IH1611
Semiconductor Devices
Spring 2021

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Course contents

The general aim of the course is that you should be able to describe the function of components based on pn-junctions and MOS-structures. These components include the MOS-transistor, the bipolar transistor and memory cells. You should be able to explain, how the components are used in applications. You should be able to derive and calculate currents inside the components and be able to analyse the charge distribution, the electric field and the current density for given terminal voltages. You should be familiar with the process flow that is used to produce modern microelectronics.

Intended learning outcomes

Having passed the course, the student shall be able to:

- describe the electronic band structure for insulators, semiconductors and metals qualitatively
- calculate electron and hole concentrations in semiconductors
- derive and calculate the current density in semiconductors and semiconductor components by means of the drift-diffusion model
- analyse and calculate the internal electrostatics (charges, electric field and potential) in semiconductor components based on pn and MOS-structures
- describe the function and the application areas for the pn-diode, the MOS-transistor and common types of memory cells and some kind of semiconductor sensor
- describe the basic properties for CMOS-inverters and how these are used to implement integrated circuits.

Organization of the course

To achieve the course goals it is necessary to actively study during all weeks of the course. It is assumed that the students have followed the reading instructions before each lecture, since the lectures contains sections that require active participation from the students.

Note that the weekly student recitations which also require preparation ahead of each class!

The course gives 7.5 credits (HEC) (200 hours of which 46 hours are in class).

Course overview

- 12 scheduled lectures (recommend attendance)
- 6 student recitations (mandatory attendance)
- 1 laboratory session with 2 seminars (mandatory attendance)

Lectures

There are reading instructions at the end of this course-PM. During the lectures there will be sections that require active participation by the students, so called concept questions or types of guided discussions.

Student recitations

The material for each student recitation is posted in Canvas. Each week six (6) new problems are assigned.

Before each student recitation the students should try their best to solve all problems.

The student should also prepare to present the solution on the board (or scanned notes in Zoom) for the class.

The level of difficulty of the problems on the student recitation corresponds to the written exam.

In detail, a student recitation is organized as follows:

1. At the beginning of the student recitation each student will sign-up (online in Canvas or Google Docs) to indicate which of the six problems he/she is prepared to present to the class
2. One student is randomly picked to present a solution
3. After the solution has been presented there is a discussion, in which all students are expected to participate. Students are expected to give feedback on the presented solution and possibly provide alternative solutions
4. When the discussion is finished a new student presents a solution to the next problem
5. When all problems have been presented and discussed the student recitation ends

The requirement for an acceptable presentation is that it should be clear to the teacher and the class that the student has made an honest attempt to solve the problem, but not necessarily getting the correct answer.

It is of course allowed (and encouraged) that students collaborate in order to prepare for the student recitations.

Laboratory work, seminars and report

Location:

Electrum building, KISTA CAMPUS, elevator C, level 3.

Signup:

Lab groups (four students) for signup will be scheduled by in Canvas.

Overview of tasks for completed lab course:

See also Lab Module in Canvas, to be announced according to current Covid-19 restrictions in February.

- Before the lab a dedicated lab seminar will introduce extraction procedure and report writing.
- During two hours measurement data is collected under the guidance of a lab assistant.
- After the lab, each student submits an individual lab report that presents the measurements, the extraction procedure and the results. The report should be submitted under the ASSIGNMENTS menu in Canvas. Submission deadline found in the schedule at the end of this course-PM.
- Feedback seminar and peer review: Reports for peer review will be assigned through Canvas. About half a page constructive feedback for each report must be posted in Canvas before the feedback seminar. At the feedback seminar each student will give (to their peers) and receive (from their peers) feedback on their reports.
- After the seminar students can improve their reports and the final report should be submitted before the second deadline stated in the schedule at the end of this course-PM.

Examination

1. Laboratory report (1.5 credits Pass/Fail))
2. Student recitations and Seminars (1.5 credits Pass/Fail)
3. Written examination. (4.5 credits and A-F grades according to criteria)

Laboratory report

Pass requirement, see above.

Student recitations

The student should attempt at least 20 out of the 36 assigned problems. The teaching assistant will keep track of your participation.

Written exam

The written exam consists of six (6) problems which are similar to the problems in the student recitations.

The grading is criteria based and a pass grade (E) requires that the students has demonstrated sufficient knowledge at E level for all intended learning outcomes. Grading criteria will be published in Canvas and discussed in class.

