**Course Objectives**

The learning objectives of the course are to provide students with the knowledge of miniaturization concept and Quantum mechanical aspects. Understand the principles of Nanofabrication process; determine the suitability of nanostructures for fabrication of devices. The course provides a strong theoretical and analytical understanding of nanostructures and devices fabrication process for its applications.

**Module 1:**

**The Science Of Miniaturization**

Miniaturization of Electrical and Electronic Devices, Moore’s law and technology road map, Quantum Mechanical Aspects, Simulation of the Properties of Molecular Clusters, Formation of the Energy Gap, Confinement Effects, Discreteness of Energy Levels, Tunneling Currents.

10 Hours

**Module 2:**

**Nanofabrication by Photons**


10 Hours

**Module 3:**

**Nanofabrication by Ion Beam**


10 Hours

**Module 4:**

**Nanofabrication by Scanning Probes**

Introduction, Principles of Scanning Probe Microscopes, Exposure of Resists- Exposure of Resist by STM, Exposure of Resist by NSOM, Additive Nanofabrication, Field Induced Deposition, Dip-Pen Nanolithography, Subtractive Nanofabrication-Electrochemical Etching, Field Induced Decomposition, Thermomechanical Indentation, Mechanical Scratching, High Throughput Scanning Probe Lithography.

10 Hours

**Module 5:**

**Fabrication of micro/nano devices**

Text Book:

Reference Book

Course Outcomes:
At the end of the course, students will be able to:
1. Understand and appreciate the importance of nanostructure and its impact device fabrication
2. Differentiate between nanofabrication process and understand the advantages and limitations of process for device fabrication
3. Understand the miniaturization of devices to Nano devices, process challenges and analyze theory for emerging Nano scale devices
4. Evaluate the advances in Nano scale technology and device fabrication their application in electronics, sensors, biomedical and energy generation and storage.
**NANOELECTRONICS**

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<th>Sub Code</th>
<th>16NT22</th>
<th>IA Marks :</th>
<th>20</th>
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<tr>
<td>Hrs/ Week</td>
<td>04</td>
<td>Exam Hours :</td>
<td>03</td>
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<tr>
<td>Total Hrs.</td>
<td>50</td>
<td>Exam Marks :</td>
<td>80</td>
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**Course Objectives:**
The learning objectives of the course in nanoelectronics are to understand the importance of nanoelectronics, technology roadmap in nanoelectronics and limitations of existing CMOS technologies for design of electronic circuits. The course provides an insight on the advances in nanoelectronics devices such as High-K devices, FINFETs, CNTFETs, Molecular Electronics and Spintronics. The course provides a strong theoretical and analytical understanding of nanoelectronic devices and its applications in design of electronic circuits.

**Course Syllabus:**

**Module 1:**

**Introduction to nanoelectronics:** Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of semiconductor devices, Quantum statistical mechanics, Energy bands in silicon, **Metal Oxide Semiconductor Field Effect Transistors (MOSFET)**, MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage characteristics, Finite Element Modeling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect.

10 Hours

**Module 2:**

**Nanoscale MOSFETs:** MOSFET as digital switch, Propagation delay, Dynamic and static power dissipation Moore’s law, Transistor scaling, Constant field scaling theory, Constant Voltage Scaling, Generalized scaling, Short channel effects, Reverse short channel effect, Narrow width effect, Subthreshold conduction leakage, Subthreshold slope, Drain Induced Barrier Lowering, Gate Induced Drain Leakage, Design of NanoMOSFET, Halo implants, Retrograde channel profile, Shallow source/drain extensions, Twin well CMOS process flow, Gate Tunneling : Fowler Nordheim and Direct Tunneling, High k gate dielectrics, Metal gate transistor, Transport in Nanoscale MOSFET, Ballistic transport, Channel quantization.

