminution: Jaw and gyratory crushers, roll crusher and their performance. Ball & rod mills - capacities and reduction ratios. Hammer mills, gravity stamps and disc crushers. Grinding - dry and wet grinding. Open and closed circuit grinding. Laws of crushing and work index. Theory of ball mill operation, Rittinger's, Kick's and Bond's laws of crushing and grinding. Screening, sizing and sampling.

Gravity concentration techniques: Theory of settling, Elementary concepts of movement of solids in fluids. Stokes and Newtons Laws. Reynold's number. Free and hindered settling. Classification and its application in mineral dressing. Practice of Hydraulic and mechanical classification, working of thickeners. Hydrocyclones and Rotary filters. Heavy media separation. Principles of jigging and Tabling. Magnetic and Electro static separation. Processes with equipments used. Important controlling factors in operation.

Flotation techniques: Application froth flotation. Frothers. Collectors. Depressants. Activators. Ph modifiers etc., multistage flotation - Principle, equipments, and application. Differential flotation. Flotation circuits. Study of basic de-watering techniques like-sedimentation – filtration – drying. Simple flow sheets for beneficiation of Fe, Mn, Cr, Cu, Pb, Zn and beach sands.

Text books:

1. Principles of Mineral Dressing: A.M. Gaudin, McGraw Hill, 1939.
2. Mineral Processing Technology: B.A. Wills, 8th Ed., Butterworth Heinemann, Elsevier, 2015.
3. Text Book of Geology: G.B. Mahapatra, CBS Publishers, 2009.

References books:

1. Mineral Processing Technology: S.K. Jain, 2nd Ed., CBS Publishers, 2001
2. Unit operation in Chemical Engineering: W.L. McCabe, J.C. Smith, P. Harriott, McGraw Hill, 7th Ed., 2017

MM205 Metallurgical Thermodynamics and Kinetics
(3-1-0) 8 credit

Introduction to Thermodynamics: Basic concept and definitions-concept of state, reversible and irreversible processes, path and state functions, extensive and intensive properties, thermodynamic equilibrium, zeroth law of thermodynamics

Laws of Thermodynamics:

1. First Law: Internal energy, enthalpy, constant volume and pressure process, isothermal and adiabatic process, heat capacity.
2. Second Law: Criterion for equilibrium, entropy and disorder, most probable microstate, statistical concepts of entropy, auxiliary functions, Maxwell's relations, Gibbs-Helmholtz equation.
3. Third Law: Variation of Gibbs energy with temperature and pressure, Clausius-Clapeyron equation;
4. Behavior of gases: Ideal gases and non-ideal gases, Thermodynamic properties of mixtures of ideal and imperfect gasses; reaction in gas, concepts of fugacity, reactions involving gases and condensed phase, Standard Gibbs energy of reactions
5. Thermodynamic stability of materials. Ellingham diagram and its importance, application of electrochemical series.
6. Behavior of solutions: Ideal solution, Gibb's-Duhem equation, Raoults and Henry's law, activity of a component, regular solutions, free energy- composition diagrams for ideal and regular solutions.
7. Phase equilibria & phase diagram: Gibbs phase rule, isobaric phase rule and application to unary, binary and ternary systems, eutectic and eutectoid, peritectic and peritectoid diagrams, lever rule and its application.
8. Introduction to kinetics: Basic kinetic laws, order of reactions, rate constant, elementary and complex reactions, rate limiting steps and Arrhenius equations, theories of reaction rates - simple collision theory, activated complex theory Heterogeneous reaction; Gas-solid, solid-liquid, liquid-liquid and solid-solid systems. Empirical and Semi-empirical Kinetics, Concept of Johnson-Mehl equation, Thermal analysis.

Text Books:

1. Introduction to Metallurgical Thermodynamics: David R. Gaskell, McGraw Hill, 4th Ed., 2009.
2. Kinetics of Materials: R.W. Balluffi, S.M. Allen, and W.C. Carter, Wiley, 2005.

Reference Books:

1. Physical Chemistry of Metals: L. Darken and R.W. Gurry, McGraw-Hill, 1953.
2. Thermodynamics of Solids: Richard A. Swalin, 2nd Ed., Wiley, 1972.

