20VL003 - Semiconductor Device Modelling

Course Objectives:

- This course provides a solid foundation in the physics of semiconductors so that students will be able to not only understand current devices and exploit them in novel applications.
- It also appreciate the workings of new semiconductor devices as they materialize and evolve in futureyears.

Course Outcomes:

Upon successful completion of this course student should be able to:

CO1: At the end of this course you should be able to Explain the equations, approximations, and techniques available for deriving a model with specified properties, for a general device characteristic with known qualitativetheory.
CO2: Apply suitable approximations and techniques to derive the model referred to above starting from drift-diffusion transport equations (assuming these equations hold).
CO3: Offer clues to qualitative understanding of the physics of a new device and conversion of this understanding intoequations.
CO4: Simulate characteristics of a simple device using MATLAB, SPICE and ATLAS / SYNOPSYS.
CO5: Explain how the equations get lengthy and parametersincrease innumberwhile developing a compact model
CO6: List mathematical functions representing various non-linearshapes

UNIT – I

SEMICONDUCTOR PHYSICS : Metals, insulator, semiconductors, intrinsic and extrinsic semiconductors, direct and indirect band gap, free carrier densities, Fermi distribution, density of states, Boltzmann statistics, thermal equilibrium, current flow mechanisms, drift current, diffusion current, mobility, band gap narrowing, resistance, generation and recombination, lifetime, internal electro-static fields and potentials, Poisson's equation, continuity equations, drift-diffusion equations.

UNIT – II

PN-JUNCTION DIODES : Thermal equilibrium physics, energy band diagrams, space charge layers, internal electro-static fields and potentials, reverse biased diode physics, junction capacitance, wide and narrow diodes, transient behavior, transit time, diffusion capacitance, small signal model.

UNIT – III

BIPOLAR TRANSISTORS : The bipolar transistor: Ebers-Moll model; harge control model; small-signal models for low and high frequency and switching characteristics

UNIT – IV

MOS TRANSISTORS : MOS capacitor, accumulation, depletion, strong inversion, threshold voltage, contact potential, oxide and interface charges, body effect, drain current, saturation voltage, gate work function, channel mobility, sub-threshold conduction, short channel effects, effective channel length, effects of channel length and width on threshold voltage, Compact models for MOSFET and their implementation in SPICE. Level 1, 2 and 3, MOS model parameters in SPICE.

UNIT – V

UDSMTRANSISTORDESIGNISSUES: Shortchannelandultrashortchanneleffects,effectofhigh k and low k dielectrics on the gate leakage and Source –drain leakage; tunneling effects; different gate structures in UDSM - impact and reliability challenges inUDSM.

TEXT BOOKS:

1. Y.P. Tsividis, The MOS Transistor, McGraw-Hill, international editioned.,1988.
2. Nandita DasGupta, AmitavaDasGupta, Semiconductor Devices: Modelingand Technology, PHI
3. S.M.Sze, Semiconductor Devices Physics and Technology, John Wiley & Sons Inc,(2/e).
4. Angsuman Sarkar, Short Channel Effects(SCE's) in sub-100nm MOSFETs: AReview.

REFERENCEBOOKS:

1. Getreu, Modeling the bipolar transistor, New York, NY: Elselvier,1978.
2. D.Roulston,BipolarSemiconductorDevices,McGrawHill,1990.
3. N.Arora, MOSFETModels for VLSICircuitSimulation, Springer-Verlag,1993.
4. P.Antognetti and G. Massobrio, SemiconductorDeviceModeling with SPICE,McGraw-Hill, 1988.
5. D.W.Greve,FieldEffectDevicesandApplications,PrenticeHallSeriesinE lectronicsandVLSI, 1998.