IH1611
Semiconductor Devices
Spring 2020
https://kth.instructure.com/courses/17258

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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. In the course there are 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).
There are 12 scheduled lectures, 6 student recitations and one laboratory session with 2 associated seminars. Schedule and reading instruction are placed at the end of this course-PM.

Lectures

There are *Reading Instructions* at the end of this course-PM. The lectures are based on the assumption that the students have read according to Reading Instruction *before the lecture*. During the lectures there will be sections that require *active participation* by the students.

Student recitations

There are 6 student recitations in the course.
At the *first lectures 6 sheets containing 6 problems* (totally 36 problems) are distributed. The sheets are numbered as S1, S2, S3, S4, S5 and S6. Before each student recitations the student should try to solve the 6 problems on the sheet related to the student recitation in question. The *student* should also *prepare* to present the *solution on the board* 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 put a cross on a list to indicate which of the 6 problems he/she is prepared to present to the class
2. One student is randomly picked to present each problem.
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 6 problems have been presented and discussed the student recitation ends.

The number of crosses a student has on the list indicates how many problem the student has solved. The total number of problems is 36. To *be allowed* to attend *the written exam* the student has to acquire a *minimum of 20 crosses* after the 6 student recitations.

The scheduled time for each problem is 15 minutes but it would be appreciated if the student could present his/her solution faster to allow for discussion with the class.

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. For solving the problems any aid is allowed, but remember that on the written exam the only allowed aid is "IH1611 Material Properties and formulas" and a calculator.

If it is obvious that the student has NOT made an honest attempt to solve the problem (but has still crossed it on the list) all the crosses for the student from that student recitation is removed.

Laboratory work, seminars and report

Course lab includes a laboratory exercise in groups of four students. The place of the lab is in the Electrum building, KISTA CAMPUS, elevator C, level 4. Labs will be scheduled by signup in Canvas. During two hours measurement *data are collected* under the guidance of a lab assistant. After the lab, *each student independently determines device parameters* from measurements. Each student receives an individual assignment and will write an individual lab report that presents the measurements, the extraction procedure and the results. Method, results and conclusions must be clearly outlined. Results should be commented on regarding accuracy and students are expected to reflect on the relationship between measurements and theory. Results should be reported with well-structured diagrams, graphs and tables. A good lab report should be clear, as well as linguistically well-written. The *first seminar deals* with *extraction procedure* and with *report writing*.

The *laboratory report* should be submitted under the ASSIGNMENTS menu

Please use PDF only, no WORD or OPEN OFFICE files

The *first deadline* is stated in the schedule at the end of this course-PM.

All students will receive about three laboratory reports and and perform a peer review of these. The reports should be read and about half a page *constructive feedback* must be *prepared before the feedback seminar*. The written feedback should be brought in two copies (one to their peers and one to the course responsible) to the *feedback seminar* (date and time is given in the schedule at the end of this course-PM). 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

The course has three examinations that examine the course goals.

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

Laboratory report

The Laboratory work is awarded 1.5 credits. The grade on the Laboratory work is Pass/Fail. To be awarded the grade pass the student needs to participate in the laboratory session, the feedback seminar and file an individual laboratory report before the deadline.

Student recitations

To be allowed to attend the written exam the student has to acquire at least 20 crosses during the 6 student recitations.

Written exam

The written exam consists of six (6) problems which are similar to the problems dealt with on 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. The students are only allowed to bring "IH1611 Material Properties and formulas" and a calculator to the written exam. 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.

Teachers and additional information

Lectures & Course responsible

Associate Professor Gunnar Malm, lectures and course responsible

Teachers and lab assistant

Assistant Corrado Capriata, Student recitations 1-6, labs and seminares.

Assistant, laboratory sessions, 2h per group of four students

Examiner

Associate 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 16	10-12	D41	Course-PM, Bond model, Energy Band model, Fermi-Dirac distribution function	**Ch. 1.1-1.9, 1.11, 2.1-2.2**
L2	Jan 17	8-10	D41	Energy Band model, n_o and p_o, Drift Current	**Ch. 1.1-1.9, 1.11, 2.1-2.2**
L3	Jan 20	15-17	D41	Diffusion currents Generation/Recombination	**Ch. 2.3-2.9**
S1	Jan 21	15-17	D41	Student recitation 1	**Online S1**
Sem 1 Labintro	Jan 22	9-10	E36	Extraction of properties from measurement data. What is a good written report?	**Will be summarized and posted online**
L4	Jan 27	13-15	D41	PN-diode: Electrostatics	**Ch. 4.1-4.5**
L5	Jan 29	10-12	Q15	PN-diode: Drift and Diffusion currents	**Ch. 4.6-4.9**
S2	Jan 30	8-10	D41	Student recitation S2	**Online S2**
L6	Feb 3	15-17	E32	PN: Solar cells, LEDs and Diode Lasers	**Ch. 4.12-4.15**
L7	Feb 5	10-12	D41	Schottky diodes and Ohmic contacts	**Ch. 4.16, 18-19, 21**
L8	Feb 6	15-17	E36	MOS Capacitor. Electrostatics	**Ch. 5.1-5.6**
S3	Feb 6	15-17	E32	Student recitation S3	**Online S3**
L9	Feb 11	15-17		MOSFET: Electrostatics and drain current	**Ch. 6.1-6.2, 6.4-6.6**
L10	Feb 12	10-12	Q26	MOSFET: Mobility and CMOS inverter	**Ch. 6.3 (Figure 6-9) and 6.7**
S4	Feb 13	8-10	D41	Student recitation S4	**Online S4**
L11	Feb 17	10-12	E36	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 18	13-15	E36	MOS-based memory devices and image sensors	**Ch. 6.16, Ch. 5.10 plus additional PDFs**
S5	Feb 18	15-17	E36	Student recitation S5	**Online S5**
Deadline	Feb 19	23.59	*First version of lab report submitted under ASSIGNMENTS menu*		
Sem 2 Peer Feedback	Feb 21	15-17	D34	Peer-review seminar on Laboratory report. Bring your feedback in two copies, one to the teacher and one to your peer.	
S6	Feb 25	15-17	E36	Student recitation S6	**Online S6**
Deadline	*March 2 23.59*		*Final version of lab report submitted under ASSIGNMENTS menu*		
Summary	March 2	15-17	E36	Review of all chapters and grading criteria	**All**
T	March 12	8-13	E32, E36	Written Exam *Online signup is mandatory!*	**All**

Re exam	**June 3**	**8-13**	**U61**	**Written Exam** *Online signup is mandatory!*	**All**