



VIT[®]

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

**SCHOOL OF ELECTRONICS
ENGINEERING**

M. Tech Nanotechnology

(M. Tech MNT)

Curriculum

(2018-2019 admitted students)



VISION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

Transforming life through excellence in education and research.

MISSION STATEMENT OF VELLORE INSTITUTE OF TECHNOLOGY

World class Education: Excellence in education, grounded in ethics and critical thinking, for improvement of life.

Cutting edge Research: An innovation ecosystem to extend knowledge and solve critical problems.

Impactful People: Happy, accountable, caring and effective workforce and students.

Rewarding Co-creations: Active collaboration with national & international industries & universities for productivity and economic development.

Service to Society: Service to the region and world through knowledge and compassion.

VISION STATEMENT OF THE SCHOOL OF ELECTRONICS ENGINEERING

To be a leader by imparting in-depth knowledge in Electronics Engineering, nurturing engineers, technologists and researchers of highest competence, who would engage in sustainable development to cater the global needs of industry and society.

MISSION STATEMENT OF THE SCHOOL OF ELECTRONICS ENGINEERING

1. Create and maintain an environment to excel in teaching, learning and applied research in the fields of electronics, communication engineering and allied disciplines which pioneer for sustainable growth.
2. Equip our students with necessary knowledge and skills which enable them to be lifelong learners to solve practical problems and to improve the quality of human life.



M. Tech Nanotechnology

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

1. Graduates will be engineering practitioners and leaders, who would help solve industry's technological problems.
2. Graduates will be engineering professionals, innovators or entrepreneurs engaged in technology development, technology deployment, or engineering system implementation in industry.
3. Graduates will function in their profession with social awareness and responsibility.
4. Graduates will interact with their peers in other disciplines in industry and society and contribute to the economic growth of the country.
5. Graduates will be successful in pursuing higher studies in engineering or management.
6. Graduates will pursue career paths in teaching or research.



M. Tech Nanotechnology

PROGRAMME OUTCOMES (POs)

PO_01: Having an ability to apply mathematics and science in engineering applications.

PO_03: Having an ability to design a component or a product applying all the relevant standards and with realistic constraints, including public health, safety, culture, society and environment

PO_04: Having an ability to design and conduct experiments, as well as to analyse and interpret data, and synthesis of information

PO_05: Having an ability to use techniques, skills, resources and modern engineering and IT tools necessary for engineering practice

PO_06: Having problem solving ability- to assess social issues (societal, health, safety, legal and cultural) and engineering problems

PO_07: Having adaptive thinking and adaptability in relation to environmental context and sustainable development

PO_08: Having a clear understanding of professional and ethical responsibility

PO_11: Having a good cognitive load management skills related to project management and finance



M. Tech Nanotechnology

ADDITIONAL PROGRAMME OUTCOMES (APOs)

APO_02: Having Sense-Making Skills of creating unique insights in what is being seen or observed (Higher level thinking skills which cannot be codified)

APO_03: Having design thinking capability

APO_04: Having computational thinking (Ability to translate vast data in to abstract concepts and to understand database reasoning)

APO_07: Having critical thinking and innovative skills

APO_08: Having a good digital footprint



M. Tech Nanotechnology

PROGRAMME SPECIFIC OUTCOMES (PSOs)

On completion of M. Tech (VLSI) degree, students will be able to:

- PSO1: Apply advanced concepts in Physics of semiconductor devices to design VLSI systems.
- PSO2: Design ASIC and FPGA based systems using industry standard tools.
- PSO3: Solve research gaps and provide solutions to socio-economic, and environmental problems.



M. Tech Nanotechnology

CREDIT STRUCTURE

Category-wise Credit distribution

Category	Credits
University core (UC)	27
Programme core (PC)	19
Programme elective (PE)	18
University elective (UE)	6
Bridge course (BC)	
Total credits	70



M. Tech Nanotechnology

DETAILED CURRICULUM

University Core

S. No	Course Code	Course Title	L	T	P	J	C
1.	MAT6001	Advanced Statistical Methods	2	0	2	0	3
2.	ENG5001 and ENG5002 (or) EFL5097	Fundamentals of Communication English and Professional and Communication English (or) English and Foreign Language	{0 0	{0 0	{2 2	{0 0}	2
3.	STS5001	Soft Skills	0	0	0	0	1
4.	STS5002	Soft Skills	0	0	0	0	1
5.	SET5001	SET Project-I	0	0	0	0	2
6.	SET5002	SET Project-II	0	0	0	0	2
7.	ECE6099	Master's Thesis	0	0	0	0	16

M. Tech Nanotechnology

Programme Core

S. No	Course Code	Course Title	L	T	P	J	C
1	ECE5031	Quantum Physics for Nanostructures	2	0	0	0	2
2	ECE5032	Physics and Chemistry of Solids	2	0	0	0	2
3	ECE5033	Synthesis of Nanomaterials and Thin Film Deposition	2	0	2	4	4
4	ECE 5034	Nanomaterial Characterization Techniques	3	0	2	0	4
5	ECE 6032	Nanoelectronics	2	0	2	4	4
6	ECE 6033	Nanophotonics	3	0	0	0	3



M. Tech Nanotechnology

Programme Elective

S.No	Course Code	Course Title	L	T	P	J	C
1	ECE 5035	Semiconductor Device Physics and Technology	2	0	0	4	3
2	ECE5036	MEMS to NEMS	2	0	0	4	3
3	ECE 5037	Nanosensors	3	0	0	0	3
4	ECE 5038	Carbon Nanomaterials	3	0	0	0	3
5	ECE 5039	Lithographic Techniques for Device Fabrication	3	0	0	0	3
6	ECE 5040	Plasmonics	2	0	0	4	3
7	ECE 6031	Nanomagnetism- Fundamentals and Applications	3	0	0	0	3
8	ECE 6034	Energy Technologies	3	0	0	0	3
9	ECE 6035	Spintronics	2	0	0	4	3
10	ECE 6039	Nanoelectronic Circuit Design	3	0	0	0	3

University Elective Baskets

Management courses

S.No		Course Title	L	T	P	J	C
1		University Elective [#]	-	-	-	-	6



Course Code	Course Title	L	T	P	J	C
ECE5031	QUANTUM PHYSICS FOR NANOSTRUCTURES	2	0	0	0	2
Pre-requisite	Nil					
Course Objective:						
The course is aimed to						
<ol style="list-style-type: none"> 1. Educate various concepts of quantum theory and its importance. 2. Make them understand the different quantum nanostructures and their density of states. 3. Enable them to apply quantum theory to design nanoscale devices. 						
Expected Course Outcomes:						
Students will be able to:						
<ol style="list-style-type: none"> 1. Gain the advanced concepts of quantum theory. 2. Understand the importance of Schrodinger wave equation & its applications. 3. Obtain the knowledge on quantum confinement effects. 4. Gain the knowledge in dispersion relation of electron in solids. 5. Understand the quantum nanostructures, such as quantum dots, nanowires and quantum wells and their density of states. 6. Understand the time-dependent perturbation and its applications. 						
Student Learning Outcomes (SLO): 1						
1. Having an ability to apply mathematics and science in engineering applications						
Module :1	Introduction	4 hours				
Importance of Quantum theory, Wave-particles duality, de-Broglie and Fermi Wavelengths, Wave function, Dynamical operators, Uncertainty principle, Quantum numbers and Hydrogen atom problem, Pauli exclusion principle.						
Module:2	Schrodinger equations and their formulation	3 hours				
Schrodinger time dependent and time independent wave equations - analytical solutions.						
Module:3	Potential Well, Potential Barrier and Tunnelling	4 hours				
One-Dimensional Potential well , Particle in 1D, 2D and 3D box, Rectangular Barrier, Concept of Tunneling, Reflectance, transmittance and tunnelling probability, Scanning tunnelling microscope						
Module:4	Theory of conduction in solids	4 hours				
Description of the theory of Conduction in Solids -Drude model, Nearly free electron model, Dispersion relation for electron.						
Module:5	Electronic Band Structure	5 hours				
Periodic lattice, Brillouine zones, Periodic potential, Bloch Theorem, Kronig-Penny Potential and Electronic energy bands, direct and indirect gap semiconductors.						
Module:6	Quantum Confinement and Density of States	4 hours				
Concept of Quantum Confinement, Quantum Dots, Quantum Well and Quantum Wires, Density of states in 3D, 2D, 1D and 0D solid, carrier concentration.						
Module:7	Time-dependent perturbation and applications	4 hours				
Time-dependent change in potential, First-order time-dependent perturbation, Fermi's golden rule,						



