JAWAHARLAL TECHNOLOGICAL TECHNOLOGICAL UNIVERSITY : KAKINADA
M.Tech (Nanotechnology) with effect from 2019-20

M. Tech. – I Sem.

NT101 Introduction to Nano materials and Applications

Objective:
The course is intended to cover, basics concepts of crystallography, quantum mechanics, matter and energy relations, de-Broglie hypothesis, wave function analogies, Schrodinger equation, quantum dot, wires and wells etc.

Outcome of the study:

1. Student can able to theorize the importance of crystal structure for property evaluation.
2. Student can assess different types of chemical bonding in materials.
3. To evaluate nano structures in quantum mechanical approaches.
4. Students can able to distinguish between classical electromagnetic theory and Quantum Mechanics.

Pre-requisites:
1. Basics physics
2. Quantum mechanics
3. Basic chemistry
4. Basic material science

Unit-I: Introduction to Nanomaterials – Definitions – zero, one, two and three dimensional nanostructures; Basics of Chemistry – Chemical bonding, Hybridization, Reduction potentials.
Crystal structure: Crystalline and amorphous solids; Crystal lattice and crystal structure; Translational symmetry; Space lattice - Unit cell and primitive cell - Symmetry elements in crystal - Seven crystal systems - Some imperfections in crystals - - Miller indices - Miller-Bravais indices - Indices of a lattice direction; The inter planar spacing of a set of crystal planes.

Unit-II: Reciprocal lattice and crystal imperfections: Bragg law- Reciprocal lattice – Properties of Reciprocal lattice- Reciprocal lattice of simple cube- Reciprocal lattice of bcc- Reciprocal lattice of fcc- diffraction conditions- Brillouion zones. Importance of lattice imperfections- types of imperfection-Point defects-dislocations.

Unit-III: Introduction to quantum mechanics - matter waves - De-Broglie hypothesis – wave particle duality- Heisenberg's uncertainty principle-Schrodinger wave equation – General postulates of Quantum mechanics- particle in one dimensional box. Particle in 2D and 3D Box, Bloch Theorem, Band theory of solids.

Unit-IV:Electronic,Optical and Magnetic properties:: Energy bands and gaps in semiconductors, Fermi surfaces ,localized particle, donors, acceptors, deep traps, excitons, mobility, size dependent effects, conduction electrons and dimensionality Fermi gas and density of states, semiconducting nanoparticles. optical properties of semiconductors, band edge energy, band gap, dependence on nanocrystalline size, Luminescence, Introduction of magnetic materials, basics of ferromagnetism –magnetic clusters, dynamics of nanomagnets, , nanocarbon ferromagnets, ferrofluids.

UnitV: Applications: Nanomaterials in Environment, nanoparticles in air, water and soil.
Nanomaterials in Health care, Cosmetics and Medicine. Nanomaterials for building and protection, Carbon Nanotubes – Mechanical reinforcement, Nanocomposites for surface coatings – rubber and polymer nanocomposites, Nanomaterials for clothing and textile products. : Smart electronics and sensors.– nanochips, nano batteries, photo-voltaic solar cells, dye-sensitized solar cells, Carbon nanotubes in fuel cells, catalysis.

Textbooks:

1. An introduction to solid states electronic devices by Ajay Kumar Saxena Macmillan India Ltd {Unit-I, II}
2. Solid state Physics by Kittle {Unit-I,II}
3. P.M.Mathews and K.Venkatesan, "A textbook of Quantum Mechanics", Tata McGraw Hill Publishing Company Ltd {Unit-III}
4. Quantum Mechanics – Schiff {Unit-III}
5. Quantum Mechanics by B.k.Agarwal and Hariprakash, PHI {Unit-III}
6. Fundamentals of nanoelectronics by George W.Hanson Pearson education {Unit-IV,V}

Reference Books:

1. Quantum mechanics by Brandsen & Joachem
2. J.J.Sakurari, "Modern Quantum Mechanics Mc.Graw Hill, Addison Wesley Longman Inc., USA, 1999
3. Nano Technology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer

M. Tech. – I Sem.
NT 102 Synthesis of Nanomaterials

Objective: To make students know about physical, chemical and biological methods of synthesis of nanomaterials and bring out the distinct properties like electronic, magnetic, and optical properties of nanostructures.

Outcome of the study:

1. To develop knowledge about the electronic properties of semiconductor devices.
2. To construct the magnetic properties of bulk Nano structured materials.
3. To visualize the effect of optical properties of various materials
4. Students can able to acquire knowledge based on the physical, chemical and biological methods of synthesis of nanomaterials

Pre-requisite:

1. Familiarization on energy band gap
2. Basics physics, chemistry & mechanics of solids

Unit-I Introduction to synthesis of nanostructure materials, Bottom-up approach and Top-down approach with examples, Stabilization techniques – Electrostatic and Steric stabilizations. **Physical methods:** Inert gas condensation, Arc discharge, RF-plasma, plasma arc technique, electric explosion of wires, ball milling,

Unit II:**Chemical methods:** Chemical Kinetics, Gibbs Free Energy- Thermodynamics. Thermolysis route - spray pyrolysis and solvated metal atom dispersion, sol-gel method, solvothermal and hydrothermal routes, solution combustion synthesis, Chemical vapor synthesis.

Unit-III: Advanced Chemical Techniques: Nanocrystals by chemical reduction, photochemical synthesis, electrochemical synthesis; Nanocrystals of semiconductors and other materials by arrested precipitation, emulsion synthesis, and sonochemical routes.

Unit IV:**Nano Synthesis by Seviour Plastic Deformation(SPD)::**Introduction-Different SPD Techniques –Importance- Equi channel Angular Extrusion (ECAE),-Die Design-Effect of Die Angle on Grain Refinement-ECAR Equi channel Angular Rolling - Die Design-Effect of Die Angle on Grain Refinement. sAdvantages of ECAR over ECAE. Advantages and limitations of SPD nanosynthesis over other Techniques.

Unit-V Biological methods: Use of bacteria, fungi, actinomycetes for nano-particle synthesis – magneto-tactic bacteria for natural synthesis of magnetic nano-particle.

Textbooks:

1. Inorganic Materials Synthesis and Fabrication by J.N. Lalena, D.A. Cleary, E.E. Carpenter, N.F. Dean, John Wiley & Sons Inc.
2. Introduction to Nano Technology by Charles P. Poole Jr and Frank J. Owens. Wiley India Pvt Ltd.
3. The Chemistry of nanomaterials: Synthesis, Properties and Applications, Vol-I by C.N.R. Rao, A. Muller and A.K. Cheetham

Reference books:

1. Encyclopedia of Nanotechnology by M.Balakrishna Rao and K.Krishna Reddy, Vol I to X, Campus books.
2. Encyclopedia of Nanotechnology by H.S. Nalwa
3. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill

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M. Tech. – I Sem.

NT- 1031 Thin Film Science and Technology
(Elective-I)

Objective:
The course covers the importance of thin film technology and nanofabrication, vacuum technology, various physical and chemical methods of thin film fabrication and various applications of thin films including sensors.

Outcome of the study:
1. To develop deep understanding on Vacuum Technology.
2. To compile all the Conditions for formation of thin films
3. To know the importance of Physical Vapor Deposition techniques.
4. To prioritize the role of Electrical discharges used in Thin Film Deposition
5. To improve the understanding of deposition using CVD.

Pre-requisite:
1. Vacuum pump technology
2. Basics of vacuum pump technology Pirani and gauge technology

UNIT – I: Vacuum technology: Clean Room – Clean room technology and its Classes.

Principles of vacuum pumps in range of 10^{-2} torr to 10^{-11} torr, principle of different vacuum pumps: roots pump, rotary, oil diffusion pump, turbo molecular pump, cryogenic-pump, ion pump, Ti-sublimation pump, importance of measurement of vacuum, Concept of different gauges: Bayet-Albert gauge, Pirani, Penning and pressure control.

UNIT – II: Conditions for the formation of thin films: Environment for thin film deposition, deposition parameters and their effects on film growth, formation of thin films (sticking coefficient, formation of thermodynamically stable cluster – theory of nucleation), capillarity theory, microstructure in thin films, adhesion, properties of thin films: Mechanical, electrical, and optical properties of thin films, few applications of thin films in various fields; Thermomechanical behaviour of thin film nanostructures.

UNIT-III: Physical Vapour Deposition techniques: Thermal evaporation, resistive evaporation, Electron beam evaporation, Laser ablation, Flash and Cathodic arc deposition.

UNIT –IV: Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, R.F sputtering, Triode sputtering, Ion Plating, Difference between thin films and coating.

UNIT –V: Electro deposition, molecular beam epitaxy and laser pyrolysis. Chemical vapour deposition techniques: Advantages and disadvantages of Chemical Vapour deposition (CVD) techniques over PVD techniques, reaction types, boundaries and flow, Different kinds of CVD techniques: Metal Organic CVD (MOCVD), Thermally activated CVD, CVD, Spray pyrolysis, etc.

Text Books
1. Thin Film Phenomenon by K.L. Chopra, McGraw-Hill

References

1. Methods of Experimental Physics (Vol 14) by G.L.Weissler and R.W.Carlson "Vacuum Physics and Technology"
2. A User's Guide to vacuum Technology by J.F.O'Hanlon, John Wiley and Sons
3. Vacuum Physics and Techniques by T.A. Delchar, Chapman and HallEvaporation: Nucleation and Growth Kinetics" by J.P. Hirth and G.M.Pound, Pergamon Press

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M. Tech. – I Sem.

NT- 1032 Nanomaterials for Energy Systems

(Elective-I)

Objective:
The course covers the various energy forms, alternate and renewable energy system using nanotechnology.

Outcome of the study:

1. Study the basic Energy need and role of Battery materials
2. To grade up knowledge of Super Capacitors, and its Applications.
3. Study the role of nano structured material to meet Energy Challenges.
4. Learn about the concept of Hydrogen Storage Technology.
5. Gain knowledge on role of Fuel Cell Technology.
6. Gain knowledge on Microfluidic Technology.

Pre-requisite:

Different technologies like Renewable energy technology, supercapacitors and Hydrogen storage technology.

Unit–I Battery materials and batteries: Lithium Ion based batteries. Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: quantum well and quantum dot solar cells, photo- thermal cells for solar energy harvesting, Thin film solar cells, CIGS solar cells, Die sensitized solar cells.

Unit-II: Nanomaterials used in energy and environmental applications and their properties: Evaluation of properties and performance of practical power systems that benefit from optimization of materials processing approaches.

Unit–III Hydrogen storage Technology: Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metal-organic framework materials, volumetric and gravimetric storage capacities, multiple catalytic – degradation of sorption properties, automotive applications.

Unit–IV Fuel cell Technology: Fuel cell Principles, types of fuel cells (Alkaline Electrolyte, Phosphoric acid, Molten Carbonate, solid oxide and direct methanol and Proton exchange fuel cells), Principle and operation of Proton Exchange Membrane (PEM) fuel cell, Materials and fabrication methods for fuel cell technology, micro fuel cell power sources – Biofuels.

Unit–V Microfluidic Technology: MEMS & NEMS technology for microfluidic devices: micro and nano engines and driving mechanism, power generation, microchannel battery pump (TCP), piezoelectric membrane and their applications.

Text Book

1. Renewable Energy Resources by J. Twidell and T.Weir, E&FN Spon Ltd.

References

1. Hydrogen from Renewable Energy Source by D.Infield
2. .Fundamentals of Industrial Catalytic Process by C.H. Bartholomew and Robert J. Farraoto, John Wiley & Sons Inc.
3. Fuel storage on Board Hydrogen storage in Carbon Nanostructures by R.A. Shatwell
4. Fuel cell Technology Handbook by Hoogers, CRC Press
5. Hand book of fuel cells: Fuel cell technology and applications by Vielstich, Wiley:CRC Press

M Tech. – I Sem.

NT- 1033 Nano Photonics & Plasmonics

(Elective I)

Objective:

The course is intended to cover basics of Nanophotonics and Plasmonics and their applications.

Outcome of the study:

1. To extend the knowledge on Nano photonics and Plasmonics
2. To study about quantum confined materials, photonic crystals, and Nanophotonic devices

Pre-requisite:

1. Basics physics
2. Basic chemistry

Unit I: Foundations for Nanophotonics: Photons and electrons: similarities and differences, Free space propagation; Confinement of photons and electrons; Propagation through a classically forbidden zone: tunneling. Localization under a periodic potential: Band gap. Cooperative effects for photons and electrons; Nanoscale optical interactions, axial and lateral nanoscopic localization; Nanoscale confinement of electronic interactions: Quantum confinement effects, nanoscale interaction dynamics, nanoscale electronic energy transfer; Co-operative emissions.

Unit II: Quantum Confined Materials: Inorganic semiconductors, quantum wells, quantum wired, quantum dots, quantum rings. Manifestation of quantum confinement: Optical properties nonlinear optical properties. Quantum confined stark effect; Dielectric confinement effect, super lattices; Core-shell quantum dots and quantum-dot-quantum wells; Quantum confined structures as Lasing media.

Unit III Photonic Crystals: Basics Concepts, Features of Photonic Crystals, wave propagation, photonic band gaps, light guiding; Theoretical Modeling of Photonic Crystals; Methods of Fabrication; Photonic Crystal Optical Circuitry; Nonlinear Photonic Crystals; Photonic Crystals and Optical Communications. Application to high efficiency emitters miniaturized photonic circuits and dispersion engineering; Photonic Crystal Sensors – Microstructure Fiber applications.

Unit IV: Nanophotonic Devices: Resonant cavity quantum well lasers and light-emitting diodes,, Fundamentals of Cavity QED, strong and weak coupling regime, Purcell factor, Spontaneous emission control, Application of microcavities, including low threshold lasers, resonant cavity LED; Microcavity-based single photon sources.

Unit V: Plasmonics: Metallic nanoparticles, nanorods and nanoshells, local field enhancement; Collective modes in nanoparticle arrays; particle chains and arrays; surface plasmons, Plasmon Waveguides; Applications of Metallic Nanostructures - Metamaterials.

Text Books:

1. Nanophotonics, Paras N Prasad, John Wiley & Sons (2004)

References:

1. Photonic Crystals: Towards Nanoscale Photonic Devices; Jean Michel Lourtioz, Springer ; ISBN 354024431X
2. Fundamentals of Photonic Crystal Fibers; Fredric Zolla- Imperial College Press. ISBN 1860945074
3. Photonic Crystals; John D Joannopoulos, Princeton University Press; ISBN0691037442
4. Photonic Crystals: Modeling Flow of Light; John D Joannopoulos , R.D. Meade and J.N.Winn, Princeton University Press (1995)
5. The Handbook of Photonics by Mool Chand Gupta, John Ballato

M. Tech. – I Sem.

NT 1041 **Nano fluidics**
(Elective II)

Objective:
To familiarize students with nanofluid science and technology.

Outcome of the study:

1. To make students understand the fundamentals of nanofluids and different synthesis methods
2. To make understand conduction heat transfer and convection in nanofluids
3. To familiarize the theoretical modeling of thermal conductivity of nanofluids.
4. To make understand boiling of nanofluids

Pre-requisite:
Basics of physics, chemistry, materials science and fluid mechanics

UNIT I

Introduction: Fundamentals of cooling, Fundamentals of nanofluids, Making nanofluids, Mechanisms & Models for enhanced thermal transport, Future research. Synthesis of nanofluids: General issues of nanofluids, Synthesis methods-common issues, Study of nanoparticles, Variety in nanomaterials, Micro emulsion based methods for nanofluids, Solvo thermal synthesis, Synthesis using supports, Synthesis using biology, Magnetic nanofluids, Inert gas condensation, Anisotropic nanoparticles, Other nanofluids, summary.

UNIT II

Conduction heat transfer in nanofluids: conduction heat transfer, Measurement of thermal conductivity of liquids, Thermal conductivity of oxide nanofluids, Temperature dependence of thermal conductivity enhancement, Metallic nanofluids, nanofluids with CNTs.

UNIT III

Theoretical modeling of thermal conductivity of nanofluids: Simple mixture rules, Maxwell approach, Particle distribution, Particle geometries, Symmetrical equivalent medium theory, Matrix particle interfacial effects, Dynamic models of thermal conductivity of nanofluids.

UNIT IV

Convection in nanofluids: Fundamentals of convective heat transfer, convection in suspensions & slurries, Convection in nanofluids, Analysis of convection in nanofluids, Numerical studies of convection in nanofluids.

UNIT V

Boiling of nano-fluids: Fundamentals of boiling, Pool boiling of nanofluids, Critical heat flux in pool boiling of nanofluids, Other investigations related to boiling of nanofluids.

TEXT BOOK:

1. Nano Fluids Science and Technology by Sarit Kumar Das, John Wiley and sons.

M. Tech. – I Sem.

NT 1042 Nanoscopic Dielectric and Ferroelectric materials
(Elective II)

Objective:
To familiarize students with Piezoelectric, Pyroelectric nanomaterials and their applications.

Outcome of the study:

1. To make students understand the fundamentals of piezo electric nanomaterials, their preparation methods, properties and applications
2. Students understand the fundamentals of pyro electric nanomaterials, their preparation methods, properties and applications

Pre-requisite:
Basics of physics, chemistry, and materials science.

Unit I: Introduction to Dielectrics and Concept of Polarisation; Types of Polarization – Electronic, Ionic, Orientational, and Space Charge Polarisations; Frequency Dependence of Dielectric polarisation; Classification of Dielectric materials, Smart materials, Categories of Smart materials – Conducting polymers, Shape memory alloys, Liquid Crystal materials, Piezoelectric materials, Pyroelectric materials, Ferroelectric materials and Poled Polymers; Introduction to Piezoelectricity, Inverse Piezoelectricity, and Pyroelectricity, Mathematical Description of Piezoelectric effects.

Unit II: Properties of Piezoelectric Materials – Quartz, PZT, PVDF, ZnO and Other materials, Applications to Inertial Sensors, Acoustic Sensors, Tactile Sensors, Flow Sensors and Surface Elastic Waves, Piezoelectricity in wood and bone – Applications of Piezoelectricity in Nanomedicine, Piezoelectric Nanogenerators for self-powered Nanodevices.

Unit III: Preparation methods of Piezoelectric nanoparticles – Mixed Oxide Technology, Mechanochemical Synthesis technique, Chemical Coprecipitation, Hydrothermal synthesis, Sol-gel technique, Mechanical and Electrochemical Characterization of One dimensional Piezoelectric nanomaterials – Nanomechanical Characterization – Electromechanical Characterization

Unit IV: Fundamentals of Pyroelectric materials, Pyroelectric IR detectors, Important Pyroelectric materials – Tri-Glycine Sulphate (TGS) crystals and their isomorphs, Modified Lead Titanate, PZT, $LiTaO_3$ and $LiNbO_3$, AlN, GaN, ZnO, Organic Pyroelectrics, Processing of Pyroelectric Thin film Deposition methods – Non-solution methods: Sputtering, Laser Ablation, and CVD methods, and Solution methods: Sol gel Technique, Metal-Organic Deposition Technique.

Unit V: Applications of Pyroelectric and Pyroelectric nanomaterials - IR detectors, Energy Harvesters - Flexible Pyroelectric Nanogenerators and Particle detectors.

Text Books

1. Foundations of MEMS by Chang Liu, Pearson Education Ltd., 2011
2. Piezoelectric Nanomaterials for Biomedical applications by Gianni Ciofani, Arianna Menciassi (eds.), Springer Verlag Berlin 2012,
3. Pyroelectric Materials by A K Batra and M D Agarwal, SPIE, 2013

References

1. Ya Yang, Jong Hoon Jung etal, "Flexible Pyroelectric Nanogenerators using a Composite Structure of Lead-free$KNbO_3$ Nanowires", Advanced Materials, 2012.
2. Athanasios Batagiannis, Michael Wübbenhors, Jürg Hulliger , "Piezo and Pyroelectric Microscopy", Current Opinion in Solid State and Materials Science 14 (2010) 107–115.

M. Tech. – I Sem.

NT 1043 Carbon Nanostructures and Applications
(Elective II)

Objective:

To familiarize students with different carbon nanostructures and their applications.

Outcome of the study:

1. Students can develop understanding of carbon clusters, fullerenes and carbon nanotubes
2. Students understand synthesis methods of carbon nanotubes, and their applications
3. Students can develop knowledge about graphene and graphene like nanostructures.

Pre-requisite:

Basics of physics, chemistry, and materials science.

UNIT – I Allotropy of Carbon, Carbon Nano structures - Carbon clusters Fullerenes and types of Carbon Nano tubes, growth mechanisms, Mechanical reinforcements, Solid Disordered carbon Nanostructures, Nano structured crystals; Graphene, Carbon nanofibers; Electrical, Vibrational, Mechanical Properties of CNTs, Optical properties & Raman spectroscopy of CNTs

UNIT –II , Synthesis of CNTs by Flame, CVD, Laser & Arc-discharge process; Lithium & Hydrogen adsorption & storages, Fuel cell applications and energy storage, Chemical Sensors applications of CNTs, Computer applications (Nano chip), Optical and telecommunication applications, CNT Nano composites, Silicon Nanowires.

UNIT-III Graphene - Fundamentals of Graphene, Synthesis – Different routes, Exfoliation method, Industrial applications

UNIT-IV Graphene oxide – Synthesis, Properties and Applications.

UNIT-V Graphene like Structures – Borophene, Pure Metal Single layers – Properties and Applications

Text Books:

1. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
2. Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springer publications

Reference Books:

1. Encyclopaedia of Nanotechnology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X Campus books.
2. Encyclopedia of Nanotechnology by HS Nalwa
3. Nanotechnology – Science, innovation and opportunity by Lynn E.Foster. Prentice Hall Pearson education.
4. Nano:The Essentials – Understanding Nano Science and Nanotechnology by T.Pradeep; Tata Mc.GrawHill

M. Tech. – I Sem.
NT 105 RESEARCH METHODOLOGY & IPR

RESEARCH METHODOLOGY AND IPR

Unit 1: 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

Unit 2: Effective literature studies approaches, analysis Plagiarism, Research ethics, Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Unit 3: 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.

Unit 4: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Unit 5: 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.

References:

(1) Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'"
(2) Wayne Goddard and Stuart Melville, "Research Methodology: An Introduction"
(3) Ranjit Kumar, 2nd Edition, "Research Methodology: A Step by Step Guide for beginners"
(4) Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
(5) Mayall, "Industrial Design", McGraw Hill, 1992.
(6) Niebel, "Product Design", McGraw Hill, 1974.
(7) Asimov, "Introduction to Design", Prentice Hall, 1962.
(8) (8) Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
(9) T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

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

CO1: Understand research problem formulation.

CO2: Analyze research related information

CO3: Follow research ethics

CO4: Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.

CO5: Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.

CO6: Understand that IPR protection provides an incentive to inventors for further research work and investment in R & D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

1. Niebel , "Product Design", McGraw Hill, 1974.
2. Asimov , "Introduction to Design", Prentice Hall, 1962.
3. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
4. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

M. Tech. – I Sem.

NT 106 Nanomaterials Synthesis Lab

Objective: The course is intended to cover basic preparation methods of nanomaterials

The outcome of the study:

1. Gain knowledge on the physical, chemical and biological synthesis techniques involved in experiments.
2. To fabricate thin films using spin coating and spray pyrolysis equipments
3. To construct a theoretical knowledge on the experiments.
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding synthesis of nanomaterials.

Pre-requisite: Basic chemistry, synthesis techniques, characterization

List of experiments:

1. Two methods for the synthesis of CNTs (CVD method and Flame Synthesis)
2. Nano – Catalyst Preparation by Chemical methods.
3. Synthesis of oxide Nanostructures / nano composites by Sol-gel Process
4. Preparation of any two types of Ceramic Powders, $BaTiO_3$ (ball milling) & Al_2O_3 (flame)
   - Composite preparation using Ball Milling
5. Synthesis of NiO nanoparticles using Urea as fuel by Solution Combustion method.
6. Synthesis of Silica gel (SiO_2) using Sol – gel method
7. Synthesis of Silver (Ag) nanoparticles using green synthesis
8. Fabrication of thin film by Spin Coating
9. Fabrication of thin film by Spray Pyrolysis

M. Tech. – ISem.

NT-107 Nanomaterials Simulation lab

Objective: To gain knowledge regarding simulation of computational nanochemistry methods

Outcome of the study:

1. To understand how to build atom by atom carbon based nanostructures using simulation methods.
2. To obtain a theoretical knowledge on the simulation experiments
3. To gain ability to write and present laboratory reports.

List of experiments:

Introduction to Mathematical Modeling and ARGUS Lab Experiments

1. Construction of fullerene & its energy calculations
2. Construction of Bucky balls (C_{20}, C_{40}, C_{60}, C_{80}, C_{100}, C_{120}) and geometry optimization
3. Construction of Carbon nanotubes and geometry optimization
4. Construction of graphene, geometry optimization and molecular orbital visualization

And

The students perform the experiments using either QUANTUM WISE or NANOHUB:

I. QUANTUM WISE (ATK & VNL)

1. Geometry for Transport Calculations (ATK)
2. Setting up a transport calculation with the script generator (ATK)
3. I-V Curve (ATK)
4. Building and optimizing the geometry (ATK)
5. Calculating the band structure of a SiC crystal (VNL)
6. Transmission spectrum of a graphene nanoribbon with a distortion (VNL)
7. Building a graphene nanoribbon device (VNL)

Or

II. NANOHUB

1. BJT Lab (ABACUS)
2. Carrier Statistics Lab (ABACUS)
3. Drift-Diffusion Lab(ABACUS)
4. MOSFET (ABACUS)
5. PN Junction Lab (ABACUS)

M. Tech. – I Sem.

NT108 WRITING SKILLS FOR SCIENTIFIC COMMUNICATION
(AUDIT –I)

Unit-1:
Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness**,** Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising.
Unit-2: Paraphrasing and Plagiarism, Sections of a Paper, Abstracts, Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.
Unit-3:
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-4:
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-5:
Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission

Suggested Studies:
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

COURSE OUTCOMES: The Students will be able to
CO1. Understand that how to improve your writing skills and level of readability
CO2. Learn about what to write in each section
CO3. Understand the skills needed when writing a Title Ensure the good quality of paper at very first-time submission

M. Tech. – II Sem.
NT 201 Nanomaterials Characterization Techniques

Objective:
To familiarize students with Compositional, Structural, Morphological, Spectroscopic, Electrical, Thermal and Magnetic Characterization techniques of materials at the nanoscale and interpretation of results including standards etc.

Outcome of the study:
1. To evaluate the spectroscopic characterization techniques of nano materials.
2. To compare various compositional and structural characterization techniques.
3. To infer the importance of advanced characterization techniques.
4. Student can able to develop knowledge about various electrical and magnetic characterization techniques.
5. Gain overall knowledge of various thermal and magnetic characterization techniques.

Pre-requisite:
1. Basic band gap, Electrical, Thermal and Magnetic characterization.
2. Mechanics of solids, metallurgy and materials science, and spectroscopic techniques.

UNIT-I: Compositional Analysis: X-ray Photoelectron spectroscopy (XPS), Energy Dispersive X-ray Analysis (EDX), Inductively Coupled Plasma Optical Emission Spectroscopy (ICPOES), Electron Probe Micro Analysis (EPMA).
Structural Analysis: X-ray Diffraction (XRD), Electron Diffraction, Ion Beam Techniques – SIMS and RBS.

