National Institute of Advanced Manufacturing Technology

Hatia, Ranchi-834003

(Formerly National Institute of Foundry and Forge Technology)

(Centrally Funded Technical Institute, Under MHRD, Govt of India)

(Affiliated under Jharkhand Technical University)

Syllabus

M.Tech (Materials Science and Engineering)

Department of Metallurgy and Materials Engineering

2021

Master of Technology (M. Tech) in Material Science and Engineering

Programme Objectives

- Evaluate the performance of material systems using the relationship between structures, properties and processing.
- Characterize materials and carry out research on advanced materials.
- Design and develop effective and eco-friendly materials for generic and strategic applications.
- Pursue life-long learning by enhancing knowledge and skills for professional advancement.

Programme Outcomes

- Apply phase transformation phenomena to improve the performance of materials.
- Apply principles of deformation to modify structure and properties of materials.
- Characterize and evaluate materials for specific applications.
- Design metallurgical processes to produce products as per specifications.
- Evaluate products using non-destructive testing methods and modify processes.
- Identify mechanisms for protecting engineering materials from degradation.
- Synthesize ceramic, polymer, composite and non-ferrous materials.
- Design advanced materials for aerospace, biological, nuclear and high temperature applications.
- Apply project management techniques effectively to address issues related to metallurgical industries.
- Practice professional ethics and engage in lifelong learning for improved professional advancement, moral and human values.

Curriculum Structure

Semester I

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	MS-5101	Thermodynamic and Kinetics	3	0	0	3
2	MS-5102	Advanced Physical Metallurgy	3	0	0	3
3	MS-513*	Programme Elective I	3	0	0	3
4	MS-514*	Programme Elective II	3	0	0	3
5	MS-517*	Open Elective	3	0	0	3
6	MS-5103	Research	2	0	0	2

		Methodology and IPR				
7	MS-5111	Advanced Physical Metallurgy	0	0	4	2
8	MS-5112	Metal shaping Laboratory	0	0	4	2
9	MS-5129	Audit Course I	2	0	0	0
					Total	21

Semester II

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	MS-5201	Characterization of Materials	3	0	0	3
2	MS-5202	Mechanical Behavior of Materials	3	0	0	3
3	MS-525*	Programme Elective III	3	0	0	3
4	MS-526*	Programme Elective IV	3	0	0	3
5	MS-527*	Programme Elective V	3	0	0	3
6	MS-5211	Materials Characterization Technique Laboratory	0	0	4	2
7	MS-5212	Mechanical Behaviour of Materials Laboratory	0	0	4	2
8	MS-5229	Audit Course II	2	0	0	0
9	MS-5221	Mini Project	0	0	4	2
					Total	21

Semester III

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	MS-6122	Dissertation part- I	0	0	20	10
2	MS-6223	Industrial Training	4 weeks			0
					Total	10

Semester IV

Sr. No.	Course Code	Course Name	L	T	P	Credits
1	MS-6222	Dissertation part- II	0	0	32	16
					Total	16

Programme Electives - I (3.0.0) Semester I

Serial No	Course Name
MS-5131	Advanced Metal Casting Technology
MS-5132	Metal Shaping processes
MS-5133	Metal Forming Technology
MS-5134	Methoding of Casting
MS-5135	Instrumentation and Control
MS-5136	Automotive Materials

Programme Electives - II (3.0.0) Semester I

Serial No	Course Name
MS-5141	Surface Engineering and Coating Technology
MS-5142	Environmental Degradation of Materials
MS-5143	Biomaterials
MS-5144	Functional Materials
MS-5145	Electronic and Magnetic Materials
MS-5146	High Temperature Materials

Open Electives - (3.0.0) Semester I

Serial No	Course Name
MS-5171	Mechanical Testing of Materials
MS-5172	Advances in Materials Science
MS-5173	Heat treatment of Materials
MS-5174	Principles of Materials Engineering
MS-5174	Structure of Materials and X-ray Diffraction

Programme Electives - III (3.0.0) Semester II

Serial No	Course Name
MS-5251	Advanced iron and Steel Making
MS-5252	Secondary steel making process
MS-5253	Extraction of Nonferrous Metals
MS-5254	Ferroalloy production
MS-5255	Materials Selection and Design
MS-5256	Materials handling

Programme Electives - IV (3.0.0) Semester II

Serial No	Course Name
MS-5261	Light Metals and Alloys
MS-5262	Advanced Metal Joining processes
MS-5263	Failure Analysis
MS-5264	Fracture Mechanics
MS-5265	Testing of Materials
MS-5266	Creep, Fatigue and Fracture

Programme Electives - V (3.0.0) Semester II

Serial No	Course Name
MS-5271	Advanced powder Metallurgy
MS-5272	Additive Manufacturing
MS-5273	Nuclear Materials
MS-5274	Ceramic Polymers and Composites
MS-5275	Nanotechnology
MS-5276	Computational Materials Engineering

Audit course 1 & 2 (MS5129 & MS5229)
English for Research Paper Writing
Disaster Management
Sanskrit for Technical Knowledge
Value Addition
Constitution of India
Pedagogy Studies
Stress Management by Yoga and aerobics
Personality Development through Life Enlightenment Skills.

MS-5101 Thermodynamic and Kinetics

Module 1: Introduction to thermodynamics and kinetics **8 Lectures**

Introduction to thermodynamics and kinetics- different approaches, emphasis on metallurgical thermodynamics.

Module 2: Law of thermodynamics and related applications 8 **Lectures**

Law of thermodynamics and related applications, Concepts of free energy and entropy, criteria for spontaneity.

Module 3: Introduction to solutions **8 Lectures**

Introduction to solutions, Partial molar quantities, Gibbs- Duhem relations, thermodynamic aspects of metallic solutions and salt melts, Raoult's and Henry's Law, Regular and quasi chemical models.

Module 4: Thermodynamic aspects of phase diagrams **8 Lectures**

Thermodynamic aspects of phase diagrams, Similarity in thermodynamic approach towards different classes of materials, thermodynamic aspect of defect formation in metals and ceramics.

Module 5: Principles of metallurgical kinetics **8 Lectures**

Principles of metallurgical kinetics, reaction rates and reaction mechanism.

Reference Books:

1. Gaskell, David, R., Introduction to Metallurgical Thermodynamics, McGraw Hill.

2. Mohanty, A. K., Rate processes in metallurgy, Prentice Hall of India.

3. Upadhayaya, G.S., and Dube, R.K., Problems in metallurgical thermodynamics and kinetics, Pergamon 4. Darken, L.S., and Gurry, R.W., Physical chemistry of Metals, McG

Course outcomes: Upon completion of the course, the student will be able to

- Understand the basic laws of thermodynamics
- Understand the multiple approaches to thermodynamics, from the bulk property point of view and from the atomistic point of view
- Understand concepts such as the theory of solutions, free energy, entropy, criteria for equilibrium and conditions for feasibility
- Obtain the skill to use metallurgical thermodynamic concepts and equations for understanding phase diagrams, phase transformations, theory of solutions
- Obtain problem solving skills in order to improve / modify industrial processes, esp. In extraction metallurgy, liquid metal treatment and in heat treatment
- Understand the concept behind rate of chemical reactions and order of chemical reactions
- Understand concepts behind the determination of phase diagrams with the help of thermodynamic principles.
- Understand concepts behind the experimental determination of phase diagrams

MS-5102 Advanced Physical Metallurgy

Module 1: Classification of Transformations **4 Lectures**

Phase transformation of first degree and second degree, Energy aspects of homogeneous and heterogeneous nucleation, nucleation ratio, fraction transformation at constant rate of nucleation and growth, Nucleation in solids.

Module 2: Recovery, Recrystallisation and Grain growth **6 Lectures**

Property changes, Driving forces, N- G aspects, annealing twins, textures in cold worked and annealed alloys, Polygonization.

Module 3: Austenite – Pearlite Transformation **6 Lectures**

Austenite – Pearlite Transformation, role of diffusion and temperature on lamellar spacing.

Module 4: Bainite transformation **6 Lectures**

Nature of carbide in Bainite, Upper and lower Bainite, Isothermal transformation in Austempered ductile iron.

Module 5: Martensitic transformation **6 Lectures**

Crystallographic aspects and mechanism of atom movements, Comparision between twinning and Martensitic transformations; Effect of grain size, Plastic deformation, arrested cooling on kinetics.

Module 6: Order- disorder transformations **6 Lectures**

Common structures in ordered alloys, variation of order with temperature; determination of degree of ordering, effect of ordering on properties, applications. Spinodal decomposition.

Module 7: Precipitation hardening **6 Lectures**

Structural changes, mechanism and integration of reactions, effect of retrogression, Double peaks, Spinodal decomposition.

Reference Books:

1. Raghavan, V.,, Phase transformations, Prentice Hall

2. Smallman, R.E., Modern physical metallurgy

3. Reed Hill, R.E., Principles of physical metallurgy, Affiliated East West Press.

4. Sharma R.C., Principles of Heat Treatment of Steels, New Age International.

5. . Sinha A.K., Physical Metallurgy Handbook, McGraw Hill.

6. Singh V., Heat Treatment of Metals, Standard Publishers.

Course outcomes (COs):

Upon completion of this class, the students will be able to:

- Evaluate critically the relevance of phase diagrams, isothermal transformation diagrams and continuous cooling transformation diagrams to understand real alloys and their microstructure.
- Apply the fundamentals of phase transformation to steels and other engineering materials.
- Display a critical awareness of the relevance of key areas, e.g. diffusion, defects, transformation type, to current problems in designing, processing and exploiting real alloys.
- Interpret the different heat treatments (annealing, normalising, quenching, tempering).
- Define and differentiate engineering materials on the basis of structure and properties for engineering applications
- Select proper processing technologies for synthesizing and fabricating different materials
- Analyse the microstructure of metallic materials using phase diagrams and modify the microstructure and properties using different heat treatments.

MS-5201 Characterization of Materials

Module 1: Introduction to Materials Characterization Techniques 6 Lectures
Different techniques and their purposes; Optical Microscopy - Introduction, Optical principles, Instrumentation, Specimen preparation-metallographic principles, Imaging Modes, Applications, Limitations.

Module 2: Transmission Electron Microscopy (TEM) 6 Lectures
Introduction, Principle, construction and operation of TEM, Interaction of electrons with specimen, preparation of specimens, bright and dark field imaging, selected area diffraction, Image modes- mass density contrast, diffraction contrast, phase contrast, Applications, Limitations.

Module 3: Scanning Electron Microscopy (SEM) 6 Lectures
Introduction, Construction and working principle of SEM, Operational variables, imaging modes-Secondary electron, back scattered mode of imaging and energy dispersive analysis of x-rays, Sample preparation, Applications, Limitations.

Module 4: Electron Probe Micro Analyzer (EPMA) 4 Lectures
Introduction, Sample preparation, Working procedure, Applications, Limitations.

Module 5: X- Ray Spectroscopy for Elemental Analysis 6 Lectures

Introduction, Characteristics of X-rays, X- ray Fluorescence Spectrometry, Wavelength Dispersive Spectroscopy-Instrumentation, Working procedure, Applications, Limitations.

Module 6: Energy Dispersive Spectroscopy **2 Lectures**
Instrumentation, Working procedure, Applications, Limitations.

Module 7: Scanning Probe Microscopy & Atomic Force Microscopy **3 Lectures**
Introduction, Instrumentation, Scanning Tunneling Microscopy-Basics, probe tips, working environment, operational modes, Applications, Limitations.

Module 8: Atomic Force Microscopy (AFM) **3 Lectures**
Basic principle, Instrumentation, Operational module, Applications, limitations.

Module 9: Thermal Analysis **4 Lectures**
Instrumentation and principles of differential scanning calorimetry (DSC), differential thermal analysis (DTA), Thermogravimetric analysis (TGA), Dilatometry, Applications, Limitations.

Readings:

1. Yang Leng: Materials Characterization-Introduction to Microscopic and Spectroscopic Methods - John Wiley & Sons (Asia) Pte Ltd, 2008

2. ASM Handbook: Materials Characterization, ASM International, 2008.

3. V. T. Cherapin and A. K. Mallik: Experimental Techniques in Physical Metallurgy, Asia Publishing House, 1967.

4. S.J.B. Reed: Electron Microprobe Analysis, Cambridge University Press, London, 1975.

5. B.D. Cullity, S.R. Stock, "Elements of X-Ray Diffraction", Pearson; 3 edition, 2001

6. Robert F. Speyer: Thermal Analysis of Materials, Marcel Dekker Inc., New York, 1994.

<u>MS-5202 Mechanical Behavior of Materials</u>

Module 1 **Lectures 8**
Strength of Materials: Basic assumptions, elastic and plastic behavior, stress- strain relationship for elastic behavior, elements of plastic deformation of metallic materials, Mohr's circle, yielding theories.

Module 2 **Lectures 8**
Theory of plasticity: Dislocation theory, properties of dislocations, stress fields around dislocations, application of dislocation theory to work hardening, solid solution strengthening, grain boundary strengthening, dispersion hardening.

Module 3 **Lectures 8**

Ductile and brittle fracture: Charpy and Izod testing, Significance of DBTT, ECT, NDT and FATT; Elements of fractography; Griffith theory, LEFM- COD and J integral, determination of KIC, COD and J integral.

Module 4 **Lectures 8**

Fatigue failure: Initiation and propagation of Fatigue cracks, factor affecting fatigue strength and methods of improving fatigue behavior, testing analysis of fatigue data, mechanism of fatigue crack propagation, Corrosion fatigue.

Module 5 **Lectures 8**

Creep failure: Creep mechanism, creep curve, variables affecting creep, accelerated creep testing, development of creep resisting alloys, Larsen- Miller parameter, Manson Hafred parameter.

Reference Books:

1. Dieter, G. E., Mechanical metallurgy, McGraw Hill.

2. Hertzberg, R.W., Deformation and fracture mechanics of engineering materials, John Wiley

3. Hull, D., Introductions to dislocations, Pergamon.

4. Garofalo, F., Fundamentals of creep and creep rupture in metals, McMillan.

5. Meyers, M. A., and Chawla, K.K., Mechanical behavior of materials, Prentice Hall

1. **Course Objective (CO)**
   (i) In this post graduate course, the mechanical behavior of materials has to be taught where the materials' response to tensile or compressive loads are to be studied, with their industrial and engineering applications.
   (ii) To study how an alternating load play a role for a catastrophic failure of an engineering structural part. Quantification of the life in such environment of a structural part.
   (iii) To understand material's behaviour when it is exposed to high temperature and how the temperature activated deformation process leads to failure of a part.

To study, determine and quantify how existence of internal flaw (cracks, voids etc) leads to material failure

<u>MS-5131 Advanced Metal Casting Technology</u>

Module 1 **Lectures 5**

Critical review of some foundry operations: Various casting processes, mould reinforcements, mould factors in metal Flow, moulding factors in casting design, limitations in controlling some moulding factors in casting design, Effect of process variables on property of core and mould making sand.

Module 2 **Lectures 6**

Properties of liquid metals: Thermal properties, viscosity, surface tension and density of liquid metals and their role in foundry technology; Gases in liquid metals: Simple gases in metals, complex gases in metals, gas defects and their control.

Module 3 **Lectures 14**

Solidification of metals and alloys: Plane front solidification, interface stability, dendritic growth, cellular growth, independent nucleation. Structure of casting as influenced by alloy constituents, thermal conditions, inherent nucleation and growth condition in the liquid like temperature gradient, liquidus temperature profile and G/R ratio. Control of structure; principles of gating and risering, Directionality in solidification, Characteristics of different alloys, Chworinov rule, Design of gating system, Wlodawer system of determining the feeder head requirements. Feeder head efficiency, concept of feeding range, use of supplementary techniques and introduction of design modifications.

Module 4 **Lectures 5**

Special casting processes: Investment casting, Die casting, centrifugal casting, full mould casting, vacuum shield casting etc.

Module 5 **Lectures 5**

Industrial melting practices: Aim of melting and melting practices as adopted in case of Cast Irons, Steel, Cu, Al and its alloys.

Module 6 **Lectures 5**

Casting defects & their remedies: Shaping faults arising in pouring, Inclusions and sand defects, gas defects, shrinkage defects during solidification in liquid phase. Contraction defects, Dimensional errors, compositional errors and segregation.

Reference Books:

1. Beeley, P.R., Foundry Technology, Butterworth and Co.

2. Webster, P.D., Fundamentals of Foundry Technology,

3. Mukherjee, P.C, Fundamentals of Metal casting Technology

Course outcomes (COs):

CO1: Understand and apply the principles of metal casting processes and develop analytical relation between input and output process parameters.

CO2: Understand, analyze and apply the concept of cooling rate of materials in metal casting.

CO3: Apply theoretical and experimental techniques for measurement of important outcomes of casting processes like hardness, dimensional accuracy etc.

CO4: Understand the model of casting economics and optimization and its measurement.

CO5: Apply the fundamentals of physics to develop theoretical relations for different types of casting processes

MS-5132 Metal Shaping processes

Module 1 **Lectures 8**
Introduction to Metal Shaping processes: different approaches, technical and economic considerations, significance of material properties with respect to selection of Metal Shaping processes.

Module 2 **Lectures 8**
Conventional casting processes: advantages and limitations, melting practices, design of castings, special casting processes.

