ACADEMIC CURRICULA

UNDERGRADUATE DEGREE PROGRAMME

Minor in Semiconductor Technology

Learning Outcomes-Based Curriculum Framework (LOCF)

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University u/s 3 of UGC Act, 1956)

Kattankulathur- 603203, Chengalpattu District, Tamil Nadu, India

Programme Structure

Foundation Courses (F) *(3 Courses)*					
Course Code	*Course Title*	*Hours/ Week*			*C*
		L	*T*	*P*	
21MNT001F	Semiconductor Devices and Integrated Circuits: Principles and Practices	*3*	*0*	*0*	*3*
21MNT002F	Semiconductor Materials and Devices Characterization	*3*	*0*	*2*	*4*
21MNT003F	Semiconductor Nanofabrication	*3*	*0*	*0*	*3*
Total Learning Credits					***10***

Elective Courses (E) *(Any Three Courses)*					
Course Code	*Course Title*	*Hours/ Week*			*C*
		L	*T*	*P*	
21MNT001E	Advanced Packaging and Heterogeneous Integration	*3*	*0*	*0*	*3*
21MNT002E	Optoelectronic and Photonic Devices	*3*	*0*	*0*	*3*
21MNT003E	Surfaces and Interfaces of Electronic Materials	*3*	*0*	*0*	*3*
21MNT004E	2D Semiconductors	*3*	*0*	*0*	*3*
21MNT005E	Photovoltaics and Energy Conversion	*3*	*0*	*0*	*3*
21MNT006E	Microelectromechanical Systems	*3*	*0*	*0*	*3*
Total Learning Credits					***09***

SRMIST STRONGLY ENCOURAGES THE USE OF SWAYAM (Study Web of Active Learning by Learning by Young and Aspiring Minds) PLATFORM, THE STUDENTS ARE ENCOURAGED TO CHOOSE ATLEAST ONE CORE/ ELECTIVE COURSE FROM SWAYAM ON THE RECOMMENDATION OF THE FACULTY ADVISOR AND THE CREDITS WILL BE TRANSFERRED

Course Code	21MNT001F	**Course Name**	SEMICONDUCTOR DEVICES AND INTEGRATED CIRCUITS PRINCIPLES AND PRACTICES	**Course Category**	F	Foundation Course	L T P C 3 0 0 3

Pre-requisite Courses	*Nil*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Provides foundational knowledge of semiconductor materials and manufacturing processes essential for advanced device development.*
CLR-2 :	*Covers key semiconductor components and their operations, enabling students to design and analyze various electronic devices.*
CLR-3 :	*Introduces photonic devices and display technologies, essential for understanding modern optoelectronics and display systems.*
CLR-4 :	*Focuses on practical design and simulation skills, crucial for developing and testing semiconductor devices using advanced tools.*

Program Outcomes (PO) (1-Low, 2-Medium, 3-High)

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 *Engineering Knowledge*	2 *Problem Analysis*	3 *Design & Development*	4 *Analysis, Design, Research*	5 *Modern Tool Usage*	6 *Society & Culture*	7 *Environment & Sustainability*	8 *Ethics*	9 *Individual & Team Work*	10 *Communication*	11 *Project Mgt. & Finance*	12 *Life Long Learning*
CO-1 :	*Understand semiconductor materials, crystal growth processes, and industry trends.*	3	3	-	2	-	-	-	-	-	-	-	-
CO-2 :	*Will be able to analyze and design basic and advanced semiconductor devices.*	3	3	-	2	-	-	-	-	-	-	-	-
CO-3 :	*Understand the principles and applications of photonic devices and modern display technologies.*	3	3	-	3	-	-	-	-	-	-	-	-
CO-4 :	*Acquire skills in designing and simulating various semiconductor devices using TCAD tools.*	-	3	3	3	-	-	-	-	-	-	-	-

Module-1: Fundamentals of Semiconductors and Crystal Growth — ***12 Hours***

Introduction to ICs, Moore's law, More than Moore's law, IRDS Roadmap, Worldwide Semiconductor Manufacturing Fabs. Semiconductor ecosystem. ISM and India FABs. Clean-room practices and contamination, Basics of Semiconductors: Crystal Structure, Defects and Properties, Carrier Transport phenomena, Silicon Crystal Growth: Electronic Grade Silicon, Compound Semiconductor Crystal Growth Methods, Wafer Manufacturing and Orientation,

Module-2: Junctions, Transistors, and Advanced Semiconductor Devices — ***9 Hours***

P-N junction, Metal-semiconductor junction, Tunnel diodes, Bipolar Junction Transistor, Heterojunction, MOS capacitor, Capacitance-Voltage characteristics, MOSFET, JEFET, Current-Voltage characteristics, Memory (NAND or Flash), Compound semiconductor devices (GaN, InGaAs, SiC) Operational amplifier (Op-Amp) and its mathematical operations, Design rules, Lambda-based Design Rules.

Module-3: Photonic Devices and Display Technologies — ***12 Hours***

LED, Photovoltaics, Photodetector, Phototransistors, Photomultiplier tube, CCD and CMOS sensors, CIS image sensor, LED-based display, understanding of RGB pixel technology, OLED and AMOLED displays, QLED, touch screen display

Module-4: Design and Simulation of Semiconductor Devices — ***12 Hours***

Design and simulation of PN junction using TCAD, Simulation of MOSFET, IV Characteristics of tunnel diode and its temperature response, simulation of MOS capacitor, Simulation of Operation amplifier, and designing of CMOS Gates and study its response.

Learning Resources	*1. K. Abbas, "Handbook of Digital CMOS Technology, Circuits, and Systems", "Springer", 1st ed., 2020.* *2. Robert L. Boylestad and L. Nashelsky, "Electronic Devices and Circuit Theory", "Pearson Education", 11th ed., 2014.* *3. S. M. Sze and M. K. Lee, "Semiconductor Devices: Physics and Technology", 3rd ed., John Wiley & Sons Inc., 2012.*	*4. Peter Y. Yu and M. Cardona, "Fundamentals of Semiconductors: Physics and Materials Properties", "Springer-Verlag Berlin", 4th ed., 2010.* *5. David A. Bell, "Electronic Devices and Circuit", "Oxford University Press", 5th ed., 2008.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	10%	-	20	-
Level 2	Understand	20%	-	20%	-	20	-
Level 3	Apply	30%	-	35%	-	30	-
Level 4	Analyze	30%	-	35%	-	30	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Hemant Dixit, Global Foundries, USA, aplahemant@gmail.com	1. Prof. Rajesh Kumar, IIT Indore, rajeshkumar@iiti.ac.in	1. Dr. Shailendra Saxena, SRMIST
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India. Krishna.muvvala@saintgobain.com	2. Dr. Tejendra Dixit, IIIT Kanchipuram tdixit@iiitdm.ac.in	2. Prof. Sarin Sundar JK, SRMIST

