FIRST SEMESTER 2022-2023

Course Handout Part II

Date: 19 Aug 2022

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

Course No. :MEL G631
Course Title : PHYSICS AND MODELING OF MICROELECTRONIC DEVICES
Instructor-in-Charge : Surya Shankar Dan

Description: Physics and properties of semiconductor - a review; pn junction diode; bipolar transistor; metal-semiconductor contacts; JFET and MESFET; MOSFET and scaling; CCD and photonic devices

Prerequisites of the course:

- Electronic Devices (ECE/EEE/INSTR F214) or its equivalent
- Microelectronic Circuits (ECE/EEE/INSTR F244) or its equivalent

Textbooks:

1. Yuan Taur & Tak H. Ning, “Fundamentals of Modern VLSI Devices,” 2ed, Cambridge
2. Yannis P. Tsividis & Colin McAndrew, “The MOS Transistor,” 3ed, Oxford
3. Jean-Pierre Colinge & Cynthia A. Colinge, “Physics of Semiconductor Devices,” Springer
4. Muller & Kamins, “Device Electronics for Integrated Circuits”, 3ed, Wiley

Basic references:

1. Robert F. Pierret, “Semiconductor Device Fundamentals”, Pearson
2. M. S. Tyagi, “Introduction to Semiconductor Materials and Devices”, Wiley
3. Michael Shur, “Physics of Semiconductor Devices”, Pearson
4. Chenming Hu, “Modern Semiconductor Devices for Integrated Circuits”, Pearson
5. Roger T. Howe & Charles G. Sodini, “Microelectronics: An Integrated Approach”, Pearson

Advanced references:

1. David Jiles, “Introduction to the Electronic Properties of Materials,” 2ed, Nelson Thornes
2. Angus Rockett, “The Materials Science of Semiconductors,” Springer
3. Peter Y. Yu & Manuel Cardona, “Fundamentals of Semiconductors,” 3ed, Springer
4. Marius Grundmann, “the Physics of Semiconductors,” Springer
5. James D. Patterson & Bernard C. Bailey, “Solid-State Physics,” Springer
6. Karlheinz Seeger, “Semiconductor Physics,” 9ed, Springer
7. Manijeh Razeghi, “Fundamentals of Solid State Engineering,” Springer
8. Herald Ibach and Hans Luth, “Solid-State Physics,” Springer

Tentative lecture plan:

1. Relevant quantum mechanics (4 lec)
2. Relevant solid state physics (6 lec)
3. Relevant statistical physics (4 lec)
4. Equilibrium carrier statistics in semiconductors (3 lec)
5. Classical transport in semiconductors (3 lec)
6. Contact potentials (4 lec)
7. p-n junctions (6 lec)
8. Metal semiconductor contacts (2 lec)
9. 2T MOS structure: MOS capacitor (8 lec)
    1. Flatband voltage
    2. Potential and charge balance
    3. Effect of on surface condition
    4. Accumulation and depletion
    5. Inversion
    6. Small-signal capacitance
10. 3T MOS structure: Gated diode (3 lec)
    1. Contacting the inversion layer
    2. Body effect
    3. Regions of inversion
    4. A control point of view
11. 4T MOS structure: MOSFET devices (10 lec)
    1. Transistor regions of operation
    2. Complete all-region model
    3. Simplified all-region models
    4. Models based on quasi-Fermi potentials
    5. Regions of inversion in terms of terminal voltages
    6. Strong inversion
    7. Weak inversion
    8. Moderate-inversion and single-piece models
    9. Source-referenced vs. body-referenced models
    10. Effective mobility
    11. Effect of extrinsic source and drain series resistances
    12. Temperature effects
    13. Breakdown
    14. The p-channel MOS transistor
    15. Enhancement-mode and depletion-mode transistors
    16. Model parameter values, model accuracy, and model comparison
    17. Long-channel MOSFETs
    18. Short-channel MOSFETs

12. CMOS device design
    1. MOSFET scaling
    2. Threshold voltage
    3. MOSFET channel length
13. CMOS performance factors
    1. Basic CMOS circuit elements
    2. Parasitic elements
    3. Sensitivity of CMOS delay to device parameters
    4. Performance factors of advanced CMOS devices
14. Small-channel and thin oxide effects ()
    1. Carrier velocity saturation
    2. Carrier length modulation
    3. Charge sharing
    4. Drain-induced barrier lowering
    5. Punchthrough
    6. Combining several small-dimension effects into one model
    7. Hot carrier effects
    8. Velocity overshoot and ballistic operation
    9. Polysilicon depletion
    10. Quantum mechanical effects
    11. DC gate currents
    12. Junction leakage; band-to-band tunneling; GIDL
    13. Leakage currents
    14. Quest for ever-smaller devices

Lecture plan:

Evaluation scheme:

#	Component	Duration	Marks	Weight	Date & time	Evaluation
1	Literature review	3 wks	20	10 %	To be announced later	Open
2	Mid laboratory evaluation	2 hrs/wk	20	10 %	Regular evaluation	Open
3	Mid semester	90 min	70	35 %	02/11 3.30 - 5.00PM	Open
4	End laboratory evaluation	2 hrs/wk	10	5 %	Regular evaluation	Open
5	End semester (Comprehensive)	180 min	80	40 %	23/12 AN	Open
	Total		200	100 %		

Laboratory: All modeling assignments will be carried out using open source tools: spyder3, python3, numpy, scipy, sympy & matplotlib, scikit-learn, pandas.

Notices: All notices related to the course will be put on the CMS and google classroom and shared through institute email.

Make-up policy: Make-ups will be considered for genuine reasons and applied at least 1 day before the tests.

Academic Honesty and Integrity Policy: Academic honesty and integrity are to be maintained by all the students throughout the semester and any mode of academic dishonesty will not be acceptable.

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INSTRUCTOR-IN-CHARGE