MALAVIYA NATIONAL INSTITUTE OF TECHNOLOGY JAIPUR

MATERIALS RESEARCH CENTRE

Scheme for B. Tech Engineering with Minor in "Functional Materials"

Semester V

S. No.	Course Title	Category	L	T	P	Credits	Contact hours
1.	Fundamentals of Material Science	PC	3	0	0	3	3
2.	Synthesis and Spectroscopic Characterization of Functional Materials	PC	3	0	0	3	3

Semester VI

S. No.	Course Title	Category	L	T	P	Credits	Contact hours
1.	Structural Characterization of Functional Materials	PC	3	0	0	3	3
2.	Laboratory for Synthesis and Characterization of Functional Materials	PC	0	0	6	3	6

Semester VII

S. No.	Course Title	Category	L	T	P	Credits	Contact hours
1.	Nanomaterials and their Applications	PC	3	0	0	3	3

Semester VIII

S. No.	Course Title	Category	L	T	P	Credits	Contact hours
1.	Advanced Materials and their Applications	PC	3	0	0	3	3

B. Sharma

Head, MRC

Kamakshi

DUGC Convener

Fundamentals of Materials Science

	L	T	P
Prerequisite: Basic understanding of Physics and Chemistry	L	T	P
Type: Core	3	0	0
Credit: 03			

Course Description: This course will introduce the students to the fundamentals of materials, their properties and applications.

Course Content

Unit 1 (10L)	Classification of engineering materials, Structure property relationship, Chemical bonding, Crystalline & non-crystalline states of solid, Imperfections in crystals -Point & linear defects, Dislocations and their properties, Surface imperfections, Grain size determination.
Unit 2 (6L)	Diffusion mechanisms in solid, Steady state diffusion, Non-steady state diffusion, Applications based on second law of diffusion, Atomic model of diffusion, Factors affecting diffusion.
Unit 3 (6L)	Mechanical properties of solids, Elastic, Inelastic & Viscoelastic behavior, Plastic deformation & creep in crystalline materials, Fracture- types, Mechanisms & protection.
Unit 4 (8L)	Electrical properties of solids- Band theory, Classical and quantum free electron theory, Density of states, Kronig-Penny model, Conductors, Semiconductors, Insulators, Fermi level in Semiconductors, Direct and Indirect semiconductors, Compound Semiconductors.
Unit 5 (9L)	Corrosion & degradation of materials- Electrochemical properties, Mechanisms of corrosion, Corrosion rates, Passivity, Forms of corrosion, Corrosion Environments & corrosion preventions, Oxidation, Degradations in ceramics and polymers, Corrosion prevention.
References	1. Raghavan, V. Materials Science and Engineering, PHI 2. Callister, W.D. Materials Science and Engineering An Introduction, Wiley 3. Askeland, D. R., Phule, P.P. Essentials of Materials Science and Engineering, CENGAGE Learning.
Course Outcomes	CO1: To understand the role played by the defects in determining the properties of the materials. CO2: To understand the distinction between different types of materials and the effect of structure on their properties. CO3: To understand the basic concepts and principles of corrosion and its prevention. CO4: To understand the mechanical behavior of materials for structural applications.

Synthesis and Spectroscopic Characterization of Functional Materials

Prerequisite: Basic understanding of Physics and Chemistry	L	T	P
Type: Core	3	0	0
Credit: 03			

Course Description: This course will introduce the students to various synthetic approaches for synthesis of a variety of materials and the basics of spectroscopic techniques used for their characterization.

Course Content

Unit 1 (3L)	Strategies for material synthesis: Top down and Bottom- up approach, Nucleation and growth, Ostwald ripening, LaMer Diagram.
Unit 2 (8L)	Synthesis of materials by Wet Chemical Methods: Colloidal synthesis, Hydrothermal synthesis, Microwave-assisted synthesis, Sonochemical synthesis, Sol-gel method. Examples for synthesis of Quantum dots, core-shell nanostructures, carbon nanomaterials, 2D materials.
Unit 3 (9L)	Fabrication of materials by Physical and Chemical Methods And their industrial applications: Inert gas condensation, Arc discharge, RF- plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Chemical vapor deposition (CVD), Catalyst assisted chemical vapor deposition (CCVD). Protective coatings, Semiconducting thin films for device fabrication.
Unit 4 (6L)	Synthesis of materials by biological routes: 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 5 (3L)	General Concepts of Spectroscopy, Quantization of energy, Regions of the spectrum, Representation of spectrum, Resolving power, Width and intensity of spectral transitions.
Unit 6 (10L)	UV-visible spectroscopy- Colour and light absorption, Principle of electronic spectroscopy, Instrumentation and sampling, solvent effects, Application of UV-visible spectroscopy in material characterization. Vibrational spectroscopy- Raman and Infrared, Principles of vibrational spectroscopy, Fourier transform infrared spectroscopy, modes of vibration, Factors affecting vibrational frequencies, Instrumentation, sampling techniques and application in identification of functional groups. Fluorescence spectroscopy- Jablonski diagram, principle of fluorescence, quenching mechanism, FRET, Inner filter effect.

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References	1. Rao, CNR, Biswas, K. *Essentials of Inorganic Materials Synthesis*, 1st Edition, John Wiley & Sons, Inc. 2015. 2. Kulkarni, S. K. *Nanotechnology: Principles and Practices*, 3rd Edition, Springer, 2015. 3. Banwell, C. N., McCash, E. M. *Fundamentals of Molecular Spectroscopy*, 4th Edition, Tata McGraw-Hill Publishing Company, 2006. 4. Kemp, W. *Organic Spectroscopy*, 3rd Edition, Palgrave Publishers Ltd., 2002.
Course Outcomes	CO1: To understand the basic mechanism underlying the synthesis of materials. CO2: To apply various bottom-up and top-down approaches for synthesizing materials. CO3: To understand the basic concepts and principles of spectroscopic techniques. CO4: To characterize materials using UV-visible, FTIR or fluorescence spectroscopy.

Structural Characterization of Functional Materials				
Prerequisite: Basic Quantum mechanics, Solid State Physics		L	T	P
Type: Core		3	0	0
Credit: 03				
Course Description: This course comprises of the fundamental principles and techniques for structural characterisation of different classes of materials.				
Course Content				
Unit 1 (10L)	Fundamental crystallography, Packing factors and packing efficiency, Miller indexes for crystallographic planes and directions, Structure determination by Brag's X-ray diffraction method, Generation and detection of X-rays, X-ray diffraction, Phase identification, Indexing and lattice parameter determination.			
Unit 2 (10L)	Scanning electron microscopy (SEM) Instrumentation, Electron beam-specimen interaction, secondary electron and backscattered electron imaging, Energy dispersive spectroscopy (EDS).			
Unit 3 (10L)	Transmission electron microscopy (TEM) Instrumentation, Concept of wave particle duality of electron, Diffraction in TEM, Concept of Ewald sphere, Electron sources, Image modes, Image contrast.			
Unit 4 (9L)	Basic principle of X-Ray Photoelectron Spectroscopy (XPS), Instrumentation-Notation of Atomic Electron Levels, Qualitative XPS, Principle of XPS Analysis, Photoelectron Spectra: Elemental Identification.			
References	1. Elements of X-ray diffraction, B.D. Cullity and S.R. Stock, 2001, Prentice Hall, Inc. USA. 2. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM, R. Egerton, 3 ed., 2001 3. Transmission electron microscopy, D.B. Williams and C. Barry Carter, 4 volumes, Springer, 1996. USA 4. Auger- And X-Ray Photoelectron Spectroscopy in Materials Science: A User Oriented Guide, Siegfried Hofmann			
Course Outcome	CO1: To familiarize students with X-Ray diffraction, SEM, TEM and XPS characterization techniques for structural material characterization. CO2: Nurture an ability to develop and conduct appropriate experimentation.			

