National Institute of Advanced Manufacturing Technology

Hatia, Ranchi-834003

(Deemed to be University under Distinct Category)

(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 – Material Engineering (Nanotechnology)

Department of Applied Sciences and Humanities

Master of Technology (M. Tech) in Material Engineering (Nanotechnology)

National Institute of Advanced Manufacturing Technology (NIAMT)

Ranchi, Jharkhand

Department of Applied Sciences and Humanities

M.Tech in Material Engineering (Nanotechnology)

Semester I

Course Code	Core/ Elective	Subjects	L	T	P	Credits
ME-611	Core 1	Fundamentals of Materials Science	3	0	0	3
ME-612	Core 2	Properties and Characterization of Materials	3	0	0	3
ME-613	Core 3	Nano Science and Technology	3	0	0	3
ME-614*	Elective-1	**ME-614(a)** Thin Films and Surface Engineering **ME-614(b)** Introduction to Electrochemical Systems	3	0	0	3
ME-615	Open Elective	**ME-615(a)** Semiconductor Devices and Technology **OR** **ME-615(b** Energy Storage Materials	3	0	0	3
ME-616	Core Lab-I	Synthesis of Nanomaterials LAB	0	0	4	2
ME-617	Core Lab-II	Fabrication and Characterization of Nanomaterials Lab	0	0	4	2
ME-618	MLC	Research Methodology & IPR	2	0	0	2
ME-619	Audit 1	Audit Course 1	2	0	0	0
					Total	**21**

Semester II

Course Code	Core/ Elective	Subjects	L	T	P	Credits
ME-711	Core 1	Processing and Design of Materials	3	0	0	3
ME-712	Core 2	Composite Science and Technology	3	0	0	3
ME-713	Core 3	Smart and Intelligent Materials	3	0	0	3
ME-714*	Elective-2	**ME-714(a)** Advanced Semiconductor Devices **ME-714(b)** Materials for Renewable Energy Conversion **ME-714(c)** Aerospace Materials **ME-714(d)** Nanotribology	3	0	0	3
ME-715*	Elective-3	**ME-715(a)** Lithographic Techniques **ME-715(b)** MEMS/NEMS Design and Applications **ME-715(c)** Advanced Energy Storage Materials and Technology **ME-715(d)** Nano Bio-Technology **ME-715(e)** Computational Materials Science	3	0	0	3
ME-716	Core Lab-I	Nanostructured Material and Application Lab	0	0	4	2
ME-717	Core Lab-II	Simulation Lab	0	0	4	2
ME-718	Core	Mini Project with Seminar	0	0	4	2
ME-719	Audit 2	Audit Course 2	2	0	0	0
					Total	**21**

Semester III

ME-811	Industrial Training 4 weeks	0	0	0	0
ME-812	Dissertation Phase-I	0	0	20	10

Semester IV

ME-911	Dissertation Phase-II	0	0	32	16

Total Credit 21+21+10+16= 68

Eligibility Criteria

M.Sc. ***or*** **M.S.** in Chemistry (all branches)/Physics/Materials Science/Nanoscience and Technology (GATE papers: CY/PH /XE)

B.Tech ***or*** **B.E.** or equivalent degree in Polymer Science and Technology/Chemical Engineering/Rubber Technology/Plastic Technology/Metallurgy and Materials Science/Physical Sciences/ Chemical Technology/ (GATE papers: CH/ XE/ MT)

Audit course 1 & 2

- 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.

SEMESTER-I

ME-611 FUNDAMENTALS OF MATERIALS SCIENCE

Syllabus: Structure of solids, Significance of structure property relationship; Diffusion phenomenon, Applications of diffusion; Principles of solidification, Phase diagrams and phase transformations, Heat treatment; Ceramic materials, Classification, Synthesis, Properties, Characterization and applications.

Detailed version

Structure of solids: Introduction to engineering materials, Description of materials science tetrahedron, Force - interatomic distance curve, Structure - description of unit cell and space lattices, Coordination number, APF for cubic and hexagonal close packed structures, Miller indices, Non crystalline structures properties of crystalline and amorphous structures, Crystal imperfections Significance of structure property correlations in all classes of engineering materials.

Diffusion phenomenon: Diffusion in ideal solutions, Kirkendall effect, Rate and mechanism of diffusion, Fick's first and second law of diffusion, Applications of diffusion, Concept of uphill diffusion.

Principles of solidification and phase equilibria: Concept of free energy and entropy; Structure of liquid metals; Energetics of solidification; Nucleation and growth, Homogeneous and heterogeneous nucleation, Dendritic/Equiaxed growth, Origination of grain and grain boundaries, Cast structure; Significance of alloying, Intermediate alloy phases, solid solutions and its types.

Phase diagrams and phase transformations: Basic definitions; Gibbs phase rule, Introductions to binary, ternary and quaternary system; Construction of binary isomorphous diagram from cooling curves, Time scale for phase diagrams, Transformations in steels, Precipitation process, recrystallization and growth.

Heat treatment: TTT curves, CCT curves, Annealing, Normalising, Hardening, Tempering

Ceramics: Introduction to ceramic materials; Classification of ceramics, Crystal structure and bonding of common advanced ceramic materials; Mechanical behavior of ceramics, Glass and glass ceramics, Preparation and characterisation of ceramics powders; Characterisation of ceramic materials; Applications of ceramics in advanced technologies
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Books:

1. R. Abbaschian, R.E. Reed-Hill, *Physical Metallurgy Principles*, 4th ed., Cengage Learning, 2009.
2. D.R. Askeland, P.P. Phule, W.J. Wright, *The Science and Engineering of Materials*, 6th ed., Cengage Learning, 2010.
3. W.D. Callister, D.G. Rethwisch, *Materials science and Engineering: An Introduction*, 8th ed., Wiley, 2010.
4. B.S. Mitchell, *An Introduction to Materials Engineering and Science for Chemical and Materials Engineers*, 1st ed., Wiley- Interscience, 2003.
5. C. Kittel, *Introduction to Solid State Physics*, 8th ed., Wiley, 2005.

6. V. Singh, *Physical Metallurgy*, 1st ed., 2008.
7. S.H. Avener, *Introduction to Physical Metallurgy*, 2nd ed., Tata McGraw-Hill Education, 2011.
8. V. Raghavan, *Materials Science & Engineering: A first course*, 5th ed., PHI Learning, 2004.
9. W.D. Kingery, *Introduction to Ceramics*, 2nd ed., John Wiley & Sons, 1999.

ME-612 PROPERTIES AND CHARACTERIZATION OF MATERIALS

Syllabus: Basics- electronic, magnetic and optical properties in metals, semiconductors, ceramics and polymers; Electronic properties- dielectric properties, Concept of doping- high, very high and ultra-high frequency fields; Organic semiconductors, □-conjugated polymers; Magnetic domains- magnetic materials, thin films, nanoparticles.
Introduction to materials and techniques; Spectroscopic methods- UV-visible and vibrational spectroscopy- Infrared and Raman, Electron spectroscopies - X-ray photoelectron spectroscopy, Ultra-violet photoelectron spectroscopy, Optical microscopy, Electron microscopy- SEM, TEM; Scanning Probe Microscopies: STM, AFM; Thermal analysis- TGA, DTA, DSC.

ME-613 NANO SCIENCE AND TECHNOLOGY

Syllabus:
Introduction- Size and shape dependent properties and their uniqueness; surface characteristics and stabilization; Quantum confinement; Zero dimensional, one dimensional and two dimensional nanostructures - Processing of nanomaterials - down and bottom up approaches- metal nanoparticles, quantum dots, nanoclusters, carbon based nanomaterials, core-shells, organic, inorganic, hybrid nanomaterials, biomimetic nanomaterials. – Techniques for characterization and property evaluation relevant applications- societal implications and risk factors.

<u>Detailed Version:</u>
General introduction and theory of nanomaterials- History of nanomaterials; Size and shape dependent properties and their uniqueness; Energy at nanoscale - surface characteristics and electrostatic and steric stabilization – Quantum confinement - zero dimensional, one dimensional and two dimensional nanostructures

Synthesis of nanomaterials- Introduction to nanoparticle synthesis – top-down and bottom up approaches - physical nanofabrication techniques (PVD, MBE, CVD, self-assembly, lithographic techniques etc.) and wet chemical methods for the synthesis of zero dimensional one dimensional and two-dimensional nanostructures-metal nanoparticles, quantum dots, nanoclusters, nanowires and rods, thin films.

Functional nanomaterials- Synthesis, properties and applications of organic, inorganic, hybrid nanomaterials – core-shells, nanoshells, self-assembled nanostructures, superlattices, nanoceramics metallic, polymeric, and ceramic nanocomposites, nanoporous materials, nanofluids, nanolayers and carbon based nano materials - Occurrence, production, purification, properties and applications of fullerene, carbon nanotube, graphene, carbon onion, nanodiamond and films, Biomimetic nanomaterials -introduction to biomimetics, mimicking mechanisms found in nature, synthesis and applications of bio inspired nanomaterials and self-assemblies.