Module 3 **Lectures 8**
Conventional material joining processes: concept of weldability, need for dissimilar joints, machining proceses, concept of machinability, material examples, developments in machining processes.

Module 4 **Lectures 8**
Rolling, forging, extrusion, drawing, sheet metal forming; classification, advantages and limitations.

Module 5 **Lectures 8**
Introduction to powder metallurgy, recent developments especially in forging and mechanical alloying, concept of near net shape praceesing, concept and applications of rapid proto typing, emerging technologies for nano processing.

Reference Books:

1. Rao, P.N, Manufacturing Technology, Tata McGraw Hill

2. Kalpakjian, S., Manufacturing Engineering and Technology, Addison Wesley

MS-5133 Metal Forming Technology

Module 1 **Lectures 6**
Classification of metal forming processes, hot, cold and warm working. Flow curve for materials, effect of temperature, Strain rate and microstructural variables, residual stresses, experimental techniques, yielding theories, processing maps. Friction in metal working, Lubrication.

Module 2 **Lectures 8**

Rolling of Metals: Classification of rolled products, Types of rolling mills, Terminology used; Forces and Geometrical relationships in rolling, Rolling variables, Theories of design, Mill type, Lay out and rolling practice, adopted for some common products such as slabs, blooms, billets, plates, sheets etc., Rolling defects and their control.

Module 3 **Lectures 8**

Forging of Metals: Forging principles, Type of Forgings and equipment needed; Calculation of Forging load under sticking and slipping Plain strain forging analysis, friction conditions. Manufacture of rail wheels and tyres. Forging defects and their control.

Module 4 **Lectures 6**

Extrusion: Types, Principles and equipments, Variables in extrusion, deformation in extrusion, Calculation of extrusion pressure under plain strain conditions, extrusion defects, production of tubes and seamless pipes.

Module 5 **Lectures 6**

Wire drawing: Drawing of rods, wire and tubes, Calculation of drawing loads, drawing defects.

Module 6 **Lectures 6**

Sheet metal forming: Forming methods such as bending, stretch forming, shearing, blanking, deep drawing and redrawing. Formability diagrams, Defects in formed products. Special forming methods such as high energy forming: explosive forming, electrohydraulic and magnetic forming processes.

Reference Books:

1. Dieter G.E., Mechanical Metallurgy, McGraw Hill.

2. Harris J.N., Mechanical Working of Metals- Theory and Practice, Pergamon. 23

3. Kalpakjian S. and Schmid S.R., Manufacturing Processes for Engineering Materials, Pearson.

Course outcomes (COs)

CO1: Understand and apply the mechanism of deformation for different metal forming processes and develop analytical relation between input and output parameters of process.

CO2: Understand and analyze the concept of yield criteria applicable to different material deformation processes.

CO3: Apply theoretical and experimental techniques for measurement of important outcomes of metal forming processes.

CO4: Understand the different lubrication mechanisms, lubricants and other valuable affecting the metal forming processes under different working conditions

CO5: Understand the different types of defects, causes and apply their remedial measures in metal forming processes.

MS-5134 Methoding of Casting

Unit I: Principles of casting design, pattern design considerations, pattern allowances, pattern design and construction **(10 Lectures)**

Unit II: Design of different types of cores and core prints. **(08 Lectures)**

Unit III: Fundamentals of fluid flow, design of gating system, slag traps and filters etc. Risering curves, NRL, Caine method, Gating systems and their characteristics.

(08 Lectures)

Unit IV: Directional and progressive solidification, differential methods of feeder design, feeding distance, , feeding efficiency. **(08 Lectures)**

Reference Books:

1. Heine R.W., Lopper C.R. & Rosenthal P.C., Principles of Metal Casting, McGraw Hill.

2. Davis, G.J., Solidification in Casting, Applied Sciences.

3. Beeley P.R., Foundry Technology, Butterworth.

4. Kondic V., Metallurgical Principles of Foundry, Edward Arnold

Course outcomes (COs)

At the end of the course, students will be able to:

CO1: Have the basic knowledge for pattern design.

CO2: Have an Understand the technology variables and complexity involved in producing a core.

CO3: To impart knowledge about principles/methods of casting with detail design of gating/riser system needed for casting

CO_4: To inculcate the principle, thermal and metallurgical aspects during solidification of metal and alloys.

MS-5135 Instrumentation and Control

Module 1 **Lectures 10**

Generalized measurement systems. Basic standards; static and dynamic measurements; measurement of temperature, pressure, velocity, force strain, vibration and acceleration by transducers.

Module 2 **Lectures 10**

Role of transducers in automatic control systems, Feed back systems and their characteristics.

Module 3 **Lectures 10**

P.I.D. controllers; Response characteristics and compensation of electrical, hydraulic and pneumatic systems.

MS-5136 Automotive Materials

Module 1 **Lectures 10**

Classes of materials and its properties: metals, alloys, polymers, ceramics, composites, body materials: aluminium alloys, steels, special steels, magnesium materials sandwich materials.

Module 2 **Lectures 20**

engine materials: cylinder, piston, cam shaft, valve materials, plastic materials, functional materials, electronic materials , smart materials advanced materials, light weighting automobiles, future vehicles and materials, materials selection in design.

Readings

1. Brain Cantor, Patrick Grant, Colin Johnston, Automotive Engineering:Lightweight, Functional, and Novel Materials, Taylor& Francis, 2008

2. Hiroshi Yamagata, The science and technology of materials inautomotive engines, Woodhead Publishing, 2005

3. Jason Rowe, Advanced materials in automotive engineering, Woodhead Publishing, 2012

4. Sobey, A field guide to automotive technology, Chicago Review Press,2008

MS-5141 Surface Engineering and Coating Technology

Module 1 **Lectures 6**

Introduction - Importance and need of surface engineering, Past, present and future status of surface engineering, Classification of surface engineering processes, Substrates and their pretreatments, Difference between diffusion coatings and overlay coatings, Coating characteristics: Coating thickness, continuity, hardness, adhesion, porosity, bond strength.

Module 2 **Lectures 10**

Overlay coatings: Process fundamentals, advantages, limitations, and applications of (a) Thermally sprayed coatings, Thermal barrier coatings, Powders for thermal spraying and Factors influencing thermal spray coatings, Applications of thermal spraying, Recent developments in thermal spraying, (b) Electrochemical coatings-Electroplating (Cu, Ni, Cr, Zn), Electro-less nickel plating and anodizing, Coating on plastics; (c) Micro arc oxidation-Basics, technology and fundamentals of micro-arc oxidation, Advantages, shortcomings and applications of micro-arc oxidation; (d) Electro-spark coating-process-Fundamentals, mechanism of coating formation, advantages and limitations, applications, Case studies.

Module 3 **Lectures 6**

Diffusion coatings: Process fundamentals, advantages, limitations and applications of Carburising – Overview of pack, liquid, and gas carburizing; Nitriding – Overview of gas and liqud nitriding; Carbonitriding and Nitrocarburising; Boronizing, Aluminized coatings, Chromized and Siliconized coatings; Plasma processes - Plasma carburizing and Plasma nitriding; Plasma immersed ion implantation, Plasma enhanced chemical vapour deposition; Plasma enhanced physical vapour deposition.

Module 4 **Lectures 6**

Thermal modification processes: Different types of lasers and their applications, Laser assisted surface modification processes-Laser surface cleaning, Laser surface hardening, Laser surface cladding, Laser surface alloying.

Module 5 **Lectures 6**

Thin film coating technology: Chemical vapour deposition (CVD), Physical vapour deposition (PVD), Electron beam evaporation, Magnetron sputtering; Diamond like carbon coating technology; Sol-gel coating technologies.

Module 6 **Lectures 6**

Evaluation of coatings: Thickness, bond strength and porosity measurement, Hardness, wear and corrosion resistance.

Readings:

1. Tadeusz Burakowski and Tadeusz Wierzchon, Surface Engineering of Metals: Principles, Equipment, Technologies, CRC Press LLC, 1999

2. K. G. Budinski, Surface Engineering for Wear Resistance, Prentice Hall, New Jersey, 1998.

3. J. R. Davis, Surface Engineering for Corrosion and Wear resistance, ASM International, 2001

4. Howard E. Boyer, Case Hardening of Steel, ASM International, Metals Park, OH 44073.

ASM Hand Book, Surface Engineering, Volume 5, ASM Metals Park. Ohio. USA. 1994

Course Outcome

Upon completion of this class, the students will be able to:

- Identify and describe wear mechanism and corrosion mechanisms, and recognize appropriate mitigation technology and methods.
- Describe the surface analysis techniques used for routine investigation of surface characteristics.
- Identify, compare and contrast surface engineering processing technologies, including vacuum technology as used in many surface engineering processes.
- Know the types of Pre-treatment methods to be given to surface engineering
- Select the Type of Deposition and Spraying technique with respect to the application & Study of surface degradation of materials
- Describe various surface coating technologies and their applications in industry
- Apply measurement techniques and carry out characterization of industrial coated surfaces
- Describe standard methods of testing of modified surfaces
- Fundamentals of tribology and related contact mechanics and Pros and cons of different approaches in surface engineering.

