Revised B.Tech. Curriculum: Materials Science and Metallurgical Engineering
Updated on 27 July, 2020

Summary of Credits distribution: MSME

Semester	Soft Skills (SS)	Basic Sciences (BS)	Basic Engineering (BE)	LA/CA	Free Electives (FE)	Departmental Credits (DC+DE)	Total credits
1	2	7	3	0	0	3	**15**
2	1	6	6	0	0	2	**15**
3	0	0	5	0	0	13	**18**
4	0	1	0	0	0	17	**18**
5	0	0	0	2	3	13	**18**
6	0	0	0	2	4	10	**16**
7	1	0	0	2	0	13	**16**
8	0	0	0	3	4	5	**12**
Total	**4**	**14**	**14**	**9**	**11**	**76**	**128**
%	3	11	11	7	9	59	100

Note:

- Total Number of Credits = 128
- *DC includes 6 credits for the department core electives
- Number of 3-credit courses out of all (DC+DE) courses = 59% (decimals are rounded off)
- Majority of 3-credit Departmental courses have a 1-credit laboratory component included (Experimental + Computational)
- Following courses will be part of Soft Skills:
    i. English Communication (SS) – 2 credits
    ii. Personality Development (SS) - 1 credit
    iii. Entrepreneurship (SS) – 1 credit

MSME: New UG Curriculum and Detailed Syllabus

Code*	Course Name	Cre dits	Type of course
	SEM-I		**15**
PHxxxx	Physics	2	BS
CYxxxx	Chemistry	2	BS
MA1110	Mathematics (Calculus-I)	1	BS
MA1220	Mathematics (Calculus-II)	1	BS
LAxxxx	English Communication	2	SS
ID1063	Introduction to Programming	3	BE
MS1210	Introduction to Materials Science and Engineering	2	DC
MS1211	Materials Tinkering Laboratory	1	DC
EP1118	Mathematics for Physics	1	BS
	SEM-II		**15**
PHxxxx	Physics Laboratory	2	BS
CY1031	Chemistry Laboratory	2	BS
ID1054	Digital Fabrication	2	BE
MS1220	Structure of Materials	2	DC
MS1230	Physics of Solids – I	3	BE
MAxxxx	Mathematics – II (Linear Algebra + Differential Equations)	2	BS
IDxxxx	Introduction to AI/ML	1	BE
SSxxxx	SS	1	SS
	SEM-III		**18**
MS2210	X-ray Diffraction in Materials Science	3	DC
ID1041	Engineering Drawing	2	BE
MS2220	Fundamentals of Physical Metallurgy	3	DC
MS2230	Physics of Solids – II	3	DC
MS2240	Thermodynamics of Materials	3	DC
MS2310	Mechanics of Materials	3	BE
MS2211	Metallography Laboratory	1	DC
	SEM-IV		**18**
MS2250	Imaging in Materials Science	3	DC
MS2260	Materials Synthesis	3	DC
MS2270	Mechanical Behaviour of Materials	3	DC
MS2280	Transport Phenomena in Materials Processing	2	DC
MS2290	Diffusion in Solids	3	DC
MS2300	Computational Methods in Materials Science	3	DC
BTxxxx	Introduction to Life Science	1	BS
	SEM-V		**18**
MS3310	Phase Transformations	3	DC
MS3320	Soft Materials	3	DC
MS3330	Fundamentals of Extractive Metallurgy	2	DC
MS3311	Functional Materials Processing Laboratory	2	DC
MS3321	Mechanical Behavior Laboratory	1	DC
xxxxx	Free Electives	3	FE
MS3340	Spectroscopic Techniques in Materials Science	2	DC
LA/CA	LA/CA	2	LA/CA
	SEM-VI		**16**
XXXX	Free Electives	4	FE
	Option 1: MS3315: Internship (only for CGPA >= 8) Option 2. MS3035 Departmental Project (open to all) Option 3: Department Electives (open to all)	6	DE

MS3350	Iron and Steel Making	3	DC
MS3280	Powder Metallurgy Processing	1	DC
	LA/CA	2	LA/CA
	SEM-VII		**16**
MS4310	Welding and Additive Manufacturing	3	DC
MS4320	Corrosion and Electrochemistry	2	DC
MS4330	Metal Forming and Thermomechanical Processing	3	DC
MS4340	Properties of Materials	3	DC
MS4350	Metal Casting	2	DC
	SS	1	SS
	LA/CA	2	LA/CA
	SEM-VIII		**12**
	Departmental Elective	3	DE
MS4311	Metal Forming Laboratory	2	DC
	LA/CA	3	LA/CA
	Free Electives	4	FE

Syllabus (Course contents) for the Proposed New Courses and Modified Courses.

Course name: **Introduction to Materials Science and Engineering**
Course Code: MS1210
Credits: 2

Syllabus: Materials classes, structure and basic properties of different materials classes, materials usage in modern technology; challenges and opportunities for future developments

References:

1. Callister, W. D. and D. G. Rethwisch (2007). Materials Science and Engineering: An Introduction, Wiley.

Course name: **Materials Tinkering Laboratory**
Course Code: MS1211
Credits: 1

Syllabus:

This laboratory course is designed to introduce the students to the wonderful world of Materials Science and Metallurgical Engineering. It aims to make an indelible impression upon the minds of the students of the importance of materials in the contemporary world. The course is a subtle attempt to inspire students for an in-depth study of materials in the years to come. In a major part of this course, students will perform some “magic experiments” to physically experience how materials behave under various external stimuli and to discover how a little tinkering with the structure of materials through thoughtful processing can bring about desired changes in the properties of materials. Further, the course will include some original demonstrations to strikingly illustrate the students how materials scientists and engineers literally play with materials and develop useful products. All the experiments and demonstrations conducted in this course will be carefully chosen to capture the imagination of the students. For the purpose of preserving the “surprise factor” of the course, the course contents may be deliberately changed from batch to batch. All the faculty members of the Department of Materials Science and Metallurgical Engineering will actively contribute to this laboratory course.

References: web

Course name: **Structure of Materials**
Course Code: MS1220
Credits: 2

Syllabus:

- Introduction to material classes, Atoms and its constituents, Electronic structure, Periodic Table, Types of bonding

- Basics of Crystallography (lattices and structures, planes and directions, Stereographic projection)

- Symmetry operations, Point groups and Space groups

- Types of close packing - hcp and ccp, packing efficiency, ionic radius ratios; structure types with examples

- Thinking in the Reciprocal Space

- Mathematical formulations and introduction to solving crystal structures using diffraction techniques

References:

1) C. Hammond - The basics of crystallography and diffraction

2) Marc de Graef - Structure of Materials: An introduction to Crystallography, Diffraction and Symmetry

3) Fundamentals of Materials Science by Eric J. Mittemeijer

Course name: Physics of Solids – I
Course Code: MS1230
Credits: 3

Syllabus:

Introduction to black body radiation – Postulates of quantum mechanics – wave functions – operators – eigen value – uncertainty principle – physics of quantization – time independent schrodinger equation – particle in a box – illustration of bound state problems in solids – Introduction to perturbation theory - potential barrier – tunneling in nano scale devices – linear harmonic oscillators-

Hydrogen atom - Atomic structure - Chemical bonding - Types of bonds – Theory of Metals – Free electron theory of metals – Hall effect - Fermi level – Fermi surface – density of states - Crystal structure – Bravais lattice – Atomic stacking – Reciprocal lattice – Brillouin zone -Nearly Free electron model – Band formation – effective mass - Material classification

References:

1. Introduction to solid state physics - Charles Kittel, John Wiley & sons
2. Electronic Properties of Materials - E. Hummel
3. Physical Chemistry - J.D Lee
4. Introduction to Quantum Mechanics – Ajay Ghatak
5. Applied Quantum Mechanics – Walter Harrison
6. Quantum Chemistry – McQuarrie
7. Introduction to quantum mechanics - D. Griffiths

Course name: **X-ray Diffraction in Materials Science**
Course Code: MS2210
Credits: 3

Syllabus:

Diffraction: Fundamentals of Diffraction, X-rays - production - white and monochromatic X-rays, Laue diffraction - Reciprocal lattice - Ewald sphere construction - Bragg's law - Structure Factor - Various Geometries in X-ray diffraction -indexing diffraction pattern, calculation of lattice parameters - Determination of strain - particle size - Introduction to planar diffraction - Reciprocal space mapping - Diffraction from thin films and low dimensional structures

Lab component: Introduction to structural refinement using powder diffraction patterns- strain- particle size calculation

Reference:

1. Elements of X-ray Crystallography - L.V. Azaroff
2. Elements of X-ray Diffraction - B.D. Cullity
3. The basics of crystallography and diffraction - C. Hammond

Course name: **Fundamentals of Physical Metallurgy**
Course Code: MS2220
Credits: 3

Syllabus: General introduction, review of structure of crystalline solids, imperfections in solids, strengthening mechanisms, phase and phase diagrams, Fe-C phase diagram, binary and ternary diagrams, concepts in diffusion, phase transformations, heat treatments and effect on mechanical properties

Lab component: Microstructures of steels; eutectoid transformation in steels, martensitic and non-equilibrium transformation in steels.

Reference:

1. Reed-Hill, R. E. (1972). Physical Metallurgy Principles, John Wiley & Sons, Incorporated.
2. Avner, S. H. (1974). Introduction to Physical Metallurgy, McGraw-Hill.
3. Raghavan, V. (2006). Physical Metallurgy: Principles and Practice, PHI Learning.
4. Haasen, P. and B. L. Mordike (1996). Physical Metallurgy, Cambridge University Press.

Course name: **Physics of Solids – II**
Course Code: MS2230
Credits: 3

Syllabus:

Semiconductor crystals - Band formation in semiconductors – Direct & Indirect Band gap semiconductors – Concept of holes – carrier concentration – Effective mass – heavy and light mass carriers – Doping in semiconductors - Band bending – Heavily doped semiconductors – Excitons – metal-semiconductor contacts - pn diodes - Lattice – optical and acoustic phonons – thermal conductivity – Theory of specific heat capacity in solids

Lab component:

1. Measurement of carrier density in semiconductors (Hall effect)
2. pn-diode characteristics
3. Electrical contacts - Ohmic and Shottkey contacts

Reference:

1. Introduction to solid state physics - Charles Kittel, John Wiley & sons

2. Physics of Semiconductor Devices - S.M.Sze
3. Solid State Physics – A.J Dekker

Course name: **Thermodynamics of Materials**
Course Code: MS2240
Credits: 3

Syllabus:

Thermodynamic systems and properties; Laws of thermodynamics: enthalpy, heat capacity, entropy, absolute zero; Statistical interpretation of entropy; Thermodynamic functions: Helmholtz free energy, Gibbs free energy;

Maxwell relations; Equilibrium and stability in thermodynamic systems;

Phase stability in unary heterogeneous systems – Clausius-Clapeyron equation;

Thermodynamics of solutions: partial molal quantities, chemical potential, activity, Henry's law, Raoult's law, ideal and nonideal solutions, excess thermodynamic quantities;

Quasichemical models for solutions – ideal, regular and nonregular solutions, sublattice models for order-disorder transitions;

Equilibrium in multicomponent heterogeneous systems – Gibbs phase rule, invariant reactions, binary phase diagrams, ternary phase diagrams, Lever rule for tie lines and tie triangles;

Free-energy vs. composition (G-X) diagrams in binary systems; reference states; common tangent construction, two-phase and three-phase equilibria; intermediate phases; metastable phase diagrams; calculation of phase diagrams from thermodynamic data;

Basics of computer calculation of phase diagrams – introduction to CALPHAD;

Multiphase reacting systems – Richardson-Ellingham diagrams for oxidation; Pourbaix diagrams;

Thermodynamics of surfaces – surface excess properties; surface tension and surface energy; capillary effects on phase diagrams; anisotropy of surface energies – equilibrium shapes; equilibrium at triple lines – Young's equation; Thermodynamics of defects – vacancies and interstitials.

(Includes demonstrations and projects with ThermoCalc, experimental measurement of heats of transformation, heat capacity, determination of activity-composition diagrams for simple solutions, experimental determination of phase diagram in binary eutectic systems)

Reference:

1. "Thermodynamics of Solids", Richard A. Swalin, Wiley VCH (Second Edition, 1973)
2. "Thermodynamics in Materials Science", Robert DeHoff, CRC Press (Second Edition, 2006)

Course name: Mechanics of Materials
Course Code: MS2310
Credits: 3

Syllabus:

- **Basic principles of mechanics:** Concepts of force and moment of force, conditions of equilibrium, friction
- **Mechanics of deformable bodies:** Uniaxial loading and deformation, elastic energy - Castigliano's theorems

- **Analysis of structures (trusses, beams, columns, shafts)**: axial force, shear force, bending moment, twisting moment; Analysis of distributed and concentrated loads - differential equilibrium relationship; concentrated loads and singularity;

- **Concepts of stress and strain**: stress at a point, plane stress, principal stress and Mohr's circle of stress in 2D, state of stress in 3D, displacement and strain at a point, plane strain, principal strain, generalized elastic stress-strain relations (tensor forms), tensile test and stress-strain curves (engineering and true), stress concentration, thermal strain, stress and strain invariants, failure criteria

- **Concepts of plasticity:** flow curve, ideal plastic flow, yield surface and hardening theories, rate-dependent plasticity

- **Concepts of fracture:** modes of fracture, Griffith's theory - strain energy release rate and stress intensity factor

Books/References:

- Archer, Cook, Crandall, "Introduction to mechanics of solids", Second edition, McGraw-Hill

- Dieter, "Mechanical Metallurgy", 3rd edition, McGraw-Hill

- Ashby and Jones, "Engineering Materials", Butterworth-Heinemann, 2012

Course name: **Imaging in Materials Science**
Course Code: MS2250
Credits: 3

Syllabus:

Introduction to Imaging techniques for materials characterisation:

Optical Microscopy:

- Introduction to wave optics- Amplitude, polarisation and phase of light - image formation in microscope - resolution - optical microscopic techniques - application for imaging isotropic and anisotropic (ex. liquid crystals) samples

Surface Probe Microscopic Techniques:

- Scanning Tunneling Microscopy, Atomic Force Microscopy, Magnetic Force Microscopy, Scanning Kelvin Probe and Scanning Electrochemical Microscopy

Scanning and Transmission Electron Microscopy:

- Introduction to EM, the necessity of characterisation using SEM and TEM techniques. SEM and TEM imaging modes and brief introduction to spectroscopic analysis in electron microscopes.

Specimen Preparation techniques for all microscopic investigations

Lab component:

1. Familiarizing with the optical microscope and different possible modes
2. Measuring the resolution of the microscope.
3. Building own microscope (eg. paper microscope, etc)

Reference:

1. Transmission Electron Microscopy: A Textbook for Materials Science, Second Edition. David B. Williams and C. Barry Carter. Springer, New York, 2009.

2. Goodhew, Peter J., and John Humphreys. Electron microscopy and analysis. CRC Press, 2000.

3. Physical Principles of Electron Microscopy by Ray F. Egerton.

4. Optics - E. Hecht

5. Fundamentals of photonics - B.E.A. Saleh and M.C. Teich 3

Course name: **Materials Synthesis**
Course Code: MS2260
Credits: 3

Syllabus:

Introduction to chemical synthesis of ceramic materials, Basics of nucleation and growth processes in solution based synthesis. Solution based approaches- co-precipitation, sol-gel, hydrothermal, sonochemical.

Solid State route- solid state reaction basics, combustion synthesis, Basics of sintering process- chemical reaction and phase transformation kinetics in solids.

Vapour phase synthesis –PVD, CVD, molecular beam epitaxy etc. Solid substrate- vapour interactions in CVD, PVD. Effect of vapor deposition conditions on growth and morphology of ceramic films.

Synthetic approaches, properties and applications of 0D, 1D, 2D and 3D (porous) nanostructured materials

Reference:

Inorganic Materials Synthesis and Fabrication; John N. Lalena, David A. Cleary, Everett Carpenter – Wiley 2008

Chemical approaches to the synthesis of inorganic materials, C. N. R. Rao, Wiley, 1994

Course name: **Mechanical Behaviour of Materials**
Course Code: MS2270
Credits: 3

Syllabus:

Introduction to mechanical behavior of materials.

Elastic and plastic deformation (atomistic mechanisms), modulus, slip in perfect crystal, CRSS, Dislocations and their role in plastic deformation, twinning, deformation in single crystals.

More on dislocations: Orowan's equation, stress field around an edge and screw dislocations, forces acting on dislocations, strain energy, dislocations in difference crystal structures (FCC, BCC and HCP), Thompson tetrahedron, dislocation sources, dislocation interactions, barriers to dislocation motion.

Strengthening mechanisms

Uniaxial testing: Quasi-static strain rate (recap), strain energy, instability in tension, effect of temperature and strain rate on flow properties.

Hardness: different types of hardness testing methods, relation between hardness and flow stress.

Fracture and fracture mechanics: Types of fracture, metallographic aspects of fracture, DBTT, Impact test, embrittlement, fractography, high temperature fracture, Theoretical cohesive strength, Griffith theory of brittle fracture (recap), Stress concentration, different fracture modes, strain energy release rate, stress intensity factor, plane stress fracture toughness, Factors affecting fracture toughness, crack opening displacement, J integral.

Fatigue: Stress cycles, fatigue test, S-N curve, cycle stress strain curve, low cycle and high cycle fatigue, effect of mean stress on fatigue, structural features of fatigue, Fatigue crack propagation, factors affecting fatigue: surface condition and metallurgical variables,.

Creep and fracture at high temperature: High temperature deformation-importance, creep and stress rupture tests, creep curve, different stages of creep curve, Sherby-Dorn equation, mechanisms of creep deformation, superplasticity, prediction of long time properties, fracture at elevated temperature, design of creep resistant alloys.

Reference:

1. Mechanical Metallurgy, George E. Dieter, 3rd edition, McGraw-Hill,
2. Mechanical Behavior of Materials, Thomas H. Courtney, MeGraw-Hill. 1990
3. Mechanical Metallurgy, Principles and Applications, Marc Andre Meyers and Krishan Kumar Chawla.

Course name: **Transport Phenomena in Materials Processing**
Course Code: MS2280
Credits: 2

Syllabus:

Generalized conservation principles for momentum, heat, and mass transfer - coupling between conservation and constitutive relations; Mathematical basis of transport phenomena: basics of vector and tensor calculus; Control volume method and concepts of shell balance;

Dimensional analysis in transport processes - introducing key dimensionless parameters in momentum, heat, and mass transfer;

Fluid Mechanics: Newtonian and non-Newtonian fluids; Navier Stokes equations for fluid flow -simplifications for one-dimensional flow; Exact solutions in simple geometries; Boundary layer description of flow near surfaces; laminar flow and turbulence;

Heat and Mass Transfer: basics of heat transfer - conduction, convection and radiation; basics of mass transfer - diffusion in fluids and solids; control volume methods for transport of heat and species - steady and transient states; Heat and mass transfer problems for simple geometries;

Coupling between momentum, heat and mass transfer - empirical correlations, dimensional analysis;

Applications of fluid flow, heat and mass transfer in materials processing - crystal growth, fiber drawing, casting, film growth during chemical vapor deposition, doping in semiconductors, bulk and surface heat treatment

Reference:

1. Transport phenomena in materials processing : D.R. Poirier and G.H. Geiger, TMS, 2of 010 (reprint)
2. Fundamentals of Momentum, Heat and Mass Transfer, 4th Edition: James R. Welty, Charles E. Wicks, Robert E. Wilson and Gregory Rorrer; John Wiley & Sons
3. Transport phenomena, 2nd Edition: R. Byron Bird, Warren E. Stewart and Edwin N Lightfoot; John Wiley and Sons

Course name: **Diffusion in Solids**
Course Code: MS2290
Credits: 3

Syllabus:

Continuum theory of diffusion - *Fick's law, solutions of diffusion equation*, Random walk theory and atomic jump processes, Diffusion mechanisms and correlation effects, Temperature and pressure effects on diffusion, Interdiffusion and Kirkendall effect, Experimental techniques to measure diffusion - *Radiotracer analysis, SIMS,* Impurity diffusion - interstitial and substitutional solutes, Diffusion in binary intermetallics, Diffusion in multi-phase binary alloys, High diffusivity paths - Grain boundary and dislocation pipe diffusion.

The course will include a lab component, which will include:

1. Preparing interdiffusion couples of Ni/Al and observing phase growth behaviour and simple kinetic calculations at the interface.
2. Introduction to DICTRA and simple simulations for Ni/Al system.

Reference:

1. Mehrer, H. (2007). *Diffusion in solids: fundamentals, methods, materials, diffusion-controlled processes* (Vol. 155). Springer Science & Business Media.
2. Paul, Aloke, Tomi Laurila, Vesa Vuorinen, and Sergiy V. Divinski. *Thermodynamics, diffusion and the Kirkendall effect in solids*. Cham: Springer International Publishing, 2014 3

Course name: **Computational Methods in Materials Science**
Course Code: MS2300
Credits: 3

Syllabus:

Length and time scales in computational modeling of materials;

review of thermodynamic models, conservation and continuity equations, constitutive laws in materials engineering; introduction to

computational linear algebra - linear and nonlinear system of equations,

interpolation and curve fitting, numerical differentiation and integration,

basic numerical optimization - applications in thermodynamics,

ordinary and partial differential equations – initial and boundary value problems, numerical methods – finite difference, finite volume, and finite element methods;

random numbers and random walk models, Monte Carlo simulations of phase transformations in model binary alloys (Ising model), concepts of potentials and Molecular Dynamics simulations, mesoscale models, introduction to ICME concepts and tools

This course uses MATLAB/Python and open source tools to develop numerical routines. Students will develop numerical routines to solve problems involving heat transfer, diffusion, phase change, Metropolis Monte Carlo algorithms of phase separation and ordering in model binary systems. Students will learn to use open source ICME tools for performing simulations in simple materials