MM202 Process Metallurgy
(3-1-0) 6 credit

General methods of extraction in Pyrometallurgy - drying, calcination, roasting, smelting, carbothermic and metllothermic reduction, refining techniques like liquation, distillation, vacuum distillation etc.
Principles of hydro and electrometallurgy with suitable examples
Leaching techniques, leaching solvents, theory of leaching, bacterial leaching, electrochemical nature of leaching, gold and silver extraction. Pressure leaching, Sherritt - Gorden process for copper, nickel, cobalt ores; solvent extraction, ion exchange.
Electrometallurgy - electrolysis of aqueous solutions and fuses salts, cell design, recovery of metal values by cementation, electro-winning, electro-refining etc.
Principles and important applications. Extraction of metals from oxides - magnesium and titanium extraction, Bayer's process, Hall Héroult process. Extraction of metals from sulphides. Extraction of copper, lead, zinc and nickel.

Reference books:

1. Extraction of Non-ferrous Metals: H.S. Ray, R. Sridhar, K.P. Abraham, Affiliated East-West Press, 2006.
2. Principles of Extractive Metallurgy: Terkel Rosenquist, 2nd Ed., McGraw Hill, 2004.
3. Serynkova; General Metallurgy
4. Theory of Metallurgical Processes: Anton Volsky, 2nd Ed., Mir Publication, 1971.

Text Books:

1. Philipova N.; Theory of Metallurgical Processes, Mir Publication; 1975.
2. Jackson Eric; Hydrometallurgical Extraction; John Wiely & Sons, 1986.
3. Bray J.L.;. Extraction of Non-ferrous Metals; John Wiely & Sons, 1959.
4. Hydrometallurgy: S. Venkatachalam, Narosa Publishing, 1998.

MM204 Phase Transformation and Diffusion
(3-1-0) 8 credit

Introduction to phase transformation: Definition of phase changes, long rage and short range diffusion, diffusion- less changes, classification phase transformations.

Diffusion in solids: Steady state diffusion, non-steady state diffusion, solution of Fick's second law, Grube solution, Matano-Boltzmann solution, diffusivity, diffusion in ionic crystal, diffusion along grain boundary.

Thermodynamics and kinetics of phase transformation: Free energy of elemental crystal and solid solutions, Thermodynamic order of transformation, First order and second order transformation, kinetics of nucleation and growth homogeneous and heterogeneous nucleation, strain energy effect, interface control and diffusion control growth. Overall transformation kinetics Empirical equations, The Johnson-Mehl model and Avrami model.

Liquid-solid transformation: Nucleation, homogeneous and heterogeneous, growth continuous and lateral, interface stability, alloy solidification cellular and dendritic, eutectic, off-eutectic, peritectic solidification, welding, casting and rapid solidification.

Solid state diffusive transformation: Classification, nucleation and growth - homogeneous and heterogeneous mechanism, precipitate growth under different conditions, age hardening, spinodal decomposition, precipitate coarsening, transformation with start range diffusion, moving boundary transformations recrystallization, 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, nucleation and growth, orientation relationships, surface relief, classical and non-classical morphology, effect of alloying elements.

Non-diffusive transformation: Characteristics of transformation, thermodynamics and kinetics, nucleation and growth, morphology, crystallography, stabilization, strengthening mechanisms, nonferrous martensite, shape memory effect/alloys.

Text Books:

1. Solid State Phase transformation: V. Raghavan, Prentice Hall India, 1987.
2. Phase Transformation in Metals and Alloys, D.A. Porter and K. Easterling, 3rd Ed., CRC Press, 2009.

Reference Books:

1. Physical Metallurgy Principles, Robert E. Reed-Hill, Affiliated East-West Press, 2008.
2. Physical Metallurgy, Vijender Singh, Standard Publishers Distributors, 2010.
3. Introduction to Physical Metallurgy, Sidney H. Avner, Tata McGraw-Hill.