Course Code	21MNT002F	**Course Name**	SEMICONDUCTOR MATERIALS AND DEVICE CHARACTERIZATION	**Course Category**	F	Foundation Course	L	T	P	C
							3	0	2	4

Pre-requisite Courses	*Semiconductor Physics (Introductory level)*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	The purpose of learning this course is to:
CLR-1 :	*To understand the types of defects in semiconductor materials and devices.*
CLR-2 :	*To equip students with the skills to perform and interpret various characterization techniques*
CLR-3 :	*Learning about various growth and fabrication techniques of semiconductor materials and devices*
CLR-4 :	*To bridge the gap between theoretical concepts and practical applications in semiconductor technology*
CLR-5 :	*To prepare students for the rapidly evolving field of semiconductor technology by exposing them to current trends, cutting-edge research, and emerging applications*

Program Outcomes (PO)
(1- Low, 2 – Medium, or High-3)

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 *Engineering Knowledge*	2 *Problem Analysis*	3 *Design & Development*	4 *Analysis, Design, Research*	5 *Modern Tool Usage*	6 *Society & Culture*	7 *Environment & Sustainability*	8 *Ethics*	9 *Individual & Teamwork*	10 *Communication*	11 *Project Mgt. & Finance*	12 *Lifelong Learning*
CO-1 :	*Identify and analyze various types of defects in semiconductor materials and understand their effects on device reliability and lifetime*	-	3	-	3	3	-	-	-	-	-	-	-
CO-2 :	*Demonstrate skills in electrical measurement of semiconductor materials*	-	3	3	-	3	-	-	-	-	-	-	-
CO-3 :	*Analyze the quality of metal contacts and electrical performance of FET devices.*	3	3	-	3	-	-	-	-	-	-	-	-
CO-4 :	*Develop skills in optical characterization of semiconductor materials and special device structures.*	3	3	-	-	3	-	-	-	-	-	-	-
CO-5 :	*Critically evaluate the quality of semiconductor materials using electron beam and ion beam techniques.*	-	3	-	-	3	-	-	-	-	-	-	-

Module-1**: **Characterization of Defects and Impurities in Semiconductors — ***15 Hours***

Defects and impurities in silicon materials – Metal contaminants in Si wafers, Shallow-level and deep-level impurities, Impurity diffusion and precipitation, Generation-recombination statistics, Point defects and dislocations, Impact of defects and impurities on materials properties and device performance, Failure mechanism, Defect engineering in silicon materials and gettering of metal contamination. Detection of impurities using mass spectrometers, x-ray fluorescence analysis, deep-level transient spectroscopy, Electrical and other optical defect evaluation techniques.

***Lab**: DFT modeling of defects and impurities in silicon, Interpretation of the experimental DLTS spectra, Interpretation of the TEM images and XRD spectra in the analysis of defects and strain*

Module-2**: **Electrical Characterization of Semiconductor Materials — ***15 Hours***

Electrical resistivity – Definitions and units, Resistivity measurement by four-point probe and Eddy current techniques, Advanced measurement tools for in-line continuous single-point measurement and wafer mapping, Resistivity profiling, Hall effect and carrier mobility measurements, Carrier and doping density measurements by capacitance-voltage and Hall measurements

***Lab:** Four-point probe and Hall measurement of electrical resistivity, Interpretation of C-V measurement results for determining the doping density*

Module-3: Electrical Characterization of Semiconductor Devices **15 Hours**

Metal/semiconductor contacts – Various measurement geometries, barrier height and contact resistance measurements, Measurement of FET channel parameters, Field-effect mobility, Measurement of oxide and interface parameters in MOS devices, Wafer probing, Reliability and failure analysis

***Lab**: I-V and C-V measurements on transistors, FET characteristics analysis, Contact resistance measurement using TLM contact structures, Determination of interface trapped charges and oxide thickness using capacitance measurements.*

Module-4: Optical Characterization Methods **15 Hours**

Optical microscopy – Principles, visualizing photoresist profiles, Thin film thickness measurement system - Ellipsometry and Optical profilometer, Carrier lifetime analysis by time-resolved spectroscopy techniques (photoluminescence, transient absorption), Impurity and quantum efficiency analysis using photoluminescence spectroscopy, Wafer-level emission uniformity test, Raman spectroscopic analysis of strain in heteroepitaxial growth of compound semiconductors, X-ray absorption spectroscopy (XAS), Photoreflectance spectroscopy.

***Lab**: Microscopic visualization and qualitative analysis of microfabricated structures, Analysis of PL emission and decay spectra, Determination of lattice strain using experimental Raman spectra of thin film samples*

Module-5: Electron Beam, Ion Beam and X-Ray Methods **15 Hours**

Structure analysis using scanning electron microscopy, Transmission electron microscopy, and scanning tunneling microscopy, Near-surface compositional analysis using Auger electron spectroscopy (AES) and x-ray photoelectron spectroscopy (XPS), Bulk and interface analysis using secondary ion mass spectroscopy (SIMS), Rutherford backscattering (RBS), x-ray diffraction (XRD), and x-ray reflectivity (XRR).

***Lab**: XRD analysis of a standard sample, Microscopic image analysis and interpretation.*

Learning Resources	*1. Dieter K. Schroder "Semiconductor Material and Device Characterization", "John Wiley & Sons, Inc.", 3rd ed., 2006.* *2. Y. Yoshida and G. Langouche "Defects and Impurities in Silicon Materials", "Springer", 2015.* *3. Donald A. Neamen, "Semiconductor Physics and Devices", "McGraw Hill", 4th ed., 2012* *4. K. Abbas, "Handbook of Digital CMOS Technology, Circuits, and Systems", "Springer", 1st ed., 2020.*	*5. R.F. Egerton, "Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM", "Springer", 2nd ed., 2016.* *6. D. Keith Bowen and Brian K. Tanner, "X-ray Metrology in Semiconductor Manufacturing", "CRC Press", 1st ed., 2006.* *7. Alain C. Diebold, "Handbook of Silicon Semiconductor Metrology", "CRC Press", 1sr ed., 2001.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	-	20%	20%	-
Level 2	Understand	20%	-	-	20%	20%	-
Level 3	Apply	30%	-	-	35%	30%	-
Level 4	Analyze	20%	-	-	35%	20%	-
Level 5	Evaluate	5%	-	-	-	5%	-
Level 6	Create	5%	-	-	-	5%	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. M Satish, CSIR-CECRI, msathish@cecri.re.in	*Dr. C. Venkateswaran, University of Madras, venkateshwaran@unom.ac.in*	*Dr. Sougata Mallick, SRMIST*
Dr. V. Jayaraman, IGCAR, Kalpakkam, vjram@igcar.gov.in	*Dr. V. Gunasekaran, Central University TN, gunasekaran@cutn.ac.in*	*Prof. Sarin Sundar, SRMIST*

