Universitat Autònoma de Barcelona

2023/2024

Nanomanufacturing

Code: 103306
ECTS Credits: 6

Degree	Type	Year	Semester
2501922 Nanoscience and Nanotechnology	OB	4	1

Contact

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Teaching groups languages

You can check it through this link. To consult the language you will need to enter the CODE of the subject.
Please note that this information is provisional until 30 November 2023.

Teachers

Xavier Borrise Nogué

Prerequisites

It is recommended to have passed the subjects of the three previous courses, especially those related to the areas of physics, engineering and electronics.

Objectives and Contextualisation

The objective of the module is to present the techniques and methods that exist of manufacture at a micro and nanometric scale, so that the student will be capable of defining an appropriate sequence of processes for the realization of any type of device or functional structure. The content is focused on the manufacture of structures and functional devices, and not on the obtaining of materials. There will be practical and varied examples of fabrication of nanometric structures and devices (nanomechanical structures, graphene-based devices, nanosensors, photonic devices, micro / nano fluidic, etc.). An introduction to the operation and execution of processes in a Clean Room will also be carried out.

Competences

- Adapt to new situations.
- Apply the concepts, principles, theories and fundamental facts of nanoscience and nanotechnology to solve problems of a quantitative or qualitative nature in the field of nanoscience and nanotechnology.

- Apply the general standards for safety and operations in a laboratory and the specific regulations for the use of chemical and biological instruments, products and materials in consideration of their properties and the risks.
- Be ethically committed.
- Communicate clearly in English.
- Communicate orally and in writing in one's own language.
- Demonstrate knowledge of the concepts, principles, theories and fundamental facts related with nanoscience and nanotechnology.
- Handle the standard instruments and materials of physical, chemical and biological testing laboratories for the study and analysis of phenomena on a nanoscale.
- Lead and coordinate work groups.
- Learn autonomously.
- Manage the organisation and planning of tasks.
- Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
- Operate with a certain degree of autonomy.
- Propose creative ideas and solutions.
- Reason in a critical manner
- Recognise and analyse physical, chemical and biological problems in the field of nanoscience and nanotechnology and propose answers or suitable studies for their resolution, including when necessary the use of bibliographic sources.
- Recognise the terms used in the fields of physics, chemistry, biology, nanoscience and nanotechnology in the English language and use English effectively in writing and orally in all areas of work.
- Resolve problems and make decisions.
- Show motivation for quality.
- Show sensitivity for environmental issues.
- Work correctly with the formulas, chemical equations and magnitudes used in chemistry.
- Work on the synthesis, characterisation and study of the properties of materials on a nanoscale from previously established procedures.

Learning Outcomes

1. Adapt to new situations.
2. Apply the acquired theoretical contents to the explanation of experimental phenomena.
3. Be ethically committed.
4. Communicate clearly in English.
5. Communicate orally and in writing in one's own language.
6. Correctly characterise nanomanufacturing processes using the suitable techniques in each case.
7. Correctly handle the specific equipment used in nanomanufacturing processes.
8. Critically evaluate experimental results and deduce their meaning.
9. Describe the general aspects of nanoscale synthesis, manufacture and processing.
10. Describe the main technological processes of planar technology and the physical, technological and economic limits of miniaturisation.
11. Describe the principles of atomic and molecular manipulation.
12. Describe the processes of nanostructure growth and devices from nanometric elements (nanophylls, molecules, nanotubes,?) and with the use of templates.
13. Describe the self-assembly processes in the manufacture of functional nanostructures and devices: Copolymers blocks, molecular coupling, self-ordering of particles
14. Distinguish the different types of nanolithography: by electron and ion welding, nanoprinting, nanostenciling and local probe microscopy techniques.
15. Draft reports on the subject in English.
16. Follow correctly the safety protocols for laboratories with ambient controlled and white rooms.
17. Identify the situations in which the different methodologies studied can help to resolve problematic situations and know how to select the best techniques.
18. Lead and coordinate work groups.
19. Learn autonomously.
20. Manage the organisation and planning of tasks.

21. Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
22. Operate with a certain degree of autonomy.
23. Perform bibliographic searches for scientific documents.
24. Perform nanomanufacture processes to obtain devices and systems on a nanoscale.
25. Present brief reports on the subject in English.
26. Propose creative ideas and solutions.
27. Propose suitable methods to characterise each of the processes used during nanomanufacture
28. Propose suitable nanomanufacture processes to obtain structures and devices on a nanoscale.
29. Reason in a critical manner
30. Recognise the correct terms for topics related to methodologies and experimentation in nanoscience and nanotechnology.
31. Resolve problems and make decisions.
32. Resolve problems with the help of the provided complementary bibliography.
33. Show motivation for quality.
34. Show sensitivity for environmental issues.
35. Specify the main characteristics of a white room.
36. Understand texts and bibliographies in English on each of the techniques, methodologies, tools and instruments in the subject area.
37. Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

Content

The subject is divided into four main blocks:

Module 1. Planar technology (10 h.T, 5 h.P)

The main processes of planar technology are described individually and the general aspects of micro / nano electronics technology are presented, as well as their evolution (miniaturization)

Introduction to planar technology: concept, waffers, sequence of processes, etc.
Individual technological processes: deposition (PVD and CVD), engravings (dry and wet), thermal processes, implantation, lithography.
Integration of processes, CMOS technology.
Evolution and limits of micro / nano electronics

Module 2. Nanolithography and "nanopatterning" (8 h.T, 4 h.P)

Lithography and nanopatronization techniques are described for the definition of nanostructures and nanodevices in surfaces. Examples of the current state of the art are presented.

Advanced optical lithography
Lithography by electron beam
Lithograph by ion beam
Nanoimprint lithography
Nanofabrication through SPMs
Other nanolithographies

Module 3 Nanofabrication "bottom-up" (6h.T)

We describe methods for performing nanostructures and devices based on a "bottom-up" approach, based on the assembly of individual nanometric elements to build structures and functional devices.

Self assembly and guided self assembly.
Structures and devices based on nanofiles and nanotubes

Structures and devices based on nanoparticles
DNA Origami
Other methods of chemical and electrochemical manufacturing

Module 4 Practical work on nanofabrication

The student is introduced to the principles of operation of a Clean Room and to the methodology of design of masks and micro-chips.

- Design of a mask with a dedicated software (two sessions).
- Optical observation of the photolithography produced using the mask that the student has designed (one session).
- Observation with electron microscope of bottom-up structures.
- Guided tour of the clean room of the National Center for Microelectronics.

In addition, some seminars have been planned with researchers specializing in nanofabrication. The number ofseminars will be a maximum of 5.

Methodology

Teaching will consist on 24 hours of theory lectures, 9 hours of problems and 15 hours of laboratory practices. In addition, 5 hours of seminar sessions are reserved to complete any aspect of the subject.

Practical sessions: The practical sessions and their corresponding reports will be carried out in groups of a maximum of two students. Groups formed by more than two students will not be accepted. The delivery of the reports will be governed by a deadline that will be communicated after having done the practice, via virtual campus.

Extra exercises: During the course, extra exercises may be given to the students that must be done out of the teaching hours and which will be evaluable.

Seminars: A maximum of five seminars can be held during the course, given by researchers working in the field of micro and nanofabrication, aimed at presenting to the student the world of research, beyond the academic vision that is given to the course. Attendance to this seminar is obligatory to be able to be evaluated of the whole course.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Exercices	9	0.36	2, 8, 33, 17, 22, 27, 29, 30, 32, 31, 37
Laboratory	15	0.6	2, 8, 6, 36, 4, 5, 33, 11, 13, 12, 14, 25, 23, 20, 17, 18, 7, 3, 34, 27, 28, 24, 15, 16, 37
Seminars	5	0.2	2, 19, 8, 5, 25, 23, 17, 18, 26, 29, 30
Theory	24	0.96	9, 10, 11, 13, 12, 14, 35

Type: Autonomous			
Reading of the class notes	30	1.2	19, 3, 21, 22
Reading of the guides of practices of laboratory	9	0.36	19, 36, 25, 23, 20, 17, 21, 22, 29, 30, 15
Work on exercises and tests	32	1.28	19, 8, 5, 11, 13, 12, 14, 20, 22, 26, 30, 31

Assessment

There will be the following evaluation activities:

Two partial exