Mission:

- Student-centered Teaching-learning processes and a stimulating R&D environment.
- To conduct and support research, development, design and engineering in nanotechnology, and transfer the technology to industrial sector in order to increase India competitiveness, improve the quality of life the environment.
- To establish and sustain state-of-art Infrastructure for professional aspirants hailing from both rural and urban areas by creating an ambience conducive for excellence in technical education and research.

Vision:

- To become a Centre of excellence in multidisciplinary engineering.
- Educate all about presence of Nano Technology in day to day life.
- Cutting edge Research in the field of various technological/engineering aspects.
- To create System designers, Scientists, Researchers, Product designers, Nano Technologists.

Program Educational Objectives (PEO's):

- To produce masters who would have developed a strong background in Nanoscience, Nanomaterials, Thin films and ability to use these tools in their chosen fields of specialization.
- To produce masters who have the ability to serve country in the R&D domain on solving the problems in existing engineering aspects using the cutting edge technology tool called nanotechnology.
- To produce masters `who would attain professional competence through life-long learning such as advanced degrees, professional registration, and other professional activities.
- To produce masters who function effectively in a multi-disciplinary environment and individually, within a global, societal, and environmental context.
- To produce masters who would be able to take individual responsibility and to work as a part of a team towards the fulfilment of both individual and organizational goals.

Programme Outcomes (PO's) :

- An ability to independently carry out research/investigation development work to solve practical problems.
- An ability to write and present a substantial technical report/document.
- Students will demonstrate a degree of mastery over the area as per the specialization of the program.The mastery should be at a level higher than the requirements in the appropriate bachelor program.
- Recognize the need for multi-disciplinary technologies, exposure to modern tools,environmental sustainability and ability to attain lifelong learning in the broader contest of Nano Technology challenges.

ACADEMIC YEAR 2017-2019
CENTRE FOR NANOSCIENCE AND TECHNOLOGY
INSTITUTE OF SCIENCE & TECHNOLOGY (AUTONOMOUS)
JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY HYDERABAD
M.Tech. (NT), COURSE STRUCTURE AND SYLLABUS (CBCS)

I Year

I Semester	Code	Course Title	Int. marks	Ext. marks	L	P	C
Core Course I	NT-101	Properties of Nano Structures	25	75	4	--	4
Core Course II	NT-102	Synthesis of Nanomaterials	25	75	4	--	4
Core Course III	NT-103	Material Characterization Techniques	25	75	4	--	4
Core Elective-I	NT-104	1. Structure, Bonding and Quantum Mechanics 2. Introduction to Nano Science and Nano Technology	25	75	4	--	4
Open Elective -I	NT-105	1. Nano Bio Technology, Materials & Devices 2. Advanced catalysis	25	75	4	--	4
Laboratory I	NT-106	Synthesis, Fabrication and Characterization Lab	25	75	--	6	3
Laboratory II	NT-107	Simulation Lab-I	25	75	--	6	3
Seminar I			100	--	--	4	2
		Total credits	**275**	**525**	**20**	**16**	**28**

II Semester	Code	Course Title	Int. marks	Ext. marks	L	P	C
Core Course IV	NT-201	Nano Sensors and Devices	25	75	4	--	4
Core Course V	NT-202	Nano Electronics and Nano Photonics	25	75	4	--	4
Core Course VI	NT-203	Carbon Nanostructures and its Applications	25	75	4	--	4
Core Elective-II	NT-204	1. Nanotechnology For Energy Systems 2. Nano Composites Design and Synthesis	25	75	4	--	4
Open Elective -II	NT-205	1. Science & Technology of Thin Films 2. Lithographic Techniques	25	75	4	--	4
Laboratory III	NT-206	Nanostructured Material Application Lab	25	75	--	6	3
Laboratory IV	NT-207	Simulation Lab-II	25	75	--	6	3
Seminar II			100	---	--	4	2
	Total Credits		**275**	**525**	**20**	**16**	**28**

II Year

	I Semester	Int. marks	Ext. marks	L	P	C
1.	Project work Review I	0	100	--	--	4
2.	Project work Review II	100	--	--	20	10
	Total Credits	**100**	**100**	**--**	20	**14**

	II Semester	Int. marks	Ext.marks	L	P	C
1	Project work Review III	100	--	--	20	10
2.	Project Evaluation (Viva-Voce)	--	100	--	24	12
	Total Credits	**100**	**100**	**--**	**44**	**22**

Total Credits = 92

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NT-101 PROPERTIES OF NANO STRUCTURES

Objective: To bring out the distinct properties like electrical, magnetic, optical, thermal and mechanical properties of nanostructures.

Course 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 thermal properties of nanomaterials.
5. To understand advanced mechanical properties of nanostructured materials.