UNIT – II: Surface characterization Techniques- High resolution microscopy; Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), scanning tunnelling microscopy (STM), Surface Area Measurements – Adsorption principle - Freundlich, Langmuir, and BET methods of measurement.

UNIT – III: Spectroscopic techniques: Fourier Transform infrared (FTIR) spectroscopy, Raman spectroscopy techniques: micro Raman and laser Raman.

UNIT – IV: Electrical characterization techniques: Measurement of resistivity by 4-probe method, Hall measurement, Seebeck coefficient measurements, Nano indentation techniques, electron beam induced current measurement (EBIC), impedance and ferroelectric measurements

UNIT-V: Magnetic and Thermal characterizations: Vibrating Sample Magnetometer (VSM), Thermal analysis – TG/DTA, DSC, TMA.

Text Books:
1. Characterization of Nanostructured Materials by Z L Wang
2. Introduction to Nanotechnology by Charles P Poole Jr and Frank J Owns, Wiley India Pvt Ltd.
3. Nano: The Essentials -Understanding Nano Science and Nanotechnology by T.Pradeep, Tata Mc.Graw Hill
4. Principles of Instrumental Analysis by D A Skoog, F J Hollen and T A Niemann
5. A Practical Approach to X-Ray Diffraction Analysis by C Suryanarayana

Reference Books:

1. Nanotechnology: Principles and Practices – Sulabha K Kulkarni – Capital Publishing Company
2. Specimen Preparation for Transmission Electron microscopy by John & Bravmno et al, published by MRS
3. Photoelectron spectroscopy by JHD Eland, Butterworth & Co. Publishers, 2nd edition
4. Encyclopaedia of Nanoscience and Nanotechnology by H S Nalwa
5. Electron Microscopy and Analysis by P J Goodhew and F J Humpreys
6. Scanning Electron Microscopy and X- ray Microanalysis by J I Goldstein
7. Modern Raman Spectroscopy: A Practical Approach by E Smith and G Dent.

M. Tech. – II Sem.
NT 202 Nanosensors and Applications

Objective:
The course is intended to cover basics and applications of Nanosensors in various fields.
Outcome of the study:
Students get exposure on Nano scale based inorganic sensors, thermal sensors, biosensors, and their applications in addition to sensor characteristics and physical effects.
Pre-requisite:
Basics of physics, chemistry, biology and electronics

UNIT I
Sensor characteristics and physical effects:
Active and Passive sensors – Static and dynamic characteristics - Accuracy, offset and linearity - First and second order sensors – Physical effects involved in signal transduction- Photoelectric and Photo dielectric effect – Photoluminescence–Electroluminescence – chemiluminescence effect – Doppler effect – Barkhausen effect – Hall effect – Ettinshausen effect – Thermoelectric effect – Peizoresistive effect – Piezoelectric effect – Pyroelectric effect –Magneto-mechanical effect (magnetostriction) – Magneto resistive effect
UNIT II
Nano based inorganic sensors: Density of states (DOS) – DOS of 3D, 2D, 1D and 0D materials – one dimensional gas sensors:- gas sensing with nanostructured thin films – absorption on surfaces – metal oxide modifications by additives – surface modifications – nano optical sensors – nano mechanical sensors – plasmon resonance sensors with nano particles – AMR, Giant and colossal magneto resistors – magnetic tunneling junctions.
UNIT III
Thermal Sensors:
Thermal energy sensors -temperature sensors, heat sensors- Electromagnetic sensors- electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetism sensors - Mechanical sensors – pressure sensors, gas and liquid flow sensors, position sensors - Chemical sensors - Optical and radiation sensors.
UNIT IV
Organic/Biosensors:
Structure of Protein – role of protein in nanotechnology – using protein in nanodevices – antibodies in sensing – antibody in nano particle conjugates – enzymes in sensing – enzyme nanoparticle hybrid sensors – Motor proteins in sensing – transmembrane sensors. Nanosensors based on Nucleotides and DNA – Structure of DNA – DNA decoders and microarrays – DNA protein conjugate based sensors – Bioelectronic sensors – DNA sequencing with nanopores – sensors based on molecules with dendritic architectures – biomagnetic sensors.
UNIT V
Sensor Detectors and Applications
Cantilever array sensors – for diagnosis of diabetes mellitus and cancer diagnosis - Nanotube based sensors - for DNA detection and capnography - Nanowire based sensors - Nanowire based electrical detection of single viruses - Nanowire based electrical detection of biomolecules. Bio receptors –Bio detectors - Nano array based detector - Nano Particle based detector - Ultra-sensitive detection of pathogenic biomarkers - Ultra-sensitive detection of single bacteria.

Text Books and References:

1. Kourosh Kalantar – Zadeh, Benjamin Fry, "Nanotechnology- Enabled Sensors", Springer , 2008
2. H.Rosemary Taylor, "Data acquisition for sensor systems", Chapman & Hall,
3. Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, Dav J. Brady, Antonio J. Ricco, David R. Walt, Charles L. Wilkins, "Biosensing: International Research and Development", Springer, 2006
4. Ramon Pallas-Areny, John G. Webster, "Sensors and signal conditioning" John Wiley & Sons, 2001.
5. Vijay.K.Varadan, Linfeng Chen, Sivathanupillai, "Nanotechnology Engineering in Nano and Biomedicine", John Wiley & Sons, 2010.W. Ranier, "Nano Electronics and Information Technology", Wiley, (2003).

M. Tech. – II Sem.

NT – 2031 **Biomedical Nanotechnology**

(Program Elective 1II)

Objective:

The course is intended to cover fundamental terms and basics of biotechnology and building blocks; biological nanostructures, biosensors and biomedical applications of nanotechnology, nanodrugs and drug delivery systems.

Outcome of the study:

1. To familiarize students with biological systems, materials and building blocks.
2. To understand the concepts of Biological Nanostructures
3. To familiarize about Biomedical Applications.
4. To prioritize the role of nano structured materials in diagnosis
5. To gain the improvements in drug delivery system using nanotechnology.
6. To study various Nanopharmacology & Drug Targeting and drugs delivery systems

Pre-requisite:

1. Basics of organic chemistry
2. Basics of Biology

Unit-I Imaging of Bionanostructures: Practical and theoretical aspects of imaging biological systems, from the cellular level through to whole-body medical imaging, basic physical concepts in imaging; Major techniques using ionizing and non-ionizing radiation including fluorescence and multi-photon microscopy, spectroscopy, OCT, MRI, X-ray CT, PET, Confocal and SPECT imaging.

Unit-II Nano Bioactive Glasses: Nanobiosensors, Nano Bioactive glasses, Biomaterials – Preparation – Methods - Nanobioactive glass powders – Properties –Mechanical-measurement of bioactivity – In vitro studies - coating on metallic implant – Characterization - Implant applications.

Unit-III Cancer Treatment: Gold and Silver nanoparticles in cancer targeting and treatment - Nanoparticles in treatment of breast cancer –Chemotherapy: Active and Passive cancer tissue targeting – micro fluidics – Chemotherapeutic agents –Immunotherapy – Vaccine immunotherapy – Radiotherapy – Thermotherapy – Photo dynamic therapy – Nano particulate targeting.

Unit-IV Delivery Mechanism: Introduction, Antibody conjugated nanoparticles, Conjugated nanoparticles interaction with biological surfaces, Biomedical nanoparticles, Liposomes, Dendrimers, Different types of drug loading, drug release and Biodegradable polymers, Applications.

Unit-V Targeted Drug Delivery: Basic and special pharmacology – strategies for targeted delivery – in nature – Bacteria – virus – prion -strategies for targeted delivery – by human – oral delivery – transdermal – transmucosal – invasive – Targeted delivery to brain – macrophage targeting.

Text Books:

1. 'Biomedical Applications of Nanotechnology' by Vinod Labhasetwar, Diandra L. Leslie-Pelecky John Wiley & Sons
2. 'Nanomedicine and Drug delivery' by Mathew Sebastian Neethu Ninan A. K. Haghi, Apple Academic Press

3. 'Nanotechnology for Cancer Therapy' by Mansoor M. Amji, CRC press

References:

1 Challa Kumar, Nanomaterials for medical diagnosis and therapy , Wiley VCH 2005

2 James A. Schwarz, Cristian I. Contescu, Karol Putyera, "Dekker encyclopedia of nanoscience and nanotechnology" CRC Press, 2004.

3 Natalie P. Praetorius and Tarun K. Mandal, Recent Patents on Drug Delivery & Formulation

4. Y. Lu, S.C. Chen, "Micro and nano-fabrication of biodegradable polymers for drug delivery" Advanced Drug Delivery Reviews, 56 (1621-1633) 2004.

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NT – 2032 **Nanocomposites and Applications**
(Program Elective 1II)

Objective:
This course intended to cover nanocomposites, reinforcing nanostructures dispersed in various matrix materials like polymers, ceramics, metals, etc,. The subject covers mainly the synthesis methods, modeling and evaluation of nanocomposites.