Course Code	21MNT003F	Course Name	SEMICONDUCTOR NANOFABRICATION	Course Category	F	Foundation Course	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Understand cleanroom processing, wafer handling, and manufacturing process flow essential for semiconductor fabrication.*
CLR-2 :	*Gain knowledge of various lithography techniques and photoresist processing for high-resolution semiconductor patterning.*
CLR-3 :	*Learn oxidation and doping processes, including thermal oxidation and ion implantation, to modify semiconductor properties.*
CLR-4 :	*Master thin film deposition methods and etching techniques crucial for creating precise semiconductor device structures.*

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 *Engineering Knowledge*	2 *Problem Analysis*	3 *Design & Development*	4 *Analysis, Design, Research*	5 *Modern Tool Usage*	6 *Society & Culture*	7 *Environment & Sustainability*	8 *Ethics*	9 *Individual & Teamwork*	10 *Communication*	11 *Project Mgt. & Finance*	12 *Lifelong Learning*
CO-1 :	*Understand cleanroom protocols, wafer production, and manufacturing process flows in semiconductor fabrication.*	3	3	-	3	-	-		-	-	-	-	-
CO-2 :	*Will be proficient in various lithography methods and photoresist processing techniques for semiconductor patterning.*	3	3	3	-	-	-	-	-	-	-	-	-
CO-3 :	*Understand the processes of thermal oxidation and doping, including ion implantation and diffusion in semiconductors.*	3	-	3	-	-	-	-	-	-	-	-	-
CO-4 :	*Acquire skills in thin film deposition methods and etching techniques, which are essential for semiconductor device fabrication.*	3	3	-	3	-	-	-	-	-	-	-	-

Module-1: Semiconductor FABs ***9 Hours***

Cleanroom Processing: Safety and Contamination Issues, Overview of Cleanroom Hazards, Vacuum Systems for Semiconductor Processing: Pumps and Leak Detection, Wafer Production, Wafer Type Selection and Cleaning Methods, Wafer handling, FOUP, Robots. Manufacturing Process Flow.

Module-2: Lithography Techniques ***12 Hours***

Overview of Lithography Technologies, Introduction to Microlithography, ArF, KrF, EUV Lithography, X-ray and e-beam Lithography, Masks Optical Exposure Systems, Diffraction, Fourier Optics and the Aerial Image, Photoresist Processing, Exposure and Resist Chemistry, Photoresist Development, Process Optimization, DOF, Process Control, Resolution Enhancement Technologies.

Module-3: Oxidation and Doping ***12 Hours***

Wet and Dry Oxidation, Thermal Oxidation, Effects of Surface Properties on the Oxidation Reaction, Oxidation Mechanism, and Electrical Measurement of Oxidation (MOS Capacitor)

Doping in Semiconductors, Dopant Diffusion in Semiconductors: Basic Concepts, Dopant Concentration Measurement: SIMS, Sheet Resistance, Role of Point Defects on Diffusion in Semiconductors, Theory and Operation of Ion Implantation Techniques and Control, Thermal Annealing and Rapid Thermal Annealing.

Module-4: Thin Film Deposition and Etching ***12 Hours***

Physical and Chemical Vapor Deposition (PVD and CVD), PVD Methods: Thermal Evaporation, Sputtering, and Molecular Beam Epitaxy, CVD Methods: PECVD, MOCVD, ALD, MLD, Atomic Layer Etching (ALE), Selective Deposition and Selective Etching

Etching: Wet and Dry Etching, Isotropic ad Anisotropic Etching, DRIE, Bosch process, TSV, Electroplating, Chemical Mechanical Planarization (CMP), Introduction to Packaging and Assembly (ATMP) processes.

Learning Resources	1. *G. S. May and S. M. Sze, "Fundamentals of Semiconductor Fabrication", "Wiley", 1st ed., 2004.*	2. *James D. Plummer, Michael D. Deal and Peter B Griffin, "Silicon VLSI Technology: Fundamentals, Practice and Modeling", "Pearson Publishers", 1st ed., 2009.*

Learning Assessment							
	Bloom's Level of Thinking	*Continuous Learning Assessment (CLA)*				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		*Life Long Learning CLA-II- Practice (10%)*			
		Theory	*Practice*	Theory	Practice	*Theory*	*Practice*
Level 1	Remember	*20%*	-	*10%*	-	20	-
Level 2	Understand	*20%*	-	*20%*	-	20	-
Level 3	Apply	*30%*	-	*35%*	-	30	-
Level 4	Analyze	30%	-	35%	-	30	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers		
Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Mr. Kulanthaivelu Ramaswamy, Technical Staff Engineer-Analog Design, Micochip Technology Inc. Kulanthaivelu.Ramasamy@microchip.com	*Prof. S. Balakumar, University of Madras, balasuga@yahoo.com*	*Prof. Sarin Sundar JK, SRMIST*
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	*Dr. Maneesh Chandran, NIT Calicut, maneesh@nitc.ac.in*	*Dr. S. Chandramohan, SRMIST*

Course Code	21MNT001E	Course Name	ADVANCED PACKAGING AND HETEROGENEOUS INTEGRATION	Course Category	E	Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes/Standards	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Understand the fundamental principles, historical evolution, and basic semiconductor packaging technologies at different levels.*
CLR-2 :	*Learn to address electrical issues and design considerations in semiconductor packaging, including parasitic effects and interconnections.*
CLR-3 :	*Gain knowledge of traditional packaging technologies, including surface mount technology, soldering methods, and failure analysis.*
CLR-4 :	*Explore advanced packaging technologies, including multichip modules, system-in-package, heterogeneous integration, and photonic integration.*
CLR-5 :	*Understand the role of interlayer dielectric materials, interposers, and emerging materials in advanced packaging technologies and thermal management.*

