1. Introduction to the programme

Materials Science and Engineering (MSE) is an interdisciplinary field of science and engineering which investigates the relationship between the structure, property and processing of materials useful for various influence its properties. It is a discipline that enables both the creation and application of materials in society. Materials scientists and engineers develop materials for new applications, improve existing materials to enhance performance and evaluate ways in which different materials can be used together. The M.Tech. degree is designed in a way to provide a holistic view on all the classes of materials including metals, ceramics and polymers. The program is intended to provide in-depth knowledge in the fundamentals, analysis and structure-property correlation of various materials system. The courses will be conducted by faculties from the Department of Materials Science & Engineering (MSE). There will be options also for taking elective courses from within and outside the department. Moreover, specialists from overseas and experts from industries will be invited to lecture for a few classes in selected modules.

2. Course structure and Syllabus

2.1 Name of the courses: Core Courses

1. MS 501: Nano-structured Materials (3-0-0-6)
2. MS 503: Advanced Materials Characterisation Techniques (3-0-0-6)
3. MS 502: Materials Processing Technology (3-0-0-6)
4. MS 504: Structural and Functional Properties of Materials (3-0-0-6)

2.2 Elective Courses (Elective I –III)

1. MS505: Thermodynamics and Phase Diagrams (3-0-0-6)
2. MS509: Surface Engineering (3-0-0-6)
3. MS511: Rubber Science and Technology (3-0-0-6)
4. MS513: Coating Technology (3-0-0-6)
5. MS515: Advanced Building Materials (3-0-0-6)
6. CH501: Nanobiotechnology (3-0-0-6)
7. CH511: Theory and Modelling in Nanoscience (3-0-0-6)
8. PH502: Nanomaterials for Solar Energy and Photovoltaics (3-0-0-6)
9. SE503: Advanced Engineering Mathematics (3-0-0-6)

2.3 Elective Courses (Elective IV –VI)

1. MS508: Advanced Ceramics and Glass (3-0-0-6)
2. MS510: Composite Science and Technology (3-0-0-6)
3. MS512: Alloy Development and Heat Treatment (3-0-0-6)
4. MS514: Joining of Materials (3-0-0-6)
5. CE509: Applied Finite Element Method for Industries (3-0-0-6)
6. CE536: Solid and Hazardous Waste Management (3-0-0-6)
7. MA512: Mathematical Modeling (3-0-0-6)
8. PH515: MEMS and NEMS (3-0-0-6)
9. SE502: Sensors and Actuators (3-0-0-6)

2.4 Lab Courses

1. MS 506: Microstructure and Phase Analysis Laboratory (0-0-6-6)
2. MS516: Materials Characterisation Laboratory (0-0-6-6)
3. Course Curriculum

**1ST SEMESTER**

<table>
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<tr>
<th>Sl. No.</th>
<th>Course Number</th>
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**2ND SEMESTER**

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**3RD SEMESTER**

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**4TH SEMESTER**

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**TOTAL CREDITS: 44+40+50+45 = 179**
Detailed syllabus: (Core courses)

MS501  
**Nano-structured Materials**  3-0-0-6
Nanocrystals, thin films & coatings, definitions, Effect on properties and phase stability in lower dimension compared to the bulk state, Materials at Reduced Dimensions, Two-dimensional nanostructures – surfaces and films, One-dimensional nanostructures – nanotubes and wires, Zero dimensional nanostructures – fullerenes, nanoparticles, nanoporous materials, Nanoclays, Graphene, polyhedral oligomeric silsesquioxane (POSS) nanoparticles, Colloidal Monodisperse Nanocrystals, nanocrystals of ferrite, oxide and chalcogenides, core-shell nanoparticles, micelle assisted nanoparticles, surfactant coated nanoparticles, microemulsion synthesis, self-assembly routes, Inorganic-organic hybrid materials, hydrophobic and hydrophilic nanoparticles, water-dispersable nanoparticles, Synthesis routes, Sol-gel technique, Nonaqueous Sol–gel route for Metal Oxide nanoparticles, hydrothermal synthesis, co-precipitation, preparation of nanocomposites, Properties and applications at the nanoscale, Electrical, Mechanical, Magnetic, (Electro)Chemical, Optical, Thermal and thermoelectric properties, Health and regulatory issues with Nanomaterials