Applications of nanomaterials- Application of nanomaterials in healthcare, biosensors, coatings environment, catalysis, agriculture, automotives, sensors, electronics, photonics, information technology, Quantum computing, energy and aerospace sectors.

Books:

1. K. J. Klabunde and R.M. Richards (Eds.), Nanoscale Materials in Chemistry, 2nd Edn., John Wiley & Sons, 2009.
2. T. Pradeep, Nano: The Essentials, McGraw-Hill (India) Pvt Limited, 2008.
3. Bharat Bhushan, (Ed.), Handbook of Nanotechnology, Springer, 2007.
4. Carl C. Koch (Ed.), Nanostructured Materials: Processing Properties and Applications, William Andrew Inc., 2007.
5. Anke Krueger, Carbon Materials and Nanotechnology, Wiley-VCH Verlag GmbH & Co. KGaA, 2010.
6. Cao, G., Nanostructures and Nanomaterials Synthesis, Properties, and Applications, Imperial College Press, 2004.
7. Wang, Z. L., (Ed.), Characterization of nanophase materials, Wiley-VCH Verlag GmbH, 2000.
8. Garcia-Martinez, J., (Ed.), Nanotechnology for the Energy Challenge. Wiley-VCH Verlag GmbH Co. KGaA, Weinheim, 2009.
9. Goddard III W.A., et. al.,(Ed.), Handbook of Nanoscience, Engineering, and Technology, Taylor Francis Group, 2007.
10. B.P.S. Chauhan (Ed), Hybrid Nanomaterials: Synthesis, Characterization, and Applications, Wiley-VCH Verlag GmbH, 2011.
11. J. Lei and F.Lin, Bioinspired Intelligent Nanostructured Interfacial Materials, World Scientific Publishing Company, 2010.
12. Challa S. S. R. Kumar (Ed.) Biomimetic and Bioinspired Nanomaterials, Wiley-VCH Verlag GmbH, 2010.

ELECTIVE-1
ME-614(a) THIN FILMS AND SURFACE ENGINEERING

Syllabus:

Surface modification techniques, Surface modification of ferrous and nonferrous metals, Surface engineering by energy beams, Film deposition techniques- Physical method of film deposition, chemical method of film deposition, other deposition techniques, Inter-diffusion, reactions and transformations in thin films, Properties and characterization of thin films, Surface engineering of nanomaterials microencapsulation, nanostructured coatings.

<u>Detailed version:</u>

Surface modification techniques: Surface engineering by material removal and material addition; Surface modification of ferrous and nonferrous metals- carburizing, nitriding, cyaniding, hot dipping, galvanizing, chromating, anodizing, phosphating of aluminium; Surface engineering by energy beams, Plasma for surface engineering, Laser assisted surface modification Film deposition techniques: Sputter deposition of thin films and coatings by RF, MF, DC, Magnetron, Pulsed laser, Ion beam, Ion implantation, electroplating, electroless plating, electro polishing, electroforming, chemical vapour deposition (CVD) and plasma enhanced CVD, atomic layer deposition, atomic layer chemical vapour deposition, molecular beam epitaxy, lithography, Langmuir Blodgett, Spin coatingInter diffusion, reactions and transformations in thin films: Fundamentals of diffusion, Inter diffusion in thin metal films, Mass transport in thin films; Properties and characterisation of thin films optical, electrical, mechanical and magnetic, structural morphology of deposited films and coatings Surface engineering of nanomaterials: Hybridization of nanomaterials, microencapsulation, synthesis, processing and characterization nano structured coatings and their application

Text Books:

1. Modern Surface Technology, Edited by Friedrich-Wilhelm Bach, Andreas Laarmann, and Thomas Wenz, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, Germany, 2006
2. M. H. Francombe, S. M. Rossnagel, A. Ulman, Frontiers of Thin Film Technology, Vol. 28, Academic press, 2001.

Reference:

1. K. L. Chopra, Thin Film Phenomena, McGraw Hill, 1979.R.F. Bunshah, Deposition Technologies for Films and Coatings, Noyes Publications, New Jersey, 1982.
2. M. Ohring, Materials Science of Thin Films, 2nd ed., Academic Press, San Diego, 2002.
3. F. A. Lowenheim, Electroplating, McGraw Hill, New York, 1978.
4. B. Bhushan, Introduction to Tribology, John &Sons, New York, 2002.
5. G.W. Stachowiak, A.W. Batchelor, Engineering Tribology, 3rd ed., Elsevier-ButterworthHeinemann, 2005.
6. ASM Metals Handbook, Surface Engineering, American Society for Metals, Vol.5, 9th ed., 1994.
7. Nanomaterials and Surface Engineering, Edited by Jamal Takadoum, John Wiley & Sons, Inc., USA

ELECTIVE-1
ME-614(b) INTRODUCTION TO ELECTROCHEMICAL SYSTEMS

Unit-1

Introduction a. Basics of electrochemical energy storage & conversion (e.g., lithium-ion battery and polymer electrolyte fuel cell as exemplar systems), Operating principles & performance metrics, Current status and future perspective

Unit-2

Thermodynamics and Kinetics: Electrochemical concepts (open circuit potential, thermodynamic equilibrium), Nernst Equation, Faraday’s law, Butler-Volmer equation, Tafel equation

Unit-3

Transport Phenomena: Species and charge transport, Transport in electrolyte - Ion transport in solution - migration, convention and diffusion -Fick’s laws of diffusion conduction - influence of ionic atmosphere on the conductivity of electrolytes-Debye Huckel theory of ion atmosphere, activity coefficients of ionic solutions, Debye Huckel-Onsager equation for the equivalent conductivity of electrolytes - experimental verification of the equation - conductivity at high field and at high frequency - conductivity of non-aqueous solutions-effect of ion association on conductivity. The electrode-electrolyte interface-electrical double layer-electro capillary phenomena- Lippmann equation - the Helmholtz- Perrin - Guoy-Chapmann and Stern models, electro kinetic phenomena Tiselius method of separation of protons of proteins - membrane potential.

Unit-4

Transport Phenomena: Porous Electrode - Materials (intercalation, conversion, diffusion and reaction driven), Porous electrode theory, Interfacial phenomena, Transport in Solids, Transport in Porous Media,

Unit-5

Electrochemical analysis: Circuit analysis (resistor and capacitor), Electrochemical impedance response, Cyclic voltammetry, Performance analysis - Simplified electrode model, Coupled species and charge transport model, Thermal analysis (heat generation and thermal transport) d. Mechanical analysis (diffusion induced stress), Design consideration - Electrode & electrolyte property (electrochemical/mechanical/thermal), Thermal safety and thermal management, Degradation (mechanical and chemical effect), Techno-economic analysis

References:

1. Newman, John, and Karen E. Thomas-Alyea. *Electrochemical Systems*. 3rd ed. Wiley-Interscience, 2004. ISBN: 9780471477563.
2. Bard, Allen J., and Larry R. Faulkner. *Electrochemical Methods: Fundamentals and Applications*. 2nd ed. Wiley, 2000. ISBN: 9780471043720.
3. O' Hayre, Ryan, Suk-Won Cha, et al. *Fuel Cell Fundamentals*. 2nd ed. Wiley, 2009. ISBN: 9780470258439.
4. Huggins, Robert A. *Advanced Batteries: Materials Science Aspects*. Springer, 2008. ISBN: 9780387764238.

OPEN ELECTIVE

ME-615 (a) SEMICONDUCTOR DEVICES AND TECHNOLOGY

UNIT 1: SEMICONDUCTOR: Energy Bands and Carrier Concentration in thermal Equilibrium: Semiconductor Materials, Basic Crystal Structure, Basic Crystal Growth Technique, Valence Bands, Energy Bands, Intrinsic Carrier Concentration, Donors and Acceptors. Carrier Transport Phenomena: Carrier Drift, Carrier Diffusion, Generation and Recombination Processes, Continuity Equation, Thermionic Emission Process, Tunneling Process, High-Field Effects.

UNIT 2: METAL-SEMICONDUCTORS: Metal-Semiconductor Contacts and Schottky Diodes: Metal- Semiconductor Junction diode Fabrication, Device Physics: Ideal MS contacts, Schottky Diode-Electrostatics, I- V characteristics, DC, AC and transient analysis. Metal-Semiconductor contacts: Ohmic contacts, Schottky contacts, Tunnel contacts and annealed and alloyed contacts. Photodiode Fabrication, device Physics of PN Junction Photodiodes, p-i-n Photo diodes. Principle of operation and fabrication technologies of Solar cell, LED, and LASER diodes. MOS capacitor, MOSFET device fabrication, MOSFET Physics: I-V characteristics, Sub- threshold region, Body effect, Capacitive effect, small and large signal model. MOSFET Short Channel effects: Punch through, DIBL, Hot electron effect, Velocity Saturation, Leakage current. MESFETs and MODFET analysis.

UNIT 3: NANOTECHNOLOGY PATHWAYS TO NEXT-GENERATION PHOTOVOLTAICS:
Overview of Photovoltaics, Basic Principles, Photovoltaic Technologies: Quantum Wells and Superlattices, Nanowires, Nanoparticles and Quantum Dots, Dye-Sensitized Solar Cells, Nanostructures for Improved Optical Performance, Nanowire Solar Cells, Organic Nanostructures by Molecular Layer Epitaxy: Molecular Nanoelectronics, Methodology of Molecular Layer Epitaxy Size-Dependent Effects in MLE Structures.

UNIT 4: SEMICONDUCTOR DEVICE TECHNOLOGY AND ITS SOCIETAL IMPACT: Energy- efficient electron devices and the sustainable and green environment, Applications to safe and green environment, human health and medicine.

UNIT 5: SEMICONDUCTOR GROWTH TECHNOLOGIES: Bulk, Thin Films, and Nanostructures: Lely growth method, Liquid-phase epitaxy method, Pulsed-laser deposition technique, Molecular beam epitaxy growth technique.

Textbooks:

1. S. M. Sze and Ming-Kwei Lee, Semiconductor Devices Physics and technology, John Wiley & Sons, 2013.
2. Grundmann and Marius, Physics of Semiconductors, Springer, 2010.
3. Semiconductor Nanotechnology, Stephen M. Goodnick· AnatoliKorkin RobertNemanichSpringer series
4. Nano-Scaled Semiconductor Devices Physics, Modelling, Characterisation, and Societal Impact, Edmundo A. Gutie´rrez-D materials, Circuits & Devices Series 27 Nano-ScaledSemiconductor Devices
5. Semiconductor Heterojunctions and Nanostructures, Omar Manasreh MCGraw Hill Nanoscience and Technology series.

Reference Books:

1. Ben G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, Pearson Ed, 2014.
2. M. S. Tyagi, Introduction to semiconductor materials and devices, John Wiley & Sons, 2008.
3. Campbell, Stephan, Fabrication Engineering at the Micro and Nanoscale, OxfordUniversity Press, 2008.
4. Robert F. Pierret, Semiconductor Device Fundamentals, Pearson Education, 2006.
5. Richard C. Jaeger, Introduction to Microelectronic Fabrication, Prentice Hall, 2

OPEN ELECTIVE
ME-615 (b) ENERGY STORAGE MATERIALS

Unit-1

Introduction: Necessity of energy storage, different types of energy storage, mechanical, chemical, electrical, electrochemical, biological, magnetic, electromagnetic, thermal, comparison of energy storage technologies. Principle of Electrical Energy storage in modern sustainable devices: Batteries, super-capacitors, Magnetic Energy storage - Superconducting systems, Mechanical-Pumped hydro, flywheels and pressurized air energy storage, Chemical-Hydrogen production and storage. Performance characteristics of energy storage systems, basic load calculations, Types of load curves, energy shift, Ragone plot. Importance of energy density and power density, Demand for Portable Energy.

Unit-2

Basic components of cell, Primary batteries - electrochemical reactions of primary batteries – carbon-zinc, carbon-zinc chloride, alkaline manganese, silver-zinc, mercury-zinc, zinc-air batteries, components of batteries – anode materials, cathode materials and electrolyte materials, battery potential, energy and power density of batteries, Primary batteries with anodic lithium – $Li-MnO_2$, $Li-(CF_x)_n$, $Li-SOCl_2$ Applications of primary batteries.

Unit - 3

Secondary batteries - components of batteries – anode materials, cathode materials and electrolyte materials, battery potential, energy and power density, electrochemical reactions of secondary aqueous batteries - Lead–acid battery, Nickel–cadmium battery (NiCd), Nickel–metal hydride battery (NiMH). Non-aqueous secondary batteries Lithium anode battery, Lithium-ion battery, Lithium-air, Lithium-sulfur batteries. Applications- Electric vehicles (EVs), future technologies, hybrid systems for energy storage.

Unit-4

Super Capacitors: Basic components of supercapacitors electrodes - activated carbons, metal oxide and conducting polymers, electrolyte - aqueous and organic. Principles, performance and applications.

Unit-5

Hydrogen storage: Physical and chemical properties, general storage methods, compressed storage-composite cylinders, glass micro sphere storage, zeolites, metal hydride storage, chemical hydride storage and cryogenic storage, Carbon based materials for hydrogen storage. Hydrogen safety aspects, backfire, pre-ignition, hydrogen emission NOx control techniques and strategies, Hydrogen powered vehicles.

References:

1. Detlef Stolten,"Hydrogen and Fuel Cells: Fundamentals, Technologies and Applications", Wiley, 2010.
2. Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, "Electrochemical Technologies for Energy Storage and Conversion", John Wiley and Sons, 2012.
3. Francois Beguin and Elzbieta Frackowiak ,"Super capacitors", Wiley, 2013.
4. Doughty Liaw, Narayan and Srinivasan, "Batteries for Renewable Energy Storage", The Electrochemical Society, New Jersy,2010.

ME-616 SYNTHESIS OF NANOMATERIALS LAB

Course Outcomes:

1. Gain knowledge on the synthesis techniques involved in experiments.
2. To construct a practical knowledge on the experiment.
3. The ability to write and present the laboratory reports.
4. To maximize knowledge regarding synthesis and processing of nanomaterials.
5. To acquire knowledge on synthesis parameters.

Experiments:

Bottom Up Approaches:

1. Synthesis of ZnO nanoparticles using Urea as fuel by Solution Combustion Method.
2. Synthesis of Core Shell PVP capped Cadmium Sulfide (CdS) nanoparticles Chemical Co-Precipitation Method.
3. Development of silica gel (SiO_2) using Sol-Gel method.
4. Preparation of Silver nanoparticles by using green synthesis from Aloe vera extract.
5. Fabrication of NiO nanomaterials by Microwave method.
6. Synthesis of MgO nanomaterials by Hydrothermal method.
7. Synthesis of Iron Oxide nanomaterials by Chemical Vapour Deposition (CVD) method.
8. Development of Polymer nanofibers by Electrospinning method.
9. Synthesis and characterization of carbon nanomaterial by cracking of gas mixture using tubular furnace.
10. To Improve Hummers method for eco-friendly synthesis of graphene oxide.
11. An ultrasonic method for the synthesis, control, and optimization of CdS/TiO_2 core–shell nanocomposites.
12. Environment-friendly biomimitic synthesis of copper oxide nanoparticles by Yeast/Fungus/Bacteria.
13. Symmetry – Breaking synthesis of Multicomponent Nanostructures.
14. Synthesis of Nanosized Metal Organic frameworks.

Top-down up Approaches:

15. To study the forming characteristics of TiO_2 nanostructure by mechanical alloying using high energy planetary ball mill.
16. Grain Refinement through heat treatment of Ni/Al_2O_3 Nanocrystals lab

ME-617 FABRICATION AND CHARACTERIZATION OF NANOMATERIAL LAB

Course Outcomes:

1. Gain knowledge on the fabrication and characterization techniques of nanomaterials.
2. Students can acquire knowledge on equipment handling like XRD, PSA, UV etc.
3. To construct a theoretical knowledge
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding fabrication and characterization of nanomaterials.

Experiments:

1. Fabrication of thin film by Dip coating.
2. Fabrication of thin film by Spin coating.
3. Fabrication of thin film by Spray Pyrolysis.
4. Fabrication of thin film by Thermal evaporation technique.
5. Determination of average Crystallite size and Macrostrain by using X-Ray diffraction Analysis.
6. To work out the charge, zeta potential and size distribution of colloidal solution of nanoparticles using dynamic light scattering method.

7. Calculation of band gap with error bar values and particle size by using UV-Visible spectroscopy.
8. Study of thermal properties of nanomaterials by using TG/DTA analysis.
9. FTIR spectroscopy method for investigation of nanoparticle nano surface phenomena.
10. Specific BET Surface Area Measurement and and pore size distribution of Nanomaterials.
11. In situ assessment of the contact angles of nanoparticles adsorbed at fluid interfaces by multiple angles of incidence ellipsometry.
12. CV characteristics of nanomaterial using three electrode system.
13. Gas sensor

ME-618 RESEARCH METHODOLOGY & IPR

UNIT I: Meaning of research problem, Sources of research problem, Criteria Characteristics of a good research problem, Errors in selecting a research problem, Scope, and objectives of research problem. Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations.

(4 lectures)

UNIT II: Effective literature studies approaches, analysis Plagiarism and Research ethics.

(4 lectures)

UNIT III: Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee.

(4 lectures)

UNIT IV: Nature of Intellectual Property: Patents, Designs, Trade and Copyright. Process of Patenting and Development: technological research, innovation, patenting, development International Scenario: International cooperation on Intellectual Property. Procedure for Grants of patents, Patenting under PCT.

(6 lectures)

UNIT V: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

(4 lectures)

UNIT VI: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs.

(4 lectures)

Books and References

1. C. R. Kothari, Gaurav Garg, Research Methodology Methods and Techniques, New Age International publishers, Third Edition.
2. Ranjit Kumar, Research Methodology: A Step by Step Guide for Beginners, 2nd Edition, SAGE, 2005.
3. Business Research Methods – Donald Cooper & Pamela Schindler, TMGH, 9th edition
4. Creswell, John W. Research design: Qualitative, quantitative, and mixed methods approach. Sage publications, 2013.

AUDIT COURSE-I
ME-619 ENGLISH FOR RESEARCH PAPER WRITING

UNIT I: Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness.

UNIT II: Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticizing, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction.

UNIT III: Review of the Literature, Methods, Results, Discussion, Conclusions, the Final Check.

UNIT IV: Key skills are needed when writing a Title, key skills are needed when writing an abstract, key skills are needed when writing an Introduction, skills needed when writing a Review of the Literature.

UNIT V: Skills are needed when writing the Methods, skills needed when writing the Results, skills are needed when writing the Discussion, skills are needed when writing the Conclusions.

UNIT VI: Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission.

Course Outcomes:
Students will be able to:

1. Understand that how to improve your writing skills and level of readability.
2. Learn about what to write in each section.
3. Understand the skills needed when writing a Title Ensure the good quality of paper at very first- time submission.

References:

1. Goldbort R (2006) Writing for Science, Yale University Press (available on Google Books)
2. Day R (2006) How to Write and Publish a Scientific Paper, Cambridge University Press
3. Highman N (1998), Handbook of Writing for the Mathematical Sciences, SIAM. Highman‘sbook .
4. Adrian Wallwork , English for Writing Research Papers, Springer New York Dordrecht Heidelberg London, 2011

SEMESTER-II

ME-711 Processing and Design of Materials

Syllabus
Introduction to materials processing; Polymer processing - rheology of polymeric materials, Compounding and processing of plastics and rubbers, fibre spinning and manufacturing processes.
Ceramic processing- Pressing, CIP, HIP, Slurry processing, Slip casting, Pressure casting, Tape casting, Gel casting, Rapid prototyping, Sol-gel processing, Thermal and plasma spraying, Thick and thin film coatings; Processing of Metallic materials-, Casting processes, Casting design and defects; Fundamentals of deformation processing, Hot and cold working, Metal joining process, Design aspects, Materials selection and design, Weighting factors, Materials performance index; Design of engineering structures, Case studies, Modern metallic, Ceramic, Polymeric and biomaterials devices and components

Detailed version
Introduction: Materials processing science with special emphasis on processing of polymers, ceramics and metals
Polymer processing: Rheology of polymeric materials, Compounding of plastics, processing techniques: Compression, Transfer, injection, blow molding, Extrusion, Calendaring, Thermoforming, Rotational molding, Compounding and processing of rubber (both latex and dry rubber) with different formulations: Casting, rubber extrusion, Dip coating (gloves, balloons etc.), fibre spinning and manufacturing processes.

Ceramic processing: Processing of traditional ceramics- spray granulation, Pressing, CIP, HIP, Slurry processing, Slip casting, Pressure casting, Tape casting, Gel casting, Injection molding, Extrusion; Rapid prototyping through Additive manufacturing, Electrophoretic deposition, Production of ceramic fibres, Electro-spinning; Drying, Binder burnout, Green machining, Sintering; Sol-gel processing, Thermal and plasma spraying, Thick and thin film coatings- PVD and CVD techniques; Vapor infiltration techniques

Metallic processing: Casting process- major casting techniques, Solidification and volume shrinkage, Casting design and defects, Fundamentals of deformation processing, Deformation work, Hot and cold working, Few forming processes and defects; Metal joining process- Concepts of Fusion and solid state welding processes, Brazing and soldering, Welding defects;

Design aspects: General principles of materials selection and design based on requirements of function, Property, Processability and cost; Quantitative methods of materials selection, Materials performance index; Design of engineering structures from the atomic- and nano-scales to macroscopic levels; Case studies- modern metallic, ceramic, polymeric and biomaterials devices and components

Books:

1. P. Boch, J-C. Nièpce, Ceramic Materials: Processes, Properties, and Applications, Wiley-ISTE, 2007.
2. J-H. He, Electrospun Nanofibres and Their Applications, Smithers Rapra Technology, 2008.
3. Z. Tadmor, C.G. Gogos, Principles of Polymer Processing, 2nd ed., Wiley International, 2006.

4. T.A.Osswald, Polymer Processing Fundamentals, Hanser Publications, 1998.
5. M.N. Rahaman, Ceramic Processing and Sintering, 2nd ed.,, CRC press
6. F.C. Campbell, Elements of Metallurgy and Engineering Alloys, ASM International, 2008.
7. J. Beddoes, M.J. Bibby, Principles of Metal Manufacturing Processes, Elsevier, 2003.
8. G.E. Dieter, Mechanical Metallurgy, McGraw-Hill, 3rd ed., 1986.
9. E. Degarmo, J.T. Black and R.A. Kohser, Materials and Processes in Manufacturing, 9th ed., Wiley, 2002.
10. S. Kalpakjian, S.R. Schmid, Manufacturing Engineering and Technology, 6th ed., Pearson, 2009.

ME-712 Composite Science and Technology

Syllabus

Introduction to Composite Materials: Classification, reinforcement; Polymer matrix composites, Thermoplastic and thermosetting resins, Common matrix reinforcement system; Concept of A stage, B stage and C stage resins; Particulate and fibre filled composites, Short fibre composites, Theories of stress transfer; Continuous fibre composites, Failure mechanism and strength, Halpin-Tsai equations, Prediction of Poisson's ratio, Various failure modes; Specialty composites, Composites for satellites and advanced launch vehicles, Design considerations, PMC- for structural composites, Nanocomposites, Design and analysis of composite structures macro mechanics, Micro mechanics, Laminate analysis, FE model and analysis, Manufacturing techniques, Testing of composites, Raw material testing

<u>Detailed version</u>

Introduction to composite materials: Definition of composites, Classification of composites; General characteristics of reinforcement- classification, terminology used in fiber science, CMC, MMC and PMC.

Polymer matrix composites: Thermoplastic and thermosetting resins; Commonly used matrix reinforcement system;Fibre, Flake and particulate reinforced composites, Reinforcements used in PMC'sglass, carbon, aramids, boron, Roving's, yarns, fabrics, etc.; Thermoset matrices for aerospace components- polyesters, epoxies, phenolics, vinyl esters, cyanate esters, etc.; Thermoplastic matrices for advanced composites- PEEK, polysulfones, polyimides, etc. concept of A stage, B stage and C stage resins

Particulate and fiber filled composites: Applications, Function of matrix, Function of fibres, Polymerfibre interface, Factors influencing the performance of composite, Coupling agents, Bonding agents, Short fibre composites, Theories of stress transfer, Analysis of short fibre composites, Critical fibre length, Rule of mixtures

Continuous fiber composites: Analysis of long fiber composites, Longitudinal behavior of unidirectional composites; Failure mechanism and strength, Factors influencing longitudinal and transverse strength and stiffness, Halpin-Tsai equations for transverse modulus, Prediction of Poisson's ratio, Various failure modes

Specialty composites: Composites for satellites and advanced launch vehicles, Design considerations PMC- for structural composites, Theory and application of ablatives.

Nanocomposites: Nano particle dispersion in polymer matrix, Polymer- nanoclay composites and polymer-carbon nanotubes composite

Design and analysis of composite structures: Macro mechanics of a lamina, Micro mechanics, Laminate analysis, FE model and analysis

Manufacturing techniques: Hand lay-up, Filament winding, Pultrusion, Resin transfer molding, Processing science of reactive polymer composites, Process steps for production, Selection of processing conditions toolings, Equipments, Carbon-carbon composites, Processing, Thermal and mechanical properties, Quality control

Testing of composites: Raw material testing, Property evaluation at laminate level, NDT techniques

Books:

1. R.M. Jones, Mechanics of Composites, 2nd ed., Taylor & Francis, 1999.
2. T. G. Gutowski, (Ed.) Advanced Composites Manufacturing, John Wiley & Sons, New York 1997.
3. P.M.Ajayan, L.Schadler, P.V.Braun Nano Composite Science and Technology,Wiley VCH, 2003.
4. E. Fitzer, L.M. Manocha, Carbon Reinforcement and Carbon/Carbon Composites, SpringerVerlag, Heidelberg, New York, 1998.
5. K.K. Chawla, Ceramic Matrix Composites, Kluwer Academic Publishers, 2003.
6. N. Chawla, K.K. Chawla, Metal Matrix Composites, Springer-Verlag, 2006.
7. J.C. Seferis, L. Nicolais, (Eds.) The Role of the Polymeric Matrix in the Processing and Structural Properties of Composite Materials, Plenum Press, New York 1983

ME-713 SMART AND INTELLIGENT MATERIALS

Syllabus: Smart materials and structures- piezoelectric materials, peizoceramics, piezopolymers; Shape memory materials- one way and two ways SME, Training of SMAs, Functional properties of SMAs; Chromogenic materials- principles and design strategies; Smart polymers- temperature responsive and light responsive polymers, Molecular imprinting using smart polymers, Smart hydrogels, Fast responsive hydrogels, Applications; Smart systems for space applications- smart corrosion protection coatings, Self-healing materials, Sensors, Actuators, Deployment devices

Detailed version

Smart materials and structures: System intelligence- components and classification of smart structures, common smart materials and associated stimulus-response, Application areas of smart systems

Ferroelectric materials: Piezoelectric materials- piezoelectric effect, Direct and converse, parameter definitions, Piezoceramics, Piezopolymers, Piezoelectric materials as sensors, Actuators and bimorphs

Shape memory materials: Shape memory alloys (SMAs), Shape memory effect, Martensitic transformation, One way and two-way SME, training of SMAs, binary and ternary alloy systems, Functional properties of SMAs

Chromogenic materials: Thermochromism, Photochromism, Electrochromism, Halochromism, Solvatochromism- principle and design strategies

Smart polymers: Thermally responsive polymers, Electroactive polymers microgels, Synthesis, Properties and Applications, Protein-based smart polymers, pH-responsive and photo-responsive polymers, Self-assembly, Molecular imprinting using smart polymers, Approaches to molecular imprinting, Drug delivery using smart polymers

Smart hydrogels: Synthesis, Fast responsive hydrogels, Molecular recognition, Smart hydrogels as actuators, Controlled drug release, Artificial muscles, Hydrogels in microfluidics

Smart systems for space applications: Elastic memory composites, Smart corrosion protection coatings, Self-healing materials, Sensors, Actuators, Transducers, MEMS, Deployment devices, Molecular machines

Books:

1. D.J. Leo, *Engineering Analysis of Smart Material Systems,* Wiley 2007.
2. M. Addington, D.L. Schodek, *Smart Materials and New Technologies in Architecture,* Elsevier 2005.
3. K. Otsuka, C.M. Wayman (Eds.), *Shape Memory Materials,* Cambridge University Press, 1998.
4. M.V. Gandhi, B. S. Thompson, *Smart Materials and Structures,* Chapman & Hall, 1992.
5. M. Schwartz, *New Materials, Processes, and Methods Technology*, CRC Press, 2006.
6. P. Ball,*Made to Measure: Materials for the 21stCentury*, Princeton University Press, 1997.
7. I. Galaev, B. Mattiasson (Eds.), *Smart Polymers: Applications in Biotechnology and Biomedicine*, 2nd ed., CRC Press, 2008.
8. N. Yui, R. J. Mrsny, K. Park (Eds.), *Reflexive Polymers and Hydrogels: Understanding and Designing Fast Responsive Polymeric Systems,* CRC Press, 2004.

ELECTIVE-2
ME-714(a) ADVANCED SEMICONDUCTOR DEVICES

UNIT 1: SEMICONDUCTOR: Energy Bands and Carrier Concentration in thermal Equilibrium: Semiconductor Materials, Basic Crystal Structure, Basic Crystal Growth Technique, Valence Bands, Energy Bands, Intrinsic Carrier Concentration, Donors and Acceptors. Carrier Transport Phenomena: Carrier Drift, Carrier Diffusion, Generation and Recombination Processes, Continuity Equation, Thermionic Emission Process, Tunneling Process, High-Field Effects.

UNIT 2: METAL-SEMICONDUCTORS: Metal-Semiconductor Contacts and Schottky Diodes: Metal- Semiconductor Junction diode Fabrication, Device Physics: Ideal MS contacts, Schottky Diode-Electrostatics, I- V characteristics, DC, AC and transient analysis. Metal-Semiconductor contacts: Ohmic contacts, Schottky contacts, Tunnel contacts and annealed and alloyed contacts. Photodiode Fabrication, device Physics of PN Junction Photodiodes, p-i-n Photo diodes. Principle of operation and fabrication technologies of Solar cell, LED, and LASER diodes. MOS capacitor, MOSFET device fabrication, MOSFET Physics: I-V characteristics, Sub- threshold region, Body effect, Capacitive effect, small and large signal model. MOSFET Short Channel effects: Punch through, DIBL, Hot electron effect, Velocity Saturation, Leakage current. MESFETs and MODFET analysis.

UNIT 3: NANOTECHNOLOGY PATHWAYS TO NEXT-GENERATION PHOTOVOLTAICS:
Overview of Photovoltaics, Basic Principles, Photovoltaic Technologies: Quantum Wells and Superlattices, Nanowires, Nanoparticles and Quantum Dots, Dye-Sensitized Solar Cells, Nanostructures for Improved Optical Performance, Nanowire Solar Cells, Organic Nanostructures by Molecular Layer Epitaxy: Molecular Nanoelectronics, Methodology of Molecular Layer Epitaxy Size-Dependent Effects in MLE Structures.

UNIT 4: SEMICONDUCTOR DEVICE TECHNOLOGY AND ITS SOCIETAL IMPACT:
Energy-efficient electron devices and the sustainable and green environment, Applications to safe and green environment, human health and medicine.

UNIT 5: SEMICONDUCTOR GROWTH TECHNOLOGIES: Bulk, Thin Films, and Nanostructures: Lely growth method, Liquid-phase epitaxy method, Pulsed-laser deposition technique, Molecular beam epitaxy growth technique.

Textbooks:

1. S. M. Sze and Ming-Kwei Lee, Semiconductor Devices Physics and technology, John Wiley & Sons, 2013.
2. Grundmann and Marius, Physics of Semiconductors, Springer, 2010.
3. Semiconductor Nanotechnology, Stephen M. Goodnick· AnatoliKorkin RobertNemanichSpringer series
4. Nano-Scaled Semiconductor Devices Physics, Modelling, Characterisation, and Societal Impact, Edmundo A. Gutie´rrez-D materials, Circuits & Devices Series 27 Nano-ScaledSemiconductor Devices
5. Semiconductor Heterojunctions and Nanostructures, Omar Manasreh MCGraw Hill Nanoscience and Technology series.

Reference Books:

1. Ben G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, Pearson Ed, 2014.
2. M. S. Tyagi, Introduction to semiconductor materials and devices, John Wiley & Sons, 2008.
3. Campbell, Stephan, Fabrication Engineering at the Micro and Nanoscale, OxfordUniversity Press, 2008.
4. Robert F. Pierret, Semiconductor Device Fundamentals, Pearson Education, 2006.
5. Richard C. Jaeger, Introduction to Microelectronic Fabrication, Prentice Hall, 2

ELECTIVE-2
ME-714(b) MATERIALS FOR RENEWABLE ENERGY CONVERSION

Syllabus: Global Energy Demand, Renewable Energy Sources, Materials for Renewable Energy Conversion- Solar Energy, Photovoltaics, Photoelectrochemical cells and Fuel cells. Mechanism, Fabrication, Evaluation, and Efficiency. Future energy economy-Hydrogen economy- Hydrogen storage, Overview of other renewable energy sources.

Detailed Version

Introduction: Global Energy Demand and Use, Impacts of conventional energy utilization, Renewable Energy Sources- Indian scenario- where we stand, our potential, Economics of conventional and renewable energy systems.

Solar Energy and Solar Cells: Solar Spectrum, Solar constant, Passive conversion –Materials for Renewable energy conversion- Photovoltaics --Silicon (Si) solar cells, Crystalline/ Semicrystalline/ Amorphous Si solar cells, Thin film solar cells. Photoelectrochemical cells -Semiconductor electrochemistry - Photoelectrolysis, photochemical cells, phootcatalysis, Mechanism- electron transfer: Factors affecting electron transfer. Organic solar cells- bilayer, Bulk heterojucntion, polymer solar cells, pervoskite based solar cells, hybrid solar cells. Efficiency; limiting factors.