Pre-requisite:

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

Unit-I: Electronic 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.

Unit-II: Magnetic properties, Introduction of magnetic materials, basics of ferromagnetism – ferro magnetic resonance and relaxation, magnetic properties of bulk nanostructures, magnetic clusters, dynamics of nanomagnets, nanopore containment of magnetic particles, nano carbon ferromagnets, ferrofluids, electron transport in magnetic multilayers.

Unit-III: Optical properties , Photonic crystals, optical properties of semiconductors, band edge energy, band gap, Core-shell nanomaterials, Quantum dots etc., for size influences of optical properties, optical transitions, absorptions, interband transitions, quantum confinements, Fluorescence/luminescence, photoluminescence/fluorescence, optically excited emission, electroluminescence, Laser emission of quantum dot, Photo fragmentation and columbic explosion, luminescent quantum dots for biological labeling.

Unit-IV: Thermal properties of nanostructures- thermal conductivity measurements for nanowires, nanotubes, thin films.

Unit-V: Mechanical Properties of nanomaterials, Types of indentation: Oliver & Pharr, Vickers indentation process, Nano Indentation by AFM, Young's modulus, Contact angle, Scratch implant measurements.

Text & Reference books:

1. Introduction to Nano Technology by Charles. P. Poole Jr& Frank J. Owens. Wiley India Pvt.Ltd.
2. Nanoindentation by Anthony C Fisher-cripps springer
3. Encyclopedia of Nano Technology by M.Balakrishna Rao and K.Krishna Reddy, Vol I to X Campus books.
4. Thermal nanosystems and Nanomaterials Sebastian Voltz
5. Hand book of Nano structured materials Vol I & V
6. Encyclopedia of Nano Technology by H.S.Nalwa
7. Hand book of Nanotechnology by Bharat Bhushan springer
8. Nanostructured materials: Processing, Properties and Potential Applications, edited by C.C.Koch, Noyes Publications (2002).
9. Introduction to Nanoscience, S.M. Lindsay, 2009

Journal references:

1. K K Nanda, Pramana J. Phys., Vol. 72, No. 4, April 2009
2. V P Skripov, V P Koverda and V N Skokov, Phys. Status Solid A66, 109 (1981)
3. R Goswami and K Chattopadhyay, Act Mater. 52, 5503 (2004)
4. V. Germain et al. J. Phys. Chem. B, Vol. 107, No. 34, 2003
5. Russell J. Gehr* and Robert W

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NT-102 SYNTHESIS OF NANOMATERIALS

Objective:

This course is intended to cover the two groups of synthesis of nanostructures namely top-down and bottom-up approach various synthesis methods, including biological methods, advantages and disadvantages etc.

Course Outcome of the study:

1. To assess the Top down and Bottom up synthesis techniques of nano structured materials.
2. To determine the physical routes involved in synthesis of nano structured materials.
3. Student can able to validate the thermolysis based approaches in preparation of nano structured material.
4. To study the biological synthesis methods involved in synthesis of Nanomaterials.
5. To understand and gain the knowledge to the scale up of nano materials.

Pre-requisite:

1. Basic chemistry fundamentals
2. Basics physics fundamentals

Unit-I: Introduction to synthesis of nanostructure materials, Bottom-up approach and Top-down approach with examples.

Unit-II: Physical methods: Inert gas condensation, Arc discharge, RF-plasma, electric explosion of wires, ball milling, molecular beam epitaxy, PVD, CVD, Chemical methods: Nanocrystals by chemical reduction, photochemical synthesis, electrochemical synthesis, co-precipitation method, Nanocrystals of semiconductors and other materials by arrested precipitation, emulsion synthesis, sono-chemical routes, microwave assisted synthesis, Template based synthesis of nanomaterials.

Unit–III: Thermolysis route - spray pyrolysis and solvated metal atom dispersion, sol-gel method, Polymer based synthesis techniques, solvothermal and hydrothermal routes, solution combustion synthesis, Chemical vapor synthesis.

Unit–IV: Biological methods – use of bacteria, fungi, actinomycetes for nano-particle synthesis-magnetotatic bacteria for natural synthesis of magnetic nano-particle, role of plants in nanoparticle synthesis, Synthesis of dendrimers, Cell and material Immobilisation

Unit-V: Scale-up of nanomaterial synthesis: Nano clay particles, 3-D bulk materials preparation, Micro reactor based synthesis: micro emulsions, colloid solutions, Health effects.