Text Book:

Reference Books:

MS503  
**Advanced Materials Characterisation Techniques**  3-0-0-6
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, stress calculation, different approaches for crystal and grain size measurements XRD
Powder characterization techniques, Particle size analysis techniques based on light scattering, Powder characterisation by microscopy techniques (light, electron), light scattering, gas adsorption (BET), Gas pycnometer for density measurement, and compositional analysis of powders by XRF and ICP techniques
Metallography and microstructures, Principles of optical microscopy -resolution, magnification, depth of focus; electron diffraction, imaging (various contrasts), Cross-Sectional and fracture
surface analysis of materials/coatings using FESEM, Crystal Identification through Selected area diffraction pattern (SADP) etc.
Tribology, Wear type and its Characterization, wear surface analysis, Tribometer, Friction, Low friction materials/coating etc.
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.
Rheological and viscoelastic properties of materials, importance of characterization for polymer systems, measurement techniques, melt flow index, capillary and slit die extrusion rheometry, oscillatory rheometry, rotational rheometry, extensional rheometry, extrudate die swell and draw down techniques.

Test Books:

Reference Books:

MS502 Materials Processing Technology 3-0-0-6
Introduction of Materials, Types, distinctions, properties and applications of Metals, Ceramics and Polymers. Different types of polymer processing operations and engineering aspects: Mixing and compounding (twin screw extruders, banbury and other mixing equipments in polymer processing), extrusion process, injection moulding, blow moulding, thermoforming, rotational moulding, compression moulding, transfer moulding, reaction injection moulding, calendering, roller and blade coating, film blowing, textile/fiber spinning technology
Technology for ceramic powder preparations, solid state reactions, Sintering operations, Types of sintering, sintering mechanisms, Colloidal processing of ceramics, DLVO theory, Porous ceramics and ceramic fibres, Co-precipitation method, Sol-Gel process, products for engineering applications
Text Books:
2. Polymer processing fundamentals, Tim A. Osswald, Hanser (eds.); 1998

MS504 Structural and Functional Properties of Materials 3-0-0-6

Electrical and electronics, magnetic and optical properties of materials, Fermi level & Hall effect in semiconductors, Band theory, Ferroelectrics & piezoelectrics, Snell’s law, Maxwell equations, luminescence, fluorescence, Microscopic origin of magnetic moments, Magnetic susceptibility, Exchange interaction, Types of Magnetism in materials, Hysteresis in ferromagnetic materials, Response of the functional materials to external parameters, e.g., pressure, temperature. Applications in Giant magneto-resistance effect, Spintronics, Material aspects and design rules of functional devices.

Text Books:

Reference Books:

(Elective Courses) (Elective I-III)

MS505 Thermodynamics and Phase Diagrams 3-0-0-6
Thermodynamics basic concepts (state variables, the first law, the enthalpy concept, heat capacity)
The second law (reversible and irreversible processes, entropy, Gibbs energy, Helmholtz energy, Gibbs-Duhem's equation, Maxwell's relationships) Equilibrium conditions (chemical potential, driving force, the third law, Clausius-Clapeyron's equations, Thermodynamic application to materials: Ellingham diagrams; Electrochemistry: Porbaix diagrams; thermodynamics of solutions, construction and interpretation of 2 component phase diagrams.