MS-5142 Environmental Degradation of Materials

Module 1 **Lectures 10**

Degradation economics, types of degradation: electrochemical, high temperature corrosion and oxidation, chemical and physical ageing of plastics, degradation of reinforced concrete, biofouling, biodegradation, corrosion of ceramics.

Module 2 **Lectures 10**

laboratory assessment of corrosion: linear polarization techniques, Tafel extrapolation, oxidation, free energy- temperature diagrams

Module 3 **Lectures 10**

Corrosion control: materials selection and design, protective coatings, inhibitors, passivators, electrical methods.

Readings

1. Myer Kutz, Handbook of Environmental Degradation of Materials, William Andrew Publishing, 2005

2. Denny A Jones, Principles and Prevention of Corrosion 2Ed., Pearson, 2014

3. R. D. Angel, Principles and Prevention of Corrosion, Narosa, 2010

4. Mars Guy Fontana: Corrosion Engineering, Tata McGraw-Hill Education, New York, 2005.

5. H.H. Uhlig, R. Winston Revie: An Introduction to Corrosion and Corrosion Engineering, 4th Ed, John Wiley & Sons, 2008.

MS-5143 Biomaterials

Module 1 **Lectures 8**

Overview: Historical development; Materials in Medical Applications; Materials Properties for Bio-applications

Module 2 **Lectures 8**

Biomaterials Classification and Synthesis: Metallic materials; Ceramic and glass implant materials; Polymeric implant materials; Collagen; Thin films; Grafts and coatings; Biological functional materials.

Module 3 **Lectures 8**

Cell Structure: Bone structure; Bone properties; Proteins; Bacteria structure; Antibacterial assay.

Module 4 **Lectures 8**

Cell-material Interaction: In vivo testing; Cell-material interaction; Cell-signalling; in vitro testing; Cytotoxicity; Clinical trials.

Module 5 **Lectures 8**

Tissue Engineering: Scaffolds, cellular materials, stem cells, regeneration engineering.

Readings

1. Buddy D. Ratner: Bio Material Science- An introduction to Materials in Medicine, Elsevier, 2013.

2. B. Basu, D. Katti and Ashok Kumar; Advanced Biomaterials: Fundamentals, Processing and Applications; John Wiley & Sons, Inc., USA, 2009.

3. S. V. Bhat ,Biomaterials; 2nd Ed., Narosa Publishing House, 2006.

4. J. Park, R.S. Lakes , Biomaterials an introduction; 3rd Ed., Springer, 2007

MS-5144 Functional Materials

Module 1 **Lectures 10**

The Origin of Functional Materials (FMs), Potential Applications of FMs, Classification of FMs, Processing Techniques: Powder Metallurgy Route, Melt-processing Route, Vacuum arc melting, Vacuum induction melting, Vapor deposition and types

Module 2 **Lectures 10**

Specific properties of functional materials: Magnetic materials, Electronic Materials and Sensors, Electric Contact Materials, Conducting Thermoplastics and polymer composites, Surface coatings for functional applications, Biomaterials and Shape memory metals, Invar alloys
Batteries and fuel cells, solar energy harvesting, Reflective and antireflective layers, Waste heat recovery materials

Module 3 **Lectures 10**

Microstructure-property correlations, characteristic dimensions and spatial variations, volume fraction, rules of mixture and effective field parameters; characterization of properties of FMs, macrostructural thermomechanical properties, effective material properties for ceramic-metal FMs, basic mathematical modeling.

Reading:

1. D.D.L. Chung: Engineering Materials for Technological Needs, Vol. 2- Functional Materials: Electrical, Dielectric, Electromagnetic, Optical and Magnetic Applications, World Scientific Publishing,2010.
2. D.D.L. Chung: Composite Materials- Functional Materials for Modern Technologies, Springer, 2002.
3. Hui-Shen Shen: Functionally Graded Materials - Nonlinear Analysis of Plates and Shells, CRC Press,2009.
4. Y. Miyamoto, W.A. Kaysser, B.H. Rabin, A. Kawasaki, R.G. Ford (Eds): Functionally Graded Materials- Design, Processing and Applications, Springer,1999.

MS-5145 Electronic and Magnetic Materials

Module 1 **Lectures 10**

Semiconductor materials, Wafer Technology, Basic patterning and surface preparation to exposure, photomasking, photoresist and their performance factors, Etching, dry and wet etching, resistor stripping, Chemical vapor deposition (CVD), Plasma Enhanced CVD, Vapor phase epitaxy, molecular beam epitaxy, MOCVD, deposited films, Photolithography process, Antireflective coatings

Module 2 **Lectures 10**

Origin of magnetism, orbital & spin, Permanent magnetic moments of atoms, Types of magnetic materials (Diamagnetic, Ferromagnetic, Ferrimagnetic and Anti-ferromagnetic), Weiss theory of ferromagnetism, Magnetic hysteresis, Domains, Susceptibility, Exchange energy, Soft and hard magnetic materials, Permanent magnets - properties and preparation (SmCo&NdFeB), Ferrites-classification and crystal structure, Nanocrystalline soft magnetic materials.

Module 3 **Lectures 10**

Melt-quenching method for soft magnetic ribbons, Super-paramagnetism, Single domain particle, Magnetic storage applications, Perpendicular magnetic recording media

Reading:

1. Peter Van Zant: Microchip Fabrication, 4thEd., McGraw Hill,2000.
2. James R. Chelikowsky: Electronic Materials- A New Era in Materials Science, Springer,2001.
3. B. D. Cullity, C.D. Graham, 2nd Ed., Introduction to Magnetic Materials, Wiley and IEEE, 2009

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MS-5146 High Temperature Materials

Module 1 **Lectures 8**

Introduction to high temperature Materials, Characteristics of engineering materials at high temperature, oxidation, high temperature corrosion, Creep, thermal fatigue, erosion, aging, structural changes, material damage, crack propagation, damage mechanics, life time analysis.

Module 2 **Lectures 10**

High temperature materials- Carbon alloy steels, Stainless steels, super alloys and titanium and its alloys, ceramics, composites, Refractory metals, alloys and Structural inter-metallic and high temperature polymers.

Module 3 **Lectures 12**

Coatings: Thermal barrier coatings, Oxidation resistant coatings.

Reading:

1. G. W. Meetham and M. H. Van de Voorde, Materials for High Temperature Engineering Applications (Engineering Materials) Springer; 1 edition (May 19, 2000)
2. J. R. Davis: ASM specialty Hand book: Heat-Resistant materials, ASM, 1997
3. Neil Birks, Gerald H. Meier, and Frederick S. Pettit, Introduction to the High Temperature Oxidation of Metals by Cambridge University Press; 2 edition (July 23, 2009)
4. Sudhansu Bose, High Temperature Coatings, Butterworth-Heinemann; 1 edition (February 6, 2007)
5. K. L. Mittal, Polyimides and Other High Temperature Polymers: Synthesis, Characterization and Applications, Brill Academic Publications, 2009
6. R.W. Evans, and B. Wilshire, Creep of metals and alloys, Institute of Metals, London, 1985.
7. Krishan Kumar Chawla, Composite Materials- Science and Engineering, Springer, 2012.

Course outcomes: After the successful completion of this course, the students would be able to

- Understand the theory and principles behind mechanism of deformation by creep and fatigue at higher temperatures.
- Understand the principles behind oxidation of components at higher temperatures and related calculations involved behind thickness of an oxidized layer.
- Predict Life cycle of a service component under the influence of high temperature
- Predict life cycle of a component under corrosive environments.
- Understand mechanism of void growth leading to ductile failure.

MS-5171 Mechanical Testing of Materials

Unit I:

Material Testing: Importance, Classification: DT and NDT. Selection of testing methods. Importance of instruments calibration, Calibration methods and standards for various tests.

(7 Lectures)

Unit II:

Tensile Testing: Engineering stress-strain curve. Tensile properties. True stress-strain curve. Factors affecting tensile properties. Tensile testing machines.

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(7 Lectures)

Unit III:

Hardness Testing: Various hardness tests. Advantages and limitations of various hardness tests. Microhardness testing.

