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230852 - SEM - Surface Engineering and Microdevices

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 739 - TSC - Department of Signal Theory and Communications
Academic year: 2019
Degree: MASTER'S DEGREE IN ENGINEERING PHYSICS (Syllabus 2018). (Teaching unit Compulsory)
ECTS credits: 5 Teaching languages: English

Teaching staff

Coordinator: Pradell Cara, Lluis

Others: Llorca Pique, Jordi
Casals Terre, Jasmina
Pradell Cara, Lluis

Prior skills

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

Requirements

- Course on Electromagnetic Waves

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 know the structure of the surfaces and the main characterization techniques
- To understand the physical and chemical phenomena that take place on the surfaces of solid materials and their applications
- To develop the ability to modify a solid surface with desired properties
- To know how to apply the knowledge acquired to develop microreactors
- To understand the behavior of fluids at a micro scale

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- 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

Study load

Total learning time: 125h	Hours large group:	44h	35.20%
	Self study:	81h	64.80%

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Content

1. Physical Chemistry of surfaces

Learning time: 15h
Theory classes: 15h

Description:
Design, preparation, characterization and applications of solid surfaces.

1.1 Introduction to surfaces

Learning time: 2h
Theory classes: 2h

Description:
The surface boundaries. Surfaces at the nanoscale, microscale and macroscale. The importance of deffects.

1.2 Structure of surfaces

Learning time: 3h
Theory classes: 3h

Description:
Ordered vs. amorphous surfaces. Epitaxial relationships. Surface vacancies

1.3 Solid-liquid and solid-gas interphases

Learning time: 2h
Theory classes: 2h

Description:
Surface reconstruction and relaxation. Adsorption and desorption phenomena.

1.4 Characterization techniques

Learning time: 3h
Theory classes: 3h

Description:
Surface characterization techniques. Electron microscopy techniques (HRTEM, STEM), scanning probe microscopies (AFM, STM), and spectroscopies (IR, Raman, XPS).

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1.5 Applications in sensors and catalysis	Learning time: 3h Theory classes: 3h

Description:
Reactivity of surfaces. Gas-solid interactions. Chemical transformations. Sensors and catalysts.

1.6 Functionalization of nano- and microreactors	Learning time: 2h Theory classes: 2h

Description:
The microreactor concept. Surface activation. Plasma treatment. Surface functionalization

2. Mechanics and Fluid mechanics at micron scale	Learning time: 15h Theory classes: 15h

Description:
Introduction to Fluid mechanics. Newtonian, nonNewtonian fluids, Flow over infinite plates, laminar and turbulent flow, Compressible and Incompressible flows. Types of flows. Flow rate calculations.

2.1 Introduction to micromechanic and microfluidic behavior	Learning time: 3h Theory classes: 3h

Description:
Introduction Nanotechnology and MEMS, MEMS design, and fabrication technology – Lithography, Etching, MEMS material, Bulk micromachining, Surface micromachining, Microactuator, electrostatic actuation.

2.2 Biosensor structure	Learning time: 2h Theory classes: 2h

Description:
Review of sensing principles and micro/nano devices for bio-sensing a. Basic principle of biosensors. b. Bioelectric potentials and typical bio-targets. b. Amperometric, potentiometric and impedimetric biosensors. D. Electrochemical sensors and FET-based biosensors. e. Acoustic and piezoelectric biosensors. f. Optical biosensors

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2.3 Design and simulation of the biosensor fluidic behavior	Learning time: 3h Theory classes: 3h

Description:
Finite element modelling of a microfluidic mixer.

2.4 Design and simulation of the biosensor mechanic behavior	Learning time: 3h Theory classes: 3h

Description:
Finite element modeling of a mechanical microswitch.

2.5 Case studies in bioengineering and communications	Learning time: 2h Theory classes: 2h

Description:
Sample preparation microchips: From macro to micro. MEMS-based bio-chip/sensors for Molecules detectio

3. RF-MEMS micro-devices applied to communication circuits	Learning time: 15h Theory classes: 15h

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

3.1 Introduction to RF-MEMS micro-devices and planar circuits	Learning time: 3h Theory classes: 3h

Description:
Structure of a micro-device. Surface micromachining. Fabrication materials. Integration in planar circuits. Planar transmission lines (microstrip and CPW). Lumped elements and distributed elements

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3.2 Design and simulation of planar RF-MEMS micro-switches	Learning time: 3h Theory classes: 3h

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)

3.3 RF-MEMS micro-switch electromagnetic simulation	Learning time: 3h Theory classes: 3h

Description:
Electromagnetic analysis of planar circuits. Comparison with circuit analysis. Co-simulation. Optimization

3.4 Application of RF-MEMS micro-switches to reconfigurable communication circuits. Circuit simulation	Learning time: 3h Theory classes: 3h

Description:
Amplifiers. Reconfigurable matching networks. Band-pass filters. Design and simulation

3.5 Experimental characterization of RF-MEMS micro-switches	Learning time: 3h Theory classes: 3h

Description:
Experimental set-up. Laboratory measurement of RF-MEMS micro-switches: pull-in and pull-out voltages. Microwave OFF and ON characteristics

Qualification system

E1: Written exams: 50-60%
E3: Assignments: 40-50%

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Bibliography

Basic:

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Rebeiz, G.M. RF MEMS: theory, design, and technology. Hoboken: Wiley-Interscience, 2003. ISBN 0471201693.

Adamson, A.W.; Gast, A.P. Physical chemistry of surfaces. 6th ed. New York: John Wiley & Sons, 1997. ISBN 9780471148739.

Bruus, H. Theoretical microfluidics. Oxford: Oxford University Press, 2008. ISBN 9780199235094.

Senturia, Stephen D. Microsystem design. Boston: Kluwer Academic, 2001. ISBN 0792372468.

Others resources:

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