Text Books:

MS509 Surface Engineering 3-0-0-6
Introduction to surface Engineering, Differences between surface and bulk, Properties of surfaces, surface energy concepts, degradation of surfaces, wear and its type, Adhesive, Abrasive, Fretting, Erosion wear, Surface fatigue, Different types of Corrosion and its prevention, Galvanic corrosion, Passivation, Pitting, Crevice, Microbial, High-temperature corrosion, Corrosion in nonmetals, polymers and glasses, Protection from corrosion through surface modifications

Changing the surface metallurgy: Localized surface hardening (flame, induction, laser, electron-beam hardening, Laser melting, shot peening), Changing the surface chemistry: Phosphating, Chromating, Anodizing (electrochemical conversion coating), Carburizing, Nitriding, Ion implantation, Laser alloying, boriding, Organic coatings (paints and polymeric or elastomeric coatings and linings), Hot-dip galvanizing (zinc coatings), Ceramic coatings (glass linings, cement linings, and porcelain enamels), Advanced surface coating methods: Gaseous State (CVD, PVD etc), Solution State (Chemical solution deposition, Electrochemical deposition, Sol gel, electroplating), Molten or semimolten State (Laser cladding and Thermal spraying)

Characterization of surface and coatings, Surface Characterization (physical and chemical methods, XPS, AES, RAMAN, FTIR etc), Structural Characterization, Mechanical Characterization (Adhesion, Hardness, Elastic Properties, Toughness, Scratch and Indentation etc.), Tribological Characterization, Corrosion tests
Text Books:

1. Introduction to Surface Engineering and Functionally Engineered Materials, Peter Martin; Wiley, 2011.

Reference Books:


MS 511 Rubber Science and Technology 3-0-0-6

Elastomers: Natural rubber, Synthetic rubbers:-Polybutadiene, Styrene-butadiene rubber, Acrylonitrile butadiene rubber-Nitrile rubber, Poly-2-chlorobutadiene, Chloroprene rubber, Polyisoprene rubber, Butyl rubber, Halogenated copolymers of butyl rubber, Ethylene propylene rubber (EPM and EPDM), Ethylene vinylacetate copolymers, Chlorinated polyethylene, Chlorosulfonated polyethylene, Acrylic rubbers and ethylene acrylate copolymers, Epichlorohydrin rubber, Polypropylene oxide rubber, Fluoroelastomer, Polynorbornene, Polysiloxane and silicone rubber, Polysulfide rubber, Polyester and polyether rubber, Polyurethane elastomer, New elastomers

Blends:-Thermoplastic elastomers and thermoplastic vulcanizates, Different rubber based blends, Rubber chemicals and additives:- Mastication and peptizers, Vulcanizing agents, Accelerators, Activators, Retarders, Aging, fatigue and ozone protective agents, Antioxidants, Reinforcing and non-reinforcing fillers, Other fillers and new fillers, Pigments, Plasticizers, processing aids and factice, Blowing agents, Adhesion promoters, Latex technology:-Natural rubber latex, styrene butadiene rubber latex, nitrile rubber latex, polychloroprene latex, latex compounding, latex processing, Processing of elastomers:- Compound preparation, Processing to sheets, Manufacture of extruded products, Manufacturing of molded goods, Elastomer testing and analysis: Mechanical testing, Adhesion testing, Electrical testing, Chemical testing, Thermal testing, Morphology

Text books:

MS513  
Coating Technology  
3-0-0-6

Introduction to coatings for different temperature applications, Properties of surfaces - wear, corrosion, optical, roughness, electrical and thermal properties, wetability


Text Books:
1. Introduction to Surface Engineering and Functionally Engineered Materials, Peter Martin; Wiley, 2011.

Reference books:

MS515  
Advanced Building Materials  
3-0-0-6

Text Books:

CH501 Nanobiotechnology 3-0-0-6
Module 1: Generic Methodologies for Nanobiotechnology Introduction to Nanobiotechnology; challenges and opportunities associated with biology on the Nanoscale; nanobiotechnology systems; introduction to bioelectronics; Biologically relevant molecular nanostructures—Carbon nanotubes, quantum dots, metal based nanostructures, nanowires, polymer based nanostructures, protein and DNA based nanostructures; Characterisation techniques for biological molecular nanostructures.

