BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI- HYDERABAD CAMPUS

SECOND SEMESTER 2021-2022

COURSE HANDOUT PART II

Date: 15/01/2022

In addition to Part-I (General Handout for all courses appended to the timetable) this portion gives further specific details regarding the course.

Course No.	**:**	**EEE F477**
Course Title	**:**	**Modeling of Field-Effect NanoDevices**
Instructor-in-charge	**:**	**Dr. Sayan Kanungo**

1. Course description:

Basics of MOSFET operation (1D electrostatics, 2D electrostatics, MOSFET I-V Characteristics, CMOS technology, Performance limits), MOSFET scaling, Small-dimensional effects (Hot electron effect, Velocity saturation, Drain-induced barrier lowering, Gate-induced drain leakage, Poly-silicon depletion, Gate-tunneling currents, Quantum effects, Variability issues), Quantum mechanical Description of Transport (Distribution function, Density of States, Carrier Density, Ballistic transport, Scattering), Nano-scale MOSFET (Physics of nano-MOSFET, Ballistic nano-MOSFET, Scattering in nano-MOSFET).

2. Course Objective:

This course deals with the physics and operation of Metal Oxide Semiconductor Field Effect Transistor (MOSFET) structure under downscaling. In this course, the different limiting factor for performance of MOSFET at nano-scale device dimensions will be analyzed and the subsequent device engineering strategies for performance improvement will be emphasized. Finally, the state-of the art MOSFET architectures will be investigated in details and their modelling approach will be detailed in context of quantum mechanical carrier transport description. The course is expected to develop advance-level knowledge on MOSFETs, typically its electrostatics and carrier transport phenomenon at scaled down technology nodes and thereby skills for analyzing and modelling nano-scale devices in general. The course material will also incorporate certain research perspectives of the subject. Therefore, in addition to relying on the subject oriented text books and reference books, the students are advised to follow technical articles and study materials that are shared by the instructor from time to time.

3. Text Books

[T1] Mark Laundstrom, Fundamentals of Nano Transistors, Word Scientific, 1st ed., 2008.

4. Reference Books

[R1] Mark Laundstrom, Jing Guo, Nanoscale Transistors, Springer, 1st ed., 2008.

[R2] Supriyo Datta, Quantum Transport- Atom to Transistor, Cambridge, 1st ed., 2005.

4. Course Plan

Sl.No	Topics to be covered	Learning Objectives	Ref. to Book	No. of Lectures
1	Introduction to the course and its components	Course Handout Discussion		1
2	Basics of MOSFET operation (Structure, I-V Characteristics, Device Matrices)	Basics of MOSFET Physics and Operation	T1: Ch. 1.2	3
3	MOSFET as Barrier Controlled Device (Energy Band Diagram Picture, Correlation with I-V Characteristics)	Physical Insight in MOSFET Operation	T1: Ch. 1.3	3
4	Basic Model for Nanoscale MOSFET (Different Operation Regime, MOSFET Downscaling, Level-0 Virtual Source Model, Limitations)	Analysis and Modelling of I_D-V_{DS} characteristics at different regions	T1: Ch. 1.4-1.5	6
5	MOSFET Electrostatics (1D Electrostatics, 2D Electrostatics, I-V Characteristics of Nanoscale-MOSFET, Short Channel Effects, Quantum Confinement, Device Design Aspects- High-k/Metal-Gate, SOI, Multi-Gate)	Analysis of Device Operations in Scaled-down Technology Nodes and Innovative Design Improvements	T1: Ch. 2.1- 2.5	10
6	Advanced Model for Nanoscale MOSFET (Level-1 Virtual Source Model, Capacitive Model)	Analysis and Modelling of I_D-V_{DS} / I_D-V_{GS} characteristics at different regions including Short Channel Effects	T1: Ch. 2.6	6
7	Ballistic MOSFET (Landauer Approach to Transport, MOSFET as Nano-device, Relation with Virtual Source Model)	Quantum Mechanical Description of Carrier Transport-part1	T1: Ch. 3.1- 3.4	8
8	Transmission Theory for MOSFET (Carrier Scattering and Transmission)	Quantum Mechanical Description of Carrier Transport-part2	T1: Ch. 4.1-4.2	5
		Total Number of Lectures		42

6. **Evaluation Scheme**

Component	Weightage	Duration	Date & Time	Nature of Component
Midsem Test	30%	90 mins	10/03 11.00am to12.30pm	Close Book
Quizzes	30%	To be announced	To be announced	Open Book
Comprehensive Exam	40%	120 mins	06/05 AN	Close Book

7. **Chamber Consultation Hour**: To be announced
8. **Notices**: Notices concerning this course will be on CMS.

9. Academic Honesty and Integrity Policy: Academic honesty and integrity are to be maintained by all the students throughout the semester and no type of academic dishonesty is acceptable.

Dr. Sayan Kanungo
Instructor-in-Charge