(7 Lectures)

Unit IV:

Impact Testing: **I**mpact tests with their merits and demerits. Ductile-brittle transitions behavior and its significance. **(7 Lectures)**

Unit V:

Fatigue Testing: S-N curves. Mechanisms of fatigue in metals. Factors affecting fatigue properties. **(7 Lectures)**

Unit VI:

Creep Testing: Typical creep curve. Mechanism of creep deformation in metals. Factors affecting creep behavior. **(7 Lectures)**

Recommended Books:

1. Testing of Metallic Materials -A. V. K. Suryanarayan (Pub.-PHI, New Delhi)
2. Mechanical Behaviour and Testing of Materials , Jan 2011, Sharma C. P. & Bhargava A. K., PHI.
3. Testing of Metals, Alok Nayar, Mc Graw Hill education

List of Course Outcomes (COs)

At the end of the course, students will be able to:
CO1: Explain concepts and Procedures of various Metal Testing
CO2: Able to perform various Destructive Tests on Metals
CO3: Understand the importance of Calibration of Test equipment
CO4: Able to select Testing Methods & derive conclusion about the properties of the Metals

MS-5172 Advances in Materials Science

Fundamentals of structure in crystalline solids, Imperfections in materials, Characterization Techniques, Phase Diagrams (Fe-C, Al-Si, Pb-Sn, Al-Cu etc.), Phase transformations in metals, Solidification in metals and alloys, Diffusion in solids, Mechanical working of metals, Strengthening mechanisms in metals, Mechanical properties of materials, Failure in materials, Non-destructive testing of materials, Composite materials, Corrosion of materials, Electrical properties of materials, Magnetic properties of materials, Thermal properties of materials, Optical properties of materials, Recycling of materials.

Texts / Reference Books:

1. William D. Callister, *Jr.Materials Science and Engineering*
2. V. Raghavan, Materials Science and Engineering: A First Course

MS-5173 Heat treatment of Materials

Heat Treatment -IT and CCT diagrams in steels, quench hardening and tempering of martensite, hardenability of steels, surface hardening processes, tool steels and their heat treatments, heat treatment of aluminium alloys, magnesium alloys, Ni-base super alloys and Ti alloys, Thermo-mechanical treatments; Hardenability, thermo-chemical and thermo-mechanical and thermo cycling treatments; Failure analysis of heat treated products.

Texts / Reference Books:

1. Gregory J. Bonami, *Heat Treatment: Theory, Techniques, and Applications (Materials Science and Technologies).*

MS-5174. Principles of Materials Engineering

Introduction: Solid Engineering Materials- their classification and characteristic properties. Structure of solids: crystal systems/lattices, crystal structure, crystallographic planes and directions, interstitial sites, crystalline metals, ceramics, semiconductors and polymers. Microstructures and metallography; Amorphous or glassy state; Solidification of pure metal: homogeneous and heterogeneous nucleation processes, cooling curve, concept of supercooling, microstructure of pure metals. Defects in solids: point, line, planar and volume defects. Fundamentals of plastic deformation of metals, deformation by slip and twin, plastic deformation in polycrystalline metals, concept of cold working, preferred orientation; Annealing: recovery, recrystallization and grain growth; hot working; Properties of materials: Definition, units and common tests conducted to evaluate important engineering properties like physical, mechanical, chemical, electrical, magnetic, semi/super-conducting, optical, and thermal properties in engineering materials; Concept of formation of alloys: Types of alloys, solid solutions, factors affecting solid solubility, order-disorder transformation; Binary phase diagrams: isomorphous, eutectic, peritectic, eutectoid and peritectoid systems, effect of non-equilibrium cooling: coring and homogenization; Iron-cementite phase diagram: Construction and interpretation of Fe-Fe3C and Fe-Graphite diagrams. Microstructure, and properties of different alloys in steel and cast iron, types of cast iron, their microstructures and typical uses; Heat treatment: T-T-T and C-C-T diagrams, concept of heat treatments of steel: annealing, normalizing, hardening and tempering; microstructural effects brought about by these processes and their influence on mechanical properties. Effect of common alloying elements in steel, concept of hardenability, factors affecting it; Common alloy steels, stainless steel, tool steel, high speed steel, high strength low alloy steel, micro-alloyed steel, specifications of steels; Physical metallurgy of common non-ferrous alloys: Cu-,Al- and Ni- based alloys. Microstructures and heat treatment of common alloys of these systems; Engineering ceramics and polymers: Structure, properties and application of common engineering ceramics and polymers.

Texts / Reference Books:

1. William D. Callister, *Jr.Materials Science and Engineering,* Wiley India (P) Ltd.

2. V.Raghavan, Materials Science and Engineering: *A First Course 5th Ed, Prentice Hall of India*, New Delhi (2000).
3. Sidney H. Avner, *Introduction to Physical Metallurgy*, Tata McGraw-Hill.
4. Butterworth-Heinemann, Michael Ashby, Hugh Shercliff and David Cebon, *Materials Engineering, Science, Processing and Design*

MS-5175. Structure of Materials and X-ray Diffraction

Production and detection of X-rays; Crystallography: lattice, motif, unit cells and crystal structures, symmetry elements, point groups, space groups, defects; Diffraction: Wave theory and electromagnetic waves, single crystal diffraction method and applications, powder diffraction method and applications, indexing of powder diffraction patterns, Bragg's law and Laue equation, reciprocal space and its application; Fourier transforms: analysis of diffraction patterns, structure factor and pair distribution function; Determination of crystal structures from symmetry and geometry; Rietveld method and precise crystal structures; Qualitative and quantitative phase identification.

Texts / Reference Books:

1. B. E. Warren, *X-Ray Diffraction*.
2. B. D. Cullity, S.R. Stock, *Elements of X-ray diffraction*.
3. Buerger, Martin J, *Elementary Crystallography: An Introduction to the Fundamental Geometrical Features of Crystals*.
4. F. C. Phillips, *An Introduction to Crystallography*.
5. Norman ,F. M., and Kathleen Lonsdale, *International Tables for X-Ray Crystallography. Vol. 1*
6. *International Tables for Crystallography/ Volumes A(2006) / A1(2011) / B(2010) / C(2006)/ D(2006) / E(2010) / F(2012) / G(2006).*

MS-5251 Advanced iron and steel making

Module 1 **Lectures 10**

Preparation of ore: Sintering and palletizing, blast furnace burdening and distribution, testing of raw materials for B.F Design: B.F profile , Stove and gas cleaning units, instrumentation , refractory used in B.F and stove Reactions: Fe-C-O, Fe-O-H phase equilibrium, Reaction in stack, bosh and hearth, formation of primary slag , bosh slag and hearth slag . Slag composition and its control, Metal –slag reactions, control of hot metal composition Process Control: Factors affective fuel consumption and productivity, Recent development in B.F Operations like, Bell-less top charging system, High top pressure, Humified and oxygen enrichment of B.F and auxilliary fuel injections through tuyers. Irregularitions in B.F Operations and their remedies. B.F Stoichiometry, mass and enthalpy balance, problems based on charge calculations. Alternate routes of Iron Making: Processes of sponge iron production. Coal based and gas based. Smelting reduction processes.

Module 2 **Lectures 10**

LD Process: Design of converter & lance, Quality of raw materials charged, Operation of the converter and control of bath and slag composition. Chemical reactions involved, Temperature and residual bath oxygen control. Use of oxygen sensor, some characteristics of L.D blow viz emulsion formation, slopping, maneuvering lance height for dephosphorisation and dacarburisation. Catch carbon technique, Recovery of waste heat, OBM/Q-BOP process, Concept and operation of the process. Mixed/ Combined blowing process. Oxygen top blowing with inert gas purging at bottom, Oxygen top blowing with inert and oxidizing gases at bottom, Oxygen top and bottom blowing, Steel making Scenario in India.

Module 3 **Lectures 10**
Electric arc furnace: Advantages, charging, melting and refining practices for plain carbon and alloys steels. Use of DRI in arc furnaces and its effect on performance. UHP electric arc furnace with DC supply. Duplex processes of stainless steel making using VOD, AOD and CLU. Induction Furnace: Advantages, Principles of induction heating, Use in steel industry. Deoxidation of liquid steel: Requirement of deoxidizers, deoxidation practice, Stoke's law, use of complex deoxidizers, Inclusions and their influence on quality of steel. Killed, semi killed and rimming steels. Secondary refining of steels: Objectives, principles of degassing, Different industrial processes such as DH, RH, VAD, SD, LF and ESR. Limitations and specific applications.

Module 4 **Lectures 10**
Continuous casting of steel: Advantages, Types of machines, Mould lubrication and reciprocation, Developments in Technology with respect to productivity, quality and energy conservation, Near Net shape casting, Strip casting.