MM206 Mechanical Metallurgy
(3-1-0) 8 credit

Elasticity: Introduction, elastic constants and atomistic origin, Mohr circle, stress tensor, strain tensor, stress-strain relations, non-liner elasticity and viscoelasticity, mechanical testing

Plasticity: Elements of plasticity, Stress- strain flow curve, Von Mises and Tresca criterion, Single Crystal Slip, Critically resolved shear stress, Theoretical Shear strength

Dislocations: Types of dislocations, Burgers vectors, slip systems, dislocation motion: jogs, kinks, cross-slip, climb, Peierls stress, stress field of dislocation, forces on dislocations, dislocation multiplication, interaction of dislocations with defects, dislocation dissociation, stacking faults, twins

Strengthening Mechanisms: Work-hardening, yield point phenomena, strain aging, solid solution strengthening, strengthening from fine particles, grain size strengthening and Hall-Petch relationship, heat treatment, case studies

Fracture: Types of fracture, brittle fracture, Griffith‟s criteria, fracture in ductile material, fracture toughness, notch effects, fracture mechanics, environmentally assisted fracture, case studies

Fatigue: Fatigue testing, S/N curve, low cycle fatigue, structural features, surface effects, mechanisms, Case studies

Creep: Creep testing, creep curve, creep mechanisms, types of creep, diffusion creep, dislocation creep, deformation mechanism maps, superplasticity, case studies

Text books:

1. Mechanical Metallurgy: G.E. Dieter, 3rd Ed., McGraw Hill, 2017.

Reference Books:

1. Mechanical Behavior of Materials: Thomas H. Courtney, 2nd Ed., Waveland Press Inc., 2005.
2. Introduction to Dislocations: D. Hull and D.J. Bacon, Butterworth-Heinemann, Elsevier, 2011.
3. Deformation and Fracture Mechanics: R.W. Hertzberg, R.P. Vinci, J.L. Hertzberg, 5th Ed., Wiley, 2012.

MM301 Techniques of Materials Characterization
(2-0-2) 6 credit

X-ray Diffraction: Importance and the need for materials characterization, highlights of various characterization techniques, Crystal structure & polymorphism determination techniques, X-Ray Diffraction (XRD), Bragg's Law, phase identification and analysis by XRD, Atomic scattering factor, Geometrical structure factor. Indexing of Diffraction patterns, Selection rules. Determination of structure and lattice parameters. Stress calculation, different approaches for crystal and grain size measurements XRD

Powder characterization techniques: Particle size analysis techniques based on light scattering, Light scattering, Coulter counter and Sedimentation method for particle size measurements, gas adsorption (BET), Gas pycnometer for density measurement, and compositional analysis of powders by XRF and ICP techniques

Optical and Electron Microscopy: Metallography and microstructures, Principles of optical microscopy -resolution, magnification, depth of focus; electron diffraction, imaging (various contrasts), Principle, construction and operation of Scanning Electron Microscope. Principle, construction and working of Transmission Electron Microscope (TEM). Sample preparation of different materials for SEM and TEM. Electron diffraction, Bright field and dark field images, selected area diffraction, Elemental analysis using Energy dispersive analysis of X-rays and wave length dispersive analysis of X-rays with SEM and TEM, Crystal Identification through Selected area diffraction pattern (SADP)

Thermal analysis: Instrumentation and principles of techniques used for thermal analysis (DSC, DTA, DMA, TG, DTG, EGD, RMA, DPC, DETA, TMA) and micro-thermal analysis, combined method of thermal analysis and their applications in materials characterization.

Test Books:

1. Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Yang Leng; 2nd Ed., Wiley, 2013.
2. Scanning Electron Microscopy and X-Ray Microanalysis: Joseph Goldstein, Eric Lifshin, Charles E. Lyman, David C. Joy and Patrick Echlin, 3rd Ed., Springer, 2003.
3. Physical Methods for Materials Characterization, P.E.J. Flewitt, R.K. Wild, Institute of Physics Publishing Ltd., 1994.
4. Thermal characterization of polymeric materials, Edith A. Turi (ed.), Academic Press, 1996.

Reference Books:

1. Elements of X-Ray Diffraction: B.D. Cullity and S.R. Stock, 3rd Ed., Pearson, 2001.
2. Transmission Electron Microscopy: A Textbook for Materials Science: David B. Williams and C. Barry Carter, Springer, 2009.
3. Structure of Materials: An Introduction to Crystallography, Diffraction and Symmetry, Marc De Graef, Michael E. McHenry; 2nd Ed., Cambridge University Press, 2012.
4. Crystal Structure Determination: Werner Massa; 2nd Ed., Springer, 2010.
5. Crystal Structure Analysis: Principles and Practice, Peter Main, William Clegg (ed.), Alexander J. Blake, Robert O. Gould, Vol. 6, Oxford Science Publication, 2001.

MM303 Iron and Steel making
(3-0-0) 6 credit

I. Ferrous Extractive Metallurgy I (Iron Making):

Brief details of coke making, beneficiation of iron ores and metallurgical coals, sizing of iron ores, agglomeration of iron ore fines, sintering and pelletising. Importance of sizing & beneficiation of raw materials, evaluation of properties of blast furnace burden materials and application to blast furnace performance, functions/role of coke in blast furnace.

Chemical processes in blast furnace, reactions in Tuyere, hearth and bosh zone. Reduction and coke gasification, reactions in stack and exit gases. Thermodynamics of blast furnace process requirement in blast furnace, critical hearth temperature, temperature. Profile in the furnace. Free energy and equilibrium consideration in blast furnace. A brief discussion on blast furnace stoichiometry and enthalpy balance. Basic idea of blast furnace aerodynamics.

Blast furnace plant and operation-modern blast furnace, plant layout, details of construction of blast furnace and its main accessories; gas cleaning system, hot blast generation. Blast furnace refractories and blast furnace cooling system. Blowing in, blowing out and banking of blast furnace, role of burden charging and distribution in iron extraction. Irregularities in blast furnace operation and their remedies. Blast furnace products. Their quality control and disposal, coke rate and fuel efficiency of B.F. operations.

Modern trends in blast furnace practice-production of super flux sinter, pellets, super flux and cold bonded pellets. Auxiliary fuel injection in the blast furnace. High temperature blast, humidified and oxy-generated blast, detailed discussion of high top pressure, desulphurization of hot metal & decrepitation.

Alternate route for iron making: charcoal blast furnace, low shaft furnace and electro thermal processes of iron making. Direct reduction processes, their classification, choice of DR process. Applicability and present status of technology in India.

Production of ferro-alloy, ferro alloy industry in India. Beneficiation of indigenous raw materials for ferro alloy industry. Production of various ferro-alloys Fe-Mn, Fe-V, Fe-Cr etc. uses of ferro-alloys in iron and steel industry.

Text Books:

1. The manufacture of Iron: G.R. Bashforth, Chapman and Hall, 1964.
2. An Introduction to Modern Iron Making: R.H. Tupkary and V.R. Tupkary, Khanna Publishers, 2004.
3. Principles of Blast Furnace iron making: A.K. Biswas, Cootha Publishers, 1981.
4. Production of ferro-alloys: M.A. Riss and Lipnitzky
5. Steel Making: A.K. Chakrabarti, 3rd Ed., Prentice-Hall of India, 2007.

Reference Books:

1. The Making Shaping and Treating of steel: Vol., 11th Ed., The AISE Steel Foundation, 1998.

2. Physical Chemistry of Iron and Steel Manufacture: C. Bodsworth and H.B. Bell, 2nd Ed., Prentice Hall Press, 1978.
3. The reduction of Iron Ores: L.V. Bogdandy and H.-J. Engell, Springer, 1971.
4. The theory and practice – Blast Furnace ltd. – J.H. Siressearger

II. Ferrous Extractive Metallurgy II (Steel Making and Continuous casting):

World and Indian steel scenario, detailed layout of steel making plant, Intergrated Vs mini steel plant, raw materials and refractories for steel making, external treatment of hot metal, brief idea about historical steel making – Bessemer, open hearth and modified open hearth steel making.

Thermodynamics and kinetics of steel making reactions, laws of thermodynamics and application to the treatment of ferrous melts and slags, reactions of carbon, silicon, manganese, phosphorous and Sulphur, steel furnace slags, properties, and slag control, slag theories: Molecular & ionic theories, interpretation of the above reactions in terms of ionic theory of slag, deoxidation practice, refining of ferrous – melt under oxygen jet; mechanism of refining and kinetics.

Basic oxygen furnace (BOF) STEEL MAKING, top and bottom down blown oxygen steel making furnaces, thermal balance in oxygen converter, process control in L.D. converter, some characteristics of L.D. blow viz. Emulsion formation, slopping, lance height for dephosphorisation & decarbunisation, treatment of high phosphorous iron in modified L. D. processes.