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.BalakrishnaRao and K.Krishna Reddy, Vol I to X, Campus books.
2. Encyclopedia of Nanotechnology by H.S. Nalwa
3. Nano: The Essentials — by T.Pradeep; Tata Mc.Graw Hill

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NT-103 MATERIAL CHARACTERIZATION TECHNIQUES

Objective:

To familiarize students with Spectroscopic, Electrical, Thermal and Magnetic characterization techniques and interpretation of results including standards etc.

Course 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 technique.
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: Spectroscopic Techniques: UV- Visible Spectroscopy, Photo-luminescence Spectroscopy, Mossbauer spectroscopy, Fourier Transform infrared (FTIR) spectroscopy, Raman spectroscopy techniques: micro Raman and laser Raman, ICPMC.

Unit-II: Compositional and structural Characterization techniques: X-ray Photoelectron Spectroscopy (XPS), Energy Dispersive X-ray analysis (EDAX), Principles and applications of X-ray diffraction; electron diffraction, Electron probe microanalysis (EPMA), Ion beam techniques: SIMS & RBS, BET, PSA and Zeta sizer.

Unit-III: Advanced Microscopy Techniques: High resolution microscopy; Scanning electron microscopy (SEM), Transmission electron microscopy (TEM), Atomic force microscopy (AFM), scanning tunneling microscopy (STM).

Unit-IV: Electrical and Magnetic characterization techniques: Measurement of resistivity by 4-prob method, Hall measurement, Electron beam induced current measurement (EBIC), Vibrating Sample Magnetometer, SQUID magnetometer, Impedance analyzer

Unit-V: Thermal and Mechanical characterization techniques:Thermal-analysis:TGA,DTA,DSC,DMA; Nanoindentation technique, Micro tensile testing, Micro UTM

Text books:

1. Nano: The Essentials -Understanding Nano Science and Nanotechnology by T.Pradeep, TataMc.Graw Hill
2. Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
3. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
4. Electron Microscopy and analysis by P.J. Goodhew and F.J. Humpreys
5. Characterization of nanostructured materials by Z.L. Wang
6. Modern Raman Spectroscopy: A practical approach by E. Smith and G.Dent
7. Principles of Instrumental analysis by D.A. Skoog, F.J. Hollen and T.A. Niemann
8. Atomic and Molecular Spectroscopy: Basic Aspects and Applications by S.Svanberg.

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 education.
4. Encyclopedia of Nanotechnology by H.S. Nalwa

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NT-104: STRUCTURE, BONDING AND QUANTUM MECHANICS

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.

Course Outcome of the study:

1. Student can able to theorize the importance of crystal structure for property evaluation.
2. Student can asses different types of chemical bonding in materials.
3. To evaluate nano structured in quantum mechanical approaches.
4. Students can able to distinguish between classical electromagnetic theory and quantum mechanics.
5. To predict the free electron gas theory of metals and in Hydrogen atom.

Pre-requisite:

1. Basics physics
2. Quantum mechanics
3. Basic chemistry
4. Basic material science

Unit-I: Crystal structure: Crystalline and amorphous solids- Crystal lattice and crystal structure-Translational symmetry-space lattice-unit cell and primitive cell-symmetry elements in crystal-the seven crystal systems- Miller indices-Miller-bravais indices-Indices of a lattice direction. 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 II: Bonds: Chemical bonding, Valance shell, Types of bonds and its characteristics, Sigma bond, Pi bond, Ionic bond, Covalent bond, Coordinative covalent bond, Polar bond, Hydrogen bond, Modern theories of chemical bonding, Valance bond theory, Molecular orbital theory.

Unit-III: Introduction-Why quantum mechanics - matter waves-length scales - De-Broglie hypothesis – wave particle duality- Heisenberg‘s uncertainty principle-Schrodinger wave equation – General postulates of Quantum mechanics- particle in one dimensional box, Bohr‘s correspondence principle.

Unit-IV: Quantum mechanics of electronics: Electron as particle and electron as wave-Time independent Schrodinger equation and boundary condition on the wave function-Analogies between quantum mechanics and classical electromagnetic theory-Probabilistic current density-multiple particle systems.

Unit-V: Free and confined electrons: Free electrons-the free electron gas theory of metals-electrons confined to abounded region of space and quantum numbers-electrons confined to atom-the hydrogen atom and the periodic table-quantum dots-wires-wells , Fermi level and Fermi function.

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. Introduction to Nanotechnology by Charles P.PooleJr& Frank J. Owens;Wiley India Pvt. Ltd
2. The Feynman lectures on Physics; Vol I to III
3. Quantum mechanics by Brandsen&Joachem
4. J.J.Sakurari, –Modern Quantum Mechanics Mc.Graw Hill, Addison Wesley Longman Inc., USA, 1999
5. Nano Technology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer

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NT-104: INTRODUCTION TO NANO SCIENCE & NANO TECHNOLOGY

Objective:

To familiarize students with basics of nanoscience and technology, Nanobiotechnologies and Nanomaterials for environmental and toxicology.

