NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

Honors in

METALLURGICAL AND MATERIALS ENGINEERING

SCHEME OF INSTRUCTION AND SYLLABI

(for students of B.Tech., Metallurgical and Materials Engineering)

Effective from 2021-22

DEPARTMENT OF

METALLURGICAL AND MATERIALS ENGINEERING

SCHEME OF INSTRUCTION

Honors - Metallurgical and Materials Engineering

3 credits x 6 courses = 18 credits

S.No	Course Code	Course Name	Year/SEM
1	MMH01	Diffusion in Solids	3/1
2.	MM5201	Phase transformations in Materials (MT(I))	3/1
3.	MM5153	Additive Manufacturing (MT/IM(II))	3/2
4.	MM5211	Aerospace Materials (MT(I))	4/1
5.	MMH02	Advanced ceramics for strategic applications (Online course-NPTEL)	4/1
6.	MM5163	Special Steels (IM(II))	4/2

IM: MTech- Industrial Metallurgy

MT: MTech- Materials Technology

COURSE CODE MMH01	DIFFUSION IN SOLIDS	Credits 3-0-0: 3

Pre-Requisites: Introduction to Materials Science, Transport Phenomena, Physical Metallurgy

Course Outcomes:

At the end of the course, the student will be able to

CO1	Discuss the thermodynamic basis of crystal defects.
CO2	Explain the laws governing the diffusion.
CO3	Describe the mechanisms of diffusion.
CO4	Suggest a method to measure diffusion rate.
CO5	Analyse the role of diffusion in microstructure development.

Syllabus:

Thermodynamics and defects in solids: Concept of free energy, enthalpy and entropy Gibb's free energy, change with temperature in a single component system, Thermodynamic parameters in a binary system, Thermodynamics and phase diagrams, Concept of the chemical potential and the activity of elements, Point defects: Equilibrium vacancy concentration in a pure element. Equilibrium concentration of interstitial atoms, Defects in the ordered phases, Calculation of thermodynamic parameters

Fick's laws: Fick's laws of diffusion and thin film solution, Solution in semi-infinite diffusion couples (error function analysis), Solution for homogenization (separation of variables)

Diffusion under chemical potential gradient, the composition profiles in an inter- diffusion zone and diffusion as a tool to make products: Diffusion under the thermodynamic driving forces, Driving force for diffusion and Fick's laws of diffusion, Product phase formations because of diffusion in real systems, Diffusion process as a tool to make products, Definition and description of different diffusion terms.

Atomic mechanism of diffusion: Interstitial diffusion, Concept of random walk, Substitutional diffusion, Activation energy for diffusion, Orientation dependence Diffusion in the ordered phases.

Determination of different kinds of diffusion parameters: Matano-Boltzmann analysis, Calculation of diffusion parameters using the Matano-Boltzmann analysis, Den Broeder and Wagner's approach, Problem of finding the initial contact plane, Effect of molar volume in a hypothetical diffusion couple, The Kirkendall effect, The intrinsic diffusion, Darken analysis and the van Loo relation, Integrated diffusion coefficient, Calculations of the integrated diffusion coefficients, Tracer diffusion coefficient and the vacancy wind effect, Recent developments on the Kirkendall effect, Physico-chemical approach, Grain boundary diffusion.

Phase diagram and diffusion in ternary and multicomponent systems: Ternary phase diagrams, Ternary and multicomponent diffusion, Intrinsic, integrated and the average diffusion coefficients, Phase diagram determination by the diffusion couple technique.

Text Books:

1. Shewmon, Paul, Diffusion in Solids, Springer, 2016.
2. Helmut Mehrer, Diffusion in Solids: Fundamentals, Methods, Materials, Diffusion-Controlled Processes, Springer, 2009
3. Alok Paul, Tomi Laurila, Vesa Vuorinen, Sergiy V. Divinski, Thermodynamics, Diffusion and the Kirkendall Effect in Solids, Springer, 2014

Reference Books:

1. Philibert J., Atom movements, EDP Sciences, 2021
2. Porter DA, Easterling KE. Phase transformations in metals and alloys, CRC press, 2009

Online Resources:

1. http://alexandria.tue.nl/extra2/200412361.pdf

Course Code: MM5201	PHASE TRANSFORMATIONS IN MATERIALS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Apply the thermodynamic principles to study the phase diagrams of materials
CO2	Describe liquid to solid and solid to solid-state transformations
CO3	Discuss the phase transformations during non-equilibrium processing of materials
CO4	Apply the science of phase transformations to develop advanced and novel materials

Syllabus:

Introduction: Crystal geometry, crystal structures, Construction of phase diagrams, Gibbs free energy, Chemical potential, Diffusion, Thermodynamics of phase transformations, free energy vs composition curves in relation to phase diagrams. Classification of phase transformations, Theory of nucleation in liquid and solid states

Liquid-to-Solid Transformations: Solidification of pure metals and alloys - thermal and constitutional super-cooling. Solute redistribution and coring, Eutectic solidification and eutectic structures, Peritectic and Monotectic solidification

Solid-to-Solid Transformations: Diffusional and non-diffusional solid-state transformations: nucleation and growth of phases, Decomposition of solid solutions; ordering reactions; spinodal decomposition; The role of the eutectoid transformation on the formation of pearlite and other diffusional products. Bainitic and martensitic transformations; hardenability; tempering; Theory of transformation kinetics and the origin of transformation diagrams.

Phase Transformations during Non-equilibrium Processing of Materials: Mechanical milling, Rapid solidification processing, Vapor deposition, Formation of metallic glasses, Crystallization of metallic glasses, Phase transformations at nanoscale, Formation of metastable phases

Text Books:

1. D.A. Porter, K.E. Easterling: Phase Transformations in Metals and Alloys, Van Nostrand Reinhold (International), 1989.
2. A.K. Jena, M.C. Chaturvedi: Phase Transformations in Materials, Prentice Hall,1992.
3. S.P. Gupta: Solid State Phase Transformations, Allied Publishers, New Delhi, 2004.

Reference Books:

1. P.G. Shewmon: Transformations in Metals, McGraw Hill Book Company, 1980.
2. R.E. Reed-Hill and R. Abbaschian: Physical Metallurgy Principles, 1992.
3. M.F. Ashby and D.R.H. Jones, Engineering Materials 1–An Introduction to Properties, Applications and Design, 4th ed. (2011), Butterworth-Heinemann Publishers, Massachusetts, USA

Online Resources:

1. NPTEL lectures: https://www.youtube.com/watch?v=vyR82mXAmxw&t=28s

Course Code: MM5153	ADDITIVE MANUFACTURING	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Explain the basic concepts and importance of additive manufacturing
CO2	Describe the principles, processes and advantages of additive manufacturing systems
CO3	Apply the knowledge of additive manufacturing for various real-life applications
CO4	Suggest mitigation techniques for additive manufacturing defects

Syllabus:

Introduction: Overview, basic principles 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, importance and applications.

Text Books:

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

Reference Books:

1. Additive Manufacturing Processes, Editor: David L. Bourell, William Frazier, Howard Kuhn, and Mohsen Seifi, ASM Hand Book, Volume 24, ASM International, 2020Title of the Text Book, Author(s), Publisher, Year and Edition

Online Resources:

1. https://additivemanufacturing.com/basics/
2. https://www.additivemanufacturing.media/

Course Code: MM5211	AEROSPACE MATERIALS	Credits 3-0-0: 3

Pre-requisites: None

Course Outcomes:

At the end of the course, the student will be able to

CO1	Outline the material selection criteria for aerospace applications
CO2	Identify components and materials in aeroplanes and space vehicles
CO3	Provide solutions for materials selection, processing, testing and performance evaluation.
CO4	Discuss the creep, fatigue and high-temperature degradation phenomena with respect to aerospace and gas turbine engine components
CO5	Suggest advanced materials for the aerospace applications

Syllabus:

Requirements of space and aerospace materials, land base and aerospace materials, identification of components of aeroplanes and space vehicles, materials usage in each section and criticality of the components and their materials selection, gas turbine, and aero engines; creep, fatigue and corrosion; Nickel and Cobalt based super alloys, special steels, aluminium alloys, titanium alloys, intermetallics, ceramics and their composites, Carbon-Carbon composites, new high strength and advanced materials in aerospace structural components.

Text Books:

1. Aerospace Materials and Material Technologies-Aerospace Materials (Vol. 1) and Aerospace Material Technologies (Vol. 2), N. Eswara Prasad, R.J.H. Wanhill, Indian Institute of Metals Series, Springer, 2017.
2. Materials Selection in Mechanical Design, Michael F. Ashby, Butterworth-Heinemann, 2005
3. Aircraft Materials and Processes, George F. Titterton, Himalayan Books, New Delhi, 1998
4. Manufacturing Technology for Aerospace Structural Materials, F. C. Campbell, Elsevier, UK, 2006
5. Aerospace Materials with Materials Technology for Engineers, Vol. 1-4, Balram Gupta, S. Chand & Co., New Delhi, 1996 and 2002.