Module 2: Biosensors Introduction to biosensors; the biological component; the sensor surface; Immobilisation of the sensor molecule; Transduction of the sensor signal—Optical sensors; Electrochemical sensors; Suppression or subtraction of non-specific background interaction at sensor surfaces; Sensor stabilisation; Data analysis.

Module 3: Imaging of Βionanostructures Practical and theoretical aspects of imaging biological systems, from the cellular level through to whole-body medical imaging, basic physical concepts in imaging. Major techniques using ionising and non-ionising radiation including fluorescence and multi-photon microscopy, spectroscopy, OCT, MRI, X-ray CT, PET, Confocal and SPECT imaging.

Module 4: Bionanomaterials Biomolecules for designing nano-structures; nanoprinting of DNA, RNA and Proteins, use of these nano-structures in biological and medical applications. Principles of self-assembly, self-organisation and its application to biology. DNA nanostructures, DNA robot, DNA microarrays, Bio-MEMS: biological and biomedical analysis and measurements and micro total analysis systems.

Module 5: Toxicological and Medical Applications of Nanobiotechnology Environmental behaviour and speciation of nanoparticles; Introduction to Nanomaterials for toxicology; bioaccumulation of Nanomaterials, Nanoparticles cytotoxicity, Applications of Nanostructures in Drug discovery, Delivery, and Controlled Release.

Text Books:
1. Nanodevices for the Life Sciences, Challa S. S. R. Kumar (Editor), John Wiley & Sons, Inc.
2. Bionanotechnology, by Elisabeth Papazoglou, Publisher: Morgan & Claypool

Reference Books:
1. Bionanotechnology: Global Prospects
2. David E. Reisner (Editor), CRC Press (Taylor and Francis)

CH511 Theory and Modelling in Nanoscience 3-0-0-6
1. Molecular Dynamics;
2. Monte Carlo Methods;
3. Computations of Phase Transition under Confinement;
4. General Basis for predicting physical properties of nanocrystals and large clusters;
5. Quantum Confined Systems & computational techniques
6. Computational Electrodynamics Methods;
7. Large Scale Electronic Transport Calculations;
8. Density Functional Calculations in Carbon Nanotubes;
9. Time Dependent Density Functional Theory;
10. Computational Study of Nanotubes;
11. Excited State Properties (GW, BSE);
12. Computing Mechanical Properties and Modeling Growth;
13. How Well does Computation do with respect to Experiment
14. Present Day Scenario: regarding computation in the field.

Text Books:

PH502 Nanomaterials for Solar Energy and Photovoltaics 3-0-0-6
Solar radiations as a source of energy and mechanism for its entrapment; Measurements and limits of solar energy entrapment; Flat plate collectors and solar concentrators; Solar energy for industrial process heat (IHP) and design of solar green house; Solar refrigeration and conditioning; Solar thermo-mechanical power.
Introduction of energy storage/conversion devices, State-of-the art status of portable power sources, Solar/photovoltaic (PV) cells as a source of green energy; Fundamentals, Materials, Design and Implementation aspects of PV energy generation and consumption; Solar cell technologies (Si-wafer based, Thin film, GaAs based, dye-sensitized, PESC and organic solar cells), Efficiency of solar cells and PV array analysis, Photovoltaic system design (stand alone and grid connected) and applications; Balance of system (BOS) with emphasis on role of storage batteries; Cost analysis, Case study for performance evaluation and problem identification in wide-spread commercialization of the technology.

Text Books:

Reference Books:

SE503 Advanced Engineering Mathematics 3-0-0-6
Linear Algebra: Matrix algebra; basis, dimension and fundamental subspaces; solvability of Ax = b by direct Methods; orthogonality and QR transformation; eigen values and eigenvectors, similarity transformation, singular value decomposition, Fourier series, Fourier Transformation, FFT.
Vector Algebra & Calculus: Basic vector algebra; curves; grad, div, curl; line, surface and volume integral, Green’s theorem, Stokes’s theorem, Gauss-divergence theorem.