Course Outcome of the study:

1. To discuss the basic concepts of nano technology.
2. To understand the importance of nano biotechnology
3. To study the influence of nanotechnology in the field of environment and toxicology.
4. To evaluate the concepts of nano electronics.
5. To classify the applications of nano materials.

Pre-requisite:

1. Basic chemistry fundamentals
2. Basic material science

Unit-I: Background of Nanotechnology

Scientific Revolutions, Nanotechnology and Nanomachines,The Periodic Table, Atomic Structure, Molecules and Phases, Energy, Molecular and Atomic size, Surfaces and Dimensional Space, Top down and Bottom up approach.

Unit-II: Nanobiotechnologies: Concept-Structural principle of Bionanotechnology-Classification of Nanobiotechnologies -Micro- and Nanoelectromechanical Systems- Function of Biological Nanomolecules-DNA computers and DNA microprocessors- Biotechnology based genetic engineering -Function of Biological Nanomolecules- Bionanomachines in Action. Drug deliveries -Targeting Ligands based Drug Delivery- Cancer Treatment- Mediated Delivery - Tissue Regeneration, Growth and Repair,Tissue Bioengineering.

Unit-III: Nano Materials For Environment And Toxicology : Green nanotechnology and its principles, Nano-convergence and Environmental Engineering, different environmental systems, Potential impacts of nanomaterials on organisms and ecosystems, Environmental applications, Nanotechnology and Our Energy Challenge of nanomaterials, Nanotechnology and Renewable Energy, Introduction to toxicology, principles of toxicology,Nanotoxicology, dosage-Response curve, classification of toxicity, factors affecting toxicity, LC50, LD 50, Air borne Particles,

Unit-IV: Nanoelectronics

Approaches to nanoelectronics, Fabrication of integrated circuits, MEMS, NEMS, Nano circuits, Quantum wire, Quantum well, DNA-directed assembly and application in electronics.

Unit-V: Applications

Coatings, Optoelectronic Devices, Environmental Applications, Nanomedicine, Biomedical applications, Energy storage

Text Books

1. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India
2. Introduction to Nanoscience and Nanotechnology, Chatopadhyaya.K.K, and Banerjee A.N,
3. Introduction to nano tech by phani kumar
4. Nanotechnology and the Environment, Kathleen Sellers,Christopher Mackay, Lynn L. Bergeson, Stephen R. Clough, Marilyn Hoyt, Julie Chen, Kim Henry, Jane Hamblen, crc press, 2009

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NT-105: NANO BIO-TECHNOLOGY, MATERIALS & DEVICES

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.

Course Outcome of the study:

1. Students can able to develop deep understanding of fundamental concepts of biotechnology.
2. Student can able to compile all the biological nano structures and their applications.
3. To know the importance of nano technology in medical field.
4. To prioritize the role of nano structured materials in diagnosis.
5. To gain the improvements in drug delivery system using nanotechnology.

Pre-requisite:

1. Basics of organic chemistry
2. Basics of Biology

Unit–I: Fundamentals terms in biotechnology, Biological building blocks: Sizes of building blocks and Nanostructures, nucleic acids, genetic code and protein synthesis, Enzymes, DNA double nano wires, protein nanoparticles and polypeptide nanowires, Path ways(Glycology and TCS etc) .

Unit-II: Biological Nanostructures: Bio-mimitics with examples, Bio mineralization, Bio compatible Bio sensors, Examples of proteins, micelles, vesicles, bilayers, and Multilayer films, application of bio- nanotechnology: bio nano machines, molecular modeling.

Unit-III: Nano bio-sensors and biomedical applications, organic semiconductors, biological neurons and their functions, bio-chemical and quantum mechanical computers: DNA computers, parallel processing, Bit and _Q' bit, Quantum parallelism.

Unit-IV: Biomolecular sensing for cancer diagnostics using carbon nanotubes, nano devices in biomedical applications, nanoscale polymer fabrication for biomedical application, nanotechnology in cancer drug therapy: A biocomputational approach, Nanotoxicology

Unit-V: Introduction to drugs, Classification of drugs, Encapsulation of drugs, Nano drug delivery: Conventional drug delivery, targeted drug delivery, chemistry of drug delivery, role of nanotechnology in drug delivery, bionanoimaging, magnetic nanoparticles for MR imaging, Magnetic hyperthermia in cancer treatment, Multifunctional nanoparticles.