Photon emission due to electronic transitions, Fermi's golden rule for stimulated optical transitions, Semiconductor laser.			
Module:8		Contemporary issues:	2 hours
		Total Lecture:	30 hours
Text Book(s)			
1	A. F. J. Levi, Applied Quantum Mechanics, Second edition, Cambridge University Press, 2006.		
2	Richard L. Liboff, Introductory Quantum Mechanics, Fourth edition, Pearson Education Inc, India, 2003.		
Reference Books			
1	Robert Eisberg and Robert Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles, second Edition, John Wiley & Sons, Canada, 1985.		
2	A. Ghatak and S. Lokanathan, Quantum Mechanics–Theory & Applications, Macmillan India Limited, New Delhi, 2002.		
3	A. Beiser, Concepts of Modern Physics, Sixth edition, TataMcGraw- Hill Edition, New Delhi, 2003.		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies		13-12-2015	
Approved by Academic Council		No. 40	Date 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE5032	PHYSICS AND CHEMISTRY OF SOLIDS	2	0	0	0	2
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to: <ol style="list-style-type: none"> 1. Provide understanding of properties of materials from an atomistic view point, and to classify solids. 2. Outline the properties and structure of crystalline materials, various modes of bonding in solids with appropriate examples. 3. Render them about thermodynamics and statistical mechanics of solids. 						
Expected Course Outcomes:						
Students will be able to: <ol style="list-style-type: none"> 1. Gain knowledge on crystal structure 2. Understand various types of atomic bonding in solids. 3. Classify the materials based on their properties. 4. Identify different imperfections in solids. 5. Understand thermodynamics and elementary statistical mechanics. 6. Apply Magnetic, Optical & Thermal properties of different material for potential applications. 						
Student Learning Outcomes (SLO): 1, 17						
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications. 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice. 						
Module 1	Structure of Matter	6 hours				
Crystal structure & Bonding- Crystals, Polycrystals, Symmetry, Unit cells, Bravais lattices, Crystallographic directions, Crystallographic planes, Miller indices, Bragg's law, Single crystal and Powder X-ray diffraction.						
Module 2	Chemical Bonding	3 hours				
Atomic Bonding in solids - Types of bond: Metallic, Ionic, Covalent and van der Waals bond; Hybridization; H-bonding Molecular orbital theory for simple molecules such as diatomic molecule etc.						
Module 3	Classification of Materials	2 hours				
Different types of materials -Metals, Semiconductors, Composite materials, Ceramics, Alloys, and Polymers.						
Module 4	Imperfections in solids	2 hours				
Imperfections of crystal structure –point defects, Grain boundaries, phase boundaries, Dislocations Screw, Edge and Mixed Dislocations						
Module 5	Introduction to Thermodynamics and Elementary Statistical Mechanics	6 hours				
The first and second laws of thermodynamics, Thermodynamic functions, enthalpy, entropy and Microstates, Introduction to Ionic Conductivity, Gibb's freeenergy, Gibb's paradox, Liouville's						



theorem, Classical Statistical systems, Boltzman statistics, quantum statistical systems, Fermi-Dirac and Bose-Einstein Statistics and their applications.			
Module 6	Phase Transformations	4 hours	
Mechanisms of phase transformation; homogeneous and heterogeneous nucleation; spinodal decomposition; order-disorder transformations; Martensitic transformation			
Module 7	Magnetic, Optical & Thermal properties of solid	5 hours	
Magnetic properties- Different kind of magnetism in nature: Dia, Para, Ferro, Antiferro, Ferri, Superpara; Optical Properties- Photoconductivity, Optical absorption & transmission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence; Thermal Properties- Concept of phonon, Thermal conductivity, Specific heat, Exothermic & endothermic processes.			
Module 8	Contemporary issues:	2 hours	
		Total Lecture:	30 hours
Text Book(s)			
1	Charles Kittel, Introduction to Solid State Physics, 2012, eighth Edition, John Wiley & Sons		
2	H. I bach and H. L�th, Solid-State Physics: An Introduction to Principles of Material Science 2009, fourth edition, Springer		
Reference Books			
1	A.J. Dekker, Macmillan, Solid State Physics, 1969		
2	L. H. Van Vlack, Elements of materials science, Pearson Education, 2002		
3	Atkins Peter, Paula Julio, Physical Chemistry, Oxford University Press, 2008		
4	K. Huang, Chapman and Hall, Introduction to Statistical Physics, CRC, 2009		
5	Stephen Elliott & S. R. Elliott, The Physics and Chemistry of Solids, John Wiley & Sons, 1998.		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies		13-12-2015	
Approved by Academic Council		No. 40	Date 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE5033	SYNTHESIS OF NANOMATERIALS AND THIN FILM DEPOSITION	2	0	2	4	4
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to : 1. Make them understand the fabrication of nanostructures for advanced devices. 2. Provide and train the students about nanomaterial synthesis and thin film deposition techniques.						
Expected Course Outcomes::						
At the end of the course students will be able to 1. Identify and understand various top-down and bottom-up approaches for nanomaterial synthesis. 2. Understand and apply vacuum technology for nanomaterial synthesis. 3. Know various deposition techniques at the atomic and molecular level. 4. Acquire knowledge about structure and properties of thin films. 5. Learn the advanced concepts in various vapour deposition techniques. 6. Synthesise and deposit nanomaterials by various methods.						
Student Learning Outcomes (SLO):		14, 17				
14. Having an ability to design and conduct experiments, as well as to analyze and interpret data. 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice						
Module 1	Nanomaterial Synthesis - Top-Down Approach	4 hours				
Physical methods- Inert gas condensation, aerosol method, Arc discharge, RF-plasma, Plasma arc technique, laser ablation, Gas-phase synthesis, Spray Pyrolysis, Ball Milling, Combustion						
Module 2	Nanomaterial Synthesis - Bottom-up approach	6 hours				
Chemical Methods - Zero dimensional, one dimensional and two dimensional nanostructures, Nucleation theory, Homogeneous and heterogeneous nucleation, Metal nanocrystals by reduction, Solvothermal/Hydrothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Thermolysis routes, Sonochemical routes, Hybrid methods, Sol- gel, Micelles and microemulsions, Bio-Synthesis.						
Module 3	Vacuum technology	3 hours				
Concept of different vacuum pumps - rotary, diffusion, Turbo molecular pump, Cryogenic-pump, Ti-sublimation pump; Concept of different gauges - pirani, penning, Pressure control.						
Module 4	Wafer Growth and Epitaxial Deposition	3 hours				
Crystal Growth - CZ, Float zone technique; Basic Properties of different substrates (e.g. semiconductor, glass); Wafer cutting; Sources and related effects of various contamination; Wafer processing; Epitaxial growth- Growth kinetics of epitaxy, Doping, Growth modes.						



Module 5	Structure and properties of thin films	4 hours
Definition of thin films- Environment (Gas phase and plasma) for thin film deposition, Deposition parameters and their effects on film growth; Physical parameters for evaluation of thin films- Surface roughness; Density; Stress in thin films; Adhesion; Stoichiometry.		
Module 6	Physical vapor deposition (PVD) techniques	4 hours
Evaporation- Thermal evaporation, resistance evaporation, Electron beam evaporation, Ion vapor evaporation and Cathodic arc deposition; Molecular Beam Epitaxy; Sputtering- Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering; Atomic layer deposition (ALD)- Importance of ALD technique.		
Module 7	Chemical vapor deposition techniques	4 hours
Fundamentals, Advantages and limitations of Chemical vapor deposition (CVD) techniques; Different kinds of CVD techniques- Metallorganic (MO) CVD, Photoassisted CVD, Thermally activated CVD, Plasma enhanced (RF, μ -Wave) CVD, Low pressure (LP) CVD, Atmospheric pressure (AP) CVD etc.,.		
Module 8	Contemporary issues:	2 hours
Advanced Topics		
Total Lecture:		30 hours
Text Book(s)		
1.	Guozhong Cao. Ed Nanostructures and Nanomaterials: Synthesis, Properties, and Applications, World Scientific Series in Nanoscience and Nanotechnology, 2011.	
2.	G.A. Ozin and A.C. Arsenault, Nanochemistry: A chemical approach to nanomaterials, Royal Society of Chemistry, 2009.	
Reference Books		
1.	Bharat Bhushan, Handbook of Nanotechnology, Springer, 2005	
2.	Hari Singh Nalwa, Handbook Of Nanostructured Biomaterials And Their Applications In Nanobiotechnology, Journal of Nanoscience and Nanotechnology, 2005.	
3.	D.M. Hata, Introduction to Vacuum Technology, Prentice Hall New Jersey, 2007.	
4.	K. Jousten, Handbook of Vacuum Technology, John Wiley and sons, Weinheim, 2008.	
5.	S. Schmidt et.al., CFx thin films deposited by high power impulse magnetron sputtering: synthesis and characterization Surf.Coat.Technol. 2011, 206, pp. 646-653.	
6.	J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.	
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).		
Typical Projects		
<ol style="list-style-type: none"> 1. Green synthesis of nanoparticles and analysis using UV-Vis. 2. Kinetic analysis of growth of silver nanoparticles. 3. Demonstration of Electroless deposition process. 4. Growth of thin films by Electrodeposition technique. 5. Preparation and study of ferrofluids. 6. Hydrothermal synthesis of TiO₂ nanoparticles and its optical study 		



