COURSE DATA

Data Subject

Code	M4-44420
Name	Physical nanomanufacturing techniques
Cycle	Master's degree
ECTS Credits	3.0

Study (s)

Degree	Center	Acad. year	Period
2208 - Master's Degree in Molecular Nanoscience and Nanotechnology	Faculty of Chemistry	1	First term

Subject-matter

Degree	Subject-matter	Character
2208 - Master's Degree in Molecular Nanoscience and Nanotechnology	4 - Physical nanomanufacturing techniques	Obligatory

Coordination

Name	Department
DÍAZ GARCÍA, MARíA ÁNGELES	Física Aplicada- U. de Alicante

SUMMARY

The aim is that students learn basic concepts related to nanofabrication based on a bottom-up approach. Particular focus will be devoted to the possibilities and limits of the lithographic techniques, as nanofabrication tools.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

There are no specified enrollment restrictions with other subjects of the curriculum.

Other requirements

Previous knowledge of chemistry, physics or materials science as taught in the degrees indicated in the recommended entry profile to the master's degree is required. Previous knowledge of molecular nanoscience and nanotechnology as taught in the Introduction Module is required.

COMPETENCES (RD 1393/2007) // LEARNING OUTCOMES (RD 822/2021)

2208 - Master's Degree in Molecular Nanoscience and Nanotechnology

- Students should apply acquired knowledge to solve problems in unfamiliar contexts within their field of study, including multidisciplinary scenarios.
- Students should be able to integrate knowledge and address the complexity of making informed judgments based on incomplete or limited information, including reflections on the social and ethical responsibilities associated with the application of their knowledge and judgments.
- Students should demonstrate self-directed learning skills for continued academic growth.
- Students should possess and understand foundational knowledge that enables original thinking and research in the field.
- To possess the necessary knowledge and abilities to continue with future studies in the PhD program in Nanoscience and Nanotechnology.
- For students from field of knowledge (e.g. chemistry) to be able to scientifically communicate and interact with colleagues from another field (e.g. physics) in the resolution of problems laid out by the Molecular Nanoscience and Nanotechnology.
- To know the methodological approaches used in Nanoscience.
- To know the main techniques for molecular systems nanofabrication.

LEARNING OUTCOMES (RD 1393/2007) // NO CONTENT (RD 822/2021)

The aim is that students acquire basic concepts related to a top-down approximation to nanofabrication. In particular, we will focus on the possibilities and limits of the different available lithographic techniques as tools for nanofabrication.

DESCRIPTION OF CONTENTS

1. M4. Physical nanofabrication techniques.

1) Introduction: Lithographic techniques in the context of nanofabrication techniques.

2) Optical lithography
2.1. Basic processes and lift-off.
2.2. Thin film deposition of resists by spin-coatting.
2.3. Photoresist exposition through a mask: methods and resolution; techniques for resolution improvement; Photoresists: types, examples, evaluation parameters, chemically amplified photoresists.

2.4. Holographic lithography
2.5. Limits and future of the technique.

3) Etching techniques
3.1 Wet etching techniques
3.2 Dry etching techniques: reactive ion etching (RIE) and variants, sputtering, laser ablation, etc
3.3 Clean rooms.

4) Nanolithography by nanoimprinting and microcontact.
5.1. Microcontact printing.
5.2. Nanoimprint lithography (NIL) and variants: thermal NIL, room temperatura NIL, solvent-assisted NIL, step and flash NIL, etc
5.3. Molding of plastics: hot embossing, injection, etc..

5) Electron beam lithography
5.1 The scanning electron microscope
5.2 Interactions between electrons and matter
5.3 Electron beam lithography: protocols and resolution
5.4 Applications and some examples: masks and nanotransistors

6) Focused Ion Beam Lithography and other direct patterning methods
6.1 Introduction
6.2 FIB methods: sputtering, milling, deposition
6.3 Appplications

7) Scanning probe lithography
7.1 The force microscope
7.2 The variety of Scanning probe lithographies
7.3 Oxidation SPL
7.4 Thermal SPL
7.5 Applications: Silicon nanowire transistors; bimolecular sensors; molecular architectures.

8) The atomic force microscope in biology and material sciences
8.1 Operational principles
8.2 AFM modes
8.3 Forces and spatial resolution
8.4 High resolution imaging of soft matter
8.5 Nanomechanical and single molecule force spectroscopies

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	15,00	100
Tutorials	5,00	100
Seminars	4,00	100
Other activities	2,00	100
Preparation of evaluation activities	39,00	0
Preparing lectures	10,00	0
TOTAL	**75,00**	

TEACHING METHODOLOGY

The classes of this subject will be taught, together with the rest of the basic module, intensively during 3 weeks in January and each year at a different university.

During the **theory classes**, the teaching staff will give an overview of the subject under study, emphasising new or particularly complex aspects. The necessary bibliographical sources will be indicated for students to study the subject in depth.

The practical classes of this subject will be devoted to the organisation of seminars in which problems related to the theoretical content will be posed and solved. Likewise, practical cases and other topics related to the subject will be discussed with the students.

The **practical classes** of this subject will be devoted to the organisation of seminars in which problems related to the theoretical content will be posed and solved. Likewise, practical cases and other topics related to the subject will be discussed with the students.

During these hours of practical activities, as far as possible, visits to laboratories and facilities related to the contents of the theoretical classes will be organised. This includes visits to device nanofabrication laboratories.

After the intensive face-to-face classes, the lecturers will ask students a series of **questions** about the contents of the course that the student will have to solve.

Professors will hold **tutorials** with the students to resolve any doubts and questions they may have. These tutorials will take place in person or remotely (email, videoconference, telephone, etc.) depending on whether the student and teacher are from the same or a different university.

Through all these activities, students will acquire the competences described in the corresponding section. The basic competences will be worked on above all during the seminars.

EVALUATION

The acquisition of the competences of the subject will be assessed by means of a written exam based on the questions posed to the students. The mark for this exam will represent 90% of the final mark for the subject.

Student participation during the training activities will represent 10% of the final grade.

In order to pass the course, it will be necessary to have attended 80% of the face-to-face training activities.

REFERENCES

Basic

- - From Instrumentation to Nanotechnology, J.W. Gardner, H.T. Hingle, Gordon & Breach Publishing Group, 1999.
  - Micromachines & Nanotechnology: The Amazing New World of the Ultrasmall, David Darling, Silver Burdett Press, 1995.
  - Zheng Cui (Author) Micro-Nanofabrication: Technologies and Applications; Higher Education Press; Springer; 2005.
  - E. Menard et al. Micro- and Nanopatterning Techniques for Organic Electronic an optoelectronic system; Chem. Rev. 107, 1117, 2007.
  - P. Rai-Choudhury (Ed) Handbook of Microlithography, Micromachining and Microfabrication, Vol. 1, SPIE Optical Engineering Press, Bellingham, WA, 1997
  - Kazuaki Suzuki & Bruce W. Smith (Eds.)Microlithography: Science & Technology, 2nd Ed. (Optical Sci. and Eng.); CRC Press, 2007
  - D. Xia, Z. Ku, S.C. Lee, and S.R.J. Brueck, Nanostructures and Functional Materials Fabricated by Interferometric Lithography, Adv. Mater. 23, 147 179 (2011).
  - Evolution in Lithography Techniques: Microlithographyto Nanolithography (Review) Ekta Sharma, Reena Rathi, Jaya Misharwal, Bhavya Sinhmar, Suman Kumari, Jasvir Dalal,and Anand Kumar. Nanomaterials 12, 2754 (2022).
  -Fundamentals of microfabrication and nanotechnology. M.J. Madou, CRC Press (2011)

Additional

- Amplitude modulation AFM, R. Garcia, Wiley-VCH (2010)
  Scanning Probe Microscopy: The lab on a tip, E. Meyer, H. Hug, R. Bennewitz, Springer (2004)
  Advanced scanning probe lithography, R. Garcia, A.W. Knoll, E. Riedo, Nature Nanotechnology 9, 577-587 (2014).
  Y.F. Dufrêne et al. Imaging modes of atomic force microscopy for application in molecular and cell biology. Nature Nanotechnology 12, 295-307 (2017).
  Controlling the emission properties of solution-processed organic distributed feedback lasers through resonator design. V. Bonal, J. A. Quintana, J. M. Villalvilla, P. G. Boj, M. A. D´az-Garc´a; Sci. Rep., 9, 11159 (2019).
  N,N´-bis(3-methylphenyl)-N,N´-dyphenylbenzidine based distributed feedback lasers with holographically fabricated polymeric resonators. V. Bonal, J.A. Quintana, J.M. Villalvilla P.G. Boj, R. Muñoz-Mármol, J.C. Mira-Martínez, M.A. Díaz-García; Polymers 13, 3843 (2021).