Text books:

1. Bio Nano Technology by Good Sell, Wiley Liss
2. Nanotechnology by John F. Mongillo
3. Introduction to Nanotechnology by Charles. P.PooleJr and Frank J. Owens, Wiley India Pvt Ltd.
4. Nano Technology, A gentle introduction to the next big idea by Mark Ranter and Daniel Ranter,Pearson education
5. Nanotechnology – science, innovation and opportunity by Lynn E Foster, Prentice Hall – Pearson education.

Reference books:

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

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NT-105: ADVANCED CATALYSIS

Objective:
The course covers the importance of adsorption principles, various catalyst methods and alternate energy sources.

Course Outcome of the study:
1. Students can able to develop deep understanding of fundamental concepts of biotechnology.
2. Student can able to compile all the biological nano structures and their applications.
3. To know the importance of nano technology in medical field.
4. To prioritize the role of nano structured materials in diagnosis.
5. To gain the improvements in drug delivery system using nanotechnology.

Pre-requisite:

1. Basics of Adsorption techniques
2. Basics of Energy Sources

Unit–I Surface science: Chemisorption & Physisorption, adsorption isotherms and methods of determination of pore size and surface area of materials using the adsorption isotherms, Catalysis – Definition, types of catalysis with suitable examples, characteristics of a catalyst, selectivity or specificity of the catalyst, activation and deactivation of catalysts, catalytic poisoning, re-construction of surface atoms.

Unit–II Necessity for the alternate energy sources and the role of catalytic technology in the energy sector – Fuel cells, Solar cells, Biomass and Biofuels, New trends in heterogeneous catalysis – catalytic sensors, membrane and monolithic reactors

Unit–III Catalysis in environmental protection & green process- Industrial catalytic wet air oxidation processes, water purification, synthesis of specialty, commodity and fine chemicals, catalysis in automobiles : catalytic converter applications, carbon nanomaterials

Unit–IV Important catalytic materials – Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids

Unit–V Mesoporous materials – Introduction, synthesis & characterization, properties and applications (with suitable examples), Significance of pore size: unipore size, bimodal pore size, supramolecular chemistry, synthesis (micelar rods).

Text Books & References
1. Basic principles in applied catalysis – Manfredlaerns
2. Nanotechnology in Catalysis – Pinzhan
3. Introduction to Nanotechnology – Charles P Poole Jr & Frank J Owens
4. Nanoscale Materials –LM Liz Marzan & Prashant V. Kamat
5. Nanostructured catalysts – SL Scott, CM Crudden & CW Jones
6. Concepts of Modern Catalysis & kinetics - I. Chorkendorff, J.W. Niemantsverdriet
7.Chemistry of Nanomaterials: Synthesis, properties & applications, Volume-I – CNR Rao, A

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NT-106: SYNTHESIS, FABRICATION AND CHARACTERIZATION LAB

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

Course outcome of the study:

1. Gain knowledge on the synthesis techniques involved in experiments.
2. Students can acquire knowledge on equipment handling like XRD, PSA, UV 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 and characterization of nanomaterials.

Pre-requisite: Basic chemistry, synthesis techniques characterization

Experiments:

1. Synthesis of ZnO nanoparticles using Urea as fuel by Solution Combustion Method
2. Synthesis of PVP capped Cadmium Sulfide (CdS) nanoparticles Chemical Co-Precipitation Method
3. Synthesis of silica gel (SiO_2) using Sol-Gel method
4. Synthesis of the TiO_2 nanoparticles by using green synthesis from Aloe vera extract.
5. Synthesis of Graphene oxide by using hummers method
6. Fabrication of thin film by Dip coating
7. Fabrication of thin film by Spin coating
8. Fabrication of thin film by Spray Pyrolysis
9. Determination of average Crystallite size and Microstarin by using X-Ray diffraction Analysis.
10. Determination of average particle size and zeta potential by using Dynamic light scattering
11. Calculation of band gap with error bar values by using U-V Visible spectroscopy.
12. Study of thermal properties by using TG/DTA analysis
13. Humidity Sensor applications
14. In-house Chemical sensor testing unit for detection of poisonous and flammable gases
15. Antibacterial applications
16. Seed germination using nanomaterials

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NT-107: SIMULATION LAB-I

Objective: The course is intended to cover understanding of nanomaterial fabrication technique and modeling.

Course Outcome of the study:

1. To gain knowledge on design and construction of carbon molecules.
2. Student can develop math work and gain knowledge on Mat-Lab.
3. To construct a theoretical knowledge on the experiment.
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding simulation components.