Mechanism of solidification & ingot casting, Types of steel- killed, semi-killed & rimmed steel, ingot structure and defects.

Evolution of continuous casting of steel, different types of caster, continuous casting theory and practice, teeming practice and recent advances- EMS, mould level controller, near net casting

Electric arc furnace -advantages, charging, melting & refining practices for plain carbon & alloy steel, use of DRI in arc furnace & it's effect on performance.

Brief introduction of secondary advance and emerging technologies for steelmaking, steelmaking challenges

Text Books:

1. Steel Making Technology: V.A. Kudrin, Mir publishers, 1985.
2. An Introduction to Modern Iron Making: R.H. Tupkary and V.R. Tupkary, Khanna Publishers, 2004.
3. Physical Chemistry of Iron and Steel Manufacture: C. Bodsworth and H.B. Bell, 2nd Ed., Prentice Hall Press, 1978.

Reference Books:

1. Converter and Open-hearth Steel Manufacture: G. Oiks, Mir Publishers, 1977.
2. Oxygen steel making for steel Makers: A. Jackson, George Newries Ltd., London.

3. Electric furnace steel Making: Vol. I and II, Metallurgical Society of AIME, Interscience Publishers, 1962.
4. The Making, shaping and Treating of steel: H.E. McGannon, J.M. Camp, and C.B. Francis, United States Steel Co., 1951.
5. Blast Furnace Theory – l Practice Strauff

III. Secondary & Special Steel Making:

The concept of cleanliness of steels, non-metallic inclusions, dissolved gases. Tramp & residual elements in steels and their effect on steel properties. Objectives and techniques adopted in secondary steelmaking, development of secondary steelmaking and their importance under Indian conditions, sources of inclusions, sulphur, phosphorus and gases in steel, role of slag and powders in inclusion control, thermodynamic and kinetic consideration of desulphurization, dephosphorisation, decarburization and degassing of steel melts, modifications of inclusion morphologies, secondary steelmaking technologies, inert gas purging, Vacuum degassing – RH/DH, OD, VAD etc. Ladle furnace, powder injection system –powder dispenser, lance, etc.; physicochemical and fluid dynamic aspects of powder injection and stirring processes, role of slag and powders in inclusion control, desulphurization, cored wire feeding, production of ultra low C, S, P and inclusion free steels, powder injection system, addition of CaSi for shape inclusion. Production of stainless steels through VOD, AOD & CLU processes. Production of ultraclean steel through post solidification treatments (VAR, ESR processes), Refractories used in secondary steelmaking furnaces, their properties and selection criteria. A critical appraisal of hybrid blowing process, UHP electric arc and induction furnaces with respect to raw materials, energy consumption, productivity and product quality; Special grade steels. Recent advance in secondary steel making.

Text Books:

1. Principles of Secondary Processing and Casting of Liquid Steels: Ahindra Ghosh, South Asia Books, 1990.
2. Secondary Steel Making: Principles & Applications: Ahindra Ghosh, CRC Press, 2000.
3. The Making, Shaping and Treating of Steel: (Steelmaking Volume), R.J. Fruehan (ed.), The AISE Steel Foundation, 2004.

MM305 Engineering Polymers (3-0-0) 6 credit

Structure property relationship in polymers. Synthesis, properties & applications of thermoplastic engineering polymers: polyamides, modified polyamides, polyesters – PET, PBT, polyacetals, PC and LCP's. Synthesis, properties & applications of high temperature resistance thermoplastic engineering polymers: PTFE, PCTFE, PVDF, PPO, PPS, polysulphones, PEEK, Polyimides, Polybenzimidazoles, aromatic polyamides. Thermoset engineering polymers. Blends of engineering polymers. Additives and compounding of engineering polymers: Fillers, antioxidants, stabilizers, lubricants, plasticizers, toughening agents, colorants, fire retardants, coupling agents, blowing agents, UV stabilizer, antistatic agents, anti blocking agents, slip & antislip agents, processing aids, mold releasing agents. Processing of engineering polymers. Testing and characterization of engineering polymers.