Outcome of the study:
1. Student can able to discuss the basic concepts of Nano Composites.
2. Student can able to prioritize the role of Ceramic Metal Composites in Nano Technology.
3. To understand the role of Synthesis Methods for various Nano Composite materials.
4. Learn about the concepts of Indentations and types of Indentations.
5. Correlate the applications of Polymer Nano Composites and ImpregnationTechniques.

Pre-requisites:
Basics of composites, properties of bulk composites

Unit – I Introduction to Nanocomposites, Composite material, Mechanical properties of Nano composite material: stress - strain relationship, toughness, strength, plasticity.

Unit – II Ceramic-Metal Nanocomposites, Ceramic based nanoporous composite, Metal matrix nanocomposites, Polymer-based nanocomposites Carbon nanotube based nanocomposites and Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites; Applications to Strategic Sector (Aerospace, Defense - CNT based structures - CNT based Nose cones for reentry vehicles), Armour protection (Polymer-Tungsten, Polymer-CNT Nanocomposites)

Unit – III Synthesis methods for various nanocomposite materials: mechanical alloying, thermal spray synthesis etc. Nano composites for hard coatings; DLC coatings; Thin film nanocomposites; Modeling of nanocomposites.

Unit – IV Nano Indentation, Types of indentation: Oliver & Pharr method, Vickers Indentation process, Berkovich indentation process, Brinell test, Knoop test

Unit – V Processing of polymer nanocomposites, properties of nanocomposites, Salt infiltration, Powder mixing, Intrusion method, Exfoliation & interaction, Gel-casting impregnation techniques: Hot melt impregnation, solution impregnation.

Text Books:

1. Nanocomposite Science & Technology by P.M. Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co.
2. Thomas E. Twardowski, Introduction to Nanocomposite Materials, Properties, Processing, Characterization, DesTech Publications, April 2007

Reference Books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopedia of Nano Technology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X
3. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens;

Wiley India Pvt Ltd.

4. Nanotechnology, A gentle introduction to the next big idea by Mark Ratner, Daniel Ratner Pearson education.

M. Tech. – I Sem.

NT 2033 Computational Nanotechnology

(Program Elective 1II)

Objective:

To familiarize students different computational simulation techniques of nanomaterials

Outcome of the study:

1. To make students understand the basics of mechanical and statistical computational techniques
2. To familiarize students with Atomistic, Molecular dynamics, Monte Carlo and Mesoscale simulation techniques to evaluate different properties of nanomaterials.

Pre-requisite:

1. Basics of computation.
2. Mechanics of solids and materials science

UNIT I

Introduction: Computational simulation, need for discrete computation. Classical Mechanics: Mechanics of Particles, D'Alembert's principle and Lagrange's equation, variational principles, Hamilton's principle, conservation theorems and symmetry properties, central force problems, virial theorem.

UNIT II

Statistical Mechanics: Review of probability and statistics, quantum states of a system, equations of state, canonical and microcanonical ensemble, partition function, energy levels for molecules, equipartition theorem, minimizing the free energy, Maxwell distribution of molecular speeds.

UNIT III

Atomistic Simulation Techniques: Molecular Dynamics (MD): Introduction, inter-atomic potential function, Lennard-Jones potential, various types of potential functions, computational aspects.

UNIT IV

Systems, Models, Simulations and the Monte Carlo Methods: Systems, Models, Simulation and the Monte Carlo Methods, Random number generation, Introduction, Congruential Generators, Statistical Tests of Pseudorandom Numbers, Random variate generation, inverse Transform Method, Composition Method, Acceptance-Rejection Method,

UNIT V

Monte Carlo integration and Variance reduction techniques: Introduction, Monte Carlo Integration, The Hit or Miss Monte Carlo Method, The Sample-Mean Monte Carlo Method, Efficiency of Monte Carlo Method, Mesoscopic Simulation Techniques: Lattice Boltzmann Method (LBM), applications of LBM.

Text Books

1. Wolfram Hergert, Computational Materials science, Springer.
2. Multiscaling in molecular and continuum mechanics by G. C. Sih, Springer.
3. A primer for the monte carlo method, llya M. Sobol' CRC Press
4. Simulation and Monte carlo method by Reuven Y. Rubisten

Reference Books

1. Probability and statistics for engineers, miller and john e. freund, prentice hall of india
2. The monte carlo method, popular lectures in mathematics by sobol.i.m

M. Tech. – II Sem.

NT 2041 **Nanoscale Magnetic Materials and Devices**
(Program Elective IV)

Objective:

The course is intended to cover basics of Nanoscale magnetic materials and devices

Outcome of the study:

1. To extend the knowledge on Nanoscale magnetic materials, hard and soft magnetic materials and measurement techniques of magnetization.
2. To study about Biomagnetism, Biomagnetic nanostructures and biomedical applications of magnetic materials.
3. To gain knowledge on ferrofluids, magnetoresistance and MRAM applications

Pre-requisite:

1. Basics physics and
2. Basic chemistry

Unit I: Nanoscale Magnetic materials – Introduction to Magnetic materials – Dia, Para, Ferro, Antiferro and Ferri magnetic materials, Super paramagnetic materials, Stern - Gerlach Experiment of Electron Spin, Magnetic forces and van der Waals forces in Magnetic nanoparticles (MNps), Magnetic clusters, Magnetization and Demagnetization – Experimental methods, Instruments for measuring Magnetization – VSM, AGM, SQUID magnetometers.

Unit II: Hard and Soft Magnetic materials - Magnetic Nanoparticles for Hard magnetic applications – FePt, CoPt, $SmCo_5$ nanocomposites, Magnetic Nanoparticles for Soft magnetic applications – Co, Fe, Ni Binary alloys – Synthesis, Properties and Applications.

Unit III: Biomagnetism and Biomagnetic Nanostructures – Examples – Haemoglobin, Ferritin and Magnetotactic bacteria – Biomedical Applications of Magnetic nanomaterials and nanostructures.

Unit IV: Ferrofluids – Synthesis, Properties and Applications.

Unit V: Other Magnetic Applications – Magnetoresistance – AMR, GMR, TMR, CMR – Core Shell Magnetic nanostructures – Thin Layered Films – MRAM applications, Quantum Computation and NMR.

Text Books:

1. Introduction to Magnetic materials by Cullity B D
2. Nanocrystalline materials by Glieter
3. Introduction to Nanotechnology by Poole and Owens

References:

1. Encyclopedia of Nanoscience and Nanotechnology by H S Nalwa (ed.) Vol I to X.
2. Advanced Magnetic Nanostructures by Sellmyer - Springer

M. Tech. – II Sem.

NT-2042 **MEMS and NEMS**

(Program Elective IV)

Objective: The course is intended to cover deep understanding of micro and nano electromechanical systems their design and various applications as well as micro and nano fabrication techniques.

Outcome of the study:

1. To provide understanding of MEMS/NEMS applications specially sensors, and actuators, Micro machining tools etc.,
2. To provide materials for MEMS/NEMS and material structures.
3. To provide information on MEMS/NEMS design, processing and Technologies
4. To bring out scaling and packaging issues of MEMS
5. To understand different lithographic techniques of fabrication

Prerequisite:

Mechano- electronic properties, fabrication techniques.

Unit-I Introduction to MEMS and NEMS: MEMS and NEMS – multidisciplinary nature of MEMS/NEMS – working principles: as micro sensors (acoustic wave sensor, biomedical and biosensor, chemical sensor, optical sensor, capacitive sensor, pressure sensor and thermal sensor), micro actuation (thermal actuation, piezoelectric actuation and electrostatic actuation – micro gripers – micro motors – micro valves – micro pumps – accelerometers – micro fluidics and capillary electrophoresis, active and passive micro fluidic devices; Nanoelectromechanical systems – Single Electron Transistors and applications.

Unit-II Materials for MEMS/NEMS: Silicon – Compatible material systems, Silicon, Silicon oxide and nitride, Thin metal films, Polymers, Other materials and substrates, Glass and fused quartz substrates, Silicon carbide and diamond, Gallium Arsenide and other group III-V compound semi conductors, Shape - memory alloys transduction atomic bonds, Material structures.

Unit-III MEMS/NEMS design, processing and Technologies: Basic process tools, Epitaxy, Oxidation, Sputter deposition, Evaporation, Chemical vapor deposition, spin on methods, Lithography, Lift off process, Bulk Micro machining, Etching processes – Wet etching, Plasma etching, Ion milling, Wafer bonding – Silicon fusion bonding, Anodic bonding, Silicon direct bonding, sol gel deposition methods, Self assembled mono layers, EFAB. LIGA electromagnetic micro drive, DRIE

Unit-IV 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.

Unit –V Introduction to lithography and Optical lithography: Introduction to lithography-Contact, proximity printing and Projection Printing, Positive and negative photoresists; Basics of Resolution Enhancement techniques, overlay-accuracies, Mask-Error enhancement factor (MEEF), Electron Lithography; X-ray Lithography; Ion Lithography (Focused Ion Beam Lithography, Masked Ion Beam Lithography, Ion Projection Lithography).

