Approval: 10th Senate Meeting

Course Name: Microelectronics Devices and Modelling

Course Number: EE-520

Credits: 3-0-0-3 (Lectures-Assignments-Practical's-Total)

Prerequisites: Applied Electronics (IC 161 & IC 161 P) and Device Electronics for Integrated (EE311 and EE312 P)

Intended for: M.Tech EE (VLSI) / UG

Elective or Core: Core for M.Tech EE (VLSI) and Elective for UG

Semester: Odd

Preamble: This course builds the knowledge-base on the physics of semiconductors as related to the characteristics and design of solid-state electronic devices. It provides an introduction to the device electronics for integrated circuits, a foundation for the use of device models in circuit analysis and design tools and motivation for life-long learning.

Course Outline: The objective of the course is to provide the fundamental knowledge for understanding concepts of semiconductor devices. This is a required core-course for P.G students and elective for UG students. The first part of the course provides an introduction to the basic semiconductor physics/solid-state physics needed to understand device modeling of electronic devices. The second part is devoted to describe the operation of several basic semiconductor devices: p-n junctions, metal-semiconductor junctions, Diodes, metal oxide semiconductor field effect transistors (MOSFETs), Complementary MOSFETs (CMOS). The third part is exclusively devoted for the fundamental understanding of device modeling and numerical simulation techniques

Microelectronics Devices and Modelling

1. SEMICONDUCTOR ELECTRONICS: Physics of Semiconductor Materials, Band Model of Solids Thermal-Equilibrium Statistics, Carriers in Semiconductors, Drift Velocity, Mobility and Scattering, Drift & Diffusion Current, Device: Hall-Effect.

(6 lectures)

2.METAL-SEMICONDUCTOR CONTACTS and P-N JUNCTIONS: Metal-Semiconductor junctions, Current-Voltage Characteristics, Surface Effects. The pn junction, Step Junction, Linearly Graded Junction, Heterojunctions, Reverse-Biased p-n junctions and break down mechanism. Generation and Recombination.

(8 lectures)

3. **FIELD-EFFECT TRANSISTORS (MOSFETs): PHYSICAL EFFECTS AND MODELS:**

MOS Capacitor, Oxide and Interface Charge: Origin and Experimental Determination Charge-Coupled Devices, non-volatile memory.

Basic MOSFET behaviour, MOSFET scaling and short channel model. Devices: Complementary MOSFETs (CMOS), electric fields and velocity-saturation, basic leakage currents, channel length modulation, body bias effect, threshold adjustment, sub-threshold conduction .

(9 lectures)

4. Device Modeling

Limitation of long channel analysis, short-channel effects: velocity saturation, device degradation, channel length modulation, body bias effect, threshold adjustment, mobility degradation, hot carrier effects, MOSFET scaling goals, gate coupling, velocity overshoot, high field effects in scaled MOSFETs, substrate current and effects in scaled MOSFETS.

Moore law, Technology nodes and ITRS, Physical & Technological Challenges to scaling, Nonconventional MOSFET – (FDSOI, SOI, Multi-gate MOSFETs).

(10 lectures)

5. Numerical Simulation:

Numerical simulation, basic concepts of simulations, grids, device simulation and challenges. Importance of semiconductor device simulators - Key elements of physical device simulation, historical development of the physical device modeling.

Introduction to the TCAD Simulation Tool, Examples of TCAD Simulations –MOSFETs and SOI.

(8 lectures)

Text Book:

1. Semiconductor devices- Physics and Technology, 3rd Edition, by S. M. Sze and M.K. Lee (John Wiley & Sons, 2012)
2. Device Electronics for Integrated circuits by Muller and Kkammins.
3. **Computational Electronics: Semiclassical and Quantum Device Modeling and Simulation** by Dr VagicaVasileska and Stephen M. Goodnick.
4. Silicon Nanoelectronics –Shundri Oda & David Ferry, CRC Press.

References:

1. "Physics of Semiconductor Devices" by S. M. Sze and Kwok K. Ng, 3rd Eddition, (John Wiley & Sons, 2002)
2. "Solid State Electronic Devices", by Ben G. Steetman and Sanjay Banerjee 6th Edition, Prentice Hall, 2005
3. "Semiconductor Device Fundamentals", by Robert F. Pierret, Addison-Wesley Publishing, 1996
4. "Semiconductor Physics and Devices", by Donald A. Neamen, 3rd Eddition, McGrawHill, 2003
5. "Semiconductor Devices- Basic Principles", by Jasprit Singh, John Wiley and Sons Inc., 2001