COURSE OUTLINE

(1) GENERAL INFORMATION

SCHOOL	SCHOOL OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES		
DEPARTMENT	SCHOOL OF APPLIED MATHEMATICAL AND PHYSICAL SCIENCES		
LEVEL OF STUDIES	POSTGRADUATE		
MSc PROGRAM	MICROSYSTEMS AND NANODEVICES		
COURSE CODE	**9953**	**SEMESTER**	**1**
COURSE TITLE	MICRO- AND NANOSYSTEMS FABRICATION PROCESSES		

INDEPENDENT TEACHING ACTIVITIES *In cases where credits are awarded to discrete parts of the course (e.g., Lectures, Laboratory Exercises, etc.), specify them. If credits are awarded as a whole, specify weekly teaching hours and total credits.*	**WEEKLY TEACHING HOURS**	**ECTS**
Lectures – Exercises	4	7.5
Laboratory		
(Additional rows may be added if necessary. Detailed descriptions of teaching organization and methods are provided in section (d).)		

COURSE TYPE *general background, specialized background, specialization, skill development*	GENERAL BACKGROUND (for Core Courses)
PREREQUISITES:	[REQUIRED BACKGROUND KNOWLEDGE]: A foundational knowledge of undergraduate-level physics, chemistry, and mathematics, along with some basic understanding of electronics and electrical engineering.
LANGUAGE OF INSTRUCTION and EXAMINATION:	GREEK
COURSE AVAILABLE TO ERASMUS STUDENTS	YES (offered in English as a reading course).
COURSE WEBSITE (URL)	

(2) LEARNING OUTCOMES

Learning Outcomes

This section describes the learning outcomes of the course, specifying the knowledge, skills, and competencies at the appropriate level that students will acquire upon successful completion of the course.

Refer to Appendix A:

- *Description of the Level of Learning Outcomes for each cycle of studies according to the European Higher Education Area Qualifications Framework*
- *Descriptive Indicators for Levels 6, 7, & 8 of the European Qualifications Framework for Lifelong Learning and Appendix B.*
- *Concise Guide to Writing Learning Outcomes*

Knowledge:

Specialized Knowledge: Micro- and Nanomechanical Processes: In-depth understanding of micro- and nanofabrication processes in both vacuum and atmospheric conditions, specifically for constructing microsystems and microchips.

Cutting-Edge Technology Knowledge: Comprehensive knowledge of core planar technology processes used in the production of integrated circuits (ICs), integrated sensors, photonic devices, and micro- and nano-scale electronic systems (MEMS, NEMS): Key processes include silicon oxidation, diffusion and ion implantation, thin-film deposition, surface patterning using lithography and etching, and metallization.

Cross-Disciplinary Integration: Basic knowledge of packaging for ICs and micro-/nano-electromechanical systems (MEMS/NEMS). Familiarity with commercial lithography process simulators widely used in industry, and foundational knowledge of vacuum principles.

This course establishes a foundation that allows students to integrate knowledge from multiple fields, enabling them to recognize the manufacturing methods of ICs, sensors, photonic devices, or MEMS/NEMS, understand their functionality, and compare devices based on quality and capabilities.

Skills:
Upon successful completion of the course, the student will be able to:

- Understand the fabrication processes of ICs, sensors, photonic devices, and MEMS/NEMS, which draw on multiple knowledge areas (primarily Physics, Chemistry, Chemical Engineering, Materials Science, Electrical and Mechanical Engineering).
- Explain the operating principles of these devices.
- Construct basic ICs, sensors, photonic devices, or MEMS/NEMS.
- Implement solutions for surface processing challenges.
- Propose solutions to problems across diverse fields, such as food, health, environment, and energy.
- Utilize the PROLITH simulation package by KLA and other topography evolution simulators to design lithography and plasma etching processes.

Course Objectives:
Familiarization with Fabrication Processes: Equip students with a comprehensive understanding of the various fabrication processes for ICs and MEMS/NEMS using planar technology.

Practical Training: Provide hands-on experience in cleanroom processes at the Institute of Nanoscience and Nanotechnology of NCSR “Demokritos”, familiarizing students with specific planar technology techniques, as well as with the characterization and measurement of fabricated devices and systems through laboratory demonstrations

General Competencies
Considering the general competencies that graduates are expected to acquire (as stated in the Diploma Supplement), which competencies does this course aim to develop?.

Data search, analysis, and synthesis, utilizing necessary technologies *Adaptability to new situations* *Decision-making* *Independent work (primarily through assignments completed at home)* *Teamwork* *Working in an international environment* *Working in an interdisciplinary environment*	*Generation of new research ideas* *Project design and management* *Respect for diversity and multiculturalism* *Respect for the natural environment* *Exhibiting social, professional, and ethical responsibility and sensitivity to gender issues* *Critical and self-critical thinking* *Promotion of free, creative, and inductive thinking*

Competencies:
Upon successful completion of the course, students will develop the following competencies:

- **Conceptualization/Design** of an IC, MEMS/NEMS, or a specific surface processing method.
- **Independent Work** for simple constructions and **Teamwork** for more complex projects.
- **Task Organization and Delegation**: Ability to categorize and assign tasks to third parties effectively.
- **Process Formulation and Integration**: Synthesizing all necessary processes to fabricate the designed IC or MEMS/NEMS.
- **Evaluation and Characterization**: Assessing the final microsystem through measurements and quality characterization.

Learning Outcomes:

Upon completion of the course, students are expected to have acquired the following knowledge:

- Physicochemical Processes: An understanding of the fabrication processes for integrated microsystems, enabling them to comprehend issues related to the architecture of microelectronic devices and sensors.
- Basic Vacuum Technology: Fundamental knowledge of vacuum techniques relevant to microsystem fabrication.
- Surface Processing Techniques: Foundational knowledge in surface processing methods, such as plasma treatment.
- Surface Characterization: Basic skills in surface characterization techniques.
- Electrical Measurements of Devices: Fundamental understanding of electrical measurement techniques for device characterization.

(3) COURSE CONTENT

Course Description

This course introduces planar technology for the fabrication of ICs and MEMS/NEMS within cleanroom environments, covering step-by-step the fabrication processes associated with planar technology. Starting with pattern transfer after a surface process (e.g., oxidation, deposition) using lithography and etching, the course progresses to material doping to achieve p-type or n-type characteristics and concludes with the interconnection processes of various components (transistors, capacitors, resistors, etc.). Each process is accompanied by an exploration of the underlying physics and chemistry, equipment, and simulation software.

Weekly Topics Outline:

1. Introduction to Integrated Circuits (ICs): Basic functions, arithmetic operations with ICs, and an overview of planar technology, covering all fabrication steps.
2. Crystal Growth and Cleanrooms: Crystal structure of silicon, wafer manufacturing and type marking, impurity gettering and electrical deactivation, RCA wafer cleaning, and cleanroom specifications.
3. Silicon Oxidation: Equipment, oxidation mechanisms, dry and wet oxidation processes, oxide types and applications, oxide characterization, and oxidation rate simulation.
4. Diffusion and Implantation: Equipment, thermal diffusion, ion implantation, diffusion and implantation mechanisms, and dopant profile simulation.
5. Lithography (1): Basic principles and resolution.
6. Lithography (2): Contact and projection printing, processes, and equipment.
7. Lithography (3): Fourier transforms and lithography simulation using commercial software like PROLITH.
8. Vacuum Techniques: Types of vacuum, vacuum pumps (mechanical, diffusion, turbo, cryogenic), vacuum measurement (Pirani, Penning, Baratron, Bayard-Alpert gauges), and other vacuum-related techniques.
9. Etching (1): Introduction to plasma processes for pattern transfer.
10. Etching (2): Surface and gas-phase chemistry, physics, and front evolution simulation using software such as FETCH.
11. Thin Film Deposition: Vapor deposition techniques and equipment; physical methods (evaporation, sputtering); chemical methods (Chemical Vapor Deposition - CVD, Atomic Layer Deposition - ALD).
12. Film Characterization: Techniques for film analysis, including X-ray and electron diffraction, spectroscopy (FTIR, XPS, UPS), microscopy (optical, SEM, TEM, AFM, STM), optical characterization (UV-Vis-NIR reflectance-transmittance, ellipsometry), and electrical characterization (I-V and C-V measurements).
13. Metallization and Packaging: Aluminum and silicon oxide metallization (equipment, lift-off

method), copper metallization, low-k dielectrics, packaging techniques (dicing, wire bonding, Dual in Line - DIL, Surface Mount Technology - SMT, flip-chip), and packaging hierarchy.

(4) TEACHING AND LEARNING METHODS - ASSESSMENT

TEACHING METHOD *In person, Distance Learning etc.*	In person
USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) *Use of Information and Communication Technologies (ICT) in Lecturing, Laboratory Training, Communication with Students*	Course Notes, Assignments for Home Study **(**Assignments are provided by the lecturer, and students are required to submit completed work.)
ORGANIZATION OF TEACHING *A detailed description of the teaching methods and approaches used in the course, which may include:* *Lectures, Seminars, Laboratory Exercises, Fieldwork, Study and Analysis of Bibliography, Tutorials, Internships, Clinical Exercises, Art Workshops, Interactive Teaching, Educational Visits, Project Development, Report Writing/Assignments, Artistic Creation.* *The student's study hours for each learning activity, as well as hours of independent study, are outlined in accordance with ECTS principles.*	see table below

Activity	***Semester Workload***
Lectures	13x3=39 hours
Study	13x4=52 hours
Home Assignments/Exercises	13x4=52 hours
Laboratory	6 hours
Completion/Presentation of Assignment	30 hours
Educational Visits	0
Examinations	4 hours
Total Course Load	182 hours

STUDENT ASSESSMENT *Description of the Assessment Process* *Language of Assessment, Assessment Methods, Formative / Summative Assessment Methods, Multiple-choice tests, Short-answer questions, Essay-style questions, Problem-solving exercises, Written assignments, Reports, Oral examinations, Public presentations, Laboratory work, Clinical patient examinations, Artistic interpretations, Other methods, as appropriate* *The assessment criteria are clearly defined and provided to students, ensuring transparency in the evaluation process. These criteria are accessible through the course's online platform where students can review them at any time.*	**Language of Assessment:** Greek (for Erasmus students: English) **Home Assignments:** 10% of the final grade **Written Examination (problem-solving):** 80% of the final grade **Laboratory:** 0% (requires physical attendance but does not contribute to the grade) **Completion/Presentation of Project** 10% of the final grade Explicit mention of these assessment criteria will be available on the mycourses electronic platform.

(5) RECOMMENDED BIBLIOGRAPHY

- Silicon VLSI Technology, Fundamentals, Practice and Modeling, J.D. Plummer, M. D. Deal, P.B. Griffin, Prentice Hall 2000
- S. Franssila, Introduction to Microfabrication, 2010, Wiley

Related Scientific Journals

- Micro and Nano Engineering, Microsystems and Nanoengineering, Microelectronic Engineering, Journal of Vacuum Science & Technology B, Microsystems Technology