Mode of Evaluation: Review I, II and III			
List of Challenging Experiments (Indicative)			
1.	Wet Chemical synthesis of Silver Quantum Dots - Effect of viscosity on the growth and its characterization by UV-Visible spectroscopy.		6 hours
2.	Synthesis of ZnO nanoparticles by wet chemical route and its optical band gap calculation.		6 hours
3.	Mie formalism of Optical absorption of Ag and Au nanoparticles for size estimation.		4 hours
4.	Calculation of d-spacing and crystallite size of Nanomaterials from X- ray diffraction data.		4 hours
5.	Thin film deposition using Electroplating technique and morphology characterization using Optical microscope.		3 hours
6.	Fabrication of thin films using Spin coating technique.		3 hours
7.	Fabrication of metal thin films on silicon/glass substrate using Metal evaporation Unit		4 hours
Total Laboratory Hours			30 hours
Mode of Evaluation: Continuous assessment of challenging experiments /Final Assessment Test (FAT).			
Recommended by Board of Studies		13-12-2015	
Approved by Academic Council		No. 40	Date 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE5034	NANOMATERIAL CHARACTERIZATION TECHNIQUES	3	0	2	0	4
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to : <ol style="list-style-type: none"> 1. Make them understand various Nanostructure characterization techniques. 2. Train the students on state-of-the-art metrology tools such as Scanning Probe Microscopes and optical spectrosopes. 3. Enable them to study the material's structure and properties that are probed and measured. 						
Expected Course Outcomes:						
Students will be able to <ol style="list-style-type: none"> 1. Be conversant with conventional aspects of metrological tools. 2. Be aware of various morphological techniques and selecting appropriate tools for their future research. 3. Be familiar with various spectroscopic techniques. 4. Acquainted with the Scanning probe techniques for characterisation. 5. Learn advanced optical and magnetic characterization techniques. 6. Prepare, characterise and analyse the samples with suitable techniques. 						
Student Learning Outcomes (SLO):						14,17
14. Having an ability to design and conduct experiments, as well as to analyze and interpret data. 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice						
Module 1	Introduction to Metrology	4 hours				
Concepts of Metrology- Accuracy, precision and reliability; Types of Errors - Systematic Errors and Random Errors, Statistical analysis of errors.						
Module 2	Microscopy Techniques	8 hours				
Optical microscopy; Electron microscopy- Scanning Electron Microscopy, EDX, WDX; Transmission Electron Microscopy; EELS; SPM.						
Module 3	Spectroscopy Techniques	9 hours				
UV-Vis Spectroscopy; Ellipsometer; XPS; XAS; XRD; Raman Spectroscopy - Surface-enhanced Raman Spectroscopy.						
Module 4	Scanning Tunneling Microscopy	8 hours				
Basic design of Scanning Probe Microscopes; Scanning Tunneling Microscope: Principles of operation, Quantum Mechanical Tunneling phenomenon in STM, Different modes of operation; STS - Principles of operation, applications.						
Module 5	Atomic Force Microscopy	7 hours				
Atomic Force Microscope - Modes of operation of AFM, Advanced Modes of AFM - Force Modulation, Conductive AFM, EFM, MFM, SCM.						



Module 6	Near Field Scanning Optical Microscopy	5 hours
Principles of operation, Different modes of operation, Spectroscopic Applications of NSOM.		
Module 7	Magnetic Characterization	2 hours
Principles, Components of SQUID systems, Vibrating Sample Magnetometer (VSM)		
Module 8	Contemporary issues:	2 hours
Advanced Topics		
Total		45 Hours
Text Book(s)		
1.	R.W. Cahn, E.M. Lifshitz, Concise Encyclopedia of Materials Characterization: Advances in Materials Sciences and Engineering, Elsevier, 2016.	
2.	Yang Leng, Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons, 2013.	
Reference Books		
1	Richard Leach, Fundamental Principles of Engineering Nanometrology, Elsevier, 2014.	
2	Mauro Sardela, Practical Materials Characterization, Springer, 2014.	
3	Ewen Smith, Geoffrey Dent, Modern Raman Spectroscopy: A Practical Approach, John Wiley & Sons, 2013.	
4	Nikodem Tomczak, Kuan Eng Johnson Goh, Scanning Probe Microscopy, World Scientific, 2011.	
5	Ernst Meyer, Hans J. Hug, Roland Bennewitz, Scanning Probe Microscopy: The Lab on a Tip, Springer Science & Business Media, 2013.	
6	Vladimir V. Tsukruk, Srikanth Singamaneni, Scanning Probe Microscopy of Soft Matter: Fundamentals and Practices, John Wiley & Sons, 2012.	
7	H. Weinstock, SQUID Sensors: Fundamentals, Fabrication and Applications, Springer Science & Business Media, 2012.	
8	Sam Zhang, Lin Li, Ashok Kumar, Materials Characterization Techniques, CRC Press, 2008.	
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).		
List of challenging Experiments (Indicative)		
1.	STS analysis of CNT.	4 hours
2.	Analysis of magnetic nanoparticle with MFM	4 hours
3.	Application of Electrostatic Force Microscopy.	3 hours
4.	Characterization of Graphene with optical microscope.	4 hours
5.	Measure the blood glucose with electrochemical workstation	3 hours
6.	Study the band gap of semiconductor nanoparticle using UV-Vis spectroscopy	3 hours
7.	Measure the band gap and structure of crystal with XRD.	3 hours
8.	Elemental analysis using EDAX	3 hours



9.	Study the property of graphene using Raman Spectroscopy.	3 hours
Total Laboratory Hours		30 hours
Mode of Evaluation: Continuous assessment of challenging experiments /Final Assessment Test (FAT).		
Recommended by Board of Studies	13-12-2015	
Approved by Academic Council	No. 40	Date 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE6032	NANOELECTRONICS	2	0	2	4	4
Pre-requisite	ECE5031- Quantum Physics for Nanostructures					
Course Objectives:						
The course is aimed to : <ol style="list-style-type: none"> 1. Make them understand various advanced concepts in nanoelectronics. 2. Explore the fundamentals on QED, SED, Molecular electronics and spintronics. 3. Train the students on state-of-the-art computational tools for modelling and simulation of nanoelectronics devices. 						
Expected Course Outcomes:						
Student will be able to <ol style="list-style-type: none"> 4. Gain the concepts of nanoelectronics such as ballistic transport and quantum confinement. 5. Understand various nanostructures and its applications towards Quantum Electronic Devices. 6. Acquire the fundamentals of Molecular Electronics 7. Obtain the knowledge of Single Electron Devices and carbon based nanoelectronic devices. 8. Learn the fundamentals of Spintronics. 9. Design and simulate various advanced nanoelectronic devices. 						
Student Learning Outcomes (SLO): 1,6,17						
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications 6. Having an ability to design a component or a product applying all the relevant standards and with realistic constraints. 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice. 						
Module 1	Introduction to Nanoelectronics					3 hours
Limitations of the conventional MOSFETs at Nanoscales, MOSFET Scaling & implications, Introductory concepts of Ballistic transport and Quantum confinement, Differences in Few Electron Devices (as analog version) and Single Electron Devices (as digital version) of Nanoelectronic devices						
Module 2	Nanostructures and Quantum Electronic Devices					4 hours
Low-dimensional structures- Quantum wells, Quantum wires and Quantum dots; Density of states in low-dimensional structures; Quantum Interference Devices; Split –Gate Transistor; Electron – Wave Transistor; Resonant tunneling phenomena and its applications in diodes and transistors.						
Module 3	Molecular Electronics					3 hours
Overview & Basics; Fabrication of molecular electronics-based transistor devices; Conductivity of organic polymers- Conduction mechanism in organic polymers; Polymer Electronics; Self-Assembling Circuits.						



Module 4	Single Electron Devices	5 hours
Principle of operation- Single-Electron Effect, Coulomb Blockade Phenomenon; Theoretical Quantum Dot Transistor - Energy of Quantum Dot system, Single-Electron Quantum-Dot Transistor, Single transistors; Conductance Oscillation and Potential Fluctuation; Transport under Finite temperature and Finite Bias; Coulomb Blockade Devices.		
Module 5	Carbon Nanoelectronics	4 hours
Carbon nanotubes - SWCNTs and MWCNTs; 1D quantization in nanotubes- van Hove singularities; Fabrication of CNTs; CNT FETs- Device characteristics, CNT-TUBFET, CNT-SET; and NanoWire FETs; Electronic structure of graphene; Graphene FETs- GNFETs.		
Module 6	Spintronics	2 hours
Fundamentals of spintronics; Spintronic devices- spin diodes and spin transistors		
Module 7	Current Nanoelectronic Devices	7 hours
Quantum Effects in MOSFETs, Strained Silicon, Fully Depleted SOI-MOSFET, Double-Gate MOSFET, Multi-gate MOSFETs, FIN-FET, Electrically Induced Junctions for EJ-MOSFETs, Ballistic Transport, Conductance Quantization, Quantum Point Contact Devices.		
Module 8	Contemporary issues:	2 hours
Total Lecture Hours		30 hours
Text Book(s)		
1.	Shunri Oda, David Ferry, Nanoscale Silicon Devices, CRC Press, Taylor & Francis Group, 2015.	
2.	K. Goser, P. Glosekotter, Nanoelectronics and Nanosystems, Springer, 2005.	
Reference Books		
1.	Suprio Datta, Lessons from nanoelectronics, World Scientific publisher, 2015.	
2.	Karl Goser, Peter Glosekotter, Jan Dienstuhl , Nanoelectronics and Nanosystems- From Transistors to Molecular and Quantum Devices, Springer-Verlag 2004.	
3.	C.N.R. Rao and A. Govindaraj, Nanotubes and nanowires, RSC Publishing, 2005.	
4.	Konstantin K. Likharev, Single Electron Devices and their Applications, IEEE proceedings, vol. 87, no. 4, April 1999.p 606- 632.	
5.	Ziese and M. J. Thornton Spin Electronics, Springer-Verlag, 2001.	
6.	Supriyo Datta, Quantum Transport-From Atom to Transistor, Cambridge University press, 2005.	
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).		
Typical Projects		



1. Design a Double gate MOSFET with 10nm-16nm channel dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.
2. Design a 2D SOI-MOSFET with 16nm technology node by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.
3. Design a gate around FINFET with 5nm fin length and 16nm channel length dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.
4. Solve relevant mathematical equations and plot band structure and DOS of various types of CNTs.
5. Solve relevant mathematical equations and plot band structure and DOS of various types of graphene nano ribbons(GNRs).
6. Solve NEGF equation for quantum transport of a 2D graphne FET and analyze its electrical characteristics.

