The LNMIIT, Jaipur Department of Electronics and Communication Engineering Modeling & Simulation Of Advanced Semiconductor Devices (ECE7132)	

Programme: Ph.D.	Course Title: Modeling & Simulation Of Advanced Semiconductor Devices			Course Code: ECEXXX
Type of Course: Program/Research Elective	Prerequisites: Semiconductor Devices and Physics			Total Contact Hours: 40
Year/Semester: 1/Odd	Lecture Hrs/Week: 3	Tutorial Hrs/Week: 0	Practical Hrs/week: 0	Credits: 4

Learning Objective:

This course is a foundation level course on semiconductor devices. Course consist of three broad topics (1) Semiconductors properties, (2) Devices and (3) governing equations along with their boundary conditions. Course objective is to develop a sound physical and intuitive understanding of semiconductor devices and achieve ability to make some key decisions while designing applications specific semiconductor devices.

Course outcomes (COs):

On completion of this course, the students shall have the ability to:		Bloom's Level
CO-1	To **exemplify** the Si Nanoelectronics, transport factor, semiconductor band structure, density of states, etc.	2
CO-2	To **apply** the concept of p-n junctions and bipolar junction transistors for academic and industry applications as well.	3
CO-3	To **demonstrate** the advanced semiconductor devices such as heterojunction-based diodes and transistors, CMOS field-effect transistors for various applications.	3
CO-4	To **analyse** advanced concepts of semiconductor theory and models such as hydrodynamic modelling and quantum transport models for quantum-based semiconductor devices.	4
CO-5	To **design** semiconductor and photonic devices such as transistors and photonic sensors using simulation tools.	5
CO-6	To **predict** the various performance metrics such as I-V characteristics and small-signal analysis of the designed semiconductor and photonic sensors.	6

Course Topics	Lecture Hours	CO
UNIT – I: Introduction to Si Nanoelectronics	**3**	**CO1**
1.1 Si-Based Nanoelectronics and Device Scaling	1	
1.2 Nanoscale and Heterostructure Devices	1	
1.3 Crystal structure-Unit cell and Miller Indices	1	
UNIT – II: Semiconductor Properties and Device Physics	**6**	**CO1, CO2**
2.1 Reciprocal Space, Doping, Band Structure, Effective Mass	2	
2.2 Density of states, Electron Mobility, Semiconductor Statistics-Fermi-Dirac function and carrier concentration calculation	1	
2.3 Heterojunctions p-n junction under equilibrium, derivation of I-V relation, Minority carrier diffusion equation	2	
2.4 Non-idealities in the p-n junction diode (Breakdown and Generation-Recombination currents)	1	

UNIT – III: Transistors: BJT/FET/HEMT	**11**	**11**
3.1. BJT- I-V relation and gain, Ebers-Moll model, Non-idealities in BJT, Gummel Poon Model, HBT, BJT Transient and small signal behavior, Metal-Semiconductor contact (Schottky Barrier/Diode, Ohmic Contacts) and capacitance characteristics, Thermionic emission current flow and fermi-level pinning	**4**	
3.2. Field Effect Transistors (JFET, MESFET, HEMT), MOS Band diagram and C-V characteristics, Threshold voltage and Interface charges, MOSFET I-V, gradual channel approximation and frequency response, non-idealities and CMOS	**8**	
3.3. Noise Modeling of Transistors and Frequency Analysis	**3**	
UNIT-IV: Semiclassical Transport Theory and Drift-Diffusion (DD) model	**10**	**10**
4.1 Distribution Function, Boltzmann Transport Equation (BTE), Relaxation-Time Approximation (RTA), Scattering and Mobility	**3**	
4.2 Drift-Diffusion (DD) model-1 -: Drift-Diffusion Model Derivation and dielectric relaxation time, Taylor series expansion and Finite Difference method, Normalization, Scaling and Linearization of Poisson's Equation and Scharfetter–Gummel Discretization of the Continuity Equation	**4**	
4.3 Drift-Diffusion (DD) model-2 -: Generation and Recombination models, Derivation of SRH model, Boundary conditions, Gummel's Iteration Method and Newton's Method, Drift-Diffusion Application example	**3**	
UNIT-V: Hydrodynamic Modeling and Quantum Transport models	**10**	**10**
5.1 Extension of DD model, Carrier Balance, Energy balance and momentum balance Equations, Direct solution scheme through Monte Carlo simulations	**4**	
5.2 Tunneling, Schrodinger equation and free particle, potential step, potential barrier, Transfer Matrix Approach, Quantum Mechanical corrections to standard approach	**4**	
5.3 Examples through commercial device simulation tools, Models for DD, Hydrodynamic simulations, Mobility and G-R models, Selected Examples	**2**	

Textbook References:

Books and References:

1. G. Streetman, and S. K. Banerjee, "Solid State Electronic Devices," 7th edition, Pearson,2014.
2. S. M. Sze and K. N. Kwok, "Physics of Semiconductor Devices," 3rd edition, John Wiley&Sons, 2006.
3. D Vasileska, SM. Goodnick, G Klimeck, "Computational Electronics: Semiclassical and Quantum Device Modeling and Simulation," CRC Press 2010.
4. Selberherr Siegfried, "Analysis and Simulation of Semiconductor Devices", 1984

Additional Resources:

https://onlinecourses.nptel.ac.in/noc23_ee35/preview

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Evaluation Method	
Item	**Item**
Assignment/Simulation	30
Midterm	30
Final Examination	40

*Please note, as per the existing institute's attendance policy the student should have a minimum of 75% attendance. Students who fail to attend a minimum of 75% lectures will be debarred from the End Term/Final/Comprehensive examination.

CO and PO Correlation Matrix for Ph.D with ECE

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	3	3	1									3	3	1	3
CO2	3	3	2									3	3	1	3
CO3	3	3	2	1								3	3	1	3
CO4	3	2	1									3	3	1	3
CO5	3	3	3	2								3	3	1	3
CO6	3	3	3	1								3	3	2	3

Last Updated On: Januray 2023

Updated By:

Approved By: