COURSE DESCRIPTION

1. Program identification information

1.1 Higher education institution	**National University of Science and Technology Politehnica Bucharest**
1.2 Faculty	**Electronics, Telecommunications and Information Technology**
1.3 Department	**Electronic Devices, Circuits and Architectures**
1.4 Domain of studies	Electronic Engineering, Telecommunications and Information Technology
1.5 Cycle of studies	Masters
1.6 Programme of studies	Microsystems

2. Date despre disciplină

2.1 Course name (ro) (en)				Dispozitive semiconductoare de putere pentru microsisteme Power semiconductor devices			
2.2 Course Lecturer				Colaborator Dr. Mihai Brezeanu			
2.3 Instructor for practical activities				Colaborator Dr. Bogdan Ofrim			
2.4 Year of studies	1	2.5 Semester	I	2.6. Evaluation type	E	2.7 Course regime	Ob
2.8 Course type	DA	2.9 Course code		UPB.04.M1.O.03-03		2.10 Tipul de notare	Nota

3. Total estimated time (hours per semester for academic activities)

3.1 Number of hours per week	3	Out of which: 3.2 course	2.00	3.3 seminary/laboratory	1
3.4 Total hours in the curricula	42.00	Out of which: 3.5 course	28	3.6 seminary/laboratory	14

Distribution of time:	hours
Study according to the manual, course support, bibliography and hand notes Supplemental documentation (library, electronic access resources, in the field, etc) Preparation for practical activities, homework, essays, portfolios, etc.	52
Tutoring	3
Examinations	3
Other activities (if any):	0

3.7 Total hours of individual study	58.00
3.8 Total hours per semester	100
3.9 Number of ECTS credit points	4

4. Prerequisites (if applicable) (where applicable)

4.1 Curriculum	Graduation of the following courses: Electronic Devices Fundamentals Electronic Circuits Basics of Microelectronics Technologies
4.2 Results of learning	Following knowledge is necessary: Basic knowledge of physics and electronic devices

5. Necessary conditions for the optimal development of teaching activities (where applicable)

5.1 Course	Course classes will take place in a classroom having video-projector and laptop. For synchronous online broadcasting & recording, high speed Internet connection is necessary.
5.2 Seminary/ Laboratory/Project	Laboratory classes will take place in a classroom having at least as many computers as the number of students Computers have Linux like operating system and the Cadence IC design software suite Software licenses for the Cadence software

6. General objective *(Reffering to the teachers' intentions for students and to what the students will be thought during the course. It offers an idea on the position of course in the scientific domain, as well as the role it has for the study programme. The course topics, the justification of including the course in the currcula of the study programme, etc. will be described in a general manner)*

Based on fundamental knowledge of semiconductor physics, electronic devices and circuits, PSD aims to present main concepts and structures of power semiconductor devices, to illustrate their utility and applicability, developing the students' capability to design, numerically simulate, model, experimentally measure, optimize and connect them in integrated microsystems.

PSD addresses the most important and widely used power semiconductor devices structures. The course introduces P-i-N and power Schottky diodes, power MOSFETs and JFETs, power bipolar transistors, IGTBs and thyristors. Each device is presented from both theoretical and practical angles, concepts regarding their geometrical, physical, chemical, and electrical behavior being complemented by considerations regarding suitable applications and targeted market.

7. Competences *(Proven capacity to use knowledge, aptitudes and personal, social and/or methodological abilities in work or study situations and for personal and proffesional growth. They refflect the empolyers requirements.)*

Specific Competences	Demonstrates that the graduate has basic and **advanced knowledge** in the field of electronic devices and basic integrated circuits, as well as in the power semiconductor devices area, both for the design, numerical simulation, modelling, experimental measuring and optimization for carrying on power semiconductor devices projects. **Correlates knowledge** **Applies in practice the general knowledge** regarding the structure and the performance of power semiconductor devices **Applies standard methods and instruments** specific to the domain in order to evaluate and diagnoze the status of the task to be performed and, based on the conclusions identified/reported, identifies solutions. **Analyzes and arguments coherently and correctly** the base knowledge application context using key concepts and specific methodology. Oral and written communication in English language: demonstrates specific vocabulary mastering.
Transversal (General) Competences	**Works in a team and efficiently communicates**, coordinating her/his efforts to others efforts in order to solve medium size/complexity issues. **Autonomy and critical thinking**: ability to think using appropriate scientific terms, to independently search and analyze data and to draw and present conclusions / identify solutions. **Analysis and synthesis ability**: synthetically presents acquired knowledge via systematic analysis. **Follows academic ethics**: in the documentation activity properly cites the bibliographical sources.

8. Learning outcomes *(Synthetic descriptions for what a student will be capable of doing or showing at the completion of a course. The learning outcomes reflect the student's acomplishments and to a lesser extent the teachers' intentions. The learning outcomes inform the students of what is expected from them with respect to performance and to obtain the desired grades and ECTS points. They are defined in concise terms, using verbs similar to the examples below and indicate what will be required for evaluation. The learning outcomes will be formulated so that the correlation with the competences defined in section 7 is highlighted.)*

Knowledge	*The result of knowledge aquisition through learning. The knowledge represents the totality of facts, priciples, theories and practices for a given work or study field. They can be theoretical and/or factual.* Lists the most important areas of applicability of the studied device structures. Correctly defines domain-specific terms and concepts. Describes/classifies concepts / processes / phenomena / structures. Emphasizes and describes connections and consequences.

Skills	*The capacity to apply the knowledge and use the know-how for completing tasks and solving problems. The skills are described as being cognitive (requiring the use of logical, intuitive and creative thinking) or practical (implying manual dexterity and the use of methods, materials, tools and intrumentation).* Selects and groups relevant information in a specific context. Uses specific principles, based on arguments, in order to effectively design chips and achieve the “first-time-success” goal. Works productively in a team. Elaborates scientific texts. Experimentally verifies identified solutions. Solves practical applications. Correctly interprets the causality connections. Analyses and compares different design styles. Identifies solutions and elaborates solution plans/projects. Draws conclusions from the experiments. Justify identified solutions.
Responsability and autonomy	*The student's capacity to autonomously and responsably apply their knowledge and skills.* Selects appropriate bibliography and analyses it. Follows academic ethics, correctly citing sources. Proves receptivity for new learning contexts. Collaborates with her/his colleagues and teachers during the didactic process. Proves autonomy in setting up teaching/solving problem context/. Proves social responsibility by actively involving in student social live/implication in academic community events. Promotes/contributes to social live improvement by new solutions in her/his specialization domain Is aware of her/his contribution in engineering field, in identifying viable/sustainable solutions to solve socio-economic issues (social responsibility). Applies ethical principles/professional deontology in analysis of environmental effects of proposed technological solutions. Analyzes and exploits business opportunities / entrepreneurial development in the domain. Proves management abilities in real life situations (time management collaboration vs. conflict).

9. Teaching techniques *(Student centric techniques will be considered. The means for students to participate in defining their own study path, the identification of eventual fallbacks and the remedial measures that will be adopted in those cases will be described.)*

Based on students’ study characteristics analysis and their specific needs, the teaching process will explore both exposing methods (lecture, exposition) and interactive dialogues, based on discovery teaching methods that are facilitated by direct reality exploration (experiment, demonstration, modelling), and also action based methods like exercises, practical activities and problem solving.

In the teaching, activity exposition will be used based on both Powerpoint and different recordings that will be available to the students. Each class will debut by reviewing previous chapters pointing out notions in the last previous class. Presentations use images and graphs in order to facilitate notions understanding and assimilation.

This course covers information and practical activities aimed to support students in learning and optimal collaboration and communication relations development in an discovery learning favorable environment.

Active listening and assertive communication abilities practice and feedback will be main means to behavioral adjustment in various situations and for didactic activity adaptation to students' needs.

Team working abilities will be exercised in order to solve various learning tasks.

10. Contents

COURSE		
Chapter	**Content**	**No. hours**
1	Introduction 1.1 What does power electronics refer to? 1.2 Market applications	2
2	Fundamentals 2.1 Fundamentals on semiconductor physics 2.2 More than Silicon: Wide band gap semiconductors	2
3	P-N Junction, P-N Diode 3.1 Holes and electrons 3.2 P-N junction 3.3 P-N diode structure	2
4	Power P-i-N Diode 4.1 I-V characteristics 4.2 On-state 4.3 Off-state 4.4 Comparison between punch-through and non-punch-through structures 4.5 Turn-on 4.6 Turn-off 4.7 Conclusions	2
5	Power Schottky Barrier Diode (SBD) 5.1 Schottky contact 5.2 Schottky diode structure 5.3 Power P-i-N diode vs power Schottky barrier diode 5.4 Power SBD on-state 5.5 Power SBD off-state 5.6 Power SBD switching	2
6	Power MOSFET Devices 6.1 Lateral MOSFET structures 6.2 Vertical power MOSFET structures 6.3 Parasitic effects 6.4 DMOSFET 6.5 DMOS: on-state, off-state, switching 6.6 DMOS: Power consumption 6.7 Comparison between power MOSFET structures 6.8 Comparison between Si and SiC power MOSFETs	4

7	Power Bipolar Junction Transistor (BJT) 7.1 Structure 7.2 I-V characteristics 7.3 Active region 7.4 Saturation 7.5 Breakdown 7.6 Switching 7.7 Safe operating areas	2
8	Superjunctions 8.1 BV versus Ron 8.2 Brief history of the superjunction concept 8.3 On-state 8.4 Off-state 8.5 Comparison with other type of power devices	2
9	Thyristors 9.1 Semiconductor Controlled Rectifier (SCR) 9.2 SCR vs power BJT 9.3 SCR: on-state, blocking, switching 9.4 Gate Turn Off Thyristor (GTO) vs SCR 9.5 GTO: on-state, blocking, switching 9.6 Comparison of GTO and SCR with other type of power devices	3
10	Insulated Gate Bypolar Transistors (IGBTs) 10.1 Punch-through versus non-punch-through structure 10.2 On-state, blocking, switching 10.3 Latch-up, safe operating areas 10.4 IGBT vs power MOSFETs 10.5 Trench IGBT 10.6 Historic evolution of IGBTs 10.7 Comparison between all power devices studied	3
11	Edge Terminations 11.1 Introduction and motivations 11.2 Termination structures with no p-n junctions 11.3 Termination structures with p-n junctions 11.4 Field plate based edge terminations for power devices - case study on synthetic diamond	4
	Total:	28

Bibliography:

N Mohan, T M Undeland W P Robbins, "Power Electronics Converters, Applications, and Design", Wiley, 2003
B J Baliga, "Fundamentals of Power Semiconductor Devices", Springer, 2008
B J Baliga, "Silicon Carbide Power Devices", World Scientific, 2005
F Udrea, P Mawby E Napoli,Napoli, "Modern Power Devices and Applications" Course, Cambridge, 2006
State-of-the-art papers and patents on power devices structure
Datasheets of state-of-the-art power devices

LABORATORY

Crt. no.	Content	No. hours
1	Study on the Keithley 4200-SCS semiconductor characterization system	2
2	Study on probe station unit	2
3	Measure and characterize the resistance of a buried layer in bipolar-CMOS-DMOS technology & Configure, perform and analyze experimental measurements performed with semiconductor characterization system and with probe station unit	2
4	Study on power MOS transistor and on a Si-based resistive structure	2
5	Bipolar-CMOS-based power and low voltage DMOS transistors characterization. Configure, perform and analyze experimental measurements performed with semiconductor characterization system and with probe station unit – Part 1	2
6	Bipolar-CMOS-based power and low voltage DMOS transistors characterization. Configure, perform and analyze experimental measurements performed with semiconductor characterization system and with probe station unit – Part 2	2
7	Laboratory final test	2
	Total:	14

Bibliography:
1. Keithley Instruments, Inc., "Model 4200-SCS Semiconductor Characterization System – Reference Manual", Rev. L / May 2010

11. Evaluation

Activity type	11.1 Evaluation criteria	11.2 Evaluation methods	11.3 Percentage of final grade
11.4 Course	Ability to understand the concepts studied in real time, to formulate questions and to support discussions based on them.	Evaluation during the term	10%
	Knowledge of fundamental theoretical notions and ability to solve problems specific to each device studied	Evaluation during final exam - multiple choices	30%
	Ability to compare studied structures	Evaluation during final exam - problem	20%
11.5 Seminary/laboratory/project	Good understanding of notions presented during lectures and laboratory activities.	Final lab evaluation	10%
	Ability to apply lecture and lab knowledge	Final lab evaluation	20%
	Independent work abilities using appropriate software tools	Final lab evaluation	10%
11.6 Passing conditions			
Obtaining minimum 50% of the total score. Obtaining minimum 50% of the score at the final lab evaluation.			

12. Corroborate the content of the course with the expectations of representatives of employers and representative professional associations in the field of the program, as well as with the current state of knowledge in the scientific field approached and practices in higher education institutions in the European Higher Education Area (EHEA)

Due to the teaching activities, students develop power devices analysis and design abilities that are in high demand due to the unprecedented microelectronics domain development. Engineers for electronic and power devices design are necessary to sustain this rapid development.

The power devices studied are in permanent use by all commercial companies active in this field. The equipment employed and taught in the laboratory are used by virtual all companies active in Romania.

The course curricula is adapted to actual requests and tendencies of the technological evolution. Both classes and application activities provide to the students knowledge and competencies that facilitate fast enrolment into a prestigious company active in the IC design domain.

Current semiconductor market status highlights major unbalances between offer and demand that generated active, sustained and decisive actions at all decision levels of all states including the European Union. In the course development both literature described aspects, knowledge and phenomena and own contributions published or acquired in industrial activities were used.

he course has similar content to courses taught in: University of Cambridge, Univ. of Warwick, EPFL in Lausanne, etc.

Via the lab activities, practical situation management abilities are formed and developed. The course was developed in agreement with microelectronic Romanian companies like Infineon Technologies Romania, Microchip Romania and Onsemi Romania.

Date	Course lecturer	Instructor(s) for practical activities
22.10.2024	Colaborator Dr. Mihai Brezeanu	Colaborator Dr. Mihai Brezeanu

Date of department approval	Head of department
31.10.2024	Prof. Dr. Claudius DAN

Date of approval in the Faculty Council	Dean

01.11.2024 Prof. Dr. Mihnea Udrea