Program Outcomes (PO)
(1-Low, 2-Medium, 3-High)

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 *Engineering Knowledge*	2 *Problem Analysis*	3 *Design & Development*	4 *Analysis, Design, Research*	5 *Modern Tool Usage*	6 *Society & Culture*	7 *Environment & Sustainability*	8 *Ethics*	9 *Individual & Teamwork*	10 *Communication*	11 *Project Mgt. & Finance*	12 *Lifelong Learning*
											-	-	-
CO-1 :	*Understand the fundamental principles, historical context, and basic semiconductor packaging technologies at chip, board, and system levels.*	-	3	3	-	-	-	-	-	-	-	-	-
CO-2 :	*Identify and address electrical issues such as resistive, capacitive, and inductive parasitics, and implement effective interconnection designs.*	3	3	-	3	-	-	-	-	-	-	-	-
CO-3 :	*Gain proficiency in traditional packaging methods, including surface mount technology, various soldering techniques, and failure analysis.*	3	3	-	-	-	-	-	-	-	-	-	-
CO-4 :	*Will learn advanced packaging techniques, including multichip modules, system-in-package, 2.5D and 3D packaging, and photonic integration.*	3	-	-	3	-	-	-	-	-	-	-	-
CO-5 :	*Understand the application of interlayer dielectric materials, different types of interposers, and emerging technologies for advanced packaging and thermal management.*	3	3	-	-	-	-	-	-	-	-	-	-

Module-1: Introduction to Semiconductor Packaging ***9 hours***

Overview of Semiconductor Packaging, Definition and Importance, Historical Evolution, Packaging Levels: Chip, Board, and System Level, Packaging Materials and Substrates, Basic Packaging Technologies, Wire Bonding, Flip-Chip, Wafer-Level Packaging (WLP), Panel level packaging, Chiplets

Module-2: Electrical Design Considerations ***9 hours***

Electrical Issues–Resistive, Capacitive, and Inductive Parasitic; Layout guidelines and problem-solving, Interconnection, Damascene Processes, introduction to embedding and de-embedding

Module-3: Traditional Packaging Technologies ***9 hours***

Surface Mount Technology (SMD), Reflow and Wave Soldering methods to attach SMDs, Solders, Wetting of solders; Flux and its properties; Defects in wave soldering, Vapour phase soldering, ball grid array (BGA) soldering and Desoldering/Repair, Lead-free solder considerations, SMT failure analysis, Encapsulation, Introduction to MEMS packaging
Module-4: Advanced Packaging-1 ***9 hours***
Multichip modules (MCM)-types; System-in-package (SIP), Heterogeneous Integration, 2.5D and 3D Packaging, Packaging roadmaps, flip chip bumping, solder balls, and through-silicon vias (TSVs), photonic integration
Module-5: Advanced Packaging-2 ***9 hours***
Interlayer Dielectric (ILD) Materials, Interposers, Types of Interposers (Silicon, Glass, Organic), Emerging Materials and Technologies, and Thermal Management.

Learning Resources	1. *Rao R. Tummala, "Fundamentals of Microsystems Packaging", "McGraw Hill", 2001.* 2. *Andrea Chen, Randy Hsiao-Yu Lo, "Semiconductor Packaging, Materials Interaction and Reliability", "CRC Press", 2011.* 3. *John H. Lau, "Heterogeneous Integrations", "Springer", 2019.*	4. *Richard K. Ulrich, William D. Brown, "Advanced Electronic Packaging", "Wiley", 2006.* 5. *William J. Greig, "Integrated Circuit Packaging, Assembly and Interconnections", "Springer", 2007.* 6. *Eugene J. Rymaszewski, Rao R. Tummala, (eds.), "Microelectronics Packaging Handbook", "Springer", 1997.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%		10%		20	-
Level 2	Understand	20%		20%		20	-
Level 3	Apply	30%		35%		30	-
Level 4	Analyze	30%		35%		30	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Renilkumar M, Lionix International, Netherlands	*1. Prof. S. Balakumar, University of Madras, balasuga@yahoo.com*	*1. Dr. Abhay A Sagade*
2.-Prof. Sarin Sundar JK, Applied Materials India	*2. Prof. D. Paul Joseph, NIT Warangal paul@nitw.ac.in*	*2. Dr. Kiran Mangalampalli*

Course Code	21MNT002E	Course Name	OPTOELECTRONIC AND PHOTONIC DEVICES	Course Category	E	Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Know the various basic concepts of optoelectronic transitions in semiconductors*
CLR-2 :	*Explain the functionality of laser diode, LEDs and various photodetectors in terms of their design, structure, and characteristics.*
CLR-3 :	*Distinguish the operation principles, characteristics, design architectures, and trade-offs associated with various CMOS image sensors*
CLR-4 :	*Understand the various types of optical modulators and their applications.*
CLR-5 :	*To differentiate the working mechanism of different types of displays.*

		Program Outcomes (PO) (1-Low, 2-Medium, 3-High)											
		1	2	3	4	5	6	7	8	9	10	11	12
		Engineering Knowledge	*Problem Analysis*	*Design & Development*	*Analysis, Design, Research*	*Modern Tool Usage*	*Society & Culture*	*Environment & Sustainability*	*Ethics*	*Individual & Teamwork*	*Communication*	*Project Mgt. & Finance*	*Lifelong Learning*
Course Outcomes (CO):	*At the end of this course, learners will be able to:*										-	-	-
CO-1 :	*Understand the concept of optical transitions in semiconductor*	3	3	3	-	-	-	-	-	-	-	-	-
CO-2 :	*Apply the knowledge of the electron-photon, photon-electron process to comprehend the working mechanism of various devices.*	-	3	-	3	-	-	-	-	-	-	-	-
CO-3 :	*Understand the mechanism of CMOS image sensors.*	3	3	-	-	-	-	-	-	-	-	-	-
CO-4 :	*Describe the technical and physical fundamentals of various optical modulators.*	3	-	-	3	-	-	-	-	-	-	-	-
CO-5 :	*Analyze the various luminescence mechanisms to understand the different displays.*	3	3	-	-	-	-	-	-	-	-	-	-

Module-1:Optical Processes in Semiconductor — ***9 Hours***

Introduction to semiconductors, exciton absorption, donor-acceptor, and impurity band absorption, long wavelength absorption, –stokes shift in optical transitions, near bandgap transitions, Relation between absorption and emission, Radiative and non-radiative recombination, band-to-band recombination, Deep level transitions, Auger recombination, Luminescence, Type of Luminescence.

Module-2: LED and Photodetector Devices — ***9 Hours***

LED materials and device configurations, efficiency, high brightness LEDs, LED - operation, LED structures - Single Heterostructures, Double Heterostructures, Single Quantum Well, Multiple Quantum Well - device performance characteristics, White solid-state LEDs - generation of white light and applications, Semiconductor Laser- different types of semiconductor lasers and their working principles, Basics of light detectors, Opto-electronic detectors- Photoconductive detectors - junction photodiodes, P-I-N photodetector - quantum efficiency and frequency response, Avalanche photodiodes, Silicon photodiodes, Phototransistors, Photomultiplier tube.

Module-3: CMOS and CCD Image Sensors: Technology and Applications — ***9 Hours***

Introduction to image sensor – review of MOS and MOSFET- Charge generation, collection and transfer, CCD – concepts, structures, operation, and its performances, limitation to the CCDs, introduction to CMOS Sensors, basics architecture and its functions, Pixel Technology of CMOS Sensors, Passive pixel and its limitation, CMOS Active pixel technology, PN photodiode pixels – structure, operation, and performance, Pinned photodiode pixels – structure, operation and performance, Signal processing – Pixel signal readout – FPN suppression circuit - correlated double sampling, Noises in CMOS sensors.

Module-4: Modulators and Fiber Optics Devices **9 Hours**

Optical Modulators, Fanz Keldysh and Stark effect modulators, Quantum well electro-absorption modulators, electro-optic effect, fiber coupling, EO materials, Kerr modulators, scanning and switching, self-electro-optic devices, MO devices, AO devices, AO modulators. Introduction, Structure of optical fiber, Propagation of light through a numerical aperture, Pulse broadening, advantages and disadvantages of fiber optics.

Module-5: Display Technologies **9 Hours**

Introduction to displays - displays based on LED – operating principle and performance, Plasma panel, Liquid crystal display, Types of liquid crystals, Liquid Crystal displays – operating principle and performance, applications, advantages over LED displays, Microdisplay technologies - liquid crystals on silicon reflective microdisplay – basics, TFT operation and its performance, OLED and AMOLED displays, working principle and its performance, QLED and Flexible LEDs devices – working mechanism, touch screen display – basic functions, Display manufacturing process.

Learning Resources	1. John P. Dakin and Robert G. W. Brown, "Handbook of Optoelectronic Devices", "CRC Press", Vol.1, 2nd ed., 2018. 2. Konstantin D Stefanov, "CMOS Image Sensor", "IOP Publishing", 1st ed., 2022.	3. S. O. Kasap, "Optoelectronics and Photonics: Principles and Practices", "Pearson Education, Inc.", 2nd ed., 2013. 4. Ben Streetman and Sanjay Banerjee, "Solid State Electronic Devices", "Pearson Education, Inc.", 7th ed., 2015. 5. Takatoshi Tsujimura, "OLED Display Fundamentals and Applications", "Wiley", 2nd ed., 2017.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	10%	-	20	-
Level 2	Understand	20%	-	20%	-	20	-
Level 3	Apply	30%	-	35%	-	30	-
Level 4	Analyze	30%	-	35%	-	30	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Renilkumar M, Lionix International, Netherlands	1. Prof. S. Balakumar, University of Madras, balasuga@yahoo.com	1. Dr. Tamilselvan Appadurai, SRMIST
2.-Prof. Sarin Sundar JK, Applied Materials India	2. Prof. D. Paul Joseph, NIT Warangal paul@nitw.ac.in	2. Dr. Subhojit Sarkar, SRMIST

Course Code	21MNT003E	**Course Name**	SURFACES AND INTERFACES OF ELECTRONIC MATERIALS	**Course Category**	E	Elective	L T P C 3 0 0 3

Pre-requisite Courses	*Nil*	**Co-requisite Courses**	*Nil*	**Progressive Courses**	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Developing a foundational knowledge of surface energy and structure in electronic materials is essential for controlling device performance.*
CLR-2 :	*To gain practical skills in utilizing advanced surface analysis techniques*
CLR-3 :	*To explore how surface states, interfaces, and thin film deposition techniques influence semiconductor device fabrication processes*
CLR-4 :	*To understand the physics of semiconductor interfaces, including metal-semiconductor and dielectric-semiconductor interfaces*
CLR-5 :	*To examine emerging trends in surface engineering and interface technology*

Program Outcomes (PO)
(1-Low, 2-Medium, 3-High)

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 *Engineering Knowledge*	2 *Problem Analysis*	3 *Design & Development*	4 *Analysis, Design, Research*	5 *Modern Tool Usage*	6 *Society & Culture*	7 *Environment & Sustainability*	8 *Ethics*	9 *Individual & Team Work*	10 *Communication*	11 *Project Mgt. & Finance*	12 *Life Long Learning*
CO-1 :	*Understand surface properties such as energy, structure, and composition using appropriate surface analysis techniques*	-	3	-	3	-	-	-	-	-	-	-	-
CO-2 :	*Demonstrate how surface states, interface traps, and surface chemistry impact semiconductor device behavior and performance.*	-	3	-	3	-	-	-	-	-	-	-	-
CO-3 :	*Apply knowledge of surface modification and passivation techniques to optimize semiconductor device performance, reliability, and integration.*	3	3	-	3	-	-	-	-	-	-	-	-
CO-4 :	*Evaluate thin film growth models and interface engineering strategies*	3	3	3	-	-	-	-	-	-	-	-	-
CO-5 :	*Develop the ability to propose and implement solutions to semiconductor surface-related phenomena*	3	3	-	3	-	-	-	-	-	-	-	-

Module-1: Introduction to Surfaces and Interfaces — ***9 Hours***

Fundamentals of bulk and surface structure, surface preparation and cleaning techniques, surface energy, interfacial energy and interface phenomena, Surface reconstruction and relaxation, Chemical potential, the Thermodynamics and kinetics of surfaces and interfaces, and surface growth modes.

Module-2: Interfaces in Semiconductor Devices — ***9 Hours***

Role of Interfaces in Semiconductor Device Performance, Metal-semiconductor interfaces, Semiconductor heterojunctions and strain, adsorbates on semiconductors, metal-insulator-semiconductor interfaces and metal-induced gap states, Interface engineering in transistors and case studies.