Reference:

1. "Applied Numerical Analysis (7th edition)", Curtis F Gerald and Patrick O. Wheatley, Pearson Education India
2. "Mathematical Methods for Physics and Engineering (3rd edition)", K. F. Riley, M. P. Hobson, S. J. Bence, Cambridge University Press
3. Richard LeSar, "Introduction to Computational Materials Science: Fundamentals to Applications", Cambridge University Press, 2013

Course name: **Phase Transformations**
Course Code: MS3310
Credits: 3

Syllabus:

Definition of phases and concepts of thermodynamic equilibrium; phase transformations and microstructure formation; thermodynamic and mechanistic classifications of phase transformations; driving force for transformation.

Interfaces and interfacial energy; theory of nucleation: critical size and energy barrier in homogeneous and heterogeneous nucleation, driving force for nucleation, nucleation rates, role of defects in nucleation; Stefan problems and diffusional growth kinetics, main growth modes and mechanisms, combined nucleation and growth rate: JMAK equation, isothermal and continuous cooling transformation curves.

Liquid-to-solid transformations: growth modes in solidification; planar single-phase directional solidification models, macrosegregation, constitutive supercooling and interface instability; dendritic growth; eutectics, classification, and theory of lamellar growth; metallic glasses.

Solid-to-solid transformations: precipitation (driving force, Zener growth model, metastable phase formation, coherency of matrix-precipitate interfaces, coarsening, elastic stress effects on precipitate morphology); spinodal (solid solution and thermodynamic instability, chemical and coherent spinodal, critical temperature, length scale in spinodal, spinodal vs. nucleation mechanisms); ordering (sublattice and structural aspects of ordering, thermodynamic concepts from regular solution theory, ordered microstructures); discontinuous precipitation, eutectoid and massive transformations; martensitic transformations (crystallography, thermodynamics, reversibility, shape memory effect); bainitic transformations; application of phase transformation: heat treatment of steels and non-ferrous alloys.

References:

1. D. A. Porter and K. E. Easterling: Phase Transformations in Metals and Alloys.
2. M. E. Glicksman: Principles of Solidification.
3. R. Abbaschian, L. Abbaschian and R. E. Reed-Hill: Physical Metallurgy Principles.

Course name: **Soft Materials**
Course Code: MS3320
Credits: 3

Syllabus:

Introduction to ‘soft’ materials in terms of structure, property- Colloids, foams, gels, liquid crystals, soft biological materials such as DNA, and polymers (synthetic and natural) Structure (states and configuration) of polymers, synthesis, effect of temperature (glass transition and melting), branching, cross-linking on properties, crystallisation in polymers (types and mechanism), mechanical behaviour – viscoelasticity -spring dashpot models – relaxation behaviour (time and temperature effect) Self-assembly and Supramolecular organisation with reference to cellulose, silk, collagen and biological macromolecules, stability in colloids, types of liquid crystals

Reference:

1. Fundamentals of Soft Matter Science, Linda S. Hirst, CRC Press
2. Soft Matter: The Stuff that Dreams are Made of Roberto Piazza
3. Liquid Crystals: Nature's Delicate Phase of Matter, Second Edition. 2nd Edition
4. by Peter J. Collings

Course name: **Fundamentals of Extractive Metallurgy**
Course Code: MS3330
Credits: 2

Syllabus:

Basics of extractive metallurgy (thermodynamic, kinetic and electrochemical aspects). Types of extractive metallurgy processes (Pyro-metallurgy, Hydrometallurgy and electrometallurgy), extraction from oxides, halides and sulphide ores. Refining and purification. Waste management, energy and environmental issues in nonferrous metals extraction.

Chemical reactions and stoichiometry; thermochemistry; material and energy balance during processes; thermodynamics of processes: standard free energy change and Ellingham diagram, Raoult's and Henry's laws, concept of different standard states; reaction rates and reactor types; heat and mass transfer in reactors; unit operations in metallurgical processes.

