MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Materials Research Centre

Course Code : 21MST501

Course Name : Design of Materials

Credits : 3 **L -** 3 **T -** 0 **P -** 0
Course Type : Core
Prerequisites : None

Course Contents

Unit I: Introduction to material science, classification of materials. Atomic structure and Interatomic bonding, Crystalline and amorphous structure identification, Various crystal systems, plane direction representation.

Unit II: Imperfection in solids, point defects, line defects, planar defects and surface defects. Diffusion mechanisms. Mechanical response of a material-dislocation.

Unit III: Phase diagram-illustration using Iron-Carbon system. Phase transformation-with reference with microstructure and property changes. Various processing routes for metal alloys

Unit IV: Material Systems- Ceramics, Polymer and composites- their structure, properties and processing.

Unit V: Design and Materials selection Examples: Cutting tools, Combustion Engine, Thermoelectric modules, Solar Cells, Electronic Devices.

Recommended Readings

1. Text book-
   (i) Interdisciplinary Engineering Sciences: Concepts and Applications to Materials Science; AK Dubey, A Mukhopadhyay, B Basu.
   (ii) Materials Science and Engineering: An Introduction; W. D. Callister, D. G. Rethwisch.
   (iii) The Science and Engineering of Materials; D.R. Askeland et al.

2. Reference book-
   (i) Introduction to Materials Science for Engineers; James Shackelford.
   (ii) Materials Science and Engineering; V. Raghavan.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Materials Research Centre

Course Code : 21MST502

Course Name : Material Characterization Techniques

Credits : 3 L - 3 T - 0 P - 0

Course Type : Core

Prerequisites : Basic quantum mechanics, solid state physics

Course Contents

Unit I: Fundamentals of crystallography, Lattice Geometry, The Weiss Zone Law, Symmetry Elements, Translational Symmetry, Rotational Symmetry, Reflection Symmetry, Restrictions on Symmetry Elements, Possible Combinations of Rotational Symmetries, Crystal Systems, Space Lattices (Bravais Lattices).

Unit II: Reciprocal Lattice, Stereographic projection, Basics of X-Rays, X-Ray diffraction and methods, X-ray techniques: X-ray diffraction- Generation and characteristics of x-ray, Lattice planes and Bragg's law, Theory of diffraction, determination of particle size and micro/macro strains, reciprocal lattice, electron diffraction, energy loss spectroscopy, SAXS, XRF, in-situ methods in XRD.

Unit III: Optical Microscopy (working principle and data interpretation), Introduction to Electron microscopy (SEM, TEM, EDX, WDS, EPMA) – Working principle and electron matter interaction.

Unit IV: Working principle and analysis for Mechanical Characterization (Hardness, tensile test), Thermal analysis (e.g., DTA, DSC, TGA, DMA).

Recommended Readings

1. Text book-
   (i) Crystallography and Crystal Defects; Anthony Kelly and Kevin M. Knowles.
   (ii) Elements of X-ray Diffraction; B. D. Cullity and S. R. Stock.
   (iii) Scanning electron microscopy and x-ray microanalysis; Goldstein et al.
   (iv) Transmission Electron Microscopy - A Textbook for Materials Science; D.B. Williams and C.B. Carter.

2. Reference book-

   (i) Concise Encyclopedia of Materials Characterization; R. Egerton, Robert Cahn.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Materials Research Centre

Course Code : 21MST504

Course Name : Synthesis and Properties of Materials

Credits : 3 L - 3 T - 0 P - 0

Course Type : Core

Prerequisites : Basic understanding of physics and chemistry

Course Contents

Unit I: Synthesis of materials by Soft Chemical Methods, Synthesis methods of dimensionally modulated Inorganic nanostructured materials Thermolysis routes, Microwave assisted synthesis; Sonochemical assisted synthesis, Core-Shell nanostructure, Organic –Inorganic Hybrids, Quantum dot (QDs) synthesis. Carbon Nanotubes, Graphene nanosheets.

Unit II: Fabrication of Nanomaterials by Physical Methods: Inert gas condensation, Arc discharge, RF- plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy (MBE), Chemical vapour deposition (CVD) method. Template assisted synthesis; Catalyst assisted chemical vapour deposition (CCVD).

Unit III: Amino acids, Carbohydrates and enzymes for the synthesis of nanomaterials. Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Role of plants in nanoparticle synthesis.

Unit IV: Concept of energy band diagram for materials, electrical conductivity effect of temperature on conductivity, intrinsic and extrinsic semiconductors, dielectric properties, piezoelectric properties, ferroelectric and pyroelectric materials.