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	CO3: Utilize knowledge to analyze and interpret data, and use engineering judgment to draw conclusions. CO4: To relate the data obtained with the different materials characterization techniques to the behaviour of materials and their properties.

Laboratory for Synthesis and Characterization of Functional Materials

	L	T	P
Prerequisite: Basic understanding of Physics and Chemistry	L	T	P
Type: Core	0	0	6
Credit: 03			

Course Description: This course will introduce the students to various synthetic approaches for synthesis of a variety of materials and the basics of spectroscopic techniques used for their characterization.

Course Content

Experiment 1	Synthesis of semiconducting zinc oxide nanoparticles by sol-gel method and calculation of absorption coefficient & optical bandgap using UV-Vis spectrometer.
Experiment 2	SEM and XRD Analysis of ZnO nanoparticles synthesized by sol-gel method.
Experiment 3	Fabrication of metal thin film by sputtering method and its structural & electrical characterizations.
Experiment 4	Synthesis of Au/Ag nanoparticles by biological method and its characterizations.
Experiment 5	Synthesis of Cu-Al alloy nanoparticle by ball milling method and quantitative composition analysis by XRD.
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 evaluate the contact angle measurement of material using wetting.
Experiment 9	Compositional analysis of material by XPS.
Experiment 10	Comparative optical characterization of the commercial drug (paracetamol) with lab synthesized drug.
References	1. Nanotechnology: Principles and Practices; S.K. Kulkarni, 3rd edition, Springer, 2014. 2. Essentials of Inorganic Materials Synthesis; CNR Rao, K. Biswas, John Wiley & Sons, 2015.
Course Outcomes	CO1: To understand the basic mechanism underlying the synthesis of materials. CO2: To apply various bottom-up and top-down approaches for synthesizing materials. CO3: To write a report with analysis and documentation of results CO4: To characterize materials using various spectroscopic and microscopic techniques.

Nanomaterials and Their Applications

Prerequisite: Basic knowledge of Chemistry, Physics and Biology	L	T	P
Type: Core	3	0	0
Credit: 03			

Course Description: The course will introduce the students underlying physical/chemical principles of nanotechnology, and technological impact and applications in various fields.

Course Content

Unit 1 (5L)	Introduction to nanomaterials: History of nanomaterials, Surface area to volume ratio, General properties of nanomaterials, Effect on properties and phase stability of nanomaterials compared to the bulk state, Electronic structure of nanomaterials and Fermi Surface, Thermodynamics of Nanomaterials.
Unit 2 (10L)	Different classes of nanomaterials: Materials at reduced dimensions, Two-dimensional nanostructures – surfaces and films, One dimensional nanostructures – nanotubes and wires, Zero dimensional nanostructures – fullerenes, metallic nanoparticles. Metallic nanoparticles: Surface plasmon resonance, Anisotropic nanoparticles. Metal nanoclusters, Bimetallic nanoparticles, Quantum Dots: Quantum confinement, Band gap tuning and properties of quantum dots, Surface defects and doping in quantum dots, Carbon nanostructures: Graphene, graphene oxide, carbon dots Soft Nanomaterials-Gels, Gel-nanoparticle composite, Properties of gels.
Unit 3 (8L)	Nanomaterials for catalysis, optical sensing and as artificial enzymes; Catalysis: Types of catalysis, Metallic nanoparticles and nanoclusters as catalyst, metal oxide and carbon nanostructures for photocatalysis; Optical Sensing: Principles of optical sensing, Fluorescence and Quenching mechanisms, Metal nanoparticles and fluorescent nanostructures as optical sensors for heavy metal ions, important biomolecules and explosives with examples of paper and film based sensing devices; Artificial enzymes: Enzymes, Importance of nanozymes;
Unit 4 (6L)	Nanomaterials for energy and environmental protection; Nanomaterials for solar cells, Nanomaterials for pollution prevention, Green chemistry, Nanomaterials for clean water & air.
Unit 5 (10L)	Nanotechnology for medical diagnostics and therapy: Disease diagnostics: Quantum dot conjugation strategies with DNA-aptamer, Protein and antibody and FRET based assays for disease diagnostics. Drug delivery: Lipid and polymeric nanoparticles as drug delivery vehicles; Polymeric, peptide and metal-organic gels for drug delivery, Nanotechnology for therapy: Metallic nanostructures and nanoscale metal-organic frameworks for phototherapy of cancer; Magnetic nanoparticles as MRI contrast agents.