Mode of Evaluation: Review I, II and III

Recommended by Board of Studies | 13-12-2015

Approved by Academic Council | No. 40 | Date | 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE6033	NANOPHOTONICS	3	0	0	0	3
Pre-requisite	ECE5031 - Quantum Physics for nanostructures					
Course Objectives:						
The course is aimed to:						
<ol style="list-style-type: none"> Expose them to the emerging area of nanophotonics and the phenomena involved in such devices. Provide deep understandings of light – matter interaction at nanoscale. Study different types of nanophotonic crystal based devices and systems. 						
Expected Course Outcomes:						
At the end of course student will be able to						
<ol style="list-style-type: none"> Gain the foundations of nanophotonics. Understand the mathematical synthesis of Maxwell equations for Photonic systems. Acquire the understanding and importance of confinement and propagation. Obtain the knowledge of 1-D, 2-D and 3-D Photonic Crystals. Gain the design and scope of nano-photonics applications. Learn the foundation of plasmonics. 						
Student Learning Outcomes (SLO):		1,5				
<ol style="list-style-type: none"> Having an ability to apply mathematics and science in engineering applications. Having design thinking capability. 						
Module 1	Foundations of Photonics	4 hours				
Photons and Electrons - Similarities and differences, Light Interaction with Matter, Complex refractive index and dielectric constant, Dispersion in Materials.						
Module 2	Maxwell equations for Photonic systems	6 hours				
Basic Maxwell equations and their interpretations, Master's Equation for dielectric medium and its analytical solution.						
Module 3	Confinement and Propagation	6 hours				
Confinement of Photons and Electrons, Co-operative effects for Photons and Electrons, Propagation through Classically Forbidden Zone- Tunneling, Concept of Near-Field phenomena in Photonic Crystals and Evanescent wave.						
Module 4	Photonic Crystals	8 hours				
1-D, 2-D and 3-D Photonic crystal, Theoretical and mathematical description of Photonic band gap, Features and fabrication of Photonic crystals.						
Module 5	Applications of Photonics	6 hours				
TE/TM Mode, Optical fiber, filters, switching devices, Kerr effect devices; Super Lenses – Micro and Nano Lenses, Prisms and Meta-materials, Graphene photonics.						
Module 6	Phosphor materials in Photonics	7 hours				
Flourescence, Phosphorescence, rare earth doped nanostructures, activator and sensitizer, energy transfer process, life time, down and up conversation, FRET.						



Module 7 Plasmonics				6 hours	
Fundamentals, wave equations, surface plasmon-polaritons, Plasmonics in gold and silver nanomaterials					
Module 8 Contemporary issues:				2 hours	
				Total Lecture: 45 hours	
Text Book(s)					
1.	Paras Prasad, Nanophotonics, Wiley-Interscience, 2004.				
2.	John D. Joannopoulos, Steven G. Johnson, Joshua N. Winn, Robert D. Meade, Photonic Crystals: Molding the Flow of Light, second Edition, Princeton University Press, 2008				
Reference Books					
1.	Motoichi Ohtsu, Kiyoshi Kobayashi, Tadashi Kawazoe, Takashi Yatsui, Makoto Naruse, Principles of Nanophotonics, CRC Press, Taylor & Francis Group, 2008.				
2.	Stefan A. Maier, Plasmonics: Fundamentals and Applications, Springer Science, 2007.				
3.	J. R. Lakowicz, Principle of Fluorescence Spectroscopy, third Edition, Kluwer Academic Publisher, Newyork, 2007				
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).					
Recommended by Board of Studies			13-12-2015		
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Programme Electives

Course Code	Course Title	L	T	P	J	C
ECE5035	SEMICONDUCTOR DEVICE PHYSICS AND TECHNOLOGY	2	0	0	4	3
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to:						
<ol style="list-style-type: none"> 1. Make them understand the physics of semiconductor materials and devices. 2. Educate the working mechanism and design of optoelectronic devices. 3. Train them to solve bandgap models and design different semiconductor devices. 						
Expected Course Outcomes:						
Students will be able to						
<ol style="list-style-type: none"> 1. Gain in-depth knowledge in semiconductor physics 2. Acquire knowledge of mathematical model of various device fabrication processes 3. Gain in-depth knowledge of formation and properties of PN junctions 4. Obtain the fundamentals of metal-semiconductor junctions 5. Gain the physics of optoelectronic devices 6. Understand the fabrication and characteristics of nanoscale MOSFETs 7. Apply the concepts and techniques to solve bandgap model equations and design various semiconductor devices. 						
Student Learning Outcomes (SLO):		1,14				
<ol style="list-style-type: none"> 2. Having an ability to apply mathematics and science in engineering applications. 14. Having an ability to design and conduct experiments, as well as to analyse and interpret data. 						
Module 1	Semiconductor Physics					6 hours
Energy Bands and Carrier Concentration in thermal Equilibrium: Semiconductor Materials, Basic Crystal Structure, Basic Crystal Growth Technique, Valence Bands, Energy Bands, Intrinsic Carrier Concentration, Donors and Acceptors. Carrier Transport Phenomena: Carrier Drift, Carrier Diffusion, Generation and Recombination Processes, Continuity Equation, Thermionic Emission Process, Tunneling Process, High-Field Effects.						
Module 2	Device Process stages I					3 hours
Device Process stages I: Mathematical models relevant to thermal diffusion and ion implantation and Annealing. Pattern transfer; Optical lithography, Photoresists, Alignment and exposure, Etching.						
Module 3	Device Process stages II					3 hours
Mathematical models relevant to Deposition; Physical and chemical vapor deposition, Epitaxy. Process Integration: Device isolation, contacts metallization.						
Module 4	P-N Junction					5 hours
Diode fabrication, Device physics: Thermal equilibrium, Internal electro-static fields and potentials, Poisson's equation, continuity equations, drift-diffusion equations. I-V Characteristics: Forward bias,						



reverse bias, Diode equation. Capacitive effect: Junction and diffusion capacitance. DC, AC and transient analysis of Diodes.

Module 5	Metal-Semiconductor Contacts and Schottky Diodes	4 hours
Metal-Semiconductor Junction diode Fabrication, Device Physics: Ideal MS contacts, Schottky diode-Electrostatics, I-V characteristics, DC, AC and transient analysis. Metal-Semiconductor contacts: Ohmic contacts, Schottky contacts, Tunnel contacts and Annealed and alloyed contacts.		

Module 6	Optoelectronic Diodes	3 hours
Photodiode Fabrication, device Physics of pn Junction Photodiodes, p-i-n Photo diodes. Principle of operation and fabrication technologies of Solar cell, LED and LASER diodes.		

Module 7	MOSFET	4 hours
MOS capacitor, MOSFET device fabrication, MOSFET Physics: I-V characteristics, Sub-threshold region, Body effect, Capacitive effect, small and large signal model. MOSFET Short Channel effects: Punch through, DIBL, Hot electron effect, Velocity Saturation, Leakage current. MESFETs and MODFET analysis.		

Module 8	Contemporary issues:	2 hours
Advanced Topics		

	Total Lecture:	30 Hours
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Text Books(s)	
1.	S. M. Sze and Ming-Kwei Lee, Semiconductor Devices Physics and technology, John Wiley & Sons, 2013.
2.	Grundmann and Marius, Physics of Semiconductors, Springer, 2010

Reference Books	
1.	Ben G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, Pearson Ed, 2014.
2.	M. S. Tyagi, Introduction to semiconductor materials and devices, John Wiley & Sons, 2008.
3.	Campbell, Stephan, Fabrication Engineering at the Micro and Nanoscale, Oxford University Press, 2008.
4.	Robert F. Pierret, Semiconductor Device Fundamentals, Pearson Education, 2006.
5.	Richard C. Jaeger, Introduction to Microelectronic Fabrication, Prentice Hall, 2001.

Mode of Evaluation: Flipped Class Room, [Lecture to be videotaped], Use of physical and computer models to lecture, Visit to Industry, Min of 2 lectures by industry experts

Typical Projects	
<ol style="list-style-type: none"> 1. Solve relevant mathematical equations and plot band structure then extract effective mass of direct and indirect bandgap semiconductors. 2. Solve drift-diffusion equation for transport parameters (Drift velocity, mobility and conductivity) of direct and indirect band gap materials. 3. Design a P-N junction diode with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics. 4. Design a MOSFET with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators. 5. Design a MOSFET with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators. 	



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- 6.** Design a LASER diode with smallest dimensions by referring a latest journal paper and analyze its performance through band diagram and electrical characteristics by make use of process and device simulators.