Pre-requisite: Strategies to simplify the process of implementation

List of the Experiments:

I. ARGUS LAB

1. Construction of fullerene & its energy calculations
2. Construction of Bucky balls (C20, C40, C60, C80, C100, C120, C140)
3. Construction of Carbon nanotubes

II.MATLAB

1. Introduction to MATLAB Programming
2. Program assembly, Execution, Data processing and graphic analysis
3. Study of Fermi – Dirac distribution function
4. Introduction to symbolic math computations
5. MATLAB program to plot the one-dimensional rectangular potential well with infinite potential barrier

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NT-201: NANO SENSORS AND DEVICES

Objective:

The course is intended to cover sensors and different types of sensors with their characteristics and their applications

Course Outcome of the study:

1. To develop knowledge about Sensors, Characteristics, design and its Applications.
2. To persuade about the Physical Effects of Sensor.
3. To visualize the concept of Mass Sensitivity and Conductive Sensors.
4. To understand the importance of Electro Chemical Sensors and its measurement types.
5. Student can able attain knowledge on Thermometric & Optical sensors.

Pre-requisite:

1. Basics of nano liners optics and electronics
2. Basic of sensors, physical, chemical, mechanics phenomenon‘s related to sensors.

Unit I: Introduction &Sensor Characteristics: Nanotechnology, Sensors, Nanotechnology Enabled S ensors, Sensor Characteristics and Terminology, Static Characteristics, Dynamic Characteristics, Physic al Effects Employed for Signal Transduction, Design and Applications.

Unit-II: Sensors& Physical Effects: Photoelectric Effect, Photo-dielectric Effect , Photo-luminescence Effect,Electroluminescence Effect, Chemiluminescence Effect, Doppler Effect, Barkhaus en Effect, Hall Effect, Nernst/Ettingshausen Effect, Thermoelectric (Seebeck/Peltier and Thomson) Effect, Thermoresistive Effect, Piezoresistive Effect, Piezoelectric Effect, Pyroelectric effect, Magneto-Mechanical Effect (Magnetostriction) , Mangnetoresistive Effect, Faraday-Henry Law.

Unit-III: Mass-Sensitive & Conductivity Sensors: BAW Sensors, SAW Sensors, Conductometric Sensors, Resistive and Capacitive Gas Sensors,Gas Sensors Based on PolycrystallineSemiconductors, GasSensors Made of Polymers and Gels, Resistive and Capacitive Sensors for Liquids.

Unit-IV Electrochemical Sensors: Potentiometric Sensors, Selectivity of Potentiometric Sensors Ion Selective Electrodes,The Ion Selective Field Effect Transistor (ISFET), Measurement with Potentiometr ic Sensors, Amperometric Sensors Selectivity of Amperometric Sensors, Electrode Design and Exampl es, Measurement with Amperometric Sensors, Sensors Based on Other Electrochemical Methods, Electro-Chemical Biosensors, Classes of Electrochemical Biosensors.

Unit-V: Thermometric & Optical Sensors: Sensors with Thermistors and Pellistors, Pyroelectric Sensors, Sensors Based on Other Thermal Effects, Optical Fibres as a Basis for Optical Sensors, Fibre Sensors without Chemical Receptors (Mediators), Optodes: Fibre sensors with a chemical receptor, Optodes with simple receptor layers, Optodes with complex receptor layers, Pressure Sensors

Text Books:

1. Nanotechnology-Enabled Sensors, Kourosh Kalantar-zadeh, Springer publications (2007)
2. Chemical Sensors-An Introduction for Scientists and Engineers,Peter Gr¨undler, Springer publications (2006)
3. Design and Applications of Nanomaterials for Sensors by Jorge M. Seminario, Jerzy Leszczynski, Springer, Volume-16, 2014.

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NT-202: NANO ELECTRONICS AND NANO PHOTONICS

Objective:

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

Course 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 and Nano photonics.

Pre-requisite:

1. Basics of nano linear optics and electronics

Unit-I: 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,
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Unit-II: 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: Spintronics - GMR & TMR effects and Foundations of nano-photonics - OLED

Text books:

1. Fundmentlas of nano electronics by George W Hanson Pearson publications , India 2008
2. Introduction to photoelectron Spectroscopy (Chemical Analysis Vol. 67) by P.K. Ghosh;
3. Nanophotonics by P.N.Prasad – Springer Education series.

Reference books:

1. Encyclopaedia of Nano Technology by M.Balakrishna Rao and K.Krishna Reddy (Vol I to X) Campus books.
2. Spin Electronics by M. Ziese and M.J. Thornton
3. Introduction to Nanoscience by S.M Lindsay, 2009.

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NT-203: CARBON NANOSTRUCTURES AND ITS APPLICATIONS

Objective: The course covers the structural and electronic properties of CNTs apart from various synthesis and characterization methods and applications.