Module-3: Electronic Properties of Surfaces and Interfaces	***9 Hours***
Surface states and band bending, Dangling bonds and importance, Classification of metal-semiconductor junctions: Schottky and Ohmic, Interface traps and their effects, Mott-Schottky relation, Charge transfer, and transport phenomena, Surface and interface modifications for electronic applications.	
Module-4: Characterization Techniques	***9 Hours***
Techniques for Analyzing Surfaces and Interfaces, AFM, ellipsometry, kelvin probe force microscopy, scanning tunneling microscopy and spectroscopy, secondary ion mass spectroscopy, photoluminescence, LEED, electron energy loss spectroscopy, and DLTS.	
Module-5: Surface-Interface Engineering and its Applications	***9 Hours***
Surface and interface engineering: adsorption, chemisorption, surface wettability treatments: plasma, light, chemical, Applications: photovoltaics, gas sensor, Emerging materials, and interface technologies.	

Learning Resources	*1. Hans Lüth, "Solid Surfaces, Interfaces and Thin Films", "Springer-Verlag Berlin", 6th ed., 2015.* *2. Leonard J. Brillson, "Surfaces and Interfaces of Electronic Materials", "Wiley", 2015.*	*3. Guozhong Cao, "Nanostructures & Nanomaterials: Synthesis, Properties and Applications", "Imperial College Press", 2004.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	10%	-	20	-
Level 2	Understand	20%	-	20%	-	20	-
Level 3	Apply	30%	-	35%	-	30	-
Level 4	Analyze	30%	-	35%	-	30	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Sarin Sundar, Applied Materials.	1. Dr. Aditya Sadhanala, IISc, Bengaluru	1. Dr. Eswaraiah Varrla, SRMIST
2. Dr. Pramod Rajanna, HHV Pvt Ltd	2. Dr. KDM Rao, Indian Association for the Cultivation of Science, Kolkata	2. Dr. Abhay Sagade, SRMIST

Course Code	21MNT004E	Course Name	2D SEMICONDUCTORS	Course Category	E	Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	Data Book / Codes/Standards	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*	Program Outcomes (PO) (1- Low, 2 – Medium, or High-3)											
		1	2	3	4	5	6	7	8	9	10	11	12
		Engineering Knowledge	*Problem Analysis*	*Design & Development*	*Analysis, Design, Research*	*Modern Tool Usage*	*Society & Culture*	*Environment & Sustainability*	*Ethics*	*Individual & Team Work*	*Communication*	*Project Mgt. & Finance*	*Life Long Learning*
CLR-1 :	*Understand different 2D semiconductor quantum materials and emerging new phenomena*												
CLR-2 :	*Become familiarize with the emerging field of Quantum Materials at 2D limit*												
CLR-3 :	*Understand the synthesis and nanofabrication methods for 2D semiconductors*												
CLR-4 :	*Familiarize with various characterization techniques for analyzing 2D semiconductors*												
Course Outcomes (CO):	At the end of this course, learners will be able to:											-	-
CO-1 :	*Elucidate how 2D semiconductors are different from bulk semiconductors*	3	-	3	-	-	-	-	-	-	-	-	-
CO-2 :	*Familiarize with different fabrication methods of 2D quantum materials*	3	-	3	-	-	-	-	-	-	-	-	-
CO-3 :	*Explain how 2D semiconducting materials can be characterized using optical, microscopic and spectroscopic tools*	-	-	-	3	-	-	-	-	-	-	-	-
CO-4 :	*Develop an understanding of 2D semiconductor based electronic and photonic devices*	-	-	3	3	-	-	-	-	-	-	-	-

Module-1: Introduction to 2D Materials — ***12 Lectures***

The discovery of graphene, Classification of 2D materials – Electronic properties of single-layer graphene - Bandgap opening in graphene - The case of graphene nanoribbons - Bilayer graphene - Concept of stacking order in the bilayer and multilayer graphene - Graphene twistronics - 2D Semiconducting Transition Metal Dichalcogenides (TMDs): Materials, structure, and properties - Novel phenomena in 2D semiconductors: Excitons in TMDs, Layer-dependence of the optical band gap, Valleytronics, Strain, defect and doping effect on electronic properties, Superconductivity in the 2D limit, Ferromagnetism in TMDs - Emerging 2D magnets and 2D Topological insulators

Module-2: Synthesis and Fabrication of 2D Materials	***10 Lectures***
Exfoliation of layered materials – Epitaxial growth of graphene on SiC – Molecular Beam Epitaxy (MBE) fabrication of 2D semiconductors - Chemical vapor deposition (CVD) and atomic layer deposition (ALD) of 2D semiconductors – Growth of 2D heterostructures using MBE and CVD - Layer-by-layer assembling technique for lab-scale devices – Transfer and roll-to-roll CVD processes - Lithographic patterning of 2D materials - Plasma etching and reactive ion etching of graphene and TMDs	
Module-3: Characterization of 2D Materials	***10 Lectures***
Spectroscopic and microscopic characterization of 2D materials: Optical, atomic force and electron microscopic evaluation of layer thickness, defects, and stacking order - Raman and photoluminescence spectroscopy in 2D materials research. *Metal contacts to 2D Semiconductors: Challenges and current techniques - Concept of Fermi level pinning - Evaluation of metal/2D semiconductor contact properties - TLM method*	
Module-4: Electronics and Photonics of 2D Semiconductors	***12 Lectures***
Graphene-based RF transistors for flexible electronics – Graphene-based photonics devices - Graphene transparent electrodes - Graphene as a heat spreader and substrate - Concept of van der Waals vertical heterostructure - Design principles and device integration - Vertical heterostructure photodetectors - 2D TMDs as high-performance channels: Device structure, FET characteristics - Dielectric for 2D transistors - Substrate effect on carrier mobility - 2D semiconductor devices for computing, memory functions and sensing: 2D FET sensors, 2D semiconductors for logic circuits, Neuromorphic computing, and spintronic memory devices – 2D semiconductors in photonics and integrated optoelectronics - Integration of 2D material lasers into photonic circuits and systems, including on-chip light sources, modulators, and detectors- Applications in quantum information processing - State-of-the-art technology and future roadmap	