Mode of Evaluation: Review I, II and III

Recommended by Board of Studies	13-12-2015		
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Course Code	Course Title	L	T	P	J	C
ECE5036	MEMS To NEMS	2	0	0	4	3
Pre-requisite	None					
Course Objectives:						
The course is aimed to:						
<ol style="list-style-type: none"> 1. Make them to understand the technology of MEMS and NEMS. 2. Expose them about fabrication processes for development of MEMS/NEMS devices and systems. 3. Educate about the potential applications of NEMS. 						
Expected Course Outcomes:						
At the end of course students will be able to						
<ol style="list-style-type: none"> 1. Acquire the knowledge of mechanisms in MESM/NEMS 2. Understand various engineering mechanics of microsystems 3. Gain the concept in finite element analysis of microsystems 4. Obtain the knowledge of MEMS fabrication 5. Acquire knowledge of quantum effects in MEMS/NEMS 6. Apply the knowledge of system integration in MEMS/NEMS 7. Design and simulate micro/nano sensors and actuators. 						
Student Learning Outcomes (SLO):		1,6, 14				
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications. 6. Having an ability to design a component or a product applying all the relevant standards and with realistic constraints. 14. Having an ability to design and conduct experiments, as well as to analyze and interpret data. 						
Module 1	Introduction	2 hours				
Overview of MEMS / NEMS and various devices, Scaling geometry, Rigid Body Dynamics, Forces, Electron transfer, Fluid mechanics and Heat transfer.						
Module 2	Engineering mechanics for Microsystems design	4 hours				
Static Bending of Thin plates, Mechanical vibration, Resonant vibration, Design theory of Accelerometers, and Thermal analysis, Thermal effects on Mechanical strength of Materials, Creep formation.						
Module 3	Finite Element Analysis	5 hours				
Concept of FEA, Comparison with other methods, Formulation from the governing Differential equations, Formulation based on stationary total potential, 1-D and 2-D Finite Element Analysis, Examples.						
Module 4	Overview of Micro - Scale fabrication	2 hours				
Microsystem fabrication process-Lithography, Dry and wet etching, Thin film deposition-PVD,CVD,LIGA, Micromolding, Electro-deposition						
Module 5	Quantum effects	6 hours				
Casimir Force and its influence in MEMS and NEMS, control of casimir force, Nanotribology-						



experimental techniques for studying anotribology, phonic friction, electronic friction, static friction, frictional anisotropy, stick-slip dynamics			
Module 6	NEMS	7 hours	
Introduction to nanoscale engineering, theory and characteristics of NEMS, Design and simulation techniques of NEMS – molecular dynamics, Potential energy models, Integration algorithms Molecular and Nanostructure Dynamics, Molecular Wires and Molecular Circuits			
Module 7	System Integration	2 hours	
System Integration and reliability			
Module 8	Contemporary issues:	2 hours	
Advanced Topics			
		Total Lecture:	30 hours
Text Books(s)			
1.	Tai-ran Hsu, MEMS and microsystems design and manufacture, Nanoscale Engineering, TMGH, 2008		
2.	Sergey Edward Lyshevski, MEMS and NEMS: Systems, Devices, and Structures, CRC, 2002		
Reference Books			
1.	P.Seshu, Text Book of Finite Element Analysis, PHI,2006		
2.	Sergey Edward Lyshevski, Nano- and Micro-electromechanical Systems, CRC, Press, 2000		
3.	Bharath Bhushan, Handbook of Micro/Nanotribology, CRC Press, 1999.		
4.	Cornelius T. Leondes, MEMS/NEMS Handbook, Techniques and application, Springer, 2005.		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Typical Projects			
<ol style="list-style-type: none"> 1. Design of capacitance based actuators. 2. Study of scaling effects in a magnetic systems 3. Simulation of peizo based cantilever beams 4. Molecular dynamics simulation 5. Accelerometer design 6. Design of capacitance based actuators. 			
Mode of Evaluation: Review I, II and III			
Recommended by Board of Studies		13-12-2015	
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Course Code	Course Title	L	T	P	J	C
ECE5037	NANOSENSORS	3	0	0	0	3
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to: <ol style="list-style-type: none"> 1. Offer an overview of basic nanosensor technology with examples drawn from existing products and literatures. 2. Enable them to identify suitable nanosensors and nanodevices for various potential applications. 3. Make them acquainted with various types of nanosensors and its potential applications. 						
Expected Course Outcomes:						
At the end of this course students will be able to <ol style="list-style-type: none"> 1. Identify and understand various micro and nano-sensors and their working. 2. Learn material's properties used for the fabrication of nanosensors. 3. Gain the fundamentals of packaging and characterization of nanosensors. 4. Aware of various types of mechanical, chemical and optical nano-sensing systems. 5. Use nanostructured materials for developing nanobiosensors. 						
Student Learning Outcomes (SLO):		1,6				
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications. 6. Having an ability to design a component or a product applying all the relevant standards and with realistic constraints. 						
Module 1	Micro and nano-sensors	3 hours				
Sensing principles, sensor types and classification – Mechanical, acoustic, magnetic, thermal, chemical, radiation; microsensors; sensors based on surface - acoustic wave devices, biosensor, microfluids						
Module 2	Materials for Nanosensors	8 hours				
Shape and size Dependence of Properties at Nanoscale, Surface Energy of a Solid, Core/Shell-Structured Nanoparticles, Metallic Nanoparticles and Plasmons Optical Properties of Bulk Metals and Metallic Nanoparticles, Quantum Dots, Carbon Nanotubes, Inorganic Nanowires, Nanoporous Materials.						
Module 3	Packaging and characterization of sensors	4 hours				
Design, fabrication and characterization, Method of packaging at dye level, zero level and first level.						
Module 4	Mechanical Nanosensors	8 hours				
Mass sensing- Nanogram Mass Sensing by Quartz Crystal Microbalance, MEMS/NEMS Resonators; Displacement sensor- Electron Tunneling Displacement Nanosensor, Coulomb Blockade Electrometer-Based Displacement Nanosensor, Nanometer-Scale Displacement Sensing by Single-Electron Transistor, Magnetomotive Displacement Nanosensor, Piezoresistive and Piezoelectric Displacement Nanosensors, Optical Displacement Nanosensor; Femtonewton Force Sensors- Doubly Clamped Suspended Carbon Nanotube Resonators, Suspended CNT Electromechanical Sensors for Displacement and Force, Membrane-Based CNT						



Electromechanical Pressure Sensor			
Module 5	Chemical Nanosensors	8 hours	
Gas Sensors Based on Metallic Nanoparticles, Metal Oxides, Carbon Nanotube, Porous Silicon; Thin Organic Polymer Film–Based Gas Sensors; Electrospun Polymer Nanofibers as Humidity Sensors; Nanoelectronic Nose; CNT, Nanowire, and Nanobelt-Based Chemical Nanosensors			
Module 6	Optical Nanosensors	6 hours	
Noble-Metal Nanoparticles with LSPR and UV–Visible Spectroscopy, Nanosensors Based on Surface-Enhanced Raman Scattering, Colloidal SPR Colorimetric Gold Nanoparticle Spectrophotometric Sensor, Fiber-Optic Nanosensors, Nanograting-Based Optical Accelerometer.			
Module 7	Nanobiosensors	6 hours	
Nanoparticle-Based Electrochemical Biosensors, CNT-Based Electrochemical Biosensors, Functionalization of CNTs for Biosensor, Quantum Dot-Based Electrochemical Biosensors, Nanotube- and Nanowire-Based FET Nanobiosensors, Cantilever-Based Nanobiosensors, Optical Nanobiosensors, Biochips			
Module 8	Contemporary issues:	2 hours	
Advanced Topics			
Total Lecture:			45 hours
Text Book(s)			
1.	Peter Hauptmann and Tim Pownall, Sensors: Principles and Applications , Prentice Hall, 2003		
2.	Vinod Kumar Khanna, Nanosensors: Physical, Chemical, and Biological, CRC, 2012		
Reference Books			
1.	Kevin C. Honeychurch, Nanosensors for Chemical and Biological Applications: Sensing with Nanotubes, Nanowires and Nanoparticles, woodhead publishing, 2014		
2.	Teik-Cheng Lim, Nanosensors: Theory and Applications in Industry, Healthcare and Defense, CRC, 2011		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies		13-12-2015	
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Course Code	Course Title	L	T	P	J	C
ECE5038	CARBON NANOMATERIALS	3	0	0	0	3
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to:						
<ol style="list-style-type: none"> 1. Make the students understand the importance of carbon based nanostructured materials. 2. Study various carbon allotropes, their types, structure, properties and applications. 3. Emphasize other carbon based nanostructured materials such as nanocones, nanofibers, nanodiscs and nanodiamonds. 						
Expected Course Outcomes:						
At the end of course, students will be able to:						
<ol style="list-style-type: none"> 1. Understand the importance of carbon based nanomaterials. 2. Obtain the knowledge on synthesis, characterization and application of various carbon based nanomaterials such as fullerene, carbon nanotubes and graphene. 3. Understand the functionalization and applications of CNT & Graphene. 4. Gain knowledge in other carbon based nanomaterials such as nanocones, nanofibers, nanodiscs and nanodiamonds. 						
Student Learning Outcomes (SLO):		1				
2. Having an ability to apply mathematics and science in engineering applications.						
Module 1	Carbon Nanomaterials					2 hours
Introduction to Carbon Nanomaterials, Carbon allotropes and their bonding between carbon atoms.						
Module 2	Fullerene					6 hours
Structure, Synthesis, Functionalization of fullerenes, Applications – Solar Cells, Hydrogen storage, Bio-applications.						
Module 3	Carbon nanotubes					8 hours
Types ; Structure; Properties- Electrical, Optical, Mechanical, Vibrational properties; Nanotube synthesis - carbon arc discharge, Laser ablation, Chemical Vapor Deposition, High-pressure CO process, Purification techniques of carbon nanotube.						
Module 4	Functionalization and Applications of CNTs					8 hours
Functionalization- Covalent, non-covalent, and biological; Applications - Energy storage: Batteries, Fuel Cells: H ₂ , Li storage, supercapacitors; Molecular electronics–Field emitting devices and Transistors, drug delivery, CNT based microscopy, Nanotube sensors.						
Module 5	Graphene					7 hours
Electronic band structure, Properties of Graphene: chemical, mechanical, electronic and thermal. Synthesis of Graphene – Exfoliation, Epitaxial, CVD, Hummer Method; Graphene Nanoribbon-						