Reference Books:

1. Tupkary R.H., An Introduction to Modern Steel Making, Khanna Publishers.
2. G.R. Bashforth, The Manufacture of Iron and Steel, Chapman & Hall.
3. Schrewe H.F. Continuous Casting of Steel, Stahl-eisen.
4. Edneral F.P., Electrometallurgy of Steel and Ferroalloys, Vol. 1&2, Mir

<u>MS-5252 Secondary steel making</u>

Module 1 **Lectures 4**
Objectives of secondary steel making. Various processes.

Module 2 **Lectures 4**
Vacuum ladle degassing, Recirculation Degassing (RH) – brief outline. Recirculation Degassing with oxygen top lance (RH-OB) - brief outline.

Module 3 **Lectures 4**

Ladle Degassing (VD, Tank Degassing) - brief outline .

Module 4 **Lectures 4**

Vacuum Oxygen Decarburization (VOD) - brief outline .

Module 5 **Lectures 8**

Ladle Furnace (LF) - brief outline . Ladle desulfurization by injection of active agents , Powder injection , Cored wire injection - brief outline .

Module 6 **Lectures 8**

Ladle-to-mold degassing - brief outline . Deoxidation of steel - - brief outline .

Module 7 **Lectures 8**

Deoxidation by metallic deoxidizers - Killed steels , Semi-killed steels , Rimmed steels - Deoxidation by vacuum . Diffusion deoxidation , Desulfurization of steel , Electroslag Remelting (ESR) - . - brief outline , Argon - oxygen decarburization (AOD) – basic principle and application.

Reading:

1. Modern Steel Making --- Dr. R.H.Tupkary .

2. Steel Making -- A.K.Chakrabarty -- PHI .

3. Physical Chemistry of Iron & Steel making --- R.G.Ward .

4. Manufacture of Iron & steel , Iron Production – Vol – I ,II & III --- G.R. Bashforth.

MS-5253 Extraction of Nonferrous Metals

Module 1 **Lectures 4**

General principles of extraction of metals from oxides and sulphides; Mineral resources of Non ferrous metals in India; Their production, consumption and demand. Future of Non ferrous metal industries in India.

Module 2 **Lectures 6**

Aluminum: Bayer’s process and factors affecting its operation, Hall- Heroult process: Principle and practices, anode effect, refining of aluminum. Alternate methods of production of alumina and aluminum.

Module 3 **Lectures 6**

Copper: Roasting of sulphides, Matte smelting, Converting; Refining, Byproducts recovery; Recent developments, Continuous copper production processes, Hydrometallurgy of Copper.

Module 4 **Lectures 6**

Zinc: Pyrometallurgy of Zinc; Principle and practices of roasting; sintering and smelting; Hydrometallurgy of Zinc.

Module 5 **Lectures 6**
Lead: Agglomeration of galena concentrates and roasting, blast furnace smelting, refining of lead bullion.

Module 6 **Lectures 6**
Uranium: Process for the digestion of uranium ores; Purification of crude salts; Production of reactor grade UO_2. Titanium: Methods of upgrading Ilmenite; Chlorination of Titania, Kroll and Hunter processes; Consolidation and refining.

Module 7 **Lectures 6**
Other Metals: Simplified flow sheets and relevant chemical principles of extraction of Ni, Mg, Au, Ag, Sn, Zr.

Reference Books:

1. Ray H.S., Sridhar R. & Abraham K.P., Extraction of Non Ferrous Metals, Affiliated East West.
2. Biswas A.K. & Davenport W.G., Extractive Metallurgy of Copper, Pergamon.
3. Zelikman A.N., Krein O.E. & Samsonov G.V., Metallurgy of Rare Metals, Israel Program for Scientific Translation.
4. Burkhin A.R. (ed), Production of Al & Al_2O_3, Wiley.

MS-5254 Ferroalloy production

Module 1 **Lectures 8**

Overview of Indian ferro alloy sector & alloy steel sector.

Module 2 **Lectures 10**

Basics of ferro alloys production – concepts, thermodynamic principles & techniques.

Module 3 **Lectures 10**

Existing production process of important ferro alloys , Fe-Cr, Fe-Mn, Fe-Si, Recent advances in ferro alloy technology.

Module 4 **Lectures 8**

Production of other ferro alloys – Fe-V, Fe-Ti, Fe-W, Fe-Nb, Fe-Mo, Fe-Ni, Fe-Zr, Fe-B etc.

MS-5255 Materials Selection and Design

Module 1 **Lectures 10**

Revision of engineering materials, Classification of materials- metals and alloys, ceramics, polymers and composites, Importance of materials selection and metallurgical design, Properties and applications of plain carbon steels and common non-ferrous alloys.

Module 2 **Lectures 10**

Criteria for selection of materials, Ashby charts for materials selection, application of statistics in materials.

Module 3 **Lectures 10**

specification of steels, Composition, heat treatment, microstructure and properties of ferrous and non-ferrous alloys, ceramics and polymers for light and heavy structural, corrosion resistant, high temperature, low-temperature and cryogenic, wear resistant, magnetic, electrical and electronic applications, pressure vessels and boilers, bearings, tools, medical implants and prostheses application, Composites, shape memory alloys, metallic glasses, nanocrystalline materials.

Reading:

1. M.F. Ashby: Engineering Materials, 4th Edition, Elsevier, 2005.

2. M.F. Ashby: Materials Selection in Mechanical Design, Butterworth Heinemann, 2005.

3. ASM Publication, Vol.20: Materials Selection and Design, ASM, 1997.

4. Pat L. Mangonon: The Principles of Materials Selection and Design, Prentice Hall International, Inc.1999.

MS-5256 Materials handling

Module 1 **Lectures 8**

Objectives of material handling systems, material handling engineering survey, basic features of handling, types of material handling systems, various material handling considerations including combined handling, space for movements, analysis of handling methods, economical and technical considerations of handling equipments, cost analysis of material handling systems.

Module 2 **Lectures 8**

Material handling equipments, types of material handling equipment; selection and maintenance of material handling equipments used in foundries, forging machinery and assembly shops. Lifting and lowering devices, Conveying devices.

Module 3 **Lectures 8**

Design of belt conveyers, Use of limit switches and Micro processors, Programmable logic controllers.

Module 4 **Lectures 8**

Automation in Foundries; Use of robots; Kinematics of industrial robots. Amount of equipments required and predicting in process inventory by graphical technique.

Module 5 **Lectures 8**

Procedures for travel charting, numerical problems in optimum arrangement of various departments and shops under given constraints and to check their effectiveness.

Reference Books:

1. Plant Layout and design, Moore
2. Plant Layout and Material handling, Apple
3. Plant Layout, Shubhin
4. Construction management, Verma, M.

<u>MS-5261 Light Metals and Alloys</u>

Module 1 **Lectures 8**

General introduction - strengthening by solid solution, precipitation, dispersion of second phase particles, grain refinement and work hardening.

Module 2 **Lectures 12**

Aluminum and its alloys: Production of Aluminum, Designation, temper and characteristics of cast and wrought alloys. Heat treatment of Aluminum alloys – Al-Si, Al-Cu, Al-Mg & Al-Zn-Mg systems. Development of high strength Aluminum alloys by non-equilibrium processing routes such as rapid solidification and powder metallurgy. Applications in consumer, automotive and aerospace industry.

Module 3 **Lectures 12**

Magnesium and its alloys: Production of Magnesium, Designation, temper and characteristics. Heat treatment of Magnesium alloys – Mg-Sn, Mg-Zn, Mg-Gd, Mg-Li systems. Development of high strength magnesium alloys. Applications in consumer, automotive and aerospace industry.

Module 4 **Lectures 8**

Titanium and its alloys: Production of titanium. Heat treatment of Titanium and its alloys - alpha alloys, alpha - beta alloys, beta alloys. Applications in sports, automotive, aerospace and strategic industries.

Reading:

1. I.J.Polmear, Light Alloys - From Traditional alloys to nanocrystals, Fourth Edition, Butterworth Heinemann, 2005
2. R.W.Heine, C.R.Loper, P.C.Rosenthal, Principles of Metal Casting ,Tata McGraw Hill, 1976.

3. D.H. Kirkwood, M. Surey, P. Kapranos, H.V. Atkinson, K.P. Young, Semisolid Processing of Alloys, Springer Series in materials Science, 2010.

4. M. Gupta, N.M.L. Sharon, Magnesium, Magnesium Alloys, and Magnesium Composites, Wiley, 2011

5. G. Lutjering, J.C. Williams, Titanium, Springer, 2007

6. T.W. Clyne, P.J. Withers, An introduction to metal-matrix composites, Cambridge University Press, 1993.

MS-5262 Advanced Metal Joining processes

Module 1 **Lectures 6**

Introduction: Theory and classification of welding and other joining processes. Manual metal arc (MMA): Equipment requirement, electrodes for welding of structural steels, coating, constituents and their functions, types of coatings, current and voltage selection for electrodes for welding, power sources; conventional welding transformers, rectifiers, current and voltage. The influence of power sources on welding, Metal transfer.