Learning Resources	*1. Avouris, Phaedon, Heinz, Tony, Low, Tony, eds. "2D Materials: Properties and Devices", "Cambridge University Press", 1st ed., 2017.* *2. Li Tao and Deji Akinwande, "Emerging 2D Materials and Devices for the Internet of Things: Information, Sensing and Energy Applications", "Elsevier", 1st ed., 2020.*	*3. M. Houssa, A. Dimoulas, and A. Molle, "2D Materials for Nanoelectronics", "CRC Press", 1st ed., 2016.* *4. Dongzhi Chi, K.E. Johnson Goh and Andrew T.S. Wee, "2D Semiconductor Materials and Devices", "Elsevier", 2020.* *5. Dragoman, Mircea, and Daniela Dragoman,"2D Nanoelectronics: Physics and Devices of Atomically Thin Materials", "Springer", 2016.*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Dr. M. Sathish, CSIR-Central Electrochemical Research Institute, msathish@cecri.res.in	*Dr. Vidya Kochat, IIT Bombay, vidya@matsc.iitkgp.ac.in*	*Dr. S. Chandramohan, SRMIST*
Mr. Kulanthaivelu Ramaswamy, Technical Staff Engineer-Analog Design, Micochip Technology Inc. Kulanthaivelu.Ramasamy@microchip.com	*Dr. Maneesh Chandran, NIT Calicut, maneesh@nitc.ac.in*	*Dr. Eswaraiah Varrla, SRMIST*

Course Code	21MNT005E	Course Name	PHOTOVOLTAICS AND ENERGY CONVERSION	Course Category	E	Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Department of Physics and Nanotechnology*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Understand the basics of photovoltaic devices fabricated with semiconductor materials*
CLR-2 :	*Know the fundamentals and design of crystalline Si and thin film solar cells*
CLR-3 :	*Get familiar with the different process flow of commercial solar cell technology and advanced characterization techniques*
CLR-4 :	*Analyze the design of perovskite and tandem solar cells*
CLR-5 :	*Get familiar with the different characterization techniques to evaluate the performance of solar cells*

Program Outcomes (PO)
(1-Low, 2-Medium, 3-High)

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 *Engineering Knowledge*	2 *Problem Analysis*	3 *Design & Development*	4 *Analysis, Design, Research*	5 *Modern Tool Usage*	6 *Society & Culture*	7 *Environment & Sustainability*	8 *Ethics*	9 *Individual & Teamwork*	10 *Communication*	11 *Project Mgt. & Finance*	12 *Lifelong Learning*
CO-1 :	*Know the need of photovoltaic devices and utilization of available solar energy resource*	3	-	-	3	3	-	-	-	-	-	-	-
CO-2 :	*Extend the knowledge of semiconductor physics for the design of photovoltaic devices and extract relevant parameters*	3	3	3	-	-	-	-	-	-	-	-	-
CO-3 :	*Interpret the design and working of dye-sensitized and organic solar cells*	3	-	-	3	3	-	-	-	-	-	-	-
CO-4 :	*Analyze the design of perovskite, tandem solar cells and related emerging technologies*	3	3	-	3	-	-	-	-	-	-	-	-
CO-5 :	*Break down the steps from solar wafer preparation to packaging and analyze the device performance with advanced techniques*	3	-	-	3	3	-	-	-	-	-	-	-

Module-1: Introduction to Solar Energy and Photovoltaics	**9 hours**
Introduction to renewable energy, solar energy, Solar radiation, Measurement of solar radiation, Solar insolation, Measurement of solar insolation, Energy band diagram, charge carrier dynamics in semiconductors, Light-induced charge carrier generation, Recombination, P-N junction diode and modeling, Working principle, Current-Voltage Characteristics (under light), Carrier transport, Principle of solar energy conversion, Photovoltaic effect and power conversion efficiency, Technological importance.	
Module-2: Crystalline Si and Thin Film Solar Cells	**9 hours**
Crystalline Si solar cells, Solar cell structure, Equivalent circuits, I-V Curve, Optical and electrical losses, Short-Circuit Current, Open-Circuit Voltage, Fill Factor, Factors affecting performance limit, Efficiency, Shockley–Queisser (S–Q) efficiency Polycrystalline and amorphous silicon solar cells, Applications of thin film deposition techniques for solar cell, Efficiency calculation, Semiconducting III-V chalcogenide based solar cells, device architecture.	
Module-3: Device Architectures for Emerging Photovoltaics	**9 hours**
Working principle of Dye-sensitized solar cells, Structure and fabrication of dye-sensitized solar cell, Quantum dots in dye-sensitized solar cell, Current status of dye-sensitized solar cells, Photophysics of organic solar cell, Optimization processes, Nanotechnology in organic-based solar cells, Structures, Working principle, Applications, Current status of the organic solar cell, Multi-junction (MJ) solar cells Device structure	
Module-4: Hybrid Tandems	**9 hours**
Introduction to perovskite solar cell, working principle of perovskite solar cell, Types, Fabrication technique, current status, Tandem solar cell, Design considerations, Transparency of perovskite absorbers, Metal electrodes, Protective layers, Recombination layers (RLs), tunnel junctions (TJs), Band gap tuning, Challenges, Issues related to the large-scale applications.	
Module-5: Si wafer-based Solar Cell Technology and Device Characterizations	**9 hours**
Si feedstock for the solar cell industry, process flow and processes used in commercial Si solar cell technology, determination of solar cell physical parameters, surface roughness, and film thickness, measuring current-voltage characteristics, Incident photon conversion efficiency (IPCE), Application of capacitance technique to measure carrier concentration profiles, trap density, interface state density, deep-level properties.	

Learning Resources	1. M. A. Green, "Third Generation Photovoltaics Advanced Solar Energy Conversion", "Springer", 2005. 2. J. Nelson, "Physics of Solar Cells", "Imperial College Press", 2003. 3. Gavin J. Conibeer and Arthur Willoughby, "Solar Cell Materials: Developing Technologies", "John Wiley & Sons, Inc.", 2014. 4. Loucas Tsakalakos, "Nanotechnology for Photovoltaics", "CRC Press", 2010.	5. Monika Freunek Muller, "Photovoltaic Manufacturing: Etching, Texturing, and Cleaning (Solar Cell Manufacturing)", "Wiley-Scrivener",2021. 6. I. M. Dharmadasa, "Advances in Thin-Film Solar Cells", "Jenny Stanford Publishing", 2018. 7. Chetan Singh Solanki, "Solar Photovoltaics, Fundamental Technologies and Applications", "PHI Learning Private Limited", 3rd ed., 2015.