The allowed time on the written exam is 5 hours. Date and time for the written exam is given in the schedule at the end of this course-PM. Sign-up is mandatory and will be open online.

Format of the exam under current restrictions is open book exam with submission of scanned hand-written solutions through Canvas.

Teachers and additional information

Lectures & Course responsible

Professor Gunnar Malm, lectures, some seminars and labs.

Teachers and lab assistant

Teaching assistant Corrado Capriata, Student recitations 1-6, labs and seminars.

Examiner

Professor Gunnar Malm

Course prerequisites

Electromagnetic theory, electric circuit theory, introductory solid state physics, introductory quantum mechanics alternatively thermodynamics with statistical physics, basic chemistry.

Course literature

Modern Semiconductor Devices for Integrated Circuits, Chenming Calvin Hu, 2010, Pearson Education, ISBN-10: 0-13-700668-3.

Schedule and Reading Instructions

L=Lecture, S=Student recitation, Sem=Seminar, T=Tentamen

Activity	Date	Time	Place	Content	Reading Instruction
L1	Jan 18	13-15	Zoom	Course intro Bond model, Energy Band model, Fermi-Dirac distribution function	**This document and Canvas pages** **Ch. 1.1-1.9, 1.11, 2.1-2.2**
L2	Jan 19	15-17	Zoom	Energy Band model, n_o and p_o, Drift Current	**Ch. 1.1-1.9, 1.11, 2.1-2.2**
L3	Jan 25	13-15	Zoom	Diffusion currents Generation/Recombination	**Ch. 2.3-2.9**
S1	Jan 27	10-12	Zoom	Student recitation 1	**Online S1**
Sem 1 Labintro	Jan 29	9-10 (note 1 hour only)	Zoom	Extraction of properties from measurement data. What is a good written report?	**Will be summarized and posted online**
L4	Feb 1	13-15	Zoom	PN-diode: Electrostatics	**Ch. 4.1-4.5**
L5	Feb 3	10-12	Zoom	PN-diode: Drift and Diffusion currents	**Ch. 4.6-4.9**
S2	Feb 4	10-12	Zoom	Student recitation S2	**Online S2**
L6	Feb 8	15-17	Zoom	PN: Solar cells, LEDs and Diode Lasers	**Ch. 4.12-4.15**
Lab Weeks	Feb 9 – Feb 18	Sign-up for one 2h slot	Kista Campus or online	All course content until this week	**Instructions in Canvas and notes from first Seminar**
L7	Feb 11	10-12	Zoom	Schottky diodes and Ohmic contacts	**Ch. 4.16, 18-19, 21**
L8	Feb 12	13-15	Zoom	MOS Capacitor. Electrostatics	**Ch. 5.1-5.6**
S3	Feb 12	15-17	Zoom	Student recitation S3	**Online S3**
L9	Feb 15	10-12	Zoom	MOSFET: Electrostatics and drain current	**Ch. 6.1-6.2, 6.4-6.6**
L10	Feb 16	15-17	Zoom	MOSFET: Mobility and CMOS inverter	**Ch. 6.3 (Figure 6-9) and 6.7**
S4	Feb 17	13-15	Zoom	Student recitation S4	**Online S4**
L11	Feb 22	13-15	Zoom	MOSFET OFF-state and scaling	**Chap. 7 based on Figs. 7-2, 7-5 & 6, 7-9, 7-13 & 7-14, 7-18 & 7-19**
L12	Feb 24	10-12	Zoom	MOS-based memory devices and image sensors	**Ch. 6.16, Ch. 5.10 plus additional PDFs**
S5	Feb 24	13-15	Zoom	Student recitation S5	**Online S5**
Deadline	Feb 24	23.59	*First version of lab report submitted under ASSIGNMENTS menu*		
Sem 2 Peer Feedback	Feb 26	15-17	Zoom	Peer-review seminar on Laboratory report. Post feedback in Canvas before seminar	
S6	March 1	13-15	Zoom	Student recitation S6	**Online S6**
Deadline	*March 16 23.59*		*Final version of lab report submitted under ASSIGNMENTS menu*		

Summary	March 2	15-17	Zoom	Review of all chapters and grading criteria	**All**
Exam	March 16	8-13	Canvas	Written Exam *Online signup is mandatory!*	**All**
Re-exam	June 11	8-13	Canvas	Written Exam *Online signup is mandatory!*	**All**