References	1. Rao, M. S. R., Singh, S., *Nanoscience & nanotechnology: Fundamentals of frontiers*, 1st Edition, Wiley India Pvt. Ltd., 2013. 2. Schmid, G., *Nanoparticles: From Theory to Application,* 2nd Edition John Wiley and sons, 2010. 3. Cao, G., Wang, Y., *Nanostructures and nanomaterials: Synthesis, properties, and applications*, 2nd Edition, World Scientific Press, 2011. 4. Kumar, C. S. S. R., *Nanomaterials for Medical Diagnostics and Therapy,* 1st Edition, Wiley-VCH, 2007.
Course Outcomes	CO1: To classify nanomaterials and have an understanding of their properties. CO2: To utilize surface plasmon resonance band and fluorescence of nanomaterials for optical sensing. CO3: To evaluate the structure-property relationship and size effects of nanomaterials. CO4: To apply nanostructured materials in environmental, energy, and medical fields.

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Advanced Materials and Their Applications

	L	T	P
Prerequisite: Basic knowledge of thermodynamics, Elementary crystallography and crystal structure, Mechanical behavior of materials, Basic understanding of physics and electrochemistry			
Type: Core	3	0	0
Credit: 03			

Course Description: The main objective of this course is to give students an overview on the need of the ceramics and Energy materials with their properties for several potential applications.

Course Content

Unit 1 (10L)	Structure of ceramics -crystalline solids and their defects, Non-crystalline solids, Multiphase materials, Pauling's Rules, Oxide structures, Silicate Structures, The clay Minerals, Physical principles of ceramic processes, Diffusion, Solid state reaction, Sintering and related phenomena, Nucleation, Grain growth transformation, Sintering methods and mechanisms, Control of microstructure
Unit 2 (10L)	Modes of failure- fracture, fatigue and creep mechanisms of failure, Theoretical fracture strength, Griffith flaws in brittle failure, nucleation and propagation of microcracks. Strengthening methods- Composite materials. Thermal expansion, Heat capacity and thermal conductivity. Thermal behavior and microstructure, Thermal stresses and deformations. Applications.
Unit 3 (10L)	Hydrogen merit as a fuel, Applications, Hydrogen production methods, Production of hydrogen from fossil fuels, Electrolysis, Thermal decomposition, Photochemical and photo-catalytic methods, Hydrogen storage methods, Metal hydrides, Metallic alloy hydrides, Carbon nano-tubes, low dimensional Materials.
Unit 4 (9L)	Thermoelectric Materials, Physics of thermoelectricity, Peltier, Seebeck and Thomson effects, Types of thermoelectric materials, Thermoelectric generators, Peltier cooler.
References	1. Kingery, W. David, Bowen, H. K. and Uhlmann, R., Introduction to Ceramics, 2nd Edition, Wiley & Sons New York, 1976. 2. Callister Jr., William, D., Rethwisch David G.,Introduction to Materials Science and Engineering, 10th Edition,Wiley & Sons, 2018.

	3. Nolas, G. S., Sharp, J., Goldsmid ,J., . Schwartz, M.M., Thermoelectric: Basic Principles and New Materials Developments, Springer series 2001.
Course Outcome	CO1: Grasp the basics of ceramics and Energy materials and their properties. CO2: Evaluate the mechanical and thermal properties of ceramic materials. CO2: Understanding the working principle of devices made of energy materials. CO3: Synthesis routes for Ceramics and energy materials for different targeted applications.

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