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	20%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	30%	-	30%	-
Level 4	Analyze	30%	-	30%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
Prof. Sarin Sundar J K, Applied Materials	Dr. A.K Meikap, Professor, NIT Durgapur	Dr. Subhojyoti Sinha
Dr. Hemant Dixit, Global Foundaries, USA, aplahemant@gmail.com	Dr. Paul Joseph D, Associate Professor, NIT Warangal	Dr. Tamilselvan Appadurai

Course Code	21MNT006E	Course Name	MICROELECTROMECHANICAL SYSTEMS	Course Category	E	Elective	L	T	P	C
							3	0	0	3

Pre-requisite Courses	*Nil*	Co-requisite Courses	*Nil*	Progressive Courses	*Nil*
Course Offering Department	*Physics and Nanotechnology*	**Data Book / Codes/Standards**	*Nil*		

Course Learning Rationale (CLR):	*The purpose of learning this course is to:*
CLR-1 :	*Understanding MEMS is crucial due to their extensive applications in various high-tech industries.*
CLR-2 :	*The course integrates concepts from multiple engineering disciplines, comprehensively understanding MEMS.*
CLR-3 :	*Students gain hands-on experience in micro and nanofabrication processes essential for research and development roles.*
CLR-4 :	*Mastery of MEMS technologies opens diverse and high-demand career opportunities in advanced engineering fields.*
CLR-5 :	*The course prepares students for graduate studies and innovative research in microsystems and nanotechnology.*

Program Outcomes (PO)
(1-Low, 2-Medium, 3-High)

Course Outcomes (CO):	*At the end of this course, learners will be able to:*	1 *Engineering Knowledge*	2 *Problem Analysis*	3 *Design & Development*	4 *Analysis, Design, Research*	5 *Modern Tool Usage*	6 *Society & Culture*	7 *Environment & Sustainability*	8 *Ethics*	9 *Individual & Teamwork*	10 *Communication*	11 *Project Mgt. & Finance*	12 *Lifelong Learning*
CO-1 :	*Understand and explain the fundamental principles, significance, and applications of MEMS technologies.*	3	3	3	-	-	-	-	-	-	-	-	-
CO-2 :	*Apply various lithography and deep etching techniques in the fabrication of MEMS devices.*	3	3	3	-	-	-	-	-	-	-	-	-
CO-3 :	*Develop and use mathematical models and simulation tools (COMSOL) to analyze and predict the behavior of MEMS systems.*	-	3	3	-	-	-	-	-	-	-	-	-
CO-4 :	*Demonstrate knowledge of sensing and actuation principles, including mechanical components and advanced materials.*	3	3	2	-	-	-	-	-	-	-	-	-

CO-5 :	*Evaluate the impact of packaging techniques on the functionality and reliability of MEMS and understand the integration of optical and fluidic microsystems.*	3	3	3	-	-	-	-	-	-	-	-	-

Module-1: Overview of MEMS: Definition, History, and Applications in Daily Life — ***9 hours***

Overview of MEMS: Definition, history, and everyday applications, Importance of MEMS: Technological advancements and impact on modern devices, Scaling Laws in MEMS: Dimensional analysis and implications for design, Mathematical Modeling in MEMS: Introduction to COMSOL for simulation, Microsensors and Microactuators: Principles of sensing and actuation, Case Study: Modeling a standard cantilever in COMSOL

Module-2: Fabrication Techniques — ***9 hours***

Microfabrication processes, Lithography in MEMS: Principles, techniques (photolithography, electron beam lithography), LIGA, Surface and Bulk Micromachining, Deep Etching Techniques: DRIE (Deep Reactive Ion Etching), Bosch process, and their importance, nanoimprint lithography, Template based patterning, Case study of a MEMS process flow.

Module-3: Principles of Sensing and Actuation — ***9 hours***

Principles of sensing and actuation (thermal, mechanical, radiation, magnetic, and chemical), beams, cantilevers, microplates, and their properties, Diaphragm Structures, Sensor Technologies: Capacitive, piezoelectric, and piezomechanical sensors, Measurement Methods: Techniques for strain, pressure, and flow measurement, MEMS Gyroscopes and Thermal Devices: Principles and applications.

Module-4: Advanced Materials and Sensing Technologies — ***9 hours***

Introduction to Magnetic Materials: Properties and classifications, Piezoelectric and Magnetoresistive MEMS: Principles and applications, Magnetic Sensing and Design: Techniques for object detection and direction sensing, RF MEMS: Fabrication processes and applications in resonators and phase shifters, MEMS Based on Carbon Nanotubes and Graphene: Actuation mechanisms and performance, MOEMS Components: Light modulators, beam splitters, microlenses, and micromirrors.

Module-5: Fluidic Microsystems and MEMS Packaging — ***9 hours***

Lab-on-a-Chip Technologies: Microfluidics, fluid actuation methods (dielectrophoresis, electrowetting), MEMS Packaging Techniques, Integration of MEMS with Readout Electronics: Challenges and solutions, Case Studies in MEMS Packaging and Challenges, Integration of MEMS with ICs.

Learning Resources	*1. Mahalik N P, "MEMS", "Tata McGraw-Hill Education", 2008.* *2. Laurent Duraffourg and Julien Arcamone, "Nanoelectromechanical Systems", "John Wiley & Sons, Inc.", 2015.*	*3. Sergey Edward Lyshevski, "Micro-Electro-Mechanical and Nano-Electromechanical Systems, Fundamental of Nano- and Micro-Engineering", "CRC Press", 2005*

Learning Assessment

	Bloom's Level of Thinking	Continuous Learning Assessment (CLA)				Summative Final Examination (40% weightage)	
		Formative CLA-I Average of unit test (50%)		Life Long Learning CLA-II- Practice (10%)			
		Theory	Practice	Theory	Practice	Theory	Practice
Level 1	Remember	20%	-	10%	-	20%	-
Level 2	Understand	20%	-	20%	-	20%	-
Level 3	Apply	30%	-	35%	-	30%	-
Level 4	Analyze	30%	-	35%	-	30%	-
Level 5	Evaluate	-	-	-	-	-	-
Level 6	Create	-	-	-	-	-	-
	Total	100 %		100 %		100 %	

Course Designers

Experts from Industry	Experts from Higher Technical Institutions	Internal Experts
1. Dr. Hemant Dixit, Global Foundaries, USA, aplahemant@gmail.com	*1. Prof. D. Pamu, IIT Guwahati pamu@iitg.ac.in*	*1. Dr. Mangalampalli Kiran, SRMIST*
2. Dr. Krishna Surendra Muvvala, Saint Gobain Research India, India, Krishna.muvvala@saintgobain.com	*2. Prof. M. Ghanashyam Krishna, UOHYD, mgksp@uohyd.ernet.in*	*2. Dr. Venkata Prasad Bhat, SRMIST*