Text books:

1. Specialty Plastics: R.W. Dyson, 2nd Ed., Blackie Academic & Professional, 1988.
2. Engineering Plastics Handbook: James M. Margolis, McGraw Hill, 2006.
3. Engineered Materials Handbook (Vol. 2): Engineering Plastics, ASM International 1988.
4. Modern Plastics Handbook: C.A. Harper, McGraw Hill, 2000.

References Books:

1. Introduction to Physical Polymer Science: L.H. Sperling, 3rd Ed., John Wiley & Sons, 2001.
2. An Introduction to Mechanical Properties of Solid Polymers: I.M. Ward, J. Sweeney, 2nd Ed., John Wiley & Sons, 2004.
3. Encyclopedia of Polymer Science and Technology: John Wiley & Sons, Inc., 2002
4. Industrial Polymers, Specialty Polymers, and Their Applications: Manas Chanda, Salil K. Roy, CRC Press, 2008.
5. Plastic Materials: J.A. Brydson, 6th Ed., Elsevier, 1995.

MM307 Ceramics and Glass (3-0-0) 6 credit

Introduction to Ceramic Science: Ceramic crystal structures, defects, diffusion and transport.

Ceramic phase diagrams: binary systems: complete solid solubility, eutectic diagrams with partials solid solubility and no intermediate compounds, partial solid solubility with formation of intermediate compounds; Ternary systems.

Basics of Ceramic Processing: Synthesis and characterization of ceramic powders. Colloidal phenomena, rheology of suspensions, ceramic forming methods, and drying. High temperature ceramic reactions, liquid and solid-state sintering, grain growth, microstructure development. Processing/microstructure/property relationships, controlling kinetics and thermodynamic factors. Thermal, electronic, optical and magnetic properties of ceramics.

Glass Engineering: Nature of the glassy state, Glass formation and the glass transition (Structural, Thermodynamic, and Kinetic effects on T_g, Kinetic and thermodynamic criteria for glass formation, use of Na_2O-SiO_2 and Na_2O-CaO- SiO_2 phase diagrams in glass manufacture, types of glasses and their chemical compositions, Physical properties of glasses, density, refractive index, thermal expansion and thermal stresses, thermal endurance of glass, toughening of glasses, strength and fracture behaviour of glass and its articles, effect of temperature and composition on the physical properties of glasses, durability and corrosion behavior,
Glass making raw materials, addition of cullet to the batch, reactions amongst the constituents of glass, thermal currents and flow pattern in the glass tank furnace, Defects in glass, bubbles and seeds, cords, stresses and colour inhomogeneity and their remedies, annealing of glasses
Glass ceramics; Nucleation and crystal growth in glasses, nucleation through micro miscibility, nucleating agents, properties and applications of glass-ceramics
Nature of the glassy state, Glass formation and the glass transition (Structural, Thermodynamic, and Kinetic effects on T_g, durability and corrosion behavior

Text Books:

1. Introduction to Ceramics: W.D. Kingery, H.K. Bowen, D.R. Uhlmann, 2nd Ed., Wiley, 1976.
2. Ceramic Processing and Sintering: M.N. Rahaman, Marcel Dekker, 1995
3. Ceramic Materials: Science and Engineering: C. Barry Carter, M. Norton, Springer, 2nd Ed., 2013.
4. Glass Science and Technology, D.R. Uhlmann, N.J. Kredl (ed), Vol. 1&2, Academic Press, 1990.
5. Chemistry of Glasses: Amal Paul, Chapman Hall, 1990.

Reference Books:

1. Fundamentals of Ceramics: M.W. Barsoum, McGraw Hill, 1997.
2. Introduction to Ceramics, 2nd Ed., W. David Kingery, H.K. Bowen, Donald R. Uhlmann, Wiley, 1976.
3. Hand book of Glass Manufacture: F.V. Tooley, Vol 1&2, Ashlee Pub. Co, 1984.
4. Introduction to Fine Ceramics: N. Ichinose, John Wiley & Sons Ltd, 1987.
5. A Concise Introduction to Ceramics: G.C. Phillips, VNR Publications, 1991.

MM302 Thermomechanical Processing of Metallic materials
(3-1-0) 8 credit

MM304 Corrosion and Degradation of Metallic Materials
(3-0-0) 6 credit

MM306 Functional Materials
(3-0-0) 6 credit

Free Electron Theory of Metals: Band theory, classification of materials based on band theory viz. conductors, conductors-classification and properties, factors affecting conductivity / resistivity of conductors, various conducting materials: composition, properties and applications.