Sustainable Energy Conversion: Fuel cells-, Various types, Materials- Fuels- Reforming, Electrodes, Catalyst,electrolyte -efficiency. Internal resistance, general causes for failure. Future energy economy-Hydrogen economy – Materials for hydrogen storage,

Overview of other renewable energy sources: Hydroelectric, Wind, geothermal and Tidal Energy –Conversion, potential and limitations– Bio-energy-Safety, economical and Environmental Aspects

Books:

1. B.K. Hodge, *Alternate Energy Systems and Applications*, John Wiley & sons, Inc., 2010.
2. Alan J. Heeger, Niyazi Serdar Sariciftci and Ebinazar B. Namdas, *Semiconducting and Metallic Polymers*, Oxford Univ Press 2010.
3. W. Streicher and M. Kaltschmitt (Ed.) *Renewable energy. Technology, economics and environment*, Springer, 2007.
4. N. Armaroli, V. Balzani and N. Serpone, *Powering Planet Earth – Energy Solutions for the Future*, Wiley,2012.

References:

1. C. Brabec, *Organic Photovoltaics*, Wiley-VCH, 2008.
2. Norman S. Allen (Ed.), *Photochemistry and Photophysics of Polymeric Materials*, 2010.
3. X. Moya David and Muñoz-Rojas(Ed.), *Materials for Sustainable Energy Applications Conversion, Storage, Transmission, and Consumption*, 2016, Pan Stanford Publishing Pvt. Ltd.
4. L. Liu and S.Bashir, Advanced Nanomaterials and their Applications in Renewable Energy, Elsevier Science, 2015.

ELECTIVE-2

ME-714(C) AEROSPACE MATERIALS

Syllabus:
Carbon based materials- carbon fiber, carbon-carbon composites, carbon aerogels and foams, Ceramic materials- polymer derived ceramics, ceramic fibers, ceramic matrix composites, thermal barrier coatings, ceramics aerogels and foams, Ultrahigh temperature ceramics; materials with zero thermal expansion, Metallic materials- Evolution of materials for aerospace sectors, super alloys, titanium alloys, intermetallics and metal matrix composites; High temperature polymers- aromatic liquid crystalline polyesters, polyamide, phenolics, polyimide, poly ether ether ketones; Materials for cryogenic application, Materials for space environment, Materials for spacecraft, Functionally graded materials. Space worthiness of materials.

Detailed version

Carbon based materials: Carbon fiber- precursors and production, properties; carbon-carbon composites- production, properties and applications; Carbon aero-gels; Carbon foams;

Ceramic materials: Polymer derived ceramics- synthesis, processing of pre-ceramic polymers, ceramic fibers, Ceramic matrix composites, Thermal barrier coatings, Ablative materials, Silica tiles, Ceramic aerogels, Porous ceramics and ceramic foams, Ultrahigh temperature ceramics- TiB_2, ZrB_2, HfB_2 and their composites, Materials with zero thermal expansion-glass ceramics-preparation and application

Metallic materials: Super alloys, Titanium alloys, Intermetallics and metal matrix composites, Functionally graded materials -production, properties and application

High temperature polymers: Aromatic liquid crystalline polyesters, Phenolics, Polyimide, Poly ether ether ketones- synthesis, processing and applications

Materials for cryogenic applications: Metals for low temperature applications, Austenitic stainless steel, Nitrogen containing steel, Aluminium, Aluminium-lithium alloys, Titanium alloys, Cryo insulation materials, Polymers and adhesive for cryo temperature applications

Materials for space environment: Radiation shielding materials, Atomic oxygen resistant materials, Space suit materials and materials for life support systems, Evaluation of materials for space environment and space worthiness.

Books:

1. G. Savage, Carbon-Carbon Composites, 1st ed., Chapman and Hall, 1993.
2. M. Scheffler, P. Colombo, Cellular Ceramics, Structure, Manufacturing, properties and Applications, 1st ed., Wiley-VCH, 2006.
3. W.D. Kingery, H.K. Bowen, D.R. Uhlmann, Introduction to Ceramics, 2nd ed., Wiley-Interscience, 1976.
4. J.S. Reed, Principles of Ceramic Processing, 2nd ed., Wiley-Interscience, 1995.
5. H.M. Flower, High Performance Materials in Aerospace, 1st ed., Chapman & Hall, 1995.
6. B.Horst, B. Ilschner, K.C. Russel, Advanced Aerospace Materials, Springer-Verlag, Berlin, 1992.

7. F. Mohammad, Speciality Polymers: Materials and Applications, I.K. International publishing House Pvt. Ltd , 2007.
8. W. Krenkel, R. Naslain, H. Schneider, (Eds.) High Temperature Ceramic Matrix composites, 1sted., Wiley-VCH, 2006.
9. T.W. Clyne, P.J. Withers, E.A. Davis, I.M. Ward, Introduction to Metal Matrix Composites, Cambridge Solid State Science Series, 1st ed., Cambridge University Press, 1993.
10. R.R. Luise, Applications of High Temperature Polymers, CRC press, 1st ed., 1996.

ELECTIVE-2
ME-714(d) NANOTRIBOLOGY

UNIT I: INTRODUCTION TO TRIBOLOGY: History of tribology, origin, and Significance of micro/nanotribology Tribology in design, methods of solution of tribological problems. Purpose of lubrication, modes of lubrication- hydrodynamic, Hydrostatic Boundary lubrication, hydrodynamic lubrication, Extreme pressure lubrication Lubricants - types and lubricating oils Lubricant properties-effect of temperature and pressure, oxidation stability, thermal conductivity, type of additive Bearings- classification based on mode of lubrication Bearing-Classification based on relative motion between contact surfaces. Comparison of sliding and rolling contact bearing, solving numerical on above topic.

UNIT II: SCALE EFFECTS IN MECHANICAL PROPERTIES AND TRIBOLOGY: Nomenclature, scale effect in mechanical properties, Yield strength, shear strength, Scale effect on surface roughness and contact parameters, Scale effects in friction – adhesion, stiction, two body deformation, Three body deformation, Ratchet mechanism, elastic to plastic regime, Tailoring surfaces: Modifying surface composition and structure(texture) for application in Tribology.

UNIT III: SURFACE FORCES AND MEASURING TECHNIQUES: Methods used to study surface forces- force laws Surface force apparatus (SFA)Force between dry surface, force between surfaces in liquid Adhesion and capillary forces, modes of deformation Description of AFM/FFM and various measurement techniques Surface roughness and friction force, Adhesion Scratching, wear, and machining Surface potential measurements Nanoindentation measurement, boundary lubrication, Tribological properties of SAMs.

UNIT IV: LUBRICATION, FRICTION AND WEAR: Lubricant States, viscosity of lubricant Fluid film lubrication, Theories of hydrodynamics lubrication, Lubrication design of typical mechanical elements, transformation, Parameter of surface topography, Friction of materials, solid – solid contact, Liquid mediated contact, interfacing temperature of sliding surfaces, Types of wear mechanism, Typical test geometries.

UNIT V: APPLICATIONS OF TRIBOLOGY: Introduction to various tribological phenomenon, Bio- Tribology – Tribology in the human body, artificial organs, Tribology in medical devices, Natural human synovial joints and total joint replacements, Wind turbine Tribology, Biorefining, Coating application - sliding bearings, rolling contact, Bearings, gears, erosion and scratch resistant, Magnetic recording devices, Micro components, MEMS/NEMS.

Course Outcomes:

1. To provide sound understanding of various concepts related to tribology.
2. Students can able to acquire knowledge on surface forces and measuring techniques.
3. To know the importance of Lubrication, friction, and fear.
4. To develop knowledge on Scale Effects in Mechanical Properties and Tribology.
5. To get awareness on applications of tribology.

Textbooks:

1. H.G. Phakatkar and R.R. Ghorpade, ―Tribology‖, Nirali publication, 2009.
2. Bharat Bhushan, ―Nanotribology and Nanomechanics‖, Springer Publication, Second edition, 2011.
3. Bharat Bhushan, Principles and Applications to Tribology‖, Wiley Publication, 2013.
4. C. Mathew Mate, ―Tribology on the Small Scale‖ Oxford University Press, 2008.
5. Nicholas D. Spencer, ―Tailoring surfaces‖, World Scientific IISC Press, 2011.

ELECTIVE-3
ME-715(a) LITHOGRAPHIC TECHNIQUES

UNIT I: INTRODUCTION TO LITHOGRAPHY AND OPTICAL LITHOGRAPHY: Introduction to lithography- Contact, proximity printing and Projection Printing, Resolution Enhancement techniques, overlay- accuracies, Mask-Error enhancement factor (MEEF), Positive and negative photoresists.

UNIT II: ELECTRON LITHOGRAPHY: Electron optics, Raster scan and Vector scan, Electron proximity / Projection Printing, Direct writing, Electron resists, Electron Beam Applications.

UNIT III: X-RAY LITHOGRAPHY: X-ray Proximity and projection printing X-ray masks, X-ray sources, X- ray resists.

UNIT IV: ION LITHOGRAPHY: Focused ion beam – Point sources of Ion, Ion Column, Beam writing, Focused Ion Beam Lithography, Masked Ion Beam Lithography, Ion Projection Lithography.