Course Outcome of the study:

1. Gain knowledge about Carbon nano Structures and its growth mechanism.
2. To compare various Synthesis Techniques of CNTs and Purification.
3. To upgrade our knowledge on Physical Properties of CNT.
4. To develop knowledge about Hydrogen Absorption using CNTS.
5. To compile knowledge of various applications of CNTs in diverse fields.

Pre-requisite:

1. Structure of carbon chemistry and importance and difference types of carbon like diamonds, graphite etc.

Unit–I: Carbon Nano structures and types of Carbon Nano tubes, growth mechanisms, Mechanical reinforcements, Graphene, Carbon Nano fibers, Carbon clusters, Diamond

Unit–II: Synthesis of Carbon nanostructures by Flame, CVD, Laser & Arc-discharge process, characterizations, Purification and Functionalization of Carbon nanostructures, Fluidized bed reactor

Unit–III: Electrical, Vibrational, Mechanical Properties of Carbon nanostructures, Optical and Raman spectroscopy of Carbon nanostructures.

Unit –IV: Lithium & Hydrogen adsorption & storages, Fuel cell applications and energy storage, Chemical Sensors applications of CNTs, Nano fluid based CNT's.

Unit – V: Computer applications (Nano chip), optical and telecommunication applications Nano composites, silicon Nanowires, Applications on Energy & Biomedical sectors.

Text books:

1. Introduction to Nanotechnology- Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
2. Hand book of Nanotechnology by Bharat Bhushan Springer publications
3. Carbon Nanotubes Properties and Applications- Michael J. O'Connell, © 2006 by Taylor & Francis Group, LLC
4. Graphene – Synthesis, Characterization, Properties And Applications Edited By Jian Ru Gong
5. Science of Fullerenes and carbon nanotubes- M. S. Dresselhaus, P. C. Eklund Academic press

Reference books:

1. Encyclopaedia of Nanotechnology by M.Balakrishnarao 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 Scinece and Nanotechnology by T.Pradeep; Tata Mc.Graw Hill.

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NT-204: NANO TECHNOLOGY FOR ENERGY SYSTEMS

Objective:

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

Course 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.

Pre-requisite:

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

Unit–I: Energy studies: Why clean energy, Different energies: Nuclear energy, Hydro power, Wind energy, Battery: Introduction to Battery materials and batteries: Lithium-Ion based batteries, Sodium-Ion batteries, Redox-Flow batteries.

Unit–II: Super capacitors: Super capacitor characterisation, Types of super capacitors, double layer and pseudo capacitance, hybrid super capacitors, super capacitors: Electrochemical double layer and pseudo-capacitors, Hybrid supercapacitors, advantages and disadvantages of electrochemical double layer, Psudocapacitors and hybrid supercapacitors., Applications of supercapacitors.

Unit–III: 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, Perovskite solar cells.

Unit–IV: Hydrogen storage Technology: Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metal-organic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalphy formations and thermal management during hydriding reaction, multiple catalytic – degradation of sorption properties, automotive applications.

Unit–V: 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, Microbial biofuels.

Text Books & References:

1. Electrochemical supercapacitors for energy storage and delivery by Aiping Yu, Tay.& Franc, 2013.
2. Renewable Energy Resources by J. Twidell and T.Weir, E&FN Spon Ltd.
3. Hydrogen from Renewable Energy Source by D.Infield
4. Fundamentals of Industrial Catalytic Process by C.H. Bartholomew and Robert J. Farraoto, John
5. Fuel storage on Board Hydrogen storage in Carbon Nanostructures by R.A. Shatwell
6. Fuel cell Technology Handbook by Hoogers, CRC Press
7. Electrochemical Supercapacitors , B E Conway, Kluwer Academic/Plenum publishers, NY 1999.

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NT-204 NANO COMPOSITES DESIGN AND SYNTHESIS

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.

Course 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 Impregnation Techniques.

Pre-requisite:

Basics of composites, properties of bulk composites

Unit–I: Introduction to Nanocomposites, Composite material, Mechanical properties of Nanocomposite 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.

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

Unit–IV: Types of indentation: Oliver & Pharr, Vickers indentation process, Nano-Indentation by AFM. Influence of Interface, Molding, Injection molding, Design Selection Methodology for Composite Structures.

Unit–V: Processing of polymer nanocomposites, properties of nanocomposites, Infiltration techniques, Stir mixing, Extrusion method, Intercalation and Exfoliation, Solution casting method, impregnation techniques: Hot melt impregnation, solution impregnation, spin coating.