Resistors: Materials used for heating elements viz. nichrome, kanthal, silicon carbide and molybdenum, their composition, properties and applications
Semiconductors and insulators. Intrinsic and extrinsic semi-conductors, II-VI, III-V and IV-IV group semiconductors, production of single crystal of semiconducting materials, effects of doping.

Ferro-electric, Piezo-electric and Dielectric-phenomena: Principle, materials and their applications; Ferroelectric ceramic materials, Basic Ceramic Dielectric formulation for capacitors. Multi-Layer Capacitors, Relaxor ferroelectrics, NTC and PTC thermistors.

Magnetism: Sources of magnetism-orbital and spin motion of electron, types of magnetism: Dia-, para-, ferro-, ferri- and antiferro-magnetism, domain theory, types of magnetic materials: soft and hard magnetic materials and ferrites, Effect of composition, processing and microstructure on the magnetic properties. Processing and applications.

Super conductivity: BCS theory, Meissner effect, materials, Type I and II superconductors
Ionic conductors and their applications in fuel cells and batteries.

Text Books:

1. Introduction to the Electronic Properties of Materials: David C. Jiles, 2nd Ed., CRC Press, 2001.
2. Electronic Materials: Science and Technology: Shyam P. Murarka, Martin C. Peckerar, Academic Press, 1989.
3. Electronic Materials Science: Eugene A. Irene, Wiley, 2005.
4. An Introduction to Electronic Materials for Engineers: Zhengwei Li, Nigel M. Sammes, 2nd Ed., World Scientific Publishing Company Pvt. Ltd., 2011.

Reference Books:

1. Electronic Materials and Devices: David K. Ferry, Jonathan P. Bird, Wiley, 2001.
2. Introduction to Magnetism and Magnetic Materials: David Jiles, 3rd Ed., CRC Press, 2015.

3. Electroceramics: Materials, Properties, Applications: A.J. Moulson, J.M. Herbert, Wiley, 2003.
4. Reliability and Failure of Electronic Materials and Devices: Milton Ohring, 2nd Ed., Academic Press, Elsevier, 2014.

MM401 Environmental Sustainability and Industrial Safety (3-0-0) 6 credit

Concept of sustainable development–environmental issues and crisis related to mining, metallurgy, ceramics and polymers. Operational guidelines, resource protection and management for aforementioned materials. Identification, characterization and classification of industrial wastes from metals, ceramics, plastics and rubber based industries. Handling, transportation and storage. Disposal - processing technique and equipment, regulatory process. Recovery, recycle and reuse. Impact of beneficiation process.

Industrial safety – concept of safety, safety by design, safety inspection, accident prevention, Heinrich theory of accident prevention, cost of accident, safety performance monitoring. Fire, chemical and acid safety - detection system, prevention and protection. Health hazards - hazard identification and risk assessment - FMEA and HAZOP, common industrial hazards and remedies, engineering controls and personal protective controls, QRA. Occupation diseases – silicosis, asbestosis, pneumoconiosis, aluminosis, gas poisoning - temporary and cumulative effects. Game theory approach to deal pollution.

Information on safety protocol and regulations in relevant industries. Case studies involving mining industry, iron and steel industry, blast furnace, cold-forming and hot-working of metals, foundry and furnaces, handling of powders and ceramic raw materials. Health and regulatory issues with raw materials for cement, glass, refractory and sanitary-ware. Awareness and prevention for related risks and diseases.

Text Books:

1. M.H. Fulekar, B. Pathak, R.K. Kale, Environment and sustainable development, Springer, 2014.
2. D. Petersen, Techniques for safety management - A systems approach, ASSE 1998.

Reference books:

1. S.P. Mahajan, Pollution control in process industries, Tata McGraw Hill Publishing Company, New Delhi, 1993.
2. J. Nagaraj, Industrial safety and pollution control handbook, National safety council, 1992.
3. Michael Karmis, Mine Health and Safety Management, SME, Littleton Co., 2001.
4. N.V. Krishnan, Safety in Industry, Jaico Publishing House, 1996, Mine Health and Safety Management SME, Littleton, CO, USA, 2001.