Module 2 **Lectures 6**

Submerged are welding (SAW): Process details, consumables such as fluxes and wires for welding mild steel, variations in submerged arc welding process.

Module 3 **Lectures 6**

Gas metal arc welding or MIG/MAG welding: Process details, shielding gases, electrode wires, their sizes and welding current ranges.

Module 4 **Lectures 6**

TIG Welding: Process details, power source requirements, electrode sizes & materials, current carrying capacities of different electrodes, shielding gases, applications..

Module 5 **Lectures 8**

Resistance welding: General principle of heat generation in resistance welding, application. Process details & working principles of spot, seam and projection welding. Electrode materials, shapes of electrodes, electrode cooling, selection of welding currents, voltages.

Module 6 **Lectures 8**

Welding metallurgy of carbon and alloy steels, cast irons, stainless steels, Al-and Cu- based alloys. Soldering & Brazing: Difference between both the processes, consumables used, methods of brazing, fluxes used, their purposes and flux residue treatment.

Reference Books:
1. Lancaster J.F., Metallurgy of Welding, Allen and Unwin.
2. Little R.L., Welding and Welding Technology, TMH.
3. Norrish J., Advanced Welding Processes, Woodhead.
4. Wenman K., Welding Processes Handbook, Woodhead

Course outcomes (COs):
CO1: The metallurgical changes exist in weld metal and its effect on properties.
CO2: The purpose and classification of coating of the electrodes
CO3: The various types of modes of metal transfer exist in welding processes.
CO4: The difference between various welding processes and its industrial utilization.

MS-5263 Failure Analysis

Module 1 **Lectures 10**

Types of failure and techniques for failure analysis Failure data retrieval, Procedure steps for investigation of a failure for failure analysis.

Module 2 **Lectures 10**

Failure analysis methodology, Tools and Techniques of Failure analysis.

Module 3 **Lectures 10**

Reliability concept and hazard function, life prediction, condition monitoring, application of Poisson, Exponential and Weibull distributions for reliability, bath tub curve, parallel and series system, mean time between failures & life testing.

Module 4 **Lectures 10**

Some case studies of failure analysis. Introduction to quality management, concept of ISO 9000, ISO 14000, QS 9000; Inspection; Inspection by sampling.

Reference Books:
1. Metals Handbook, Failure Analysis and Prevention, Vol.10 ASM.
2. Colangelo V.J. & Heiser F.A., Analysis of Metallurgical Failures, John Wiley

MS-5264 Fracture Mechanics

Module 1 **Lectures 8**

Griffith's crack theory, stress intensity factor, stress analysis of cracks, strain energy release rate, Derivation of relationship between strain energy release rate and stress intensity factor, crack tip plastic zone, Dugdale's plastic strip model.

Module 2 **Lectures 10**

Fracture mode transition: Plane stress vs. plane strain, crack opening displacement, plane strain fracture toughness (KIC) testing, Fracture toughness determination with elastic plastic analysis (JIC), concept of R-curve and Fracture toughness measurement using it.

Module 3 **Lectures 10**

Microstructural aspect of fracture toughness, optimizing microstructure and alloy cleanliness to enhance fracture toughness.

Module 4 **Lectures 12**

Fatigue stress life approach, Basquin's equation, Fatigue strain life approach, Low cycle fatigue, Cofin- Manson's equation, Fatigue total strain life relation, Fatigue life prediction, Neuber's analysis for notched specimens, Fatigue crack growth rate, Paris law, fatigue life calculation using this approach. Mechanism of fatigue crack nucleation and propagation, factors affecting fatigue crack growth rate, influence of load interaction, short fatigue crack; stress corrosion cracking and KIscc determination. Corrosion fatigue, temper embrittlement, hydrogen embrittlement, liquid metal embrittlement, neutron embrittlement.

Reference Books:

1. Hertzberg, R.W., Deformation and fracture mechanics of engineering materials, John Wiley.
2. Dieter, G.E., Mechanical Metallurgy, McGraw Hill
3. Metal Hand book, Failure analysis and prevention (Volume- XI), ASM Pub.
4. Metal Hand book, Fractography (Volume- XII), ASM Pub.

Course Outcome

Upon completion of this class, the students will be able to:

- Correctly apply fracture mechanics to predict brittle fracture. Identify and describe the basic fracture and fatigue mechanisms
- Understand crack resistance and energy release rate for crack criticality.
- Application of Linear Elastic Fracture Mechanics on brittle materials.

- Identify the plane stress and plane strain conditions based on the shape and size of plastic zones. This concept made them capable to select the type of analysis subjected to plane stress and plane strain condition
- Correctly identify the cause of failure of a material based on fracture surface observations
- Apply the knowledge of fracture mechanics under various conditions.
- Awareness about crack formation and crack growth in materials under various conditions.
- To understand the concepts on materials failure and fracture and should be able to analyze and take remedial steps in case of failure by fracture.
- Gain knowledge about the behavior of engineering materials having microscopic flaws.

MS-5265 Testing of Materials

Module 1 **Lectures 5**

Introduction; objectives Indentation hardness testing: Brinell, Rockwell, Meyer, Vicker and Knoop hardness testing. Meyer's law. Micro- and nano-hardness testing.

Module 2 **Lectures 5**

Tension, compression and torsion testing. Effects of specimen geometry and testing variables.

Module 3 **Lectures 7**

Impact testing with Charpy and Izod specimens.

Module 4 **Lectures 8**

Ductile to brittle transition behavior. Drop weight testing.

Module 5 **Lectures 8**

Fatigue testing to determines S-N curve. Ultra high cycle fatigue. Applicable testing standards.

Module 6 **Lectures 7**

NDE Methods – Visual, liquid penetrant testing, magnetic particle testing, ultrasonic testing, radiography, acoustic emission testing. Eddy current testing, thermography. Applicable Testing standards, Introduction of TQM in Material testing

Reference Books:

1. Miller, R and Paul, M; Non destructive testing handbook; Acoustic emission testing, Vol 5, American society for non destructive testing, 1987.

2. Spanner, J.C; Acoustic emission techniques and applications., Latex publishing, 1974

3. American Society for Metals, Non destructive inspection and quality control; Metals handbook, Vol 11, 8th edition.

4. ASM handbook, Non destructive testing and quality control, Vol. 17

MS-5266 Creep, Fatigue and Fracture

Introduction: Analysis of stresses and strains, Principal stresses and strains. Stress / Strain Invariants, Theories of Failure, Various yield criteria, Theoretical cohesive strength of metals, defects and stress concentration, stress due to crack inside a large plate, Energy balance during propagation of crack, concept of critical stress to propagate crack, Griffith theory, Common causes of engineering fracture, Fractography, Microscopic fracture modes, Fractographic observation of cleavage/brittle, quasi-cleavage and ductile/dimple fracture.

Fracture Mechanics: Concept of fracture, Classification of fracture, Mechanism of ductile and brittle fracture, Strain energy release rate, Modes of fracture, Stress intensity factor, Fracture toughness, Determination of fracture toughness (KIc), Plasticity at the crack tip, Orowan correction, Irwin's modification, Plastic zone shape and size, effect of constraint, plane stress, plane strain, thickness effect, CTOD, J integral.

Fatigue: Fatigue testing and its significance, stress cycles, S-N curve, HCF, LCF, R ratio, Goodman diagram, fatigue limit, Paris law, Miner's rule, mechanism of fatigue failure, effect of stress concentration, size, surface condition and environments on fatigue, effect of metallurgical variables on fatigue properties.

Creep: High temperature materials problem, Temperature dependent mechanical behavior, Creep test, Creep curve, Creep properties of metals, Structural change during creep, Creep mechanisms, Stress-rupture test, Deformation and fracture at elevated temperature, Prediction of long time properties, LMP, Creep resistant materials, Effect of metallurgical variables on creep.

Readings:

1. R. W. Hertzberg: Deformation and Fracture Mechanics of Engineering Materials, 4th Edition, John Wiley & Sons Inc., 2012.

2. M.A. Meyers and K.K. Chawla: Mechanical Behavior of Materials, Prentice Hall Inc., 1999.

3. T. L. Anderson: Fracture Mechanics- Fundamentals and Applications, 3rd Edition, CRC Press, 2011.

4. G. E. Dieter: Mechanical Metallurgy, 3rd Edition, McGraw-Hill, 2002

5. Michael Kassner: Fundamentals of Creep in Metals and Alloys, 2nd Edition, Elsevier Science, 2009.

MS-5271 Advanced powder Metallurgy

Scope, advantages and limitations of powder metallurgical techniques. Powder Production:Chemical reaction and decomposition, atomization of liquid metals, electrolytic deposition and mechanical processing of solid materials. Powder characteristics: Composition, structure, size, shape, surface topography, area, apparent and tap density, Flow rate, compressibility, pyrophorocity and toxicity. Compaction Methods: Die, isostatic and continuous compaction. Effect of compaction variables. Pressure, speed, particle characteristics and lubrication, characteristics of compacts. Sintering mechanism: Driving force, material transport mechanism, sintering variables, solid and liquid phase sintering, hot and warm pressing. Production of Powder metallurgy products: Bearing, sintered carbides, magnetic materials, electrical contact materials, refractory materials and cermets and SAP.