synthesis.			
Module 6	Functionalization and Applications of Graphene	6 hours	
Functionalization- Covalent, non-covalent Application of Graphene; Applications – Graphene MOSFET – Opening a Band gap, Spintronics, Solar cells, gas sensors, supercapacitors.			
Module 7	Other Carbon based materials	6 hours	
Carbon Nanocomposite, Nanocones, Nanofibers, Nanodiscs and Nanodiamonds.			
Module 8	Contemporary issues:	2 hours	
			Total Lecture: 45 Hours
Text Book(s)			
1.	Peter. J.F Harris, Carbon Nanotube Science: Synthesis, Properties and Applications, Cambridge University Press, 2011		
2.	Jamie H. Warner, Franziska Schaffel, Mark Rummeli, Alicja Bachmatiuk, Graphene: Fundamentals and Emergent Applications, Elseiver, 2013		
Reference Books			
1.	Zhong Lin Wang, Nanowires and Nanobelts- Materials, Properties and Devices, Springer, 2006		
2.	Thomas Webbester, Carbon Nanotube preparation and properties, CRC Press, 1997		
3.	R Saito, G Dresselhaus, M S Dresselhaus, Physical Properties of Carbon Nanotubes, Imperial college press, 2004		
4.	Yury Gogotsi, Volker Presser, Carbon nanomaterials, CRC Press, 2014		
5.	CNR Rao and A Govindaraj, Nanotubes and Nanowires, RCS Nanoscience and Nanotechnology series, 2011		
6.	Michael J. O’Connell, Carbon Nanotubes: Properties and Applications, CRC Taylor and Franci group, 2006.		
7.	Mikhail I. Katsnelson, Graphene: Carbon in two dimensions, Cambridge University Press, 2012		
8.	Fernando Langa, Jean-Francois Nierengarten, Fullerenes: Principles and Applications , RSC Publishing, 2007		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies		13-12-2015	
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Course Code	Course Title	L	T	P	J	C
ECE5039	LITHOGRAPHIC TECHNIQUES FOR DEVICE FABRICATION	3	0	0	0	3
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to: <ol style="list-style-type: none"> 1. Make conversant with conventional aspects of lithography, techniques related and their resolution aspects. 2. Introduce various existing Lithography techniques. 3. Study the principles, process steps and system components of the various lithographic techniques. 						
Expected Course Outcomes:						
At the end of course students will be able to: <ol style="list-style-type: none"> 1. Obtain the in-depth knowledge in optical and electron beam lithography techniques. 2. Understand the conventional aspects of lithography, techniques related and their resolution aspects of X-ray, Ion, SPM based and soft lithography. 3. Learn and understand the importance of plasmonics in lithography 						
Student Learning Outcomes (SLO):		1, 17				
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice 						
Module 1	Optical Lithography	9 hours				
Process steps involved in the optical lithography; Types - Contact, proximity printing and Projection Printing; Resolution Enhancement techniques for projection systems; Deep Ultraviolet lithography; Extreme Ultraviolet lithography; Scanning Near Field Optical Lithography.						
Module 2	Electron Beam Lithography	8 hours				
Interaction of the electrons with the substrate; Electron Lithography System components; Raster scans and Vector scans; Electron resists and processing technique; Application of Electron Beam Lithography.						
Module 3	X-ray Lithography	4 hours				
X-ray lithography system components, Resolution enhancement, X-ray mask construction, X-ray sources, x-ray resists.						
Module 4	Ion Lithography	3 hours				
Ion lithography system components; Focused Ion Beam Lithography; Masked Ion Beam Lithography; Ion Projection Lithography.						
Module 5	Scanning Probe Lithography	8 hours				



Scratching Lithography; Anodic Oxidation- Mechanism of Nano-oxidation; Dip-Pen Nanolithography - Mechanism, DPN Types: Parallel DPN, Polymer DPN, Application of DPN; Nano-shaving.			
Module 6	Soft Lithography	5 hours	
Micro-contact printing, Solvent-Assisted Micromoulding, Micromoulding in capillaries, Patterning SAMs.			
Module 7	Plasmonic Nanolithography	6 hours	
Principle of Plasmonic Lithography, Plasmonic Mask, Near-field Plasmonic Lithography, Plasmonic Contact Lithography, Plasmonic direct write lithography.			
Module 8	Contemporary issues:	2 hours	
		Total Lecture:	45 hours
Text Book(s)			
1.	M Feldman, Nanolithography: The Art of Fabricating Nanoelectronic and Nanophotonic Devices and Systems, Woodhead Publishing, 2014.		
2.	Stefano Cabrini, Satoshi Kawata, Nanofabrication Handbook, CRC Press, 2012.		
Reference Books			
1.	Bruce W. Smith, Kazuaki Suzuki, Microlithography: Science and Technology, Second Edition, CRC Press, 2007.		
2.	D Bucknall, Nanolithography and Patterning Techniques in Microelectronics, Elsevier, 2005.		
3.	Marc J. Madou, Manufacturing Techniques for Microfabrication and Nanotechnology, 3rd Edition, Vol II, CRC Press, 2011.		
4.	Mark J. Jackson, Micro and Nanomanufacturing, Springer Science & Business Media, 2007.		
5.	Ampere A. Tseng, Tip-Based Nanofabrication: Fundamentals and Applications, Springer Science & Business Media, 2011.		
6.	Hyongsok T. Soh, Kathryn Wilder Guarini, Calvin F. Quate, Scanning Probe Lithography, Springer Science & Business Media, 2013.		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies		13-12-2015	
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Course Code		L	T	P	J	C
ECE5040	PLASMONICS	2	0	0	4	3
Pre-requisite	Nil					
Course Objectives:						
The course is aimed to: <ol style="list-style-type: none"> 1. Give a clear idea of changes in optical properties of nanostructures. 2. Enable to understand the fundamentals about surface plasmon polariton and plasmonic waveguides. 3. Make acquainted with various types of Spectroscopy and sensing techniques based on plasmonics. 						
Expected Course Outcomes:						
At the end of course students will be able to: <ol style="list-style-type: none"> 1. Acquire the knowledge on electromagnetics of metallic nanoparticles. 2. Understand the fundamentals of surface plasmon polariton, and LSPR. 3. Understand the excitation dynamics at nanoscale. 4. Learn about nanocomposites and its application in the field of optoelectronics. 5. Familiar with nanostructured molecular architectures. 6. Obtain the basics on Surface-Plasmon-Polariton-Based Sensors. 7. Apply surface plasmon polariton, and LSPR concepts for designing nanophotonic devices. 						
Student Learning Outcomes (SLO):		1, 17				
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications. 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice 						
Module 1	Electromagnetics of Metallic Nano-particles	5 hours				
Metallic Nano-particles, Maxwell equation and Electromagnetic wave equation, dispersion of the free electron gas and volume plasmons, real metals and intraband transitions, Electromagnetic field in metals, Local Field Enhancement, Sub-wavelength aperture plasmonics,						
Module 2	Plasmonic waveguides	4 hours				
Elements for surface plasmon polariton propagation, surface plasmon polariton band gap structures, metal nanowires for high confinement guiding and focusing, localized modes, metal nanoparticle waveguides						
Module 3	Localized surface plasmons	4 hours				
– Normal modes of sub-wavelength metal particles, Mie theory, Observations of particle plasmons, coupling between localized plasmons, void plasmons and metallic nanoshells						
Module 4	Nanocontrol of Excitation Dynamics	4 hours				
Nanostructure and excited states. Rare earth doped nanostructures Up-converting nanophores. Photon avalanche. Quantum cutting. Site isolating nanoparticles, prism and grating coupling, near field excitation.						
Module 5	Nanocomposites	4 hours				
Nanocomposites as photonic media. Nanocomposite waveguides. Random lasers. Local field						



