UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Physics and Technology of Electronic Devices

2425-2-FSM01Q029

Aims

The course is devoted to provide the student with the fundamentals of the physics and technology of modern semiconductors devices (diodes and transitors) as well emerging and innovative devices for classical (conventional and unconventional) and quantum information processing, as well as for neuroelectronics applications . In addition to lectures the course offers two laboratory activities dedicated to state of the art electrical characterization and simulation (based on Sentaurus) of the devices.

Contents

Physics of conventional electronic devices (junctions, transistors), of ultrascaled nanoelectronic devices (single electron and single atom transistors), and of emerging and novel nanoelectronic and spintronic devices for logic and memory applications, and for quantum information processing. Nanoelectronic devices (EOS, EOSFETs, Memristors) for neuroelectronic applications will be also discussed.

Detailed program

LECTURES

1. p-n junction: unpolarized and polarized junction. Current-Voltage characteristic in ideal and real junctions. The junction capacitance. Breakdown. Models. Solar cells. PiN diodes. (PTED1-PTED9)

2. Bipolar Transistors (BJT): Currents. Active mode. Gain. (PTED10-PTED13)

3. Metal-Semiconductor Contact: Ohmic and Schottky contacts. Schottky diode. Characteristic I-V. Interface states.

(PTED14)

4. Metal Oxide Semiconductor: band structures. MOS capacitor. Accumulation, depletion and inversion. Capacitance. Effect of interface states. The MOSFET. Evolution of the MOSFET: SOI MOSFET, high mobility substrates, high-k, quantum effects in the inversion channel, the leakage currents. (PTED15-PTED22)

5. Non-volatile memory devices: FLASH memories, nanocrystals, PCM, ReRAM. (PTED23)

6. Electronic devices based on heterojunction: HBT, HEMT. (PTED24)

7. Electronic devices based on quantum effects: tunnel diodes, Tunneling-FET, low-dimensional devices, Fin-FET, single-electron transistor (SET), Coulomb blockade, spin blockade. (PTED25)

8. Emerging spintronic devices: transistors based on the transport of spin, magnetic tunnel junctions. (PTED26)

9. Solid state devices for quantum computing: introduction to quantum computing, qubit, spin in semiconductors (manipulation, entanglement, detection). (PTED27)

10. Neuroelectronic: devices for stimulation / sense neuronal activity, devices for emulating the synaptic and neuronal activity in neuromorphic circuits. (PTED28)

LABORATORY

1. Introduction to the experimental techniques and set-ups (LPTEDE1)

2. Semiconductor-metal contacts: ohmic and Schottky contacts. Zener diode. (LPTEDE2)

3. BJT: I-V (LPTEDE3)

4. MOS: C-V (doping profile, defects, high-k -EOT) (LPTEDE4)

5. MOSFET: I-V, C-V (LPTEDE5)

6. Introduction to TCAD (LPTEDS1)

7. Surviving to Linux (LPTEDS2)

8. Building up the device: SSE (LPTEDS3)

9. Practice: Zener diode / MOSFET / Bipolar (LPTEDS4)

10. Hints on discretization (LPTEDS5)

11. Meshing the device: SSE/SNMESH (LPTEDS6)

12. Practice: Zener diode / MOSFET / Bipolar (LPTEDS7)

13. Solving the device: SDevice 3h (LPTEDS8)

14. Visualizing results: SVisual 1h (LPTEDS9)

15. Practice: simulated device characterization (LPTEDS10)

Prerequisites

Solid State Physics and Physics of Semiconductors.

Teaching form

The course comprises lectures in the classroom and a laboratory part dedicated to electrical characterization and simulation.
In particular:
a) 16 two-hour lectures, in person, Delivered Didactics
b) 4 four-hour practical classes (lab), in person, Interactive Teaching

Textbook and teaching resource

- R.F. Pierret, Semiconductor Device Fundamentals, Addison Wesley

- M.S. Sze, Semiconductor devices, Physics and Technology, J. Wiley

- C. Papadopoulos, Solid State Electronic Devices: An Introduction, Springer .

- Notes from the teachers

- Slides of the lectures on the e-learning platform

Semester

1st Semester II year

Assessment method

Students must demonstrate in an interview that they know how the fundamental principles of semiconductor physics can be used
in the design and development of electronic devices with specific functions, and how the device functions can be simulated and experimentally analyzed in the laboratory using appropriate approaches. The oral test, consists of two, or three questions, on different parts of the course, where the illustration of the topic is required to be accompanied by sketches, equations and numerical data. The student chooses the first topic and must turn in the lab activity report at least 5 days before the exam. Proficiency in qualitative and quantitative aspects of electronic device functioning will be assessed, considering the physical understanding and related mathematical formalism. The experimental part will be evaluated by discussing the final laboratory report.

Office hours

By appointment.

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | CLEAN WATER AND SANITATION | AFFORDABLE AND CLEAN ENERGY | INDUSTRY, INNOVATION AND INFRASTRUCTURE | SUSTAINABLE CITIES AND COMMUNITIES