Reference Books:

1. Light Alloys: From Traditional Alloys to Nanocrystals, Polmear, I. J., Elsevier, 2005, 4th ed.
2. The Superalloys: Fundamentals and Applications, Reed, R. C., Cambridge Univ. Press, 2006.
3. Aerospace Materials, Cantor, B., Assender, H., and Grant, P. (Eds.), CRC Press, 2001.

COURSE CODE MMH02	ADVANCED CERAMICS FOR STRATEGIC APPLICATIONS	Credits 3-0-0: 3

Pre-Requisites:

Course Outcomes:

At the end of the course, the student will be able to

CO1	Illustrate ceramic processing and fabrication techniques
CO2	Identify various types of ceramic materials and properties
CO3	Develop structure-processing-property relationship of ceramics
CO4	Formulate ceramics for strategic applications

Syllabus:

Introduction: oxide and non-oxide ceramics, their chemical formulae, crystal and defect structures, nonstoichiometry and typical properties.

Powder Preparation: Physical methods (different techniques of grinding), chemical routes - coprecipitation, sol-gel, hydrothermal, combustion synthesis, high temperature reaction (solid state reaction).

Basic principles and techniques of consolidation and shaping of ceramics: powder pressing- uniaxial, biaxial and cold isostatic and hot isostatic, injection moulding, slip casting, tape-casting, calendaring, multilayering.

Sintering: Different mechanisms and development of microstructure (including microwave sintering); Preparation of single crystal, thick and thin film ceramics.

Mechanical behaviour: fracture mechanics and tribology; Electrical behaviour**:** insulating (dielectric, ferroelectric, piezoelectric, pyroelectric) semiconducting, conducting, superconducting and ionically conducting, specific materials and their applications; Magnetic behaviour**:** basic principles, materials and their applications.

Engineering applications: at room and high temperatures (including armour application) and; Bio-medical applications.

Transparent ceramics, coatings and films: preparation and applications; Porous ceramics and ceramic membrane: fabrication techniques and applications in separation technology.
Ceramics for energy and environment technologies: Fuel cell, lithium battery, gas sensor and catalytic support.

Ceramics matrix composites: different types, their preparation and properties (including nano-composites)

Exotic ceramics: functionally graded, smart/ Intelligent, bio-mimetic and nano - ceramics - basic principles, preparation and applications.

Text Books:

1. Fundamental of Ceramics by Michel W. Barsoum, McGraw Hill International edition, 1997.
2. Modern Ceramic Engineering by David. W. Richerson, Mercel Dekker, NY 1992.
3. Ceramic Processing and Sintering by M. N. Rahman, Mercel Dekker, 2003.

Reference Books:

1. Handbook of Advanced Ceramics, Parts 1 and 2, S. Somiya, Academic Press, 2006.

Online Resources:

1. NPTEL Link: https://nptel.ac.in/courses/113/105/113105015/

Course Code: MM5163	SPECIAL STEELS	Credits 3-0-0: 3

Pre-Requisites: None

Course Outcomes:
At the end of the course, the student will be able to

CO1	Discuss the development of the special steel for modern-day engineering applications.
CO2	Analyse the structure, property and processing relationship of specialty steels
CO3	Evaluate the principles of micro-alloying and thermo-mechanical processing
CO4	Discuss the heat treatment principles of tool steels and ultrafine-grained steels.

Syllabus:

General Introduction – properties and importance of various steels. Review of strengthening mechanisms applicable to steels – grain refinement, solid solution, precipitation, dispersion of second phases, martensite, twinning, work hardening.

Development of various steels – principles of alloying, microalloying, heat treatment and thermomechanical processing in steels, Production of dual-phase steels, TRIP steels, TWIP steels; bainitic steels, IF steels, HSLA &advanced high strength low alloy steels, maraging steels, stainless steels, high nitrogen stainless steels, tool steels, ultrafine-grained steels. Non-equilibrium processing of steels, Structure-property correlations in various steels.

Secondary steel making, Clean steel making, Advanced steel making

Applications – structural, consumer, automotive and aerospace industries.

Text Books:

1. W.C. Leslie: Physical Metallurgy of Steels, Tech Books, 1991.
2. F.B. Pickering: Physical Metallurgy and Design of Steels, Applied Science Publishers, 1978.
3. H. K. D. H. Bhadeshia: Bainite in Steels- Transformations, Microstructure and Properties, CUP, 2001.
4. George Adam Roberts, Richard Kennedy, G. Krauss: Tool Steels, 5th Ed., ASM, 1998.
5. Albert M. Hall: Introduction to Today's Ultrahigh-strength Structural Steels, ASTM Special Technical Publication, 1973.
6. R.F. Decker: Source Book on Maraging Steels, ASM, 1979.