Text Books

1. "An introduction to Micro electro mechanical systems Engineering" by Nadim Malut and Kirt Williams – Second edition – Artech House, Inc, Boston
2. "Micro electro mechanical systems Design" by James J Allen- CRC Press – Taylor and Francis Group
3. John N.Helbert, "Handbook of VLSI Microlithography", Noyes Publication, USA, 2001.
4. James R Sheats and Bruce W.Smith, "Microlithography Science and Technology", Marcel Dekker Inc., New York, 1998

Reference Books

1. "Springer Hand Book of Nano Technology" by Bharath Bhushan – Springer
2. " Nano and Micro electro Mechanical systems" by Sergey Edward Lysherski – CRC Press.
3. MEMS & Micrsystems Design and Manufacture-Tai-Ran Hsu, Tata McGraw Hill
4. L.A.Stelmack, C.T.Thurman and G.R. Thompson "Review of Ion-assisted Deposition: Research to Production", Nuclear Instruments and Methods in Physics Research B, 37/38,787 (1989).
5. J.M.Bennett "When is a surface clean?" p.29 in Optics and Photonics News, June, 1990.

M. Tech. – II Sem.

NT2043 **Multifunctional Nanomaterials**
(Program Elective 1V)

Objective:
This course is intended to cover multifunctional nanomaterials, smart materials, synthesis strategies, properties and applications.

Outcome of the study:

1. To assess knowledge on specific multifunctional nanomaterials and smart materials, their properties and applications.
2. To understand specific multifunctional nanomaterial like TiO_2 for water purification as photocatalyst.
3. To assess how nanoparticles are used for the treatment of Arsenic
4. To develop synthesis strategies of specific multifunctional nanomaterials.

Pre-requisite: Basics of chemistry

Unit-I : Introduction to Multifunctional Nanomaterials - Smart materials – Examples – Properties and Applications.

Unit-II: Synthesis/Strategies for Development of multifunctional Nanomaterials – TiO_2, Fe_2O_3, ZnO, SnO_2.

Unit-III: Nanostructured Catalysts – TiO_2 Nanoparticles for Water purification - TiO_2 as a semiconductor photocatalyst, Photo catalytic mechanism, general pathways & kinetics, Intrinsic, Photocatalytic activity, Reaction variables, Photocatalytic Degradation of Specific Waterborne pollutants. Nanoparticles for treatment of Arsenic: Introduction, Environmental Chemistry of Arsenic, Treatment of Arsenic using Nanocrystalline TiO_2, Treatment of Arsenic using nanoparticles other than TiO_2.

Unit IV: TiO_2 Fabrication, Superhydrophilicity – Other applications of TiO_2.
Unit V: Other Examples of Multifunctional Nanomaterials – Fe_2O_3, ZnO, SnO_2, Ag and Au nanomaterials – Properties and Applications

Text Books:

1. Nanoscale Multifunctional materials by S Mukhopadhyay – Wiley 2011
2. 'Nanotechnologies For Water Environment Applications' American Society of Civil Engineers (ASCE) Publications by Tian C.Zhang, Zhiqiang Hu et al

References:

1. 'Silver Nanoparticles – Universal Multifunctional Nanoparticles for Bio Sensing, Imaging for Diagnostics and Targeted Drug Delivery for Therapeutic Applications' by Anitha Sironmani and Kiruba Daniel
2. Silver–Polymer Composite Stars: Synthesis and Applications by Tae-Jong Yoon et al Angew. Chem. Int. Ed. 2005, 44, 1068 –1071
3. Encyclopedia of Nanoscience and Nanotechnology by H S Nalwa Vol I to Vol 10
4. Bulk Nanostructured Materials with Multifunctional properties by I Sabirov, NA Enikeev, MYu Murashkin, and RZ Valiev – Springer
5. Multifunctional Transparent Epoxy Nanocomposites As Encapsulating Materials For Led Devices by Shao-Yun Fu - iccm-central.org/Proceedings
6. Multifunctional composite core–shell nanoparticles by Suying Wei,et al - Nanoscale, 2011, 3, 4474

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M. Tech. – II Sem.
NT 205 Characterization Lab

Objective: The course is intended to cover basic characterization methods of nanomaterials
Outcome of the study:

1. Gain knowledge on the Dynamic Light Scattering, AFM, SEM, Raman Spectroscopy and Differential Scanning Calorimetry
2. To construct a theoretical knowledge on the experiments.
3. To analyze results of X-Ray diffraction, UV-Visible Spectroscopy and TG/DTA apparatus
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding Characterization of nanomaterials.

Pre-requisite: Basic chemistry, synthesis techniques of nanomaterials

List of Experiments:

1. Nano Particle Size Analysis by Dynamic light scattering
2. Three experiments on Characterization of nanopowders using AFM, SEM, etc
3. Three experiments on Characterization of 1D, 2D and 3D structures using AFM, SEM, etc
4. Raman Spectroscopy of synthesized nanomaterials using BWTEK Raman Spectrophotometer
5. Determination of average Crystallite size and microstrain by X-Ray diffraction analysis
6. Determination of energy band gap by using UV – Visible spectroscopy
7. Study of thermal properties by using Differential Scanning Calorimetry
8. Study of thermal properties by TG/DTA Analysis.

M. Tech. – II Sem.

NT-206 **Advanced Nanotechnology Lab**

Objective: The course is intended to cover the wide spectrum of applications of nanotechnology..

Outcome of the study:

1. To impart the basic knowhow in connection with the fabrication of solar cells.
2. To provide practical knowledge for performance evaluation of Lithium-ion based materials
3. To perform the anti-microbial tests
4. To detect the various gases using nanosensors.
5. To evaluate the photocatalysis process.

List of Experiments:

1. Fabrication of Dye Sensitized Solar Cell and Evaluation of performance
2. Evaluation and performance of Lithium-ion based materials for battery and using cyclic voltameter
3. Ant-microbial tests using nanomaterials
4. Evaluation and performance analysis of fuel cells
5. Germination testing using nanomaterials
6. Photocatalysis evaluation
7. Detection of Gases by metal oxide sensors
8. Biosensors using nanomaterials
9. Evaluation and performance of nanomaterials for capacitance applications using cyclic voltameter

M. Tech. – II Sem.

NT-207 Mini Project with Seminar

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NT-208 Personality development through life-enlightenment skills (Audit -II)

UNIT I

Introduction to Personality Development The concept of personality - Dimensions of personality – Theories of Freud & Erickson-Significance of personality development. The concept of success and failure: What is success? - Hurdles in achieving success - Overcoming hurdles - Factors responsible for success – What is failure - Causes of failure. SWOT analysis.

UNIT II

Attitude & Motivation Attitude - Concept - Significance - Factors affecting attitudes - Positive attitude – Advantages –Negative attitude- Disadvantages - Ways to develop positive attitude - Differences between personalities having positive and negative attitude. Concept of motivation - Significance – Internal and external motives - Importance of self- motivation- Factors leading to de-motivation

UNIT III

Self-esteem Term self-esteem - Symptoms - Advantages - Do's and Don'ts to develop positive self-esteem – Low selfesteem - Symptoms - Personality having low self esteem - Positive and negative self esteem. Interpersonal Relationships – Defining the difference between aggressive, submissive and assertive behaviours - Lateral thinking

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UNIT IV

Other Aspects of Personality Development Body language - Problem-solving - Conflict and Stress Management - Decision-making skills - Leadership and qualities of a successful leader – Character building -Team-work – Time management - Work ethics –Good manners and etiquette.

UNIT V

Employability Quotient Resume building- The art of participating in Group Discussion – Facing the Personal (HR & Technical) Interview -Frequently Asked Questions - Psychometric Analysis - Mock Interview Sessions.

Text Books:

1. Hurlock, E.B (2006). Personality Development, 28th Reprint. New Delhi: Tata McGraw Hill.
2. Stephen P. Robbins and Timothy A. Judge(2014), Organizational Behavior 16th Edition: Prentice Hall.

Reference Books:

1. Andrews, Sudhir. How to Succeed at Interviews. 21st (rep.) New Delhi.Tata McGraw-Hill 1988.
2. Heller, Robert.Effective leadership. Essential Manager series. Dk Publishing, 2002
3. Hindle, Tim. Reducing Stress. Essential Manager series. Dk Publishing, 2003
4. Lucas, Stephen. Art of Public Speaking. New Delhi. Tata - Mc-Graw Hill. 2001
5. Mile, D.J Power of positive thinking. Delhi. Rohan Book Company, (2004).
6. Pravesh Kumar. All about Self- Motivation. New Delhi. Goodwill Publishing House. 2005.
7. Smith, B . Body Language. Delhi: Rohan Book Company. 2004

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M. Tech. – III Sem.
NT 3011 **MOOCS**
(Program Elective-V)

JAWAHARLAL TECHNOLOGICAL TECHNOLOGICAL UNIVERSITY : KAKINADA
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M. Tech. – III Sem.
NT 3012 SOCIETAL IMPACT OF NANOTECHNOLOGY

(Program Elective-V)

Objective: To provide an adequate basic knowledge on social impact of Nanoscience and Nanotechnology

Outcome of the study:

1. To provide awareness to the engineering students about socio economic impact of nanotechnology and to handle the techniques effectively .
2. Understand the various social impacts of nanotechnology trend and research
3. To enhance the nanotechnology research by taking ethics and public opinion into consideration.
4. To understand of professional and ethical responsibility

UNIT I – Protection & Regulation for Nanotechnology Patentability requirements-riding the patent office pony-infringement issues-nanotech patents outside the united states copyright requirements-nanotech creation as artist works-Delegation of power of agencies-Examples of regulation of nanotechnology-environmental regulations-regulation of exports-political and judicial control over agency action.