Text books:

1. Nanocomposite Science & Technology by P.M. Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co.
2. Introduction to Nano Technology by Charles. P.PooleJr and Frank J. Owens; Wiley India Pvt Ltd.
3. Nanotechnology, A gentle introduction to the next big idea by Mark Ratner, Daniel Ratner Pearson
4. Polyoxometalate Chemistry for Nano- Composite Design
5. Rheology and processing of polymer nanocomposites by Sabu Thomas, JiJi Abraham-Wiley Publications
6. Nano Composites by K. K. Chawla,

Reference books:

1. Encyclopedia of Nanotechnology by H.S.Nalwa
2. Encyclopaedia of Nano Technology by M.Balakrishnarao and K.Krishna Reddy, Vol I to X Campus books.

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NT-205: SCIENCE AND TECHNOLOGY OF THIN FILMS

Objective:

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

Course 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 Perini and gauge technology

Unit-I: Vacuum technology: principles of vacuum pumps in range of 10^{-2} torr to 10^{-11}torr, principle of different vacuum pumps: roots pump, rotary, diffusion, 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), Zone model and Thornton model for thin film growth, capillarity theory, microstructure in thin films, adhesion, properties of thin films: Mechanical, electrical, and optical properties of thin films.

Unit-III: Physical Vapor Deposition techniques: Thermal evaporation, resistive evaporation, Electron beam evaporation, Laser ablation, Flash and Cathodic arc deposition, Electron beam and Ion beam lithography techniques

Unit-IV: Electrical discharges used in thin film deposition: Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, Ion plating, difference between thin films and coating,

Unit-V: Electro deposition, molecular beam epitaxy and laser pyrolysis. Chemical vapor deposition techniques: Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, boundaries and flow, Different kinds of CVD techniques: Metallorganic CVD (MOCVD), Plasma Enhanced CVD (PECVD), thermally activated CVD, CVD, Spray pyrolysis, etc.

Text Books & References:

1. Thin Film Phenomenon by K.L. Chopra, McGraw-Hill
2. Methods of Experimental Physics (Vol 14) by G.L.Weissler and R.W. Carlson ―Vacuum Physics and Technology‖
3. A User‘s Guide to vacuum Technology by J.F.O‘Hanlon, John Wiley and Sons
4. Vacuum Physics and Techniques by T.A. Delchar, Chapman and Hall
5. Evaporation: Nucleation and Growth Kinetics‖ by J.P. Hirth and G.M.Pound, Pergamon Press
6. Handbook of Vacuum Science and Technology by Dorothy M. Hoffman, Bawa Singh, John H. Thomas, III, Academic Press-Elsevier

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NT-205: LITHOGRAPHIC TECHNIQUES

Objective: The course is intended to cover deep understanding of basics and different types of lithographic techniques useful for Nanofabrication.

Course Outcome of the study:

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

Pre-requisite:

1. Clean room technology, thin films coating 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: Focussed 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

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. Hand book 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-bemDeposition‖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 Grain Structure 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).

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NT-206: NANOSTRUCTURED MATERIAL APPLICATION LAB

Objective: The course is intended to cover understanding of nanomaterial synthesis, fabrication and characterization technique.

Course outcome of the study:

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.

Pre-requisite: Synthesis, Fabrication and Characterization Techniques

Experiments:

1. Synthesis and Characterization of Metal oxide nanostructured material for Humidity Sensing Application
2. Synthesis and Characterization of Metal oxide nanostructured material for Gas Sensing Application
3. Synthesis and Characterization of Metal oxide nanostructured material for Glucose Sensing Application
4. Synthesis and Characterization of Metal oxide nanocomposite material for Humidity Sensing Application
5. Synthesis and Characterization of Metal oxide nanocomposite material for Gas Sensing Application
6. Synthesis and Characterization of Metal oxide nanocomposite material for Glucose Sensing Application
7. Fabrication (Dip coating) and Characterization of Thin film for Humidity Sensing Application
8. Fabrication (Spin coating) and Characterization of Thin film for Gas Sensing Application
9. Fabrication (Spray pyrolysis) and Characterization of Thin film for Glucose Sensing Application
10. Synthesis and Characterization of Nanostructured material for Seed Germination Application
11. Synthesis and Characterization of Nanostructured material for Anti-bacterial Application
12. Synthesis and Characterization of Nanostructured material for Energy Application

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NT-207: SIMULATION (NANOHUB+QUANTUM WISE) LAB-II

Objective: Objective: The course is intended to cover understanding of nanomaterial fabrication technique and modeling.

Course outcome of the study:

1. To familiarize students about applying various material design and data analysis.
2. To help in understanding the theoretical modeling of semiconductor devices and quantum structures using online in- browser simulation tools.
3. To construct a theoretical knowledge on the experiment.
4. The ability to write and present the laboratory reports.
5. To maximize knowledge regarding simulation tools.

Pre-requisite: Strategies to simplify the process of implementation

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)

II. NANOHUB

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

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