Reference Books: 1. Randal,G., Powder Metallurgy, John Wiley

2. Metal Powder Handbook, ASM

MS-5272 Additive Manufacturing

Introduction: Overview, Basic principle need and advantages of additive manufacturing, Procedure of product development in additive manufacturing, Classification of additive manufacturing processes, Materials used in additive manufacturing, Challenges in Additive Manufacturing.

Generic AM process: CAD, Conversion of STL, Transfer to AM machine and STL file manipulation, machine setup, Build, Removal, Distinction between AM and CNC machining, Reverse engineering

Additive Manufacturing Processes: Z-Corporation 3D-printing, Stereolithography apparatus (SLA), Fused deposition modeling (FDM), Laminated Object Manufacturing (LOM), Selective deposition lamination (SDL), Ultrasonic consolidation, Material Jetting, Binder jetting

Powder bed Fusion processes: Selective laser sintering (SLS), Laser engineered net shaping (LENS), Selective laser melting (SLM), Electron beam melting (EBM), Materials, Powder fusion mechanisms (Solid-state sintering, chemically induced sintering, liquid phase sintering, Full melting), powder handling challenges, powder recycling, defects

Direct energy deposition processes: DED process description, powder feeding, wire feeding, laser and electron based deposition processes

Post-Processing in Additive Manufacturing: Support material removal, surface texture improvement, accuracy improvement, aesthetic improvement, preparation for use as a pattern, property enhancements using non-thermal and thermal techniques, Brief information on characterization techniques used in additive manufacturing, Applications of additive manufacturing in rapid prototyping, rapid manufacturing, rapid tooling, repairing and coating.

Future scope in Additive Manufacturing: Scope of AM in various fields. Its importance and applications.

Readings

1. C.K. Chua, K.F. Leong, C.S. Lim: Rapid prototyping- Principles and applications, 3rd Ed., World Scientific Publishers, 2010.

2. Gibson, I, Rosen D W., and Stucker B., Additive Manufacturing Methodologies: Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010

3. Chee Kai Chua, Kah Fai Leong, 3D Printing and Additive Manufacturing: Principles and Applications: Fourth Edition of Rapid Prototyping, World Scientific Publishers, 2014

4. A. Gebhardt: Rapid prototyping, Hanser Gardener Publications, 2003.

5. L.W. Liou, F.W. Liou: Rapid Prototyping and Engineering applications: A tool box for prototype development, CRC Press, 2007.

6. A.K. Kamrani, E.A. Nasr: Rapid Prototyping- Theory and Practice, Springer, 2006.

7. P.D. Hilton, P.F. Jacobs: Rapid Tooling- Technologies and Industrial Applications, CRC Press, 2000.

8. Ian Gibson, David W Rosen, Brent Stucker: Additive Manufacturing Technologies- Rapid Prototyping to Direct Digital Manufacturing, Springer, 2010

9. D.T. Pham, S.S. Dimov: Rapid Manufacturing- The Technologies and Applications of Rapid Prototyping and Rapid Tooling, Springer, 2001.

MS-5273 Nuclear Materials

Nuclear Engineering: Concepts of nuclear reactors, Structure of the nucleus, binding energy, fission reactions, neutron cross sections, moderation of neutrons, multiplication factor. Fission reactions, Nuclear Power.

Nuclear Reactor Components: Reactors, Classification of nuclear reactors. Materials for nuclear reactors viz., fuels, moderators, control rods, coolants, reflectors and structural materials. Fabrication of fuel and cladding materials.

Processing of Nuclear Materials: Production of Nuclear Grade Materials, general methods of nuclear minerals processing, Production metallurgy of nuclear grade uranium, thorium, beryllium and zirconium, Production of enriched uranium, Processing of spent fuel and extraction of plutonium.

Radiation and Nuclear Waste Disposal: History of Radiation Effects, Radiation Units, Radiation Effects, Biological Effects of Radiation, Radiation Doses and hazard Assessment, Interaction of radiation with materials, Radiation safety and shielding, Disposal of nuclear waste.

Indian Nuclear Power Programme: Indian Reactors and Nuclear Energy Programme in India, Medical Applications of Nuclear Technology.

Readings

1. K. Linga Murty and Indrajit Charit: An Introduction to Nuclear Materials, Wiley, 2013.

2. J. Kenneth Shultis, Richard E. Faw: Fundamentals of Nuclear Science and Engineering, Marcel Dekkar, 2002.

3. John R. Lamarash: Introduction to Nuclear Engineering, 2 ed., Addison Wesley, 1983.

4. S. Glasstone, A. Sesnoke: Nuclear Reactor Engineering, CBS Publishers, 2003.

5. Bodansky: Nuclear Energy- Practices and Projects, Springer, 2004.

6. Gary S. Was: Fundamentals of Radiation Materials Science: Metals and Alloys, 2ed. Springer, 2017

MS-5274 Ceramic Polymers and Composites

Ceramics: Introduction to ceramics, properties of ceramics, crystal structure, defects in ceramics, classification of ceramics, Processing of ceramics-powder preparation, consolidation and shaping of ceramics, sintering , super plasticity in ceramics, Bio ceramics, ceramic coating, Toughening mechanism in ceramics, engineering applications of ceramics.
Polymers: Introduction to Polymers, structure and properties of polymers, degradation of polymers, high temperature polymers, processing of polymers, applications of polymers
Composites: Introduction to Composites, properties, rule of mixtures, classification of composites, various routes of processing of composites, applications of composites, fracture in composites, Case studies.
Reading:

1. W. David Kingery, H. K. Bowen and Donald R. Uhlmann, Introduction to Ceramics, 2nd Edition, John Wiley & Sons, 2004.
2. S. Somiya, Handbook of Advanced Ceramics, Parts 1 and 2, , Aacdemic Press, 2006
3. Deborah D. L. Chung , Composite Materials: Science and Applications, Second Edition, Springer, 2009
4. David. W. Richerson, Mercel Dekker, Modern Ceramic Engineering by, NY 1992.
5. Krishan Kumar Chawla, Composite Materials- Science and Engineering, Springer, 2012.
6. B. Raymond, Seymour and Charles E. CarraherJr, Polymer Chemistry, An Introduction, 2nd Edition, Marcel Dekkar, Inc. New York, 1987.

MS-5275 Nanotechnology

Significance, properties and applications nanomaterials, carbon nano structures, nano indentation, super plastic behaviour of nanomaterials, Ceramic nanosystems, quantum confinement, effect of size reduction on optical, electrical, electronic, mechanical, magnetic and thermal properties of materials, nano electronics, Nano fluidics, NEMS, photonic crystals, biomimetic nano structures.
Readings:

1. B S Murty et. al. : Textbook of Nanoscience and Nanotechnology, Universities Press (India) Private Limited 2013.
2. Sulabha K. Kulkarni: Nanotechnology Principles and Practices, Capital Publishing Company, 2007.
3. H. Hosono, Y. Mishima, H. Takezoe, K.J.D Mackenzie: Nanomaterials- From Research to Applications, Elsevier, 2008.
4. Massimilano Di Ventra, S. Evoy, James R. Heflin Jr: Introduction to Nanoscale Science and Technology, Springer, 2009.
5. Charles P. Poole Jr., Frank J. Owens

MS-5276 Computational Materials Engineering

Basics of computer programming, introduction to computation, numerical methods, physical of modelling of material problems, scales in materials structure, length and time scales in modelling, Monte-Carlo Methods: basics and applications, molecular modelling: inter atomic potential, introduction to FEA and crystal plasticity: basics, solving 1D and 2D problems, microstructure modelling, thermodynamic modelling: CALPHAD, ThermoCalc, alloy design, integrated computational materials engineering, materials selection and design.

Readings

1. Richard Laser, Introduction to Computational Materials Science, Cambridge University Press, 2013.

2. R J Arsenault, J R Beeler Jr, D M Easterling (Eds): Computer Simulation in Materials Science, ASM International, 1986.

3. Zoe Barber, Introduction to Material s Modelling, Maney Publishing, 2005.

4. June Gunn Lee, Computational Materials Science 2ed., CRC Press, 2016

5. B.S. Grewal, Numerical Methods in Engineering and Science, Mercury Learni