12 Hours

**Module 3:**

**Designing with FINFETs:** Evolution of FinFET, Principle of FinFET, Finfet Technology, FinFET Schematic, Compact Drain-Current equation, Small Signal Model of Si- Based FinFET, FinFET Fabrication Flow, Power dissipation in FinFETs, Leakage power reduction techniques, Power gating, Dual sleep, Dual stack, Sleepy stack, Basic gate design using FinFET’s, combinational logic, sequential logic, Adders, Multiplier, SRAM cell design

10 Hours

**Module 4:**

**Designing with CNTFETs:** Introduction to CNTs, CNT structure, metallic and semiconductor CNTs, energy bands in CNTs, types of CNTs: Single walled and multiwalled, physical, electrical and thermal properties of CNTs, fabrication of CNTs. CNTFETs, structure and model, small signal model, predictive technology models, N-Channel and P-Channel CNTFETs, model files of CNTFETs, basic gates using CNTFET, VI characteristics
of CNTFET based inverter, designing of sub systems using CNTFETs, combinational and sequential circuits using CNTFETs, adders, multipliers and SRAM cell using CNTFETs.

10 Hours

Module 5:
Advances in Nanoelectronics: MOLECULAR NANOELECTRONICS: Electronic and optoelectronic properties of molecular materials, TFTs- OLEDs- OTFTs – logic switches, SPINTRONICS: Spin tunneling devices - Magnetic tunnel junctions- Tunneling spin polarization, -spin diodes - Magnetic tunnel transistor - Memory devices and sensors - ferroelectric random access memory- MRAMS

08 Hours

Course Outcomes:
At the end of the course, students will be able to:
1. Understand and appreciate the importance of nanoelectronics and its impact in next generation electronics and electronic products
2. Differentiate between MOS and emerging nanodevices technology, understand the advantages and limitations of MOS based circuits
3. Understand the technology migration from MOS to nano devices, process challenges and analyze the mathematical models for emerging Nanoscale devices
4. Design logic circuits, sub systems and complex digital circuits using FINFETs and CNTFETs
5. Evaluate the advances in Nanoscale technology development and understand the importance of emerging devices and technologies of molecular electronics and spintronics

Text Books:
3. Cyril Prasanna Raj P., Designing with FINFETs and CNTFETs, MSEC E-Publication (2016)

Reference Books:
ADVANCED MATERIALS

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Course Objective
Provide foundation about crystal structure, arrangement of atoms in different structure. Course gives an overview of various advance materials and their application. Enrich students with advanced material science techniques.

Course Content
Module 1:
**Crystal structure**: Crystal systems, Crystal classes, Bravais lattice. Unit cell: Wigner-Seitz cell, equivalent positions in a unit cell. Notations of planes and directions. Atomic packing: packing fraction, Co-ordination number. Examples of simple crystal structures: NaCl, ZnS and diamond. Symmetry operations, point groups and space groups.

10 Hours

Module 2:

10 Hours

Module 3:
**Photonic Materials**: Need for New Photonic Materials, composite materials for nonlinear optics, nanostructured waveguides for nonlinear optics quantum and nonlinear optics for advanced imaging applications.

**Spintronics Materials**: Modeling the growth of Mn on semiconductor substrates, Dilute magnetic semiconductor nanocrystals, Advances in wide bandgap materials for semiconductor spintronics

10 hours

Module 4:
**Smart Materials and Systems**: Thermoresponsive materials, piezoelectric materials, electrostrictive and magnetostRICTive materials, Magnetic materials, superparamagnetism in metallic nanoparticles, Giant and colossal magnetic materials, ferrofluids, TR and MR fluids, biomimetic materials, smart gel, shape memory alloys and polymers.

10 Hours

Module 5:
Advanced materials in Biomedical Application: Zeolite Structures as Drug Delivery Systems, Mesoporous Silica Nanoparticles and Multifunctional Magnetic Nanoparticles in Biomedical Applications, Metal-Organic Frameworks for Biological and Medical Applications

10 Hours
Text Books
1. Introduction to Solid State Physics, C. Kittel, Wiley Eastern
2. A practical approach to X-Ray diffraction analysis by C. Suryanarayana

References

Course Outcome:
At the end of the course, students will be able to:
1. Understand the crystal structure and characterization of various nanomaterials
2. Evaluate the characteristic crystal structure and their influence on properties of the materials.
3. Demonstrate their knowledge in advanced material science which helps in applications of various materials in engineering applications.
CHARACTERIZATION TECHNIQUES

Sub Code : 14INT24  IA Marks : 20
Hrs/ Week : 04  Exam Hours : 03
Total Hrs. : 50  Exam Marks : 80

Course Objective:
The course aims at providing overview of various characterization techniques. Analyze the data obtained from different techniques and evaluate size, structure, morphology and properties of nanomaterials.

Module 1:
**X-Ray based characterization:** Principles and applications of X-ray diffraction, powder (polycrystalline) and single crystalline XRD techniques; Debye-Scherrer equation to treat line broadening and strain induced in nanoparticles and ultra-thin films. Basics of structure refinement (Reitveld). Rotating anode and synchrotron based X-ray diffraction for probing structure. X-ray photoelectron spectroscopy – basic principle, instrumentation, X-ray absorption techniques: XANES, EXAFS.

**12 Hours**

Module 2:

**12 Hours**

Module 3:
**Spectroscopic techniques:** UV-VIS Spectrophotometers, IR/FTIR Spectrophotometers, Principles, operation and application for band gap measurements. Raman spectroscopy principles and applications. Optical microscope: Nanoparticle size measurement by Dynamic light scattering methods zeta potential.

**10 Hours**

Module 4:
**Magnetic characterization:** Types of magnetic materials, Magnetic susceptibility, Curie-Weis plot for paramagnetic materials, Neel temperature, Curie temperature VSM and SQUID magnetometers – M vs H, M vs T, MH-loops.

**10 Hours**

Module 5:
**Electrical measurements:** Cyclic Voltameter, Impedence Measurement, IV, AC and DC electric measurements, impedance spectral information.

**06 Hours**

Text Books
1. Characterization of Nanostructure materials by XZ.L.Wang
2. Instrumental Methods of Analysis, 7th edition- Willard, Merritt, Dean, Settle
Reference Books
   - Harold P. Klug, Leroy E. Alexander
   - David B. Williams and C. Barry Carter

Course Outcome:
Students will be able to
1. Identify the characterization technique suitable for their studies
2. Analyze the data from various characterization techniques used to evaluate nanomaterial structure, size, morphology and properties.
3. Understand the size and structure relationship and their suitability for an given engineering application.
ELECTIVES – II

SENSORS AND ACTUATORS

Sub Code : 16NT251 IA Marks : 20
Hrs/ Week : 03 Exam Hours : 03
Total Hrs. : 40 Exam Marks : 80

Course Objectives
The learning objectives of the course are to Understand the basic concept and features of sensors. Learn the relation between physical effects on the main sensing/transduction mechanisms. Determine the suitability of nanostructures for sensors application. Knowing how to gather, interpret and use scientific and technical information on sensors and biosensors. The course provides a strong theoretical and analytical understanding of Nano sensor and their application.

Module 1:
Fundamentals of sensors: Micro and nano-sensors, biosensor, packaging and characterization of sensors, method of packaging at zero level, and first level. Thermal energy sensors: temperature sensors, heat sensors, electromagnetic sensors, electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetic sensors, Mechanical sensors, pressure sensors, gas and liquid flow sensors, position sensors, chemical sensors, optical and radiation sensors- gas sensor.

08 Hours

Module 2:
Sensor Characteristics and Physical Effects:

08 Hours

Module 3:
Sensor Architecture and Classification:

08 Hours

Module 4:
Actuators: What is an actuator, Transducing materials as a basis for actuator design, Energy domains and transduction phenomena, Transducer basics, The role of the actuator in a control system: sensing, processing and Actuation- Impedance matching. Emerging versus
traditional actuator, Other actuator technologies - Electrostatic actuators, Thermal, Magnetic shape memory actuators, Piezoelectric actuators

08 Hours

Module 5:

08 Hours

Text Books

References:

Course outcome
Students will be able to
1. Demonstrate the basics knowledge of sensors and actuators
2. Interpret and analyze the signal data from sensors measurement
3. Applications of nanostructures in sensors and actuators
MEMS AND NEMS

Sub Code : 16NT252    IA Marks : 20
Hrs/ Week : 03    Exam Hours : 03
Total Hrs. : 40    Exam Marks : 80

Course Objectives
1. Learn about basics and typical applications of microsystems
2. Illustrate scaling laws & microsensors and microactuators
3. Illustrate the various principles of operations of mems transducers
4. Learn basic electrostatics and its applications in MEMS sensors and actuators
5. Learn about ways to fabricate & a packaging needs MEMS device

Course Content
Module 1:
Introduction to MEMS: Historical background of Micro Electro Mechanical Systems, Feynman’s vision, Nano Technology and its Applications Multi-disciplinary aspects, Basic Technologies, Applications areas, Scaling Laws in miniaturization, scaling in geometry, electrostatics, electromagnetic, electricity and heat transfer.

10 Hours

Module 2:
Micro and Smart Devices and Systems: Principles: Transduction Principles in MEMS Sensors: Micro sensors-thermal radiation, mechanical and bio-sensors, Actuators: Different actuation mechanisms - silicon capacitive accelerometer, piezo-resistive pressure sensor, blood analyzer, conductometric gas sensor, silicon micro-mirror arrays, piezo-electric based inkjet print head, electrostatic comb-driver, Smart phone application, Smart buildings

10 Hours

Module 3:
Materials and Micro manufacturing: Semiconducting Materials., Silicon, Silicone dioxide, Silicon Nitride, Quartz, Poly Silicon, Polymers, Materials for wafer processing, Packaging Materials Silicon wafer processing, lithography, thin-film deposition, etching (wet and dry), wafer-bonding, Silicon micromachining: surface, bulk, LIGA process, Wafer bonding process.

10 Hours

Module 4:
Electrical and Electronics aspects: Electrostatics, Coupled Electro mechanics, Stability and Pull-in phenomenon, Practical signal conditioning Circuits for Microsystems, Characterization of pressure sensors, RF MEMS, Switches varactors, tuned filters, Micromirror array for control and switching in optical communication, Application circuits based on microcontrollers for pressure sensor, Accelerometer, Modeling using CAD Tools (Intellisuite)

10 Hours

Module 5:
Integration And Packaging Of Microelectromechanical Systems: Integration of microelectronics and micro devices at wafer and chip levels. Microelectronic packaging: wire and ball bonding, flip-chip. Microsystem packaging examples, Testing of Micro sensors, Qualification of Mems devices

10 Hours
Text Book:

Reference Books

Course outcome
Students will be able to
1. Understand the basics and develop applications for microsystems
2. operations of mems transducers
3. Applications of electrostatics in MEMS sensors and actuators
4. Fabricate MEMS device
**Course Objective:**
Students will learn underlying principles of drug delivery systems. Understand the application of nanostructures as drug delivery systems. Nanoparticles based drug formulation for cancer therapy and bio imaging application.

**Course Content**

**Module 1:**
**Principles of drug delivery systems (DDS):** Design of drug delivery systems, Aims of DDS, Modes of drug delivery, ADME hypothesis – controlled drug delivery, site specific drugs, barriers for drug targeting, passive and active targeting, Strategies for site specific, time and rate controlled delivery of drugs, antibody based and metabolism-based targeting.

*8 Hours*

**Module 2:**
**Nano sized Drug Carriers:** Structure and Preparation- Liposomes, Cubosomes and Hexosomes, Solid Lipid Nanoparticles (SLP). Lipid based colloidal system, Liposomal Drug Carriers, Dendrimer (PAMAM), Polymer Micelle, Ceramic and Magnetic nanoparticle, Polymer drug conjugates. Nanotubes, Nanowires, Nanocage, Nanorods, Nanofibers, and Fullerenes, Carbon nanotubes biocompatibility. Smart drug delivery systems, Multifunctional Drug carriers, organic and inorganic composites. Problems with DDS, Drug loading efficiency in nanovehicles, complexity of Nanocarriers, interface between synthetic materials and biological tissues or components, safety and ethical issues, Nanotechnology for future DDS.

*08 Hours*

**Module 3:**

*08 Hours*

**Module 4:**
**Nanomedicines:** Introduction, Applications of nanobiotechnology in medicine, Role of nanotechnology in methods of treatment, Nanomedicines for Nervous system, Developing Nanomedicines, Protocols for nanodrug Administration, Nanotechnology in Diagnostics applications, materials used in Diagnostics and Therapeutic applications - Molecular Nanomechanics, Molecular devices, Nanomedicines for Skin disorders, wound healing, eye diseases, infections, Nanotubes for detection and destruction of bacteria.