enhancement. Multiphase nanocomposites. Nanocomposites for optoelectronics. Polymer dispersed liquid crystals. Nanocomposite metamaterials.			
Module 6	Nanostructured Molecular Architectures	4 hours	
Noncovalent interactions. Nanostructured polymeric media. Molecular machines. Dendrimers. Supramolecular structures. Monolayer and multilayer molecular assemblies.			
Module 7	Spectroscopy and sensing	3 hours	
Single-Particle Spectroscopy, Surface-Plasmon-Polariton-Based Sensors, Metamaterials and Negative Index at Optical Frequencies, The Perfect Lens, Imaging and Lithography			
Module 8	Contemporary issues:	2 hours	
		Total Lecture:	30 hours
Text Book(s)			
1.	Stefan Alexander Maier, Plasmonics – Fundamental and Applications, Springer, 2007.		
2.	Paras Prasad, Nanophotonics, Wiley-Interscience, 2004.		
Reference Books			
1.	Mark L. Brongersma and Pieter G. Kik, Surface Plasmon Nanophotonics, Springer, 2007.		
2.	Ralf B. Wehrspohn, Heinz-Siegfried Kitzerow, and Kurt Busch, Nanophotonic Materials: Photonic Crystals, Plasmonics, and Metamaterials, Wiley-VCH, 2008)		
3.	Matthew Pelton, Garnett W. Bryant, Introduction to Metal–Nanoparticle Plasmonics, A Wiley–Science Wise Co–Publication, 2013		
List of Projects (Indicative)			
1. Electrodeposition of plasmonic nanomaterials			
2. Electrochemical investigation of hot electron dynamics			
3. Plasmonic simulations with light beams			
4. Photonic spin Hall effect from single nanostructure			
5. Fabrication and optical characterisation of metallic nanocubes			
6. Localized surface plasmon resonance (LSPR) of Nobel metal nanoparticles			
Mode of Evaluation: Review I, II and III			
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Course Code	Course Title	L	T	P	J	C
ECE6031	NANOMAGNETISM- FUNDAMENTALS AND APPLICATIONS	3	0	0	0	3
Pre-requisite	ECE5031- Quantum Physics for Nanostructures					
Course Objectives:						
The course is aimed to: <ol style="list-style-type: none"> 1. Make them understand the fundamentals of nanomagnetism and their applications. 2. Study the magnetism at macro- and nanoscale and their potential effects. 3. Enable students to apply the concepts of magnetic nanomaterials in the field of energy storage, biomedicine and environmental applications. 						
Expected Course Outcomes:						
At the end of course students will be able to: <ol style="list-style-type: none"> 1. Gain in-depth knowledge about the concepts of magnetism at macro and nanoscale. 2. Obtain the knowledge about magnetism of localized electrons on the atom. 3. Gain the fundamentals about ferromagnetism, antiferromagnetism and other magnetic order. 4. Identify and understand the concepts of micro- and nanoscale magnetism 5. Apply the concepts to the application of magnetic nanomaterials in the field of magnetic recording, energy storage, biomedicine and environmental applications. 						
Student Learning Outcomes (SLO):		1				
2. Having an ability to apply mathematics and science in engineering applications.						
Module 1	Magnetostatics	3 hours				
Introduction - History - Magnetism and hysteresis, Magnetic dipole moment, Magnetic fields, Maxwell's equations, Magnetostatic energy and forces.						
Module 2	Magnetism of electrons	8 hours				
Orbital and spin moments, Magnetic field effects – Zeeman effect, Theory of electronic magnetism, Magnetism of electrons in solids						
Module 3	Magnetism of localized electrons on the atom	8 hours				
The hydrogenic atom and angular momentum, The many-electron atom, Paramagnetism, Ions in solids; crystal-field interactions.						
Module 4	Ferromagnetism and Exchange	8 hours				
Mean field theory, Exchange interactions, Band magnetism, Collective excitations, Anisotropy, Ferromagnetic phenomena						
Module 5	Antiferromagnetism and other magnetic order	4 hours				
Molecular field theory of antiferromagnetism, Ferrimagnets, Frustration, Amorphous magnets,						



Spin glasses, Magnetic models			
Module 6	Micromagnetism and Nanoscale magnetism	7 hours	
Micromagnetic energy, Domain theory, Reversal, Pinning and Nucleation, Characteristic length scales, Superparamagnetism, Thin films, Thin-film heterostructures, Wires and needles, Small particles, Bulk nanostructures, Novel methods for synthesis of magnetic nanoparticles, Magnetic interactions: a tool to modify the magnetic properties of materials based on nanoparticles.			
Module 7	Applications of nanomagnetism	5 hours	
Magnetic storage and recording, Magnetic resonance Imaging, Hyperthermia, Ferrofluid, Biosensors.			
Module 8	Contemporary issues	2 hours	
Total Lecture:			45 hours
Text Book(s)			
1.	J. M. D. Coey, Magnetism and Magnetic Materials, Pearson Education, 2010.		
2.	B. D. Cullity, C. D. Graham, Introduction to Magnetic Materials, John Wiley & Sons, Inc, 2009.		
Reference Books			
1.	R. C. O'Handley, Modern Magnetic Materials: Principles and Applications, John Wiley & Sons, Inc, 2000.		
2.	C Binns, Nanomagnetism: Fundamentals and Applications, Elsevier, 2014.		
3.	David Jiles, Introduction to Magnetism and Magnetic Materials, Chapman and Hall, 1991.		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Recommended by Board of Studies		13-12-2015	
Approved by Academic Council		No. 40	Date 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE 6034	ENERGY TECHNOLOGIES	3	0	0	0	3
Pre-requisite	ECE6034 - Physics and chemistry of solids					
Course Objectives:						
1. To expose the students about various energy sources and the possibility of harvesting energy with nanomaterials						
Expected Course Outcomes:						
At the end of course the students will be able to:						
1. Understand the various renewable energy sources. 2. Acquire the knowledge on different energy harvesting methods. 3. Understand thermodynamics and kinetics of fuel cell process with nanomaterials. 4. Explain and choose suitable nanomaterials and nanostructures for photovoltaics. 5. Distinguish different types and performance of solar collectors. 6. Acquire the knowledge of electrochemical energy storage systems. 7. Understand the process and design issues in magnetic energy storage systems.						
Student Learning Outcomes (SLO):		1,9				
1. Having an ability to apply mathematics and science in engineering applications. 9. Having problem solving ability- solving social issues and engineering problems.						
Module 1	Renewable Energy Sources	2 hours				
Basics and Types of Renewable energy sources.						
Module 2	Energy Harvesting	7 hours				
Sources, Types and mechanism – Solar, Thermoelectric, Piezoelectric; Electro dynamical and Biological; Energy harvesting devices and applications. Nanomaterials for energy harvesting.						
Module 3	Energy Conversion I	7 hours				
Energy conversion – Types and mechanism; Electrochemical energy conversion, thermodynamics; Hydrogen Technology; Fuel Cells - fundamentals, classifications, Operating principles and design considerations, thermodynamics and kinetics of fuel cell process, performance evaluation of fuel cell, Fuel cell applications. Nanomaterials as electrode materials for fuel cells.						
Module 4	Energy Conversion II	7 hours				
Solar energy: Photovoltaic fundamentals, Solar cell technologies, Types – Dye sensitized, Quantum dot, Copper indium gallium selenide (CIGS), Hybrid, Organic and Plasmonic solar cells etc., Performance and parameter analysis of solar cells. Nanomaterials and Nanostructures for photovoltaics.						
Module 5	Energy Conversion III	7 hours				
Photothermal systems: Types and performance of solar collectors - Flat Plate, Hot Air, Evacuated Tube, Parabolic, Compound Parabolic and Fresnel Solar Concentrators, Thermal Analysis and performance of Solar Collectors, Current and future scope of solar energy.						



Module 6	Energy storage I	7 hours
<p>Electrochemical energy storage systems: Supercapacitors - Differences between capacitors, supercapacitors and batteries, classifications of supercapacitors. Batteries: Primary, Secondary, Lithium, Solid-state and molten solvent batteries; Lead acid batteries; Nickel Cadmium Batteries; Sodium ion and Aluminum Batteries. Nanostructured and Hybrid materials as electrodes for batteries and capacitors.</p>		
Module 7	Energy storage II	6 hours
<p>Magnetic energy storage systems (SMES); Thermal energy storage systems - Thermal energy storage materials – Types, thermo physical properties, Phase change materials for heating and cooling applications. Heat transfer fluids – Properties and mechanism.</p>		
Module 8	Contemporary issues:	2 hours
Advanced Topics		
Total Lecture:		45 hours
Text Book(s)		
1	Chetan Singh Solanki, Solar Photovoltaics – Fundamentals, Technologies and Applications, PHI Learning Private limited, 2011	
2	Ru-shiliu, Leizhang, Xueliang sun, Electrochemical technologies for energy storage and conversion, Wiley publications, 2012	
Reference Books		
1.	Caye M. Drapcho, Nghiem Phu Nhuan and Terry H. Walker, Biofuels Engineering, McGraw-Hill Companies, 2008	
2.	Viswanathan, B and M Aulice Scibioh, Fuel Cells – Principles and Applications, Universities Press ,2006	
3.	Schaeffer, John, Real Goods Solar Living Sourcebook: The Complete Guide to Renewable Energy Technologies and Sustainable Living, Gaiam,2007	
4.	Frank Kreith and D.Yogi Goswami, Handbook of Energy Efficiency and Renewable Energy, CRC Press, 2007	
5.	John Twidell and Tony Weir, Renewable Energy Resources, Taylor & Francis, USA, 2006	
<p>Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).</p>		
Recommended by Board of Studies		13-12-2015
Approved by Academic Council	No. 40	Date 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE6035	SPINTRONICS	2	0	0	4	3
Pre-requisite	ECE5031- Quantum Physics for Nanostructures					
Course Objectives :						
The course aimed to:						
<ol style="list-style-type: none"> 1. Make them understand the spin based electronics. 2. Study the magnetic materials, Spintronic based devices and fabrication. 						
Expected Course Outcomes:						
The student will be able to						
<ol style="list-style-type: none"> 1. Gain the knowledge about Paramagnetism & diamagnetism. 2. Acquire the understanding and importance of Micromagnetics. 3. Obtain the fundamental knowledge of Magnetic Materials 4. Understand the Electron Transport in Magnetic Systems 5. Study properties of magnetic materials using advanced characterization tools and techniques. 6. Obtain the design and scope of Spintronic Device fabrication Techniques 						
Student Learning Outcomes (SLO):		1,17				
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications. 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice 						
Module 1	Paramagnetism & diamagnetism	2 hours				
Magnetically ordered state, Itinerant-electron magnetism, Localized Magnetic Systems.						
Module 2	Micromagnetics	3 hours				
Magnetism of single domain systems, Domain Walls, Exchange Bias and Magnetic Anisotropy.						
Module 3	Magnetic Materials	3 hours				
High-density recording materials, Soft Magnetic Materials (Ferrites), Magnetic Thin Films, Dilute Magnetic semiconductors, Heusler Alloys, SQUID Magnetometer, Highly Spin Polarized Systems, Molecule-based magnets, Single-molecule magnets.						
Module 4	Electron Transport in Magnetic Systems	5 hours				
Degree of Spin Polarization, Idea of Tunneling, Magnetoresistance, Anisotropic Magnetoresistance (AMR), Hall Effect (Planar & Anomalous) and Spin Polarized states.						
Module 5	Characterization of Magnetic Materials	6 hours				
Magnetometry, SQUID, VSM, Torque, Faraday Balance, Kerr Effect, Magnetic Force Microscopy, Spin Polarized STM.						
Module 6	Spintronic Devices	6 hours				
Spintronics- Origins of Spin, Spin Mechanics, Origins of Spintronics, Spin current and Magnetoresistance, Giant Magnetoresistance (GMR), Colossal Magnetoresistance, Ballistic Magnetoresistance, Tunneling Magnetoresistance. Two-terminal devices-Spin valves, Tunneling MR devices, Magnetic Field sensors, Read- Heads, MRAMS, Three-terminal Devices- Spin FET,						



Spin SET, and Spin LED.			
Module 7		Spintronic Device fabrication Techniques	3 hours
Advanced device fabrication methods-Growth of multilayer Structures, Lithography and Self-Assembly.			
Module 8		Contemporary issues:	2 hours
		Total Lecture	30 hours
Text Book(s)			
1	Hirota, Sakakima, and Inomata, Giant Magneto-Resistive Devices, Springer Verlag 2002.		
2	D. Awschalom, D. Loss, and N.Samarth, Semiconductor Spintronics and Quantum Computation, Nano Science Technology series, Springer, 2002.		
Reference Books			
1	Stefan Visnovsky, Optics in Magnetic Multi-layers and Nanostructures, CRC Publishers, 2006.		
2	D.L. Mills, J. A.C. Brand Nanomagnetism, Elsevier Science and Technology, 2006.		
3	M. Ziese, M. J. Thornton Spin Electronics, Lecture Notes in Physics, Springer, 2001.		
4	Gersten and Smith, The Physics and Chemistry of Materials, Wiley, 2001.		
5	Buschow and De Boer, Physics of Magnetism and Magnetic Materials, Springer 2003.		
6	R. L. Carlin, Magnetochemistry, Springer-Verlag, Berlin, 1986.		
7	U. N.Hartmann, Magnetic Multi-layers and Giant Magnetoresistance: Fundamentals and Industrial Applications, Springer, 2000.		
8	M. Ziese, M. J. Thornton Spin Electronics, Lecture Notes in Physics, Springer, 2001.		
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).			
Typical Projects			
<ol style="list-style-type: none"> 1. Fabrication of magnetic tunnel junctions (MTJ) with MgO or AlO insulating barriers 2. Spin pumping and high frequency spin dynamics in MTJs 3. MTJ sensors for biological applications 4. Theory of spin-polarized transport and pure spin currents 5. Topological insulator-based spintronic devices. 			
Mode of Evaluation: Review I, II and III			
Recommended by Board of Studies		13-12-2015	
Approved by Academic Council		No. 40	Date 18-03-2016



Course Code	Course Title	L	T	P	J	C
ECE6039	NANOELECTRONIC CIRCUIT DESIGN	3	0	0	0	3
Pre-requisite	ECE6032 - Nanoelectronics					
Course Objectives:						
<ul style="list-style-type: none"> • To introduce students to the emerging design paradigms in various new nanotechnologies, for device and circuits. • To bridge the existing gap between nanoelectronic device research and nanosystems design. 						
Expected Course Outcomes:						
<p>The student will be able to</p> <ol style="list-style-type: none"> 1. Obtain the knowledge on advanced Nanoscale devices 2. Understand the operation and design FinFET based circuits. 3. Design reliable circuits using nanowire arrays and CNT interconnects. 4. Design logic circuits using quantum cellular automata. 5. Understand the design aspects of application specific Nanoscale ICs. 6. Model the circuits of Fin-FETs, CNT-FETs, GNR-FETs, RTDs and quantum dot devices using various SPICE versions. 						
Student Learning Outcomes (SLO):		1,17				
<ol style="list-style-type: none"> 1. Having an ability to apply mathematics and science in engineering applications. 17. Having an ability to use techniques, skills and modern engineering tools necessary for engineering practice 						
Module 1	Introduction to advanced nanoelectronic devices	2 hours				
New device structures for next generation nanotechnology - carbon nanotube field-effect transistors (CNFETs), FinFETs, nanowire FETs, III/V compound-based devices, graphene nanoribbon devices, resonant tunneling diodes and quantum dot devices.						
Module 2	FinFET circuit and SRAM design	8 hours				
Shorted-Gate and Independent-Gate FinFETs, Logic Design Using SG/IG-Mode FinFETs, Principle of TCMS, Logic Design Using TCMS, Latch Design Using SG/IG-Mode FinFETs, Precharge-Evaluate Logic Circuits, FinFET SRAM Design: Physics, Theory, and Modeling of FinFET Devices for SRAM Applications; Low-Power, High-Performance 90-nm DG-FinFET SRAM Design.						
Module 3	Reliable Circuits Design with Nanowire Arrays and CNT Interconnects	7 hours				
Nanowire Fabrication Techniques, Crossbar Technologies, Architecture of Nanowire Crossbars, Decoder Logic Design. Emerging interconnect technologies: Study of Performances of Low-k Cu, CNTs, and Optical Interconnects; Local Interconnects: CNT Bundles Versus Cu and Global and Semi-global Interconnects.						
Module 4	Circuit Design with Quantum Cellular Automata	7 hours				
QCA Fundamentals, Basic Logic Gates and Interconnect, Logic Design with QCA and Fabrication Technology and Challenges.						



Module 5	Nanoscale Application-Specific Integrated Circuits	6 hours
NASIC Building Blocks: Nanowires and xnwFETs, NASIC Circuit Styles, NASIC Logic Styles, NASIC Architectures and manufacturing methods.		
Module 6	Circuit Design with Carbon Nanotube FETs & Resonant Tunneling Diodes	8 hours
Mis-Positioned and Immune CNT Logic Design, Metallic-CNT-Immune CNFET Circuits. Metallic-CNT-Immune CNFET Circuits. Bistable Logic Using RTDs, Noise Margins of RTD-HBT Threshold Logic Gates, Monostable-Bistable Logic Elements and Circuit Examples for RTD-Based Devices.		
Module 7	Circuit design with Graphene based Transistors	5 hours
Recent developments in Graphene Transistors, Analog Circuits, Digital Circuits: GNR FET Digital Circuits, Ambipolar Logic Circuits.		
Module 8	Contemporary issues:	2 hours
Advanced Topics		
Total Lecture:		45 hours
Text Book(s)		
1.	Niraj K. Jha and Deming Chen, Nanoelectronic Circuit Design, Springer publications, 2011.	
2.	K. Goser, P. Glosekotter, Nanoelectronics and Nanosystems, Springer, 2015.	
Reference Books		
1.	Yuan Taur and TakNing, Fundamentals of Modern VLSI Devices, Cambridge University Press, Newyark, 1998.	
3.	Karl Goser, Peter Glosekotter, Jan Dienstuhl , Nanoelectronics and Nanosystems- From Transistors to Molecular and Quantum Devices, Springer-Verlag, 2004.	
4.	John P. Uyemura, Introduction to VLSI Circuits and Systems, John Wiley & Sons, Inc, 2002.	
Mode of Evaluation: Continuous Assessment Test –I (CAT-I) , Continuous Assessment Test –II (CAT-II), Seminar / Challenging Assignments / Completion of MOOC / QUIZ, Final Assessment Test (FAT).		
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