

Course Code	Course Name	Credits	Syllabus
MS1010	Science and Engineering of Materials	1	Introduction to general concepts of metallurgy and materials science and general considerations in application orientated material design - through three example case studies on bone, sensors, and defence materials, Types of materials (metals, ceramics, polymers, hybrids), general material properties (structural and functional), trade off in material properties and brief introduction to optimisation, followed by classroom discussion sessions. Overall, the course offers a wide vision on how materials have led to technological advancement in all aspects and is designed to help appreciate the courses in following semesters.
MS1020	Metallic materials	1	Structure of metals, Determination of structure and chemical composition, concepts of alloys, phase and phase diagrams
MS1030	Materials Characterization I	1	Introduction to materials characterization- Introduction to waves and EM waves - Introduction to spectroscopy - oscillators in molecules and solids - selection rules - types of spectroscopy - Vibrational (IR/Raman) and Absorption spectroscopy.
MS1040	Materials Synthesis	1	Introduction to chemical synthesis of ceramic materials by solution based approaches- co-precipitation, sol-gel, hydrothermal, sonochemical. Vapour phase synthesis -PVD, CVD, molecular beam epitaxy etc. Solid State route- solid state reaction basics, combustion synthesis
MS1050	Physics of Solids	1	Atomic structure - Chemical bonding - Types of bonds - Metals - Fermi level - Fermi surface - Crystal structure - Bravais lattice - Atomic stacking - Reciprocal lattice - Kroenig Penning model - Band formation - Material classification
MS1060	Polymers	1	Introduction to polymers- synthetic and natural, structure (states and configuration) of polymers, synthesis, effect of temperature (glass transition and melting), branching, cross-linking on properties, structure - properties relationship and application, processing techniques and product development

MS1070	Semiconductor Materials	1	Semiconductor crystals - Band formation in semiconductors - Direct & Indirect Band gap semiconductors - Concept of holes - Hall Effect - Effective mass - heavy and light mass carriers - Doping in semiconductors - Band bending - Heavily doped semiconductors - Excitons
MS1080	Computational methods in Materials Science I	1	Length scales in materials - macro to electronic structure; overview of modeling techniques at different length and time scales; concepts of linear algebra and matrix computation; Introduction to Mathematica® - symbolic and numeric calculations, basic plotting and visualization, roots of equations.
MS1090	Micromechanics of solids	1	Concepts of scalar, vectors, matrix and tensor; Cartesian tensors; Vector and tensor algebra; Deformation - displacement and strain; Stress and mechanical equilibrium; Concepts of linear elastic solids.
MS2010	Soft matter science	1	Colloids, foams, gels, surfactants soft biological materials such as DNA, liquid crystals - structure, property, characterisation and applications, theoretical concepts
MS2020	Physical Metallurgy	2	Imperfections in crystals-point defects, dislocations and voids, theory of dislocations, strengthening mechanisms, diffusion in solids, heat treatments and phase transformations, mechanical response and microstructure-property relationship
MS2030	Materials Characterization II	2	X-ray diffraction and imaging, Properties of X-ray; Diffraction: Directions and intensities; Experimental methods: Laue diffraction, Powder diffraction, Diffractometer measurements; Applications: Crystal structure and size (grain & particle); Orientation; Phase diagram; Order-disorder transformations; Chemical analysis; Stress measurement, X-ray tomography. Electron diffraction and imaging: Reciprocal space; Electron diffraction pattern; Kikuchi diffraction; Convergent beam electron diffraction (CBED) pattern; Imaging: Amplitude contrast, phase-contrast, thickness-bend contrast; Secondary electron imaging; Back scatter electron imaging

MS2040	Advanced Materials Synthesis	2	Basics of nucleation and growth processes in solution based synthesis. Solid liquid interface interactions Influence of reaction conditions on morphological properties of materials. Approaches for synthesis of nanomaterial. Basics of sintering process- chemical reaction and phase transformation kinetics in solids. Solid substrate- vapour interactions in CVD, PVD. Effect of vapour deposition conditions on growth and morphology of ceramic films
MS2050	Mechanical behaviour of Materials	2	Hardness testing, Tensile and compression testing, Torsion testing, Fatigue testing, Fracture, High temperature deformation- Creep and superplasticity, Impact testing and failure
MS2060	Functional and structural polymers	2	Structural polymers, crystallisation in polymers (types and mechanism), mechanical behaviour - viscoelasticity -spring dash pot models - relaxation behaviour (time and temperature effect), functional polymers (conducting polymers, liquid crystalline polymers, polymeric photonic crystals), characterisation- scattering by polymers, flow in polymers- rheology, polymer blends and composites, blending (solubility and compatibility),
MS2070	Ceramics and Refractories	1	Introduction, Ceramic Materials: structure, microstructure and polymorphism, synthesis of ceramics, ceramic forming processes, structural ceramics, Properties and applications. Refractory materials, Properties of Refractories, Fracture of refractories, Corrosion of Refractories, Different Refractory lines, Testing of Refractory Materials.
MS2080	Process Metallurgy	1	Introduction to stoichiometry, thermochemistry, basics of materials and energy balance, applications in minerals processing
MS2090	Electronic Materials	1	Dielectrics - Polarizability, Temperature and frequency effects - Dielectric breakdown - high-k dielectrics - DRAM devices - Ferroelectrics - structural phase transitions - Domains - Domain walls - Domain Switching - Piezo-pyro and anti-ferroelectrics - Multiferroics - Relaxor materials - NVRAM applications - low dimensional insulators - Introduction to interaction of light with electrons in solids; absorption, colour, refraction, polarization, optical process

MS2100	Rate Phenomena in Process Metallurgy	1	Mass and energy balance in metallurgical processes; Applications of heat and mass transfer in steel making; concepts of physical and mathematical modeling of metallurgical processes (iron making, steel making, etc.)
MS3010	Magnetic Materials	1	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 - CMR - magneto caloric materials - spin glasses - magneto optic materials - MOKE
MS3020	Casting and solidification	2	Pattern making, moulding processes and materials, core and core materials, pouring and feeding castings, solidification microstructures, ferrous and non-ferrous castings
MS3030	Non-Ferrous extractive metallurgy	1	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
MS3040	Thin Films	2	Introduction to thin films: Definition of thin films - Formation of thin films, Environment for thin film deposition; Deposition parameters and their effects on film growth, Substrates - overview of various substrates utilized. Vacuum technology, Physical vapor deposition (PVD) techniques, Chemical vapor deposition techniques, Metallorganic (MO) CVD, Epitaxy Thickness Determination techniques, Characterization of Thin film.
MS3050	Iron making	1	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
MS3060	Steel making	1	Acidic and basic steelmaking processes, principles of C, Si, Mn, S and P removal, selected steel making processes, ingot casting, continuous casting of steels

MS3070	Powder Metallurgy	2	Historical perspective, scope of powder metallurgy industries, techniques of near net shape manufacturing, techniques of powder manufacturing, characterization of powders, powder compaction methods, introduction to sintering, post-sintering operations.
MS3080	Computational Methods in Materials Science II	2	Conservation and continuity equations; Constitutive equations describing behaviour of materials; Numerical solution of ordinary and partial differential equations - finite difference and finite volume methods, spectral methods; numerical implementation of random walk model; overview of mesoscale modelling - phase-field models, cellular automata, dislocation dynamics; overview of atomistic simulations - molecular dynamics, Monte Carlo methods; application of quantum mechanics - electronic structure calculations.
MS3090	Phase equilibria	1	Concepts of classical thermodynamics - first, second and third laws - extensive and intensive properties; Heat capacity, enthalpy, entropy and Gibbs free energy; Partial molar quantities - chemical potential; Phase equilibrium in single component systems; Ideal and nonideal solutions; Gibbs free energy composition diagrams; Phase diagrams
MS3100	Kinetics of Materials	2	Principles of diffusion in continuum - continuity equation; Concepts of fields, fluxes and gradients; Fick's laws of diffusion - steady state and nonsteady state; Solutions to the diffusion equation; Atomic mechanisms of diffusion - random walk; Interstitial and substitutional diffusion; Solutions to diffusion equations; Interdiffusion - Kirkendall effect, Darken relations.
MS3110	Transport phenomena	2	Concepts of fluid flow, heat and mass transfer; Viscosity; Flow through porous media; Heat transfer - conduction, convection and radiation; Diffusion and advection; Analogy between heat and mass transfer; Unit operations in process metallurgy.

MS3120	Phase Transformations	2	Overview of phase transformations - thermodynamic driving force; Theory of nucleation - homogeneous and heterogeneous nucleation; Diffusional growth and interface controlled growth; Precipitation; Phase separation - spinodal microstructures; Particle coarsening; Eutectoid, massive, disorder-to-order, martensitic transformations; Elastic stress effects on microstructural evolution;
MS3130	Non Destructive Testing	1	Types of discontinuities in different product forms, principles of NDT Methods and techniques, applications, ultrasonic testing, radiographic testing and other techniques, limitations.
MS3140	Technical Communication	1	Drafting of communication- written content - organization of content elements, writing style, formatting and grammar. Data and image representation. Reference management. Ethical issues in technical communication.
MS3150	Corrosion	1	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 consideration
MS3160	Aerospace Materials	1	Aerospace materials - Past, present and future; Materials and materials requirements for aerospace structure and engine; Production, casting, processing and machining of aerospace materials; Mechanical and durability testing of aerospace materials; Degradation and protection for aerospace materials Science and engineering of aerospace materials - Aluminium alloys, Titanium alloys, Magnesium alloys, Steels, Superalloys, Polymers, Composites
MS3170	Additive Manufacturing Technology	1	Overview, Direct digital manufacturing, types of additive manufacturing processes, additive manufacturing of different materials, selective laser sintering, Direct Metal Deposition (DMD) and Laser Engineered Net Shaping (LENS), structure and properties.

MS3190	Low Dimensional Materials	1	Classification of low dimensional materials (Zero-, one-, two-, and three dimensional nanostructures-quantum dots, quantum wells, quantum rods, quantum wires.)- Synthetic approaches for nanomaterial fabrication. Effect of confinement on materials properties (optical, electronic, magnetic, mechanical etc.). Applications of nanomaterial.
MS3210	Carbon Materials	1	Classification physicochemical properties and applications of conventional carbon based materials (activated carbon, graphite, diamond). Nanocarbons (carbon nanofibers, nanotubes, fullerenes, graphene) effect of size and shape on their physical and functional properties.
MS3220	Amorphous materials	1	Amorphous semiconductors - Band tailing - Fermi pinning - phase change materials - switching behavior - optical and mobility gap - magnetic metallic glasses, Glasses, Bulk Metallic Glasses, Amorphous alloys,
MS3240	Metal Joining	2	Welding processes - Gas welding, arc welding, electro slag welding, Electron beam and Laser beam welding, resistance welding, thermit welding, solid state welding, Welding metallurgy of metals and alloys; Heat flow, residual stresses, welding defects and testing; Adhesive and diffusion bonding of materials; Soldering and brazing
MS3250	Surface Engineering	2	Surface dependent engineering properties, common surface initiated engineering failures, mechanism of surface degradation, classification and scope of surface engineering in metals, ceramics, polymers and composites, Surface protection and surface modification techniques.
MS3260	Biomaterials	2	Application of materials in medicine: introduction to structure and biological properties of hard and soft tissues and requirement of implant materials. Classification of implant materials (metallic, ceramic, polymeric), physical, mechanical and biological attributes necessary for specific implant function. Practical aspects of Implant materials- host tissue response, implant failure.

MS4010	Defects in Functional Materials	1	Types of Defects - Colour centres - optical emission - solid state lasers - Luminescence - types of luminescence - Band gap tuning - ionic conductivity - Varistors - Gas sensors - Characterization techniques of Defects - Demerits of defects - Defect induced functional failures
MS4020	Research Methodology	1	Defining research problem, laboratory safety measures, do's and don'ts of data collection and processing (graphical, statistical, image processing etc.). Ethical issues with laboratory protocol and data reporting.
MS4030	Materials Selection & Design	1	The design process - Function, material, shape and process relationship with data. The selection process - Material and shape co-selection from charts, process selection with diagrams. Various case studies.
MS4040	Recycling of Materials	1	Introduction, Environmental issues, Waste characterization, Size reduction and classification, techniques of materials separations, methods of recycling of papers, glass, plastics and metals, Recycling of precious materials.
MS4050	Fatigue and Fracture	2	Mechanisms of fatigue in metals - stages of fatigue, constitutive relations; Design for fatigue - microstructural aspects; Fracture mechanisms in brittle and ductile solids; Thermodynamics of fracture - Griffith theory; Measurement of toughness.
MS4060	Thermo-mechanical Processing	2	Work-hardening mechanisms, static and dynamic softening processes, processing techniques, thermo-mechanical processing of steel, aluminium, magnesium, titanium and advanced alloy systems
MS4070	Introduction to nanofabrication	1	Different paradigms of fabrication: Top-down and bottom-up approach; Top-down techniques: E-beam lithography; Photo lithography; Focused ion beam (FIB) lithography; Direct laser writing and laser interference lithography; Bottom-up techniques: Self-assembly from nanoparticles; DNA assisted self-assembly; Assembly using linker molecules
MS4080	Crystallographic Texture	1	Description of orientation, representation of texture, measurement of texture, Texture of FCC, BCC and HCP materials

MS4090	Wear and Tribology	1	Introduction to tribological systems and their characteristic features; analysis and assessment of surface; techniques of surface examination, friction and measurement, mechanism of wear, types of wear, quantitative laws of wear, measurement of wear, wears resistance materials.
MS4100	Supramolecular materials	1	Study of natural materials existing in different environmental conditions such as wood, bone and glass sponge - understanding of their structure, property and synthesis, Supramolecular organisation in natural fibres (cellulose, silk, collagen) and biological macromolecules (DNA)- molecular interactions (driving force for supramolecular assembly), structural properties. Implementation in material synthesis for applications
MS4110	Antifouling and Health Care Materials	1	Introduction to the interactions between cells and the surfaces of biomaterials. Surface chemistry and physics of selected metals, polymers, and ceramics; surface characterization methodology; modification of biomaterials surfaces; Introduction to materials in biosensors and microarrays, implants, drug delivery, and tissue engineering.
MS4120	Phonons in solids	1	Phonons - specific heat capacity - Free electron model, Einstein and Debye theory - Phonon dispersion in solids - Thermal conductivity - Thermal expansion - Thermoelectric solids - electron phonon scattering - soft and hard phonons - solid state spectroscopic techniques
MS4130	Liquid crystals	1	What are Liquid crystals, types of liquid crystals, theories of formation, properties of liquid crystals, phase transitions - temp driven and concentration driven, characterisation of liquid crystals - DSC, POM, SAXS, common applications and processing

MS4140	Applications of Electrochemistry in Materials Science and Engineering	2	Fundamental concepts of Electrochemistry, Electrical double layer and it's importance, concepts of electrode potential, over potential and it's practical implications, The Butler-Volmer equation, introduction to electrochemical analytical techniques like cyclic voltametry, electro chemical polarization and electrochemical impedance spectroscopy; Examples of applied electrochemistry: Batteries, Fuel Cells, the Lithium Ion Battery, applications in extractive metallurgy - electrowinning and other techniques like electrochemical deposition.
MS4150	High Entropy Materials	1	Conventional vs high entropy alloy (HEA) design, thermodynamic aspects, structure and properties of single and multiphase HEAs, special subclasses of HEAs, high entropy related materials including oxides, carbides, nitrides and borides and their properties
MS4160	Energy Materials	2	Green energy resources: Introduction to non- conventional energy resources- Overview of solar cells, battery and fuel cell technology. Materials properties, challenges and current developments in each category
MS4170	Introduction to Functional Ceramics	2	Special structures: Zinc blende, Rock salt, fluorites, perovskites, double perovskites, layered perovskites, pyrochlores and polymorphs, Transition metal oxides: Gas sensors, varistors, wide bandgap oxides, solid state electrolytes, ionic conductors. Piezoelectric ceramics: lead based and lead free piezoelectrics, piezoelectric coefficients, measurements and devices, ferroelectricity, and multiferroics.
MS4180	Semiconductors and Devices	2	Junction formation - Electronic transport in junctions - Excitons - pn diode - Band structure under biased conditions - solar cells - diode lasers - LED - Photodiodes - Quantum heterostructures - Quantum tunnelling - Tunnel diodes - Resonant Tunnel Diodes - Coloumb blockade conduction - Quantum cascade lasers - MOS capacitors - Silicon and its applications - Conversion of indirect to direct band gap semiconductors - Quantum dots - opto-electronic devices

MS4190	Recent Developments in 2D Materials Science	2	This course is aimed at introducing the various techniques and principles associated with the synthesis and characterization of novel 2D materials. We will cover the latest advances development of these 2D materials and their potential application. For example, a group of materials expected to be studied include Graphene and other 2D materials (MoS ₂ , TeS ₂ , WSe ₂ etc.).
MS4200	Composites	2	Introduction, classification of composites, strengthening mechanism in composite, types of reinforcements, production methods for reinforcements, metal matrix composites, carbon-carbon composites, ceramic matrix composites, polymer matrix composites, interfaces and interphases, properties.
MS4210	Fundamentals of Plasmonics	2	Introduction to nano-optics and plasmonic, Restrictions on materials for plasmonics, Localized plasmons, Effect of shape, size and material, Multiple particle assemblies - Analogy to molecular hybridization, Biosensing and molecular recognition (SERS/SEIRA), Molecular modification of nanoparticle surfaces, Nanofabrication using localized plasmons, Characterization techniques - Far-field techniques (BF/DF microscopy, Fourier plane imaging), near-field techniques (near-field scanning optical microscope)