UNIT II – Liability Legal Aspects of Nanotechnology The applications of civil &criminal laws-civil liability, application of negligence to nanotechnology, strict liability for nanotechnology products-warranty-class actions-nanotechnology business organization-criminal liability

UNIT III – Economic Impacts and Commercialization of Nanotechnology & Social Scenarios Introduction -Socio-Economic Impact of Nanoscale Science: Initial Results and Nanobank-Managing the Nanotechnology Revolution: Consider the Malcolm Baldrige National Quality Criteria -The Emerging NanoEconomy: Key Drivers, Challenges, and Opportunities-Transcending Moore's Law with Molecular Electronics and Nanotechnology- Navigating Nanotechnology Through Society -Nanotechnology, Surveillance, and Society: Methodological Issues and Innovations for Social Research-Nanotechnology: Societal Implications: Individual Perspectives-Nanotechnology and Social Trends-Five Nanotech

UNIT IV - Ethics, Law & Governance Ethics and Law-Ethical Issues in Nanoscience and Nanotechnology: Reflections and Suggestions-Ethics and Nano: A Survey-Law in a New Frontier-An Exploration of Patent Matters Associated with Nanotechnology -The Ethics of Ethics -Negotiations over Quality of Life in the Nanotechnology Initiative. Governance-Problems of Governance of Nanotechnology -Societal Implications of Emerging Science and Technologies: A Research Agenda for Science and Technology Studies (STS)-Institutional Impacts of Government Science Initiatives -Nanotechnology for National Security.

UNIT V – Public Perceptions & Education Public Perceptions-Societal Implications of Nanoscience: An Agenda for Public Interaction Research -Communicating Nanotechnological Risks- A Proposal to Advance Understanding of Nanotechnology's Social Impacts Nanotechnology in the Media: A Preliminary Analysis-Public Engagement with Nanoscale Science and Engineering Nanotechnology: Moving Beyond Risk-Communication Streams and Nanotechnology: The (Re)Interpretation of a New Technology- Nanotechnology: Societal Implications — Individual Perspectives-Historical Comparisons for Anticipating Public Reactions to Nanotechnology.

REFERENCES

1. Mihail. C, Roco and William Sims Bainbridge “Nanotechnology: Societal Implications II-Individual Perspectives”, Springer ,2007.

2. Geoffrey Hunt and Michael. D, Mehta “Nanotechnology: Risk, Ethics and Law”, Earthscan/James & James publication ,2006.

3. Jurgen Schulte “Nanotechnology: Global Strategies, Industry Trends and Applications”, John Wiley & Sons Ltd ,2005.

4. Mark. R, Weisner and Jean-Yves Bottero “Environmental Nanotechnology applications and impact of nanomaterial”, The McGraw-Hill Companies ,2007.

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M. Tech. – III Sem.
NT 3013 **Nano Electronics**

(Program elective-V)

Objective:
This course is intended to cover basics of electronics, transistor, band structure models, nanocapacitors, coulomb blockade, single electron transistor and spintronics.

Outcome of the study:

1. To assess knowledge on Single Electron and few Electron phenomenon.
2. To determine theory behind Scanning Tunneling Microscope by Applications of Tunneling.
3. Study the basics of coulomb blockade in Quantum mechanics.
4. To persuade Single Electron Transistor and Carbon Nano tube Transistor.
5. To extend the knowledge on Spintronics.

Pre-requisite:
1. Basics of electronics and quantum mechanics

Unit - I: Free and confined electrons: Schrodinger's time independent equation, Wave function and physical significance, Free electrons-the free electron gas theory of metals-electrons confined to a bounded region of space and quantum numbers-electrons confined to atom- the periodic table-quantum dots-wires-wells.

UNIT-II: Single-electron and few-electron phenomena and devices: Tunnel junction and applications of tunneling, Tunneling Through a Potential Barrier, Potential Energy Profiles for Material Interfaces, Metal—Insulator, Metal-Semiconductor, and Metal-Insulator-Metal Junctions, Applications of Tunneling; Field Emission, Gate—Oxide Tunneling and Hot Electron Effects in MOSFETs, Theory of Scanning Tunneling Microscope, Double Barrier Tunneling and the Resonant Tunneling Diode.

UNIT-III: Coulomb Blockade: Coulomb Blockade, Coulomb Blockade in a Nanocapacitor, Tunnel Junctions, Tunnel Junction Excited by a Current Source, Coulomb Blockade in a Quantum Dot Circuit.

UNIT-IV: The Single-Electron Transistor: The Single-Electron Transistor Single-Electron Transistor Logic, Other SET and FET Structures, Carbon Nanotube Transistors (FETs and SETs), Semiconductor Nanowire FETs and SETs, Molecular SETs and Molecular Electronics.

UNIT –V Spintronics: Introduction, Overview, History & Background, Generation of Spin Polarization, Spin injection, Spintronic devices and applications - spin filters, spin diodes, spin transistors.

Text Books:

1. Fundamentals of nano electronics by George W Hanson Pearson publications ,India 2008{Unit-I-IV)
2. Introduction to photoelectron Spectroscopy (Chemical Analysis Vol. 67) by P.K. Ghosh; Wiley Interscience
3. Nanophotonics by P.N.Prasad – Springer Education series.
4. Nanotechnology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
5. Nanomaterials: Synthesis, properties and applications\edited by A S Edelstein and R C Cammarata (Institute of Physics, UK Series in Micro and Nanoscience and Technology)

Reference Books:

1. Encyclopedia of Nano Technology by M.Balakrishna Rao and K.Krishna Reddy (Vol I to X) Campus books.
2. Nano: The Essentials – Understanding Nano Science and Nanotechnology by T.Pradeep; Tata Mc.Graw Hill
3. Spin Electronics by M. Ziese and M.J. Thornton
4. Nanoelectronics and Nanosystems – From Transistor to Molecular and Quantum Devices by Karl Goser, Peter Glosekotter, Jan Dienstuhl
5. Silicon Nanoelectronics by Shunri Odo and David Feny, CRC Press, Taylor & Franicd

Open Electives

1. Nanotechnology and its Engineering Applications
2. Nano sensors and Applications
3. NEMS and MEMS
4. Nanotechnology for energy systems

JAWAHARLAL TECHNOLOGICAL TECHNOLOGICAL UNIVERSITY : KAKINADA
M.Tech (Nanotechnology) with effect from 2019-20

NT 3021 Nanotechnology and its Engineering Applications

(Open Elective)

Objective:
The course is intended to cover, basics concepts of crystallography, quantum mechanics, matter and energy relations, de-Broglie hypothesis, wave function analogies, Schrodinger equation, quantum dot, wires and wells etc.

Outcome of the study:

1Student can able to theorize the importance of crystal structure for property evaluation.

2Student can assess different types of chemical bonding in materials.

3To evaluate nano structures in quantum mechanical approaches.

4.Students can able to distinguish between classical electromagnetic theory and Quantum Mechanics.

Unit-I: Introduction to Nanomaterials – Definitions – zero, one, two and three dimensional nanostructures; Basics of Chemistry – Chemical bonding, Hybridization, Reduction potentials.
Crystal structure: Crystalline and amorphous solids; Crystal lattice and crystal structure; Translational symmetry; Space lattice - Unit cell and primitive cell - Symmetry elements in crystal - Seven crystal systems - Some imperfections in crystals - - Miller indices - Miller-Bravais indices - Indices of a lattice direction; The inter planar spacing of a set of crystal planes.

Unit-II: Reciprocal lattice and crystal imperfections: Bragg law- Reciprocal lattice – Properties of Reciprocal lattice- Reciprocal lattice of simple cube- diffraction conditions- Brillouion zones. Importance of lattice imperfections- types of imperfection-Point defects-dislocations.

Unit-III: Introduction to quantum mechanics - matter waves - De-Broglie hypothesis – wave particle duality- Heisenberg's uncertainty principle-Schrodinger wave equation – General postulates of Quantum mechanics- particle in one dimensional box. Particle in 2D and 3D Box, Bloch Theorem, Band theory of solids.

Unit-IV:Electronic,Optical and Magnetic properties:: Energy bands and gaps in semiconductors, Fermi surfaces ,localized particle, donors, acceptors, deep traps, excitons, mobility, size dependent effects, conduction electrons and dimensionality Fermi gas and density of states, semiconducting nanoparticles. optical properties of semiconductors, band edge energy, band gap, dependence on nanocrystalline size, Luminescence, Introduction of magnetic materials, basics of ferromagnetism –magnetic clusters, dynamics of nanomagnets, , nanocarbon ferromagnets, ferrofluids.

UnitV: Applications: Nanomaterials in Environment, nanoparticles in air, water and soil.
Nanomaterials in Health care, Cosmetics and Medicine. Nanomaterials for building and protection, Carbon Nanotubes – Mechanical reinforcement, Nanocomposites for surface coatings – rubber and polymer nanocomposites, Nanomaterials for clothing and textile products. : Smart electronics and sensors.– nanochips, nano batteries, photo-voltaic solar cells, dye-sensitized solar cells, Carbon nanotubes in fuel cells, catalysis.