*08 Hours*
Module 5:

**Nanomaterials**: Nanoparticles for biological labelling, Nano-Imaging Agents, Nano particles molecular labels, Immunogold-silver staining, combined fluorescent and gold probes, Protein Labeling, gold cluster labelled peptides, gold cluster conjugates of other small molecules, gold-lipids metallosomes, Larger covalent particles labels, gold targeted to His Tabs, gold cluster nanocrystals.

08 Hours

**Text Books**

**Reference**
2. Nanoparticulate Drug Delivery Systems Deepak Thassu, Michel Deleers (Editor), Yashwant Pathak

**Course Outcome:**
Students will be able to
1. Demonstrate the knowledge to develop nanoparticle based new types of biomedical markers and therapeutic agents.
2. Evaluate the suitable nanostructure for drug delivery systems application.
3. Develop nanoparticles based drug formulation for cancer therap.
NANOPHTONICS

Sub Code : 16INT254   IA Marks : 20
Hrs/ Week : 03       Exam Hours : 03
Total Hrs. : 40       Exam Marks : 80

Course Objective:
The course gives an introduction to basic concepts of nanophotonics. It also provides an overview of various semiconductor nanomaterials and their characteristics features along with its applications.

Course Content
Module 1:
Introduction to Nanophotonics:
Nano photonics at a Glance, Multidisciplinary approach, Photons and Electrons: Similarities and Differences, Propagation, Nanoscale Optical Interaction, Free-Space Propagation, Confinement of Photons and Electrons, Nanoscale Confinement of Electronic Interactions. 08 Hours

Module 2:
Quantum-Confined Materials and characterization
Inorganic Semiconductors, Quantum Wells, Wires Dots, Rings, Manifestations of Quantum Confinement Dielectric Confinement Effect, Super lattices, Core-Shell Quantum Dots and Quantum Dot-Quantum Wells Quantum-Confined Structures as Lasing Media, Organic Quantum-Confined Structures, Characterization of Nanomaterials, Different techniques- X Ray, Electron Microscopy. 08 Hours

Module 3:
Photonic Crystals
Basics Concepts, Theoretical Modeling of Photonic Crystals, Features of Photonic Crystals, Methods of Fabrication, Photonic Crystal Optical Circuitry, nonlinear Photonic Crystals, Photonic Crystal Fibers (PCF), Photonic Crystals and Optical Communications, Photonic Crystal Sensors. 08 Hours

Module 4:
Nanolithography
Two-Photon Lithography, Near-Field Lithography, Near-Field Phase-Mask Soft Lithography, Plasmon Printing, Nanosphere Lithography, Dip-Pen Nanolithography, Nanoimprint Lithography, Photonically Aligned Nanoarrays. 08 Hours

Module 5:
Silicon Photonic Applications
Text Books
1. Paras N Prasad, Nanophotonics, Wiley Interscience, 2004
2. Graham T Reed, Silicon Photonics, John Wiely and Sons, 2008
3. David G. Bucknall. Nanolithography and patterning techniques in microelectronics, CRC Press,

Course Outcome:
Students will be able to
1. Understand the basic principles involved photonics and electronics applications
2. Demonstrate knowledge about photonic, semiconductor nanostructures in developing their applications
3. Knowledge to apply nanolithography for nanophotonics based devices.
Course Objective:
The learning objectives of the course are knowledge to design and develop the nanostructured based devices, hands on experience to fabricate the devices based on nanomaterials, Knowledge of device operation and data measurement and analyze the device performance and application.

1. Gas/Pressure Sensors device fabrication and device parameter measurement and analysis
2. Dye sensitized solar cell device fabrication, I-V measurement and Efficiency calculation
3. Preparation of electrodes for supercapacitor and calculate its specific capacitance using Cyclic voltammetry.
4. To fabricate metal oxide thin/thick film and analyze surface features using AFM
5. Fabrication of thin/thick films and its Crystal structure analysis using XRD
6. Design and Synthesis of 1D inorganic nanostructures and analyze their size and morphology by scanning electron micrograph
7. Preparation of 2D nanostructures and measure their thickness and morphology by AFM.
8. Modification of electrodes by nanomaterial for voltammetric applications
10. Fabrication of electrode for electrochemical oxidation of organic molecules.

Course Outcome:
Students will be able to
1. Design the nanomaterial for suitable application
2. Basic hands on experience to fabricate selected nanomaterials based devices
3. Knowledge to operate the device and measure data.