References:

1. Principles of Extractive Metallurgy by Hem Shankar Ray (Author), Ahinder Ghosh (Author), New age international Publishers
2. Chemical Metallurgy by J. J. Moore.
3. Metallurgical Problems by A. Butts
4. Handbook of Materials and Energy Balance Calculations in Materials Processing by A. E. Morris, G. Geiger and H. A. Fine

Course name: Functional Materials Processing Laboratory
Course Code: MS3311
Credits: 2

Syllabus:

Thin film deposition - PVD (PLD, Sputtering & Evaporation) & CVD -Chemical synthesis (Sol-Gel & Reduction based) - Electrical characterization (2 probe & 4 probe measurement including contact making using patterning) - Frequency dependent dielectric constant measurement - Refractive index measurement (Ellipsometry) - Magneto-Optic Kerr effect - Introduction to patterning (Photolithography, FIB)

Reference:

Milton Ohring - Materials Science of Thin Films

Course name: Mechanical Behavior Laboratory
Course Code: MS3321
Credits: 1

Syllabus:

Viscoelastic measurements by rheometer, time dependent behaviour, viscous and loss modulus, newtonian non newtonian behaviours

Reference:

Course name: Spectroscopic Techniques in Materials Science
Course Code: MS3340
Credits: 2

Syllabus:

Introduction to Materials characterization- Introduction to waves and EM waves Recap to EM waves- Introduction to spectroscopy - oscillators in molecules and solids - selection rules - types of spectroscopy - Absorption spectroscopy and Vibrational (IR/Raman) - Photoelectron spectroscopy

Lab component:

1. Practical for UV-Visible spectroscopy (including sample preparation)
2. Practical for Raman spectroscopy (including sample preparation and analysis)

Reference:

1. Fundamentals of Molecular Spectroscopy – Banwell

Quantum chemistry – Donald A. Macqurrie

2. Optical properties of solids - Fox

3. Optics - E. Hecht

Course name: **Iron and Steel Making**
Course Code: MS3350
Credits: 3

Syllabus:

Brief history of iron and steel making, Raw Materials for Iron Making, Burden Preparation from raw materials, Blast Furnace design and operations, Physical-Thermal-Chemical Processes in a Blast Furnace, Alternative Routes of Iron Production, Steel making - basic oxygen and electric arc furnace processes - principles, operation and design aspects. Deoxidation, ladle refining processes – VD, VOD and AOD processes - inclusions in steel. Ingot metallurgy,Continuous casting - control of solidification structure and segregation. Steel plant primary and secondary products. Yield, energy requirements and productivity in iron and steel making.

Either a plant visit or some industrial lectures can also be included as a part of the course.

Reference:

1. Tupkary, R. H., and V. R. Tupkary. "An Introduction to Modern Iron Making.", Khanna publishers (2004).

2. Tupkary, R. H., and V. R. Tupkary. "An Introduction to Modern Steel Making.", Khanna publishers (2000)

3. A. Ghosh and A. Chatterjee, Ironmaking and Steelmaking : Theory and Practice, Prentice Hall of India, New Delhi, 2008

Course Title: Welding and Additive Manufacturing
Course Code: MS4311
Course Credits: 3

· Introduction to Welding: Fundamental Concepts; Classification of Welding Processes; Evolution of Fusion and Solid-State Welding Processes; Weld Thermal Cycles

· Welding Processes: Fusion Welding (Flux- and Gas-shielded Arc Welding, Laser and Electron Beam Welding, and Other Processes); Resistance Welding Processes; Solid-State Welding Processes (Friction Welding, Friction Stir Welding, Explosive Welding, Ultrasonic Welding, Diffusion Bonding, and Other Processes); Selection of Welding Processes

· Welding Metallurgy: Weld Metal Solidification; Cracking Phenomena in Fusion Welds; Microstructure Evolution in Fusion Welds, Weldability Problems in Common Engineering Metals; Welding and Cladding of Dissimilar Metals

· Introduction to Additive Manufacturing: Fundamental Concepts, Classification of Additive Manufacturing Processes, Additive Manufacturing Process Chain, Evolution of Additive Manufacturing Processes, Advantages and Limitations of Additive Manufacturing

· Additive Manufacturing Processes: Photopolymerization, Extrusion, Sheet Lamination, Binder Jetting, Material Jetting, Directed Energy Deposition, and Powder-Bed Fusion Processes; Solid-State Additive Manufacturing and Hybrid (Additive + Subtractive) Processes; Additive Manufacturing Equipment, Post-Processing of Additive Manufactured Parts; Additive Manufacturing of Common Engineering Metals; Selection of Materials and Processes for Additive Manufacturing

Laboratory component

· Shielded-Metal Arc Welding – Steel Base Plates, Tee Joint

· Gas-Tungsten Arc Welding – Stainless Steel Base Plates, Butt Joint

· Gas-Metal Arc Welding – Aluminum Base Plates, Lap Joint

· Metallography and Hardness Testing of Welded and Additive Manufactured Samples

Reference:

1. Robert W. Messler, Jr., Principles of Welding: Processes, Physics, Chemistry, and Metallurgy, John Wiley & Sons, 2008 (ISBN: 9783527617494)

2. Sindo Kou, Welding Metallurgy, John Wiley & Sons, 2003 (ISBN: 9788126560325)

3. I. Gibson, D.W. Rosen, B. Stucker, Additive Manufacturing Technologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010 (ISBN: 9781441911193)

4. Bhaskar Dutta, Sudarsanam S. Babu, Bradley H. Jared, Science, Technology and Applications of Metals in Additive Manufacturing, Elsevier, 2019 (ISBN: 9780128166345)

Course name: **Corrosion and Electrochemistry**
Course Code: MS4320
Credits: 2

Syllabus:

Basics of Corrosion, Thermal and electrochemical basis for corrosion in metallic materials. Types of corrosion (general, Galvanic, Intergranular, Crevice, Pitting, Erosion etc.) detection and analysis of corrosion. Preventive measures and economical considerations

Fundamentals of Electrochemistry, Electrochemical Reactions, Electrochemical Measurements, Electrochemical Methods and Applications

Reference texts:

1. Revie, R. Winston. Corrosion and corrosion control: an introduction to corrosion science and engineering. John Wiley & Sons, 2008.

2. Fontana, Mars Guy. Corrosion engineering. Tata McGraw-Hill Education, 2005.

3. Allen J. Bard and Larry R. Faulkner. Electrochemical Methods: Fundamentals and Applications, John Wiley & Sons, 2001.

Course name: Metal Forming and Thermomechanical Processing
Course Code: MS4330
Credits: 3

Syllabus:

Fundamentals of metal forming, rolling, forging; extrusion, wire-drawing, sheet metal forming, strain-hardening mechanisms, microstructure and texture aspects, static and dynamic recrystallization, hot deformation, severe deformation processing, thermomechanical processing of aluminum, steels and other key engineering materials

Reference:

1. Humphreys, F. J. and M. Hatherly (2004). Recrystallization and Related Annealing Phenomena (Second Edition). Oxford, Elsevier.

2. Verlinden, B., et al. (2007). Thermo-Mechanical Processing of Metallic Materials, Elsevier Science.

3. Dieter, G. E. and D. Bacon (1988). Mechanical Metallurgy, McGraw-Hill.

Course name: **Properties of Materials**
Course Code: MS4340
Credits: 3

Syllabus:

Dielectrics properties:

Polarization, Temperature and frequency effects – Dielectric breakdown – high-k dielectris – Piezoelectric - Pyroelectrics - Ferroelectrics - structural phase transitions – Domains – Domain walls – Domain Switching.

Optical properties:

Recap of electromagnetic waves - complex refractive index & dielectric function - Drude theory for metals & Interband transitions - Kramers-Kronig relation - Propagation and Interaction with media (including periodic structures) - Anisotropic optical materials & birefringence (eg liquid crystals)

Magnetic properties:

Origin of magnetism - Types of magnetic materials: dia-para-ferro-ferri and antiferro-magnetism - Soft and Hard magnetic materials – Domains and Domain walls – Experimental observation of Domains

Reference:

1. Introduction to solid state physics, Charles Kittel, John Wiley & sons
2. Introduction to Magnetic Materials, Wiley by B.D. Cullity, C.D. Graham
3. Introduction to Magnetism and Magnetic Materials – J. M. D. Coey
4. Physical Properties of crystals – J.F. Nye
5. Optics - E. Hecht
6. Classical Electrodynamics - J.D. Jackson
7. Fundamentals of photonics - B.E.A. Saleh and M.C. Teich

Course name: **Metal Casting**
Course Code: MS4350
Credit: 2

Syllabus:

Overview of casting and solidification processing; steps in producing a cast product; relative advantages and shortcomings of casting as a processing technique; melt quality; gating and riser design; expendable and permanent mold casting processes; solidification of pure metals and alloys; casting defects; heat transfer fundamentals related to casting and solidification; solution of Stefan problem for idealized conditions; common casting alloys and their applications; foundry technology laboratory.

References:

1. S. Kalpakjian and S. R. Schmid: Manufacturing Engineering and Technology.
2. J. T. Black and R. A. Kohser: DeGarmo's Materials and Processes in Manufacturing.

3. H. Fredriksson and U. Akerlind: Materials Processing during Casting.
4. ASM Handbook Vol. 15: Casting (1998)