Textbooks:

1. An introduction to solid states electronic devices by Ajay Kumar Saxena Macmillan India Ltd {Unit-I, II}
2. Solid state Physics by Kittle {Unit-I,II}
3. P.M.Mathews and K.Venkatesan, "A textbook of Quantum Mechanics", Tata McGraw Hill Publishing Company Ltd {Unit-III}
4. Quantum Mechanics – Schiff {Unit-III}
5. Quantum Mechanics by B.k.Agarwal and Hariprakash, PHI {Unit-III}
6. Fundamentals of nanoelectronics by George W.Hanson Pearson education {Unit-IV,V}

Reference Books:

4. Quantum mechanics by Brandsen & Joachem
5. J.J.Sakurari, "Modern Quantum Mechanics Mc.Graw Hill, Addison Wesley Longman Inc., USA, 1999
6. Nano Technology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer

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NT3022 Nano Sensors and Applications

(Open Elective)

Objective:

The course is intended to cover basics and applications of Nanosensors in various fields.

Outcome of the study:

Students get exposure on Nano scale based inorganic sensors, thermal sensors, biosensors, and their applications in addition to sensor characteristics and physical effects.

UNIT I

Sensor characteristics and physical effects:

Active and Passive sensors – Static and dynamic characteristics - Accuracy, offset and linearity - First and second order sensors – Physical effects involved in signal transduction- Photoelectric and Photo dielectric effect

Doppler effect – Barkhausen effect – Hall effect – Ettinshausen effect – Thermoelectric effect – Peizoresistive effect – Piezoelectric effect – Pyroelectric effect –Magneto-mechanical effect (magnetostriction) – Magneto resistive effect

UNIT II

Nano based inorganic sensors: Density of states (DOS) – DOS of 3D, 2D, 1D and 0D materials – one dimensional gas sensors:- gas sensing with nanostructured thin films – absorption on surfaces – metal oxide modifications by additives – surface modifications – nano optical sensors – nano mechanical sensors – plasmon resonance sensors with nano particles – AMR, Giant and colossal magneto resistors – magnetic tunneling junctions.

UNIT III

Thermal Sensors:

Thermal energy sensors -temperature sensors, heat sensors- Electromagnetic sensors- electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetism sensors - Mechanical sensors – pressure sensors, gas and liquid flow sensors, position sensors - Chemical sensors - Optical and radiation sensors.

UNIT IV

Organic/Biosensors:

Structure of Protein – role of protein in nanotechnology – using protein in nanodevices – antibodies in sensing – antibody in nano particle conjugates – enzymes in sensing – enzyme nanoparticle hybrid sensors – Motor proteins in sensing – transmembrane sensors. Nanosensors based on Nucleotides and DNA – Structure of DNA – DNA decoders and microarrays – DNA protein conjugate based sensors – Bioelectronic sensors – DNA sequencing with nanopores – sensors based on molecules with dendritic architectures – biomagnetic sensors.

UNIT V

Sensor Detectors and Applications

Cantilever array sensors – for diagnosis of diabetes mellitus and cancer diagnosis - Nanotube based sensors - for DNA detection and capnography - Nanowire based sensors - Nanowire based electrical detection of single viruses - Nanowire based electrical detection of biomolecules. Bio receptors –Bio detectors - Nano array based detector - Nano Particle based detector - Ultra-sensitive detection of pathogenic biomarkers - Ultra-sensitive detection of single bacteria.

Text Books and References:

1. Kourosh Kalantar – Zadeh, Benjamin Fry, "Nanotechnology- Enabled Sensors", Springer , 2008
2. H.Rosemary Taylor, "Data acquisition for sensor systems", Chapman & Hall,
3. Jerome Schultz, Milan Mrksich, Sangeeta N. Bhatia, Dav J. Brady, Antonio J. Ricco, David R. Walt, Charles L. Wilkins, "Biosensing: International Research and Development", Springer, 2006
4. Ramon Pallas-Areny, John G. Webster, "Sensors and signal conditioning" John Wiley & Sons, 2001.

NT3023 **NEMS and MEMS**

(Open Elective)

Objective: The course is intended to cover deep understanding of micro and nano electromechanical systems their design and various applications as well as micro and nano fabrication techniques.

Outcome of the study:

1. To provide understanding of MEMS/NEMS applications specially sensors, and actuators, Micro machining tools etc.,
2. To provide materials for MEMS/NEMS and material structures.
3. To provide information on MEMS/NEMS design, processing and Technologies
4. To bring out scaling and packaging issues of MEMS
5. To understand different lithographic techniques of fabrication

Unit-I Introduction to MEMS and NEMS: MEMS and NEMS – multidisciplinary nature of MEMS/NEMS – working principles: as micro sensors (acoustic wave sensor, biomedical and biosensor, chemical sensor, optical sensor, capacitive sensor, pressure sensor and thermal sensor), micro actuation (thermal actuation, piezoelectric actuation and electrostatic actuation – micro gripers – micro motors- micro fluidics and capillary electrophoresis, active and passive micro fluidic devices; Nanoelectromechanical systems – Single Electron Transistors and applications.

Unit-II Materials for MEMS/NEMS: Silicon – Compatible material systems, Silicon, Silicon oxide and nitride, Thin metal films, Polymers, Other materials and substrates, Glass and fused quartz substrates, Silicon carbide and diamond, Gallium Arsenide and other group III-V compound semi conductors, Shape - memory alloys transduction atomic bonds, Material structures.

Unit-III MEMS/NEMS design, processing and Technologies: Basic process tools, Epitaxy, Oxidation, Sputter deposition, Evaporation, Chemical vapor deposition, spin on methods, Lithography, Lift off process, Bulk Micro machining, Etching processes – Wet etching, Plasma etching, Ion milling, Wafer bonding – Silicon fusion bonding, Anodic bonding, Silicon direct bonding, sol gel deposition methods, Self assembled mono layers, EFAB. LIGA electromagnetic micro drive, DRIE

Unit-IV 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.

Unit –V Introduction to lithography and Optical lithography: Introduction to lithography-Contact, proximity printing and Projection Printing, Positive and negative photoresists; Basics of Resolution Enhancement techniques, overlay-accuracies, Mask-Error enhancement factor (MEEF), Electron Lithography; X-ray Lithography; Ion Lithography (Focused Ion Beam Lithography, Masked Ion Beam Lithography, Ion Projection Lithography).

Text Books

1. An introduction to Micro electro mechanical systems Engineering" by Nadim Malut and Kirt Williams – Second edition – Artech House, Inc, Boston

2.Micro electro mechanical systems Design" by James J Allen- CRC Press – Taylor and Francis Group

3John N.Helbert, "Handbook of VLSI Microlithography", Noyes Publication, USA, 2001.

4. James R Sheats and Bruce W.Smith, "Microlithography Science and Technology", Marcel Dekker Inc., New York, 1998

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NT3024 Nanotechnology for energy systems

(Open Elective)

Objective:
The course covers the various energy forms, alternate and renewable energy system using nanotechnology.

Outcome of the study:

1. Study the basic Energy need and role of Battery materials
2. To grade up knowledge of Super Capacitors, and its Applications.
3. Study the role of nano structured material to meet Energy Challenges.
4. Learn about the concept of Hydrogen Storage Technology.
5. Gain knowledge on role of Fuel Cell Technology.
6. Gain knowledge on Microfluidic Technology.

Pre-requisite:

Different technologies like Renewable energy technology, supercapacitors and Hydrogen storage technology.

Unit–I Battery materials and batteries: Lithium Ion based batteries. Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: photo- thermal cells for solar energy harvesting, Thin film solar cells, CIGS solar cells, Die sensitized solar cells.

Unit-II: Nanomaterials used in energy and environmental applications and their properties: Evaluation of properties and performance of practical power systems that benefit from optimization of materials processing approaches.

Unit–III Hydrogen storage Technology: Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metal-organic framework materials, volumetric and gravimetric storage capacities, multiple catalytic – degradation of sorption properties, automotive applications.

Unit–IV Fuel cell Technology: Fuel cell Principles, types of fuel cells (Alkaline Electrolyte, Phosphoric acid, Molten Carbonate, solid oxide and direct methanol and Proton exchange fuel cells), Principle and operation of Proton Exchange Membrane (PEM) fuel cell, Materials and fabrication methods for fuel cell technology, micro fuel cell power sources – Biofuels.

Unit–V Microfluidic Technology: MEMS & NEMS technology for microfluidic devices: micro and nano engines and driving mechanism, power generation, microchannel battery pump (TCP), piezoelectric membrane and their applications.

Text Book

1. Renewable Energy Resources by J. Twidell and T.Weir, E&FN Spon Ltd.

References

1. Hydrogen from Renewable Energy Source by D.Infield
2. .Fundamentals of Industrial Catalytic Process by C.H. Bartholomew and Robert J. Farraoto, John Wiley & Sons Inc.
3. Fuel storage on Board Hydrogen storage in Carbon Nanostructures by R.A. Shatwell
4. Fuel cell Technology Handbook by Hoogers, CRC Press
5. Hand book of fuel cells: Fuel cell technology and applications by Vielstich, Wiley:CRC Press

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M Tech. – III Sem.
NT 303 **Dissertation Phase -1**

M. Tech. – IV Sem.
NT 401 **Dissertation Phase -2**