Course guide
230852 - SEM - Surface Engineering and Microdevices

Last modified: 30/05/2022

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications.

Degree: MASTER'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2018). (Compulsory subject).

Academic year: 2022 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura

Others: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma

PRIOR SKILLS

- Electromagnetic wave propagation. Guided waves. Transmission lines (input impedance, reflection coefficient, voltage standing-wave ratio, transmitted power, Smith chart)

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Basic:
CB6. (ENG) Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación
CB7. (ENG) Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.
CB10. (ENG) Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

TEACHING METHODOLOGY

MD1 – Master classes
MD5 - Individual assignments (written document)
MD7 – Practical exercises both theoretical resolution and using software tools (circuit/electromagnetic and electromechanical)
MD10 - Laboratory practice performed by teams

LEARNING OBJECTIVES OF THE SUBJECT

- To understand the behavior of fluids at a micro scale
- To know how to design microfluidic circuits
- To know the methods of integration of microfluidic systems with MEMS sensors
- To know the operation and the main configurations of RF-MEMS micro-switches
- To learn how to analyze RF-MEMS micro-switches mechanically and electromagnetically
- To know the applications of RF-MEMS micro-switches to communication circuits
- To understand and to know how to use experimental configurations to characterize MEMS micro-switches
- To know the basic theory of transmission lines and its application to transmission-line resonators
- To learn how to use trasmission-line resonators to measure the physical properties of liquids
- To understand and use the experimental setup for measurement of liquids based on microstrip transmission-line resonators

STUDY LOAD

Type	Hours	Percentage
Hours large group	48,0	37.21
Self study	81,0	62.79

Total learning time: 129 h

CONTENTS

1. Mechanics and Fluids at micron scale

Description:
This course is designed to introduce students to the science and technology of microfluidics, including basics of flow principles, transport, and special microscale phenomena, as well as the basics of designing and manufacturing microfluidics and MEMS devices.

Specific objectives:
1. Students will be familiar with the concepts of laminar flow, viscosity, surface tension, dimensionless numbers, Navier-Stokes equations.
2. Students will be able to interpret basic principles in microfluidics and dimensionless numbers.
3. Students will be able to list real-life applications of microfluidics and MEMS devices.
4. Students will be able to design and manufacture simple microfluidic components and devices.
5. Students will be able to perform basic microfluidic experiments and analyze experimental results.
6. Students will be able to communicate effectively in the scientific and technological endeavor through writing technical reports.

Related activities:
Simulation of microfluidic and micromechanical circuits
Laboratory measurement sessions:
• Microfabrication session and characterization of hair systems.
• Characterization session of colorimetric and / or electrochemical sensors.
• Fluid behavior characterization session using micro Particle Image Velocimetry

Full-or-part-time: 44h
Theory classes: 15h
Laboratory classes: 13h
Self study : 16h

1.1 Micrometric-scale fluid mechanics

Description:
Introduction to fluid mechanics. Newtonian, non-Newtonian fluids, flow on infinite plates, laminar and turbulent flow, compressible and incompressible flows. Types of flows.
Review of detection principles and micro / nano devices for biodetection. Basic principles of biosensors

Specific objectives:
Design of microfluidic circuits by analytical and numerical methods.
Microfluidic circuit simulation tools.
Application to microcapillary circuits, colorimetric and electrochemical sensors for salt concentration measurements.
Characterization of microfluidic flows.

Related activities:
Simulation of microfluidic circuits.
• PRACTICE 1: microfabrication and characterization of hair systems.
• PRACTICE 2: characterization of colorimetric and / or electrochemical sensors.
• PRACTICE 3: Session of characterization of the behavior of the fluids by means of micro Particle Image Velocimetry

Full-or-part-time: 28h
Theory classes: 9h
Laboratory classes: 9h
Self study : 10h

1.2 Micrometric-scale mechanics

Description:
The laws of scale involved in MEMS, structural mechanics, basic principles of detection and drive. Principles of device manufacturing and integration, device simulation tools and typical RF MEMS applications.

Specific objectives:
Design of micromechanical devices for analytical and numerical methods.
Micromechanical switch simulation tools.
Application of RF switches.