UNIT V: LITHOGRAPHY BASED ON SURFACE INSTABILITIES: Wetting, De-wetting, Adhesion, Limitations, Resolution and Achievable / line widths of each of the above techniques.

Course Outcomes:

1. To discuss about Lithography and Optical Lithography
2. To formulate the role of Electron Lithography
3. To construct the idea of X-ray Lithography
4. To improve our knowledge in Ion Lithography
5. To understand the importance of Lithography based on Surface Instabilities

Reference books:

1. K.L. Chopra, ―Thin Film Phenomenon‖, McGraw-Hill, 1968
2. JohnN.Helbert, ―Handbook of VLSI Microlithography‖, Noyes Publication, USA, 2001.

3. James R Sheats and Bruce w. Smith, ―Microlithography Science and Technology‖, Marcel Dekker Inc., New York, 1998.
4. S. Wolf ―Silicon processing for the VLSI era‖, Vol-1 to 4, Lattice Press.
5. J.P. Hirth and G.M. Pound ―Evaporation: Nucleation and Growth Kinetics‖ (Pergamon Press, Oxford, 1963.
6. Handbook of Microscopy for Nanotechnology- Nan Yao &Zhong ling wang Kluwer Academic publishers
7. Nanofabrication. Principles, Capabilities and Limits Zheng Cui Springer publications
8. Scanning Microscopy for Nanotechnology Techniques and Applications edited by Weilie Zhou and Zhong Lin Wang springer publications

Journals references:

1. R.F. Bunshah and C.V. Deshpandey ―Evaporation Processes‖ MRS Bulletin p.33, Dec.1988.
2. W.D. Westwood ―Sputter Deposition Processes‖ MRS Bulletin p.46, Dec.1988.
3. P. Harris ―Taking the Lead in Electron-redeposition‖ Vacuum& Thin Film, Feb.1999, p.26.
4. B. Heinz Sputter Target and Thin Film Defects‖ Vacuum & Thin Film, October 1999,p.22.
5. G.S.Bales et al., ―Growth and Erosion of Thin Splid Films‖, Science, 249, 264 (1990).
6. C.R.M. Grovenor, H.T.G. Hentzell and D.A. Smith, ―The Development of GrainStructure during Growth of Metallic Films‖ ActaMetallurgica 32, 773 (1984).
7. L.A.Stelmack, C.T.Thurman and G.R. Thompson ―Review of Ion-assisted Deposition:
8. Research to Production‖, Nuclear Instruments and Methods in Physics Research B, 37/38,787 (1989).

ELECTIVE-3
ME-715(b) MEMS/NEMS DESIGN AND APPLICATIONS

UNIT-I: INTRODUCTION TO MEMS: MEMS and NEMS – working principles- MEMS processes & features, various components of MEMS, applications and standards, micromachining, basic process tools- epitaxy, sputtering, chemical vapor deposition and spin on methods, oxidation, evaporation, lithography and etching, advanced process tools, sol gel process, EFAB.

UNIT-II: MATERIALS FOR MEMS AND ENGINEERING ASPECTS: Silicon, Silicon oxide and nitride, Thin metal films, Polymers, Other materials and substrates, polycrystalline materials, mechanics of Microsystems, static bending, mechanical vibrations, thermo mechanics, fracture mechanism, fatigue, stress and strain, young‘s modulus and modulus of rigidity, scaling laws in miniaturization.

UNIT-III: MEMS SENSORS, DESIGN, AND PROCESSING: Micro sensors (acoustic wave sensors, biomedical sensors, chemical sensors, optical sensors, capacitive sensors, pressure sensors, thermal sensors), micro actuators (thermal, piezoelectric, electrostatic actuators, micrometers, microvalves & pumps, accelerometer, microfluidics and devices), design consideration, process design and mechanical design.

UNIT-IV: MEMS/NEMS SCALING ISSUES AND PACKAGING: Introduction – Scaling of physical systems – Mechanical system scaling, Thermal system scaling, Fluidic system scaling, Electrical system scaling, Packaging- mechanical and microsystem package, design considerations, Process steps, Diepreparation- interconnects, surface and Wafer bonding, wire bonding and scaling, 3D packaging and assembly signal Thermal management, Hermetic packaging, Electrical//Micro fluidic/and optical interconnects, Signal mapping transduction, Microfluidic technology - MEMS and NEMS technology for microfluidic devices.

UNIT-V: MEMS/NEMS APPLICATIONS: Applications in automotive industry – health care – aerospace – industrial product consumer products – lab on chip – molecular machines – data storage devices – micro reactor– telecommunications, Servo systems.

Course Outcomes:
1. To improve the understanding of MEMS/NEMS.
2. To provide silicon micro fabrication techniques etc.
3. To understand the importance of MEMS Sensors, Design and Processing
4. To bring out scaling and packaging issues of physical system.
5. To provide understanding of MEMS/NEMS applications.

Textbooks:
1. An introduction to Micro electromechanical systems Engineering‖ by NadimMalut and Kirt Williams – Second edition – Artech House, Inc, Boston.
2. Micro electromechanical systems Design‖. / By James J Allen- CRC Press – Taylor and Francis Group
3. Mechanics of micro electromechanical systems ―by NicolaeLobontiu and Ephrahim Garcia Kluwer. Academic Publishers – Boston.
4. The Physics of Micro/Nano- Fabrication by Ivor Brodie and Julius J.Muray.
5. Nano- and Micromaterials by Kaoru Ohno, Masatoshi Tanaka, Jun Takeda and Yoshijuki Kawazoe.

References Books:
1. Springer Hand Book of Nano Technology by BharathBhushan – Springer
2. Nano and Micro electro Mechanical systems by Sergey Edward Lysherski – CRC Press.

ELECTIVE-3
ME-715(c) ADVANCED ENERGY STORAGE MATERIALS AND TECHNOLOGY

Unit-1
Lithium-ion Battery: Advanced anodes and cathodes – theoretical capacity – merits and demerits - Nanomaterials for anodes: carbon nanotubes, graphene, Sn, Al, Si, SnO_2, NiO, TiO_2& $LiTiO_4$. Nanomaterials for cathodes: $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$, and doped cathodes, Reversible and Irreversible Interfacial Reactions, Advanced Electrode Architectures, Fabrication of nanostructured $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$, Si, Sn and CNTs, Charge-Discharge characteristics.

Unit-2
Lithium-ion Battery: Recent development of electrolytes and their application to solid state batteries - Polymer solid electrolytes for lithium-ion conduction. Thin Film solid state Batteries: Fundamentals, Construction and application. Batteries for Automotive – Future prospects:

Degrees of vehicle electrification - Battery size vs. application - USABC and DOE targets for vehicular energy storage systems - Analysis and Simulation of batteries - Equivalent circuit and life modeling – Environmental concerns in battery production – recycling of batteries

Unit-3
Metal-Air Batteries: Sodium batteries, Magnesium battery, Aluminum battery, Silicon battery: Principle – components – anodes - cathodes, fabrication-evaluation – merits and demerits and applications. Redox flow batteries and large-scale grid application - Vanadium and iron-based batteries, Semi-fluid flow batteries

Unit-4
Super/ultracapacitors: Fundamentals of Electrochemical Supercapacitors, Pseudo and asymmetric supercapacitors, Electrode and electrolyte interfaces and their capacitances, Charge-Discharge characteristics, Reagone plot, Energy/power density, Design, Fabrication, operation and evaluation, Thermal management; Recent developments on the materials for supercapacitors and technology development - solid state micro supercapacitors – Graphene-ionic liquid supercapacitors.

Unit-5
Other Emerging Energy Storage Techniques - Hybrid Energy Storage: Battery - Supercapacitor hybridization for large vehicles, locomotives and space, Bacitor (Battery + Fuel Cell) and Flow Batteries (Battery + Capacitor + Fuel Cell) Applications: Storage for Hybrid Electric Vehicles, Regenerative Power, capturing methods. Solar Cell (Photovoltaic) hybridization Lithium-ion battery as energy storage back-up for solar energy Battery – Wind Turbine hybridization Lithium-ion battery as energy storage back-up for wind energy farms

References:
1. Robert A. Huggins, Advanced Batteries – Materials science aspects, Springer, 2009.
2. Jiujun Zhang, Lei Zhang, Hansan Liu, Andy Sun, Ru-Shi Liu, “Electrochemical Technologies for Energy Storage and Conversion”, John Wiley and Sons, 2012.
3. Francois Beguin and Elzbieta Frackowiak, “Super capacitors”, Wiley, 2013.
4. Doughty Liaw, Narayan and Srinivasan, “Batteries for Renewable Energy Storage”, The Electrochemical Society, New Jersy, 2010.
5. T. Minami, M. Tatsumisago, M. Wakihara, C. Iwakura,S. Kohijiya, Solid state ionics for batteries, Springer Publication, 2009
6. Sandeep Dhameja, Electric Vehicle Battery Systems, Newnes publication, 2001.
7. Bard, Allen J., and Larry R. Faulkner. Electrochemical Methods: Fundamentals and Applications. 2nd ed., Wiley– VCH, Verlag, GmbH, 2000.
8. Masataka Wakihara and Osamu Yamamoto, Lithium-ion Batteries Fundamental and Performance, Wiley–VCH, Verlag GmbH, 1999.

ELECTIVE-3
ME-715(d) NANO BIO-TECHNOLOGY

UNIT–I: MICRO/NANOMACHINING AND FABRICATION OF MATERIALS FOR BIOMEDICAL APPLICATIONS: Introduction, Overview of Ion Implantation Process, Micro/Nanomachining of Soft Polymeric Biomaterials, Micro/Nanomachining of Hard Metallic Biomaterials, Novel Biocompatible Photoresists, Three-Dimensional Lithography.

UNIT–II: NANOTECHNOLOGY AND DRUG DELIVERY: Introduction, Advantages of Nanostructured Delivery Systems, Activation and Targeting of Nanotechnology-Based Drug Delivery Systems (Externally and Internally), Drug Targeting through Targeting Molecules, Multifunctional Nanoparticle Systems, Exploiting Inherent Material Properties.

UNIT–III: CELL BEHAVIOR TOWARD NANOSTRUCTURED SURFACES: Introduction, Nontopographic Surfaces: Fabrication Techniques, Cell Behavior Toward Nontopographic Surfaces Created by: Electron Beam Lithography, Photolithography, Composed of Aligned Nanofibers by Electrospinning, Nanoimprinting, Self-Assembly, Phase Separation, Colloidal Lithography, Composed of Random Nanofibers, Electrospinning, Chemical Etching, Incorporating Carbon Nanotubes/Nanofibers, Polymer Demixing.

UNIT–IV: MULTISCALE COCULTURE MODELS FOR ORTHOPEDIC INTERFACE TISSUE ENGINEERING: Introduction, Cellular Interactions and the Soft Tissue-to-Bone Interface, Types of Coculture Models, Coculture Models for Orthopedic Interface Tissue Engineering, Macro- and Microscale Coculture, Two-Dimensional (2D) and Three-Dimensional (3D) Cocultures, Mechanism of Cellular Interactions During Coculture.

UNIT–V: NANOSTRUCTURES FOR TISSUE ENGINEERING/REGENERATIVE MEDICINE:
Introduction, Nanofibrous Scaffolds, Surface Patterned Scaffolds, Relevance of Nanostructured Scaffolds in Regenerative Medicine, Role of Nanostructured Scaffolds in Tissue Engineering.

Course Outcomes:
1. Students can able to develop deep understanding of Biomedical Application.
2. Student can able to compile all the Drug Delivery Systems.
3. To know the importance of Cell Behavior toward Nanostructured Surfaces.
4. To prioritize the role of Orthopedic Interface.
5. To gain the improvements in Tissue Engineering/Regenerative Medicine.

Textbooks:

1. Bio-Medical nanostructures edited by Kenneth Gonsalves, Craig R Halberstadt, Wiley-Interscience A John Wiley & Sons, Inc., Publication.
2. Introduction to Nanotechnology by Charles. P. PooleJr and Frank J. Owens, Wiley India Pvt Ltd.
3. Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter, Pearson education.

Reference books:

1. Encyclopedia of Nanotechnology by H.S. Nalwa
2. Encyclopedia of Nanotechnology by M. Balakrishna Rao and K. Krishna Reddy (Vol I to X).

ELECTIVE-3
ME-715(e) COMPUTATIONAL MATERIALS SCIENCE

Syllabus: Introduction to computational modeling and simulation for Materials Science. Molecular mechanics, Density functional theory (DFT), Molecular dynamics (MD), Monte Carlo (MC) methods, introduction to quantum MC methods, analysis exercises using softwares, Materials genomics, High through-put combinatorial algorithms for materials design.

Detailed version

Introduction to computational modeling and simulation for Materials Science, First principle methods: the beginnings of Quantum mechanics, Schrodinger wave equation, time-independent wave equation, Molecular mechanics- Force Field Methods, Postulates of quantum mechanics, Energy Hamiltonian, early first principles calculation, Born-Oppenheimer approximation, Hartree method (one electron), Hartree- Fock molecular orbital theory, Self-consistent-field (SCF) procedure;

Density functional theory (DFT): electron density in DFT, Hohenberg-Kohn theorems, Kohn-Sham approach, exchange correlation functionals, solving Kohn-Sham equations, DFT extensions and limitations. DFT exercises using software (VASP/Gaussian).

Molecular dynamics (MD): Atomic model in MD, Molecular mechanics, potentials, solutions for newton’s equation of motion, running MD: initialization, pre-set ups, periodic boundary condition, positions and velocity, time steps, ensembles, integration equilibration, minimisation in static MD run – steepest descent method, conjugate gradients method, run analysis. MD analysis exercises using software (LAMMPS/ XMD)

Monte Carlo (MC) methods: Basis of MC methods, stochastic processes, Markov’s process, ergodicity; Algorithms for MC simulations, random numbers, sampling techniques. Applications of MC methods: System of classical particles, percolation, polymer systems, nucleation, crystal growth, fractal systems. Limitations of MC methods, introduction to quantum MC methods.

Materials genomics: High through-put combinatorial algorithms for materials design.

Text Books:

1. Richard LeSar, Introduction to Computational Materials Science: Fundamentals to Applications, Cambridge University Press, 2013.
2. June Gunn Lee, Computational Materials Science: An Introduction, CRC Press, 2012.

References:

1. Kaoru Ohno, KeivanEsfarjani, Yoshiyuki Kawazoe, Computational Materials Science: From Ab Initio to Monte Carlo Methods, 2nd Ed., Springer, 2018.
2. I.N. Levine, Quantum Chemistry, 6th ed., Prentice Hall, 2009.
3. J.A. Dantzig, C.L. Tucker, Modeling in Materials Processing, 1sted., Cambridge University Press, 2001
4. Guillermo Bozzolo, Ronald D. Noebe, Phillip B. Abel (Editors), Applied Computational Materials Modeling: Theory, Simulation and Experiment, Springer, 2007.
5. A.R. Leach, Molecular modeling: Principles and Applications, 2nd ed., Pearson-Prentice Hall, 2001.

ME-716 NANOSTRUCTURED MATERIAL APPLICATION LAB

Course Outcomes:

1. To gain overall knowledge on synthesis, characterization, and application of nanomaterials.
2. Students can acquire knowledge on equipment handling like Cyclic voltammetry, Anti-bacterial applications, gas sensor etc.
3. To construct a theoretical knowledge on the experiment.
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding synthesis, characterization, and applications of nanomaterials.

Experiments:

1. Nanomaterials: Synthesis, Characterization and Humidity Sensing Application.
2. Nanoclusters for Gas Sensor Applications: Synthesis and Characterization.
3. High-performance LPG detection by chemiresistive sensor using nanomaterials and their characterization.
4. Synthesis and Characterization of nanostructured material for Glucose Sensing Application.
5. Nanoparticle-Mediated Seed Priming Improves Germination, Growth, Yield, and Quality and their characterizations.
6. Preparation of nanoparticles and their application in antimicrobial activity.
7. Nanostructured Materials for Energy Related Applications: Synthesis and Characterization.
8. Nanostructured Materials for Water Purification: Synthesis and Characterization.
9. Study of acoustic and thermodynamic factors of synthesized nanomaterials by Nanofluidic Interferometer
10. Nanostructured Materials for the Development of Superhydrophobic Coatings.
11. Preparation of Self-assembly of nanostructures towards transparent, superhydrophobic surfaces for various applications.
12. Synthesis, Characterization, and Photocatalytic behavior of nanocrystalline material.

ME-717 SIMULATION LAB

Experiments:

I. ARGUS LAB:

1. Construction of Bucky balls (C20, C40, C60, C80, C100, C120, C140)
2. Construction of Carbon nanotubes.

II. MATLAB:

1. Introduction to MATLAB Programming
2. Program assembly, Execution, Data processing and graphic analysis

III. NANOHUB:

1. BJT Lab
2. Carrier Statistics Lab
3. Drift-Diffusion Lab

4. MOSFET
5. PN Junction Lab

IV. 3 D PRINTING:

1. Materials Testing of 3D Printed PLA Samples to Guide Dog Bone Mechanical Design.
2. Electrode Substrate printing using conductive 3D Filament for electrical applications using FDM Printer.
3. 3D high durable and flexible Face shield printing using ABS Filament for face protection

Course Outcomes:

1. To familiarize students about applying various material design and data analysis.
2. Quantum structures using online in- browser simulation tools.
3. To gain knowledge on design and construction of carbon molecules.
4. Student can develop math work and gain knowledge on Mat-Lab.
5. To maximize knowledge regarding 3D Printing and components.