Unit V: Origin of magnetism, paramagnetism, diamagnetism, anti-ferromagnetism, ferromagnetism, ferrimagnetism, magnetic hysteresis. Lattice vibrations, vibrations of simple lattice-optical and acoustic phonons, Heat capacity, Thermal conductivity thermal stress in materials and characteristics in metals and non-metals. Interaction of radiation with matter, Reflection, Refraction, Transmission, Atomistic theory of optical properties, band transitions, Phosphorescence, luminescence and optical active materials.

Recommended Readings

1. Text book-
   (i) Essentials of Inorganic Materials Synthesis; CNR Rao, K. Biswas.
   (ii) Nanotechnology: Principles and Practices; S. K. Kulkarni.
   (iii) Fundamentals of Materials Science and Engineering; W D Callister.
   (iv) Essentials of Materials for Science and Engineering; Donald R. Askeland, Pradeep P. Phule.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Materials Research Centre

Course Code : 21MSP503

Course Name : Material Synthesis and Characterization Lab

Credits : 3 L - 0 T - 0 P - 6
Course Type : Core
Prerequisites : None

Course Contents

Experiment 1: Synthesis of semiconducting zinc oxide nanoparticles by sol-gel method and calculation of their absorption coefficient & optical bandgap using UV-Vis spectrometer.

Experiment 2: Biological Synthesis of coinage metal nanoparticles and study of associated surface Plasmon resonance band.

Experiment 3: Solid state synthesis of and dielectric properties of ferroelectric $BaTiO_3$.

Experiment 4: Formation of Poly-(Methyl Methacrylate) by polymerization of Methyl Methacrylate.

Experiment 5: Preparation of zinc oxide-polymer nanocomposites using wet chemical method.

Experiment 6: Microwave synthesis and fluorescent properties of Carbon dots from low-cost carbon sources.

Experiment 7: Tensile/Compression Testing of Aluminium Specimen.

Experiment 8: To observe the effect of heat treatment (Annealing and Quenching) on the microstructure and Hardness of high carbon steel using optical microscope and micro indentation.

Experiment 9: Electrochemical characterization of ZnO and ZnO polymer composite using electrochemical workstation.

Experiment 10: Photo-electrochemical characterization of Zinc oxide nanoparticles.

Recommended Readings

1. Text book-
   (i) Nanotechnology: Principles and Practices; S. K. Kulkarni, 3rd edition, Springer, 2014.
   (ii) Polymer Synthesis and Characterization: A Laboratory Manual; S. S. Sandler et al. 1998.
   (iii) Essentials of Inorganic Materials Synthesis; CNR Rao, K. Biswas, John Wiley & Sons, 2015.

2. Online resources-
   (i) https://pubs.acs.org/doi/abs/10.1021/la049258j
   (ii) https://aip.scitation.org/doi/pdf/10.1063/5.0001593
   (iii) https://pubs.rsc.org/en/content/articlelanding/2012/CC/C1CC15988G
   (iv) http://vlabs.iitb.ac.in/vlabs-dev/approved_labs.php

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Materials Research Centre

Course Code : 21MST505

Course Name : Compound Semiconducting Devices

Credits : 3 L - 3 T - 0 P - 0

Course Type : Core

Prerequisites : Basic solid state and quantum physics

Course Contents

Unit I: Direct and indirect semiconductors, charge carriers in semiconductors, effective mass, carrier concentrations, compensation and space charge neutrality, effect of temperature and doping on mobility, high field effects, p-n junction, contact potential, equilibrium Fermi level, space charge and capacitance at a junction.

Unit II: The families (III-V's, II-VI's, IV-VI's, IV-IV's), alloys, Eg vs a; band structures (E vs k; Γ, L, X minima; direct vs. indirect gaps); crystal lattices, electrical properties, optical properties; trends in properties and the periodic table. The useful compounds.

Unit III: The compound semiconductor surface; Fermi level pinning. Theories of barrier formation and of current flow; diffusive vs. ballistic flow; contrasts with p-n diodes. Theory and practice of ohmic contacts.

Unit IV: E-x Profiles: ΔEc, ΔEv, Ec(x), Ev(x); no(x), po(x); modulation doping. Conduction parallel to heterojunction; mobility in semiconductors and carrier scattering mechanisms.

Unit V: Conduction normal to junction: I-V models and characteristics. Theory of graded layers; creation of internal carrier-specific fields. Semiconductor Physics Review. Band Profiles at HJs.

Unit VI: Quantum wells: theory, fabrication, observation (verification), and application. Quantum wires and dots. Coupled quantum structures: super lattices. Resonant tunneling: RTD structure and concept. I-V theory.

Recommended Readings

1. Text book-
   (i) Semiconductor Nanostructures for Optoelectronic Applications; T. Steiner.
   (ii) Epitaxy of Semiconductors: Introduction to Physical Principles; U. W. Pohl.
   (iii) Physics of Semiconductor Devices; S.M. Sze and K.K. Ng.

2. Reference book-
   (i) Physics of Semiconductor Devices; M. Shur.
   (ii) The Physics of Low Dimensional Semiconductors; J. H. Davies.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Materials Research Centre

Course Code : 21MST506

Course Name : Spectroscopic & Microscopic Techniques for Material Characterization

Credits : 3 L - 3 T - 0 P - 0

Course Type : Core

Prerequisites : Basic knowledge of crystal geometry, theory of diffraction and quantum mechanics.

Course Contents

Unit I: Scanning Probe Microscopies: Scanning tunneling microscope (STM)-application in characterization of electronic materials; lithography; and atomic force microscope (AFM) – lateral force microscopy; phase imaging.

Unit II: General Concepts of Spectroscopy, Non-radiative spectroscopy: Auger Electron Spectroscopy (AES), X-ray Photoelectron Spectroscopy (XPS), Rutherford Backscattering Spectroscopy (RBS), Secondary Ion Mass Spectroscopy.

Unit III: UV-visible spectroscopy- Beer's law, Instrumentation, Quantitative analysis; Vibrational spectroscopy- Raman and Infrared, Principles of vibrational spectroscopy, Infrared and Raman activity, Fourier transform infrared spectroscopy, Raman spectroscopy, Micro Raman, Basics of NMR techniques.

Unit IV: Electron Microscopy- Principles of image formation in crystalline and amorphous materials at the atomic resolution level; high spatial resolution electron diffraction with emphasis on convergent beam electron diffraction; quantitative elemental compositional and chemical analysis with energy dispersive X-ray spectroscopy and electron energy loss spectroscopy; high voltage electron microscopy.

Recommended Readings

1. Text book-
   (i) Materials Characterization: Introduction to Microscopic and Spectroscopic Methods; Y. Leng.
   (ii) Fundamentals of Molecular Spectroscopy; C. N. Banwell and E. M. McCash.
   (iii) Surface Analysis: The Principal Techniques; J. C. Vickerman, I. Gilmore.

(iv) Scanning electron microscopy and x-ray microanalysis; Goldstein et al.
(v) Transmission Electron Microscopy: A Textbook for Materials Science; D. B. Williams & C. B. Carter.

2. Reference book-
(i) Materials Characterization Techniques; S. Zhang, L. Li, A. Kumar.
(ii) Microscopy Techniques for Material Science; A. R. Clarke, C. N. Eberhardt.

MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

Department/Centre : Materials Research Centre

Course Code : 21MST507

Course Name : Thermodynamics and Kinetics of Materials

Credits : 3 L - 3 T - 0 P - 0
Course Type : Core
Prerequisites : Basic understanding of thermodynamics and kinetics

Course Contents

Unit I: Thermodynamic Variables, State Variables and Functions, Thermodynamic Systems and Processes, Energy and Work, Properties of Materials.

Unit II: Stored Energy in Solids, First Law, Quasi-static Processes, Heat Capacities and Gaseous Behavior, Internal Energy and Enthalpy, Thermodynamic Functions for General Systems, The Second Law, Heat Stored during Phase Changes, Gibbs Free Energy, Entropy Content in Materials, Conditions of Equilibrium, Describing the State of an Alloy.

Unit III: Studies of kinetics of chemical reactions; rate equations, order and molecularity, reaction mechanisms, Steady state approximation. Transport processes; Fick's laws of diffusion, atomic and molecular diffusion, atomic theory of diffusion.

Unit IV: The Gibbs Phase Rule and its Application, Uniformity of Chemical Potential at Equilibrium, Important Geometrical Constructions (the common tangent construction), Phase Diagrams, Using Phase Diagrams, Solution Thermodynamics, Unstable Solutions, Equilibrium Conditions for Solid Solutions.

Unit V: Phase transformations; nucleation and growth, crystallization, Surface and interface phenomena; sintering, grain growth, recovery and re-crystallization. Phase transformations: homo- and heterogeneous nucleation, alloy solidification, martensitic transformations. Time-Temperature-Transformation diagram.

Recommended Readings

1. Text book-
   (i) Problems in Metallurgical Thermodynamics and Kinetics; R K Dubey and G S Upadhyaya.
   (ii) Kinetics of Materials; R. W. Balluffi, S. M. Allen, W. Craig Carter.
   (iii) Introduction to the Thermodynamics of Materials; David R. Gaskell, David E. Laughlin.

2. Reference book-
   (i) Materials Kinetics Fundamentals; Ryan O' Hayre.

(ii) Solid State Phase Transformations; V. Raghavan.