Related activities:
Simulation of an RF Switch using ANSYS.
Visit to ALBA Synchrotron.

Full-or-part-time: 16h
Theory classes: 6h
Laboratory classes: 4h
Self study : 6h

2. RF-MEMS micro-devices and application in communication circuits

Description:
Micro-devices applied to reconfigurable RF/microwave communication circuits

Specific objectives:
Sensing methods based on electromagnetic phenomena. High-frequency circuits are used to measure physical properties of materials (liquids) such as solvent concentration. The high-frequency circuits are based on transmission line resonators and may include RF-MEMS devices. RF-MEMS devices are used to implement RF actuators for reconfigurable sensors

Related activities:
High frequency circuit simulation.
Laboratory measurement sessions:
- High-frequency circuits based on transmission lines
- Physical properties of liquids using transmission-line resonators

Full-or-part-time: 32h
Theory classes: 10h
Laboratory classes: 10h
Self study : 12h

2.1 High-frequency (HF) circuit theory and sensing applications

Description:
Transmission line theory. Planar transmission lines (microstrip and CPW). Lumped elements and distributed elements. High frequency circuit simulation CAD tools. Transmission line resonators as material sensors.

Specific objectives:
High-frequency circuit theory and implementation of planar transmission lines in microstrip and CPW (Coplanar Waveguide) configurations.
CAD tools for simulation of high-frequency circuits.
Application of transmission-line resonators to the measurement of physical properties of materials (liquids) such as solvent concentration.

Related activities:
SImulation of transmission-line microstrip resonators.
PRACTICE 1: Measurement of transmission lines
PRACTICE 2: Measurement of materials (fluids) using transmission line resonators

Full-or-part-time: 19h
Theory classes: 4h
Laboratory classes: 8h
Self study : 7h

2.2 RF MEMS actuators for high-frequency applications

Description:
Micro-switch structures: ohmic contact and capacitive contact. Mechanical parameters. Equivalent electrical circuit at RF/microwave frequencies. Steady-state analysis. Simulation tools (circuit analysis). Measurement methods of RF-MEMS actuators. Application to reconfigurable communication circuits.

Specific objectives:
RF-MEMS actuator topologies.
Theoretical analysis and CAD simulation tools for RF MEMS.
Laboratory measurement of mechanical and electromagnetic parameters of RF MEMS using electromagnetic wave techniques.
Examples of reconfigurable communication circuits using RF MEMS

Related activities:
Circuit simulation of RF-MEMS actuators
PRACTICE 3: Measurement of the characteristic parameters of RF-MEMS actuators
Simulation of an RF-MEMS reconfigurable filter

Full-or-part-time: 13h
Theory classes: 6h
Laboratory classes: 2h
Self study : 5h

GRADING SYSTEM

E1: Written exams: 20%
E3: Assignments: 80%
No re-evaluation will be held

EXAMINATION RULES.

The written exams are done in class and require CAD sotware tools.
The assignments require CAD software tools. They include homework exercises and laboratory practices.
The laboratory practices are performed in teams of 2-3 students

BIBLIOGRAPHY

Basic:
- Pozar, D.M. Microwave engineering [on line]. 4th ed. Hoboken: Wiley, 2012 [Consultation: 09/04/2021]. Available on: https://ebookcentral.proquest.com/lib/upcatalunya-ebooks/detail.action?docID=2064708. ISBN 9780470631553.
- Rebeiz, G.M. RF MEMS: theory, design, and technology. Hoboken: Wiley-Interscience, 2003. ISBN 0471201693.
- Senturia, Stephen D. Microsystem design [on line]. Boston: Kluwer Academic, 2001 [Consultation: 21/05/2020]. Available on: http://link.springer.com/book/10.1007/b117574. ISBN 0792372468.
- Bruus, H. Theoretical microfluidics. Oxford: Oxford University Press, 2008. ISBN 9780199235094.

RESOURCES

Computer material:
- Programari ANSYS. Resource
- Programari ADS. Resource

Other resources:
- Course notes and presentations (through the UPC Atenea digital campus)
- Student license for simulation software tools