Numerical Technique: Numerical integration and differentiation; Methods for solution of Initial Value Problems, finite difference methods for ODE and PDE; iterative methods: Jacobi, Gauss-Siedel, and successive over-relaxation.

Complex Number Theory: Analytic function; Cauchy’s integral theorem; residue integral method, conformal mapping.

Statistical Methods: Descriptive statistics and data analysis, correlation and regression, probability distribution, analysis of variance, testing of hypothesis.

Text Books:

(Elective Courses) (Elective IV-VI)

MS508 Advanced Ceramics and Glass 3-0-0-6
Abrasives, abrasive operations, natural abrasives, abrasives like aluminium oxides, silicon carbide, diamond and boron nitride, miscellaneous synthetic abrasives, raw materials for abrasives, their proportioning, processing, manufacture of abrasives, grinding wheels, their drying, firing and testing.
Glassy State; Kinetic and thermodynamic criteria for glass formation, use of Na₂O-SiO₂ and Na₂O-CaO- SiO₂ 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, surface tension, viscosity and its measurement, effect of temperature and composition on the physical properties of glasses.
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

Text Books:

Reference Books:

MS510  Composite Science and Technology 3-0-0-6
Introduction and Overview of Metal based composites, overviews key technologies and issues in the area, Fabrication of Metal Matrix Composites: Commonly used Matrices, Basic Requirements in Selection of constituents, solidification processing of composites - XD process, Spray processes - Osprey Process, Rapid solidification processing, Dispersion Processes - Stir-casting & Compocasting, Screw extrusion, Liquid-metal impregnation technique - Squeeze casting, Pressure infiltration, Lanxide process), Principle of molten alloy infiltration, rheological behaviour of melt-particle slurry, Synthesis of In situ Composites.
Ceramic matrix composites, mechanical properties of ceramic matrix composites, different processing techniques for ceramic matrix composites, process capability and applications of various techniques.

Text Books:
7. Advanced Polymer composites, Bor Z.Jang; ASM International,1994

Text Books:
5. Phase Transformations in Metals and Alloys; D.A. Porter, K.E. Easterling; Taylor and Francis, 2009.

Welding, theory and classification of welding, submerged arc welding, gas metal arc welding or MIG/MAG welding, TIG welding, resistance welding. Other joining processes, soldering, brazing, diffusion bonding, and adhesive bonding of metallic materials; adhesive bonding, solvent bonding, and welding of polymer materials; brazing, frit sealing, diffusion bonding, and welding of ceramic materials and composite materials; soldering, wire bonding, flip-chip bonding, and wafer bonding of semiconductor materials; welding, soldering, adhesive bonding and bone in growth of biomaterials; welding, soldering and adhesive bonding of nanomaterials.

Text Books:

Introduction: Continuum Mechanics, Conservation laws, Riemannian Geometry and stress-strain tensors, Constitutive equation, Potential-, Strain-, and Kinetic energies, Functionals and variational
formulation, mathematical programming and weak solutions; Displacement method of FEM analyses.
Field equations: Elasticity, Structural Dynamics, Fluid Mechanics, electromagnetic fields
Alternative approaches: Hybrid FEM, Mixed FEM, Boundary Element Method, Boundary Error
Element, Mesh-less methods, Galerkin’s approach of error orthogonalization.
Error analyses: Algebraic and Integral inequalities; estimate of error; error bounds; Convergence,
super-convergence,
Computer Packaging: Pre-, Post-processing and Turbo C, Analysis Programs in FRORTAN;
Applications (as per request): Rigid-flexible assembly (ME and Bio-Mechanics); Two-phase flow
(ME & CE); Electro-magnetic application to wave-guides, MOSFET analyses (ECE); magnetic
levitation (electrical), Vibration and control of quartz substrate using smart material; Stochastic
FEM, etc.

Text / Reference Books:
Concepts and applications of finite element analysis, Robert Davis Cook.
Lecture Notes.

CE536 Solid and Hazardous Waste Management 3-0-0-6
Sources, composition and properties of municipal solid waste, Generation of solid waste, Onsite
handling, storage and processing including segregation, Collection of solid waste, Transfer and
transport, Processing technique and equipment, Recovery of resources, Conversion products and
energy, Composting and vermicomposting, Recycling, Incineration and pyrolysis, Disposal of solid
waste including sanitary landfill, Planning, site and design aspects of solid waste engineering;
Introduction to hazardous wastes, Definition of hazardous waste, The magnitude of the problem,
Risk assessment, Environmental legislation, Characterization and site assessment, Waste
minimization and resource recovery, Physico-chemical and biological treatment, Transportation of
hazardous waste, Ground water contamination, Landfill disposal.

Texts/References:
1. P. A. Vesilind, W. A. Worrel and D. R. Reinhart, Solid Waste Engineering, Thomson
2. G. Tchobanoglous, H. Theisen, and S.A. Vigil, Integrated Solid Waste Management:
2000.

MA512 Mathematical Modeling 3-0-0-6
Introduction to modeling; Elementary mathematical models and General modeling ideas; General
utility of Mathematical models Stability theory of system of differential equations; Linear and
nonlinear stability; Lyapunov’s second method; Basic idea of bifurcation; Illustrations with help of
computer programming Role of mathematics in problem solving; Concepts of mathematical
modeling; System approach; formulation, Analyses of models; Pitfalls in modeling; Illustrations
models such as Population dynamics, Traffic Flow, Social interactions, Viral infections, Epidemics,
Finance, Economics, etc. (The choice and nature of models selected may be changed with mutual
interest of lecturer and students.) Introduction to probabilistic models; Simulation approach.
Orthogonal projections, Singular Value Decomposition, Principal Component Analysis, Fourier and
Wavelet Transformation and Applications, Kernel Methods

References:

PH515 MEMS and NEMS 3-0-0-6
Nanoelectromechanical systems (NEMS) – a journey from MEMS to NEMS, MEMS vs. NEMS, MEMS based nanotechnology – fabrication, film formation and micromachining, NEMS physics – manifestation of charge discreteness, quantum electrodynamical (QED) forces, quantum entanglement and teleportation, quantum interference, quantum resonant tunneling and quantum transport, Wave phenomena in periodic and aperiodic media – electronic and photonic band gap crystals and their applications, NEMS architecture, Surface Plasmon effects and NEMS fabrication for nanophotonics and nanoelectronics, Surface Plasmon detection – NSOM/SNOM

Text Books:

Reference Books:

SE502 Sensors and Actuators (3-0-0-6)
Brief overview of measurement systems, classification, characteristics and calibration of different sensors.
Measurement of displacement, position, motion, force, torque, strain gauge, pressure flow, temperature sensor sensors, smart sensor. Optical encoder, tactile and proximity, ultrasonic transducers, opto-electrical sensor, gyroscope. Principles and structures of modern micro sensors, micro-fabrication technologies: bulk micromachining, surface micromachining, LIGA, assembly and packaging


Text Books

Lab Courses

MS506: Microstructure and Phase Analysis Laboratory

(0-0-6-6) Prerequisite NIL

Practical aspects of X-ray diffraction analysis will be emphasized; hands-on experience in qualitative and quantitative analysis techniques, use of electronic databases, and phase analysis using XRD data
hands-on experience on the applications of metallography and optical microscopy, phase analysis using microscopic information, hands-on experience in the area of microstructures of metal, ceramic and polymer materials using optical microscopy and SEM
Standard laboratory practice including safety, report writing, and error analysis are also emphasized.

MS516: Materials Characterisation Laboratory

(0-0-6-6) Prerequisite NIL

Powder characterization using XRD, SEM and BET, gas pycnometer
Thermal properties of materials, identification of materials based on their TG, DSC, DMA characteristic responses
Laboratory testing practice related to tests based on the mechanical properties of materials, e.g., hardness, elastic modulus, tensile strength etc.
Standard laboratory practice including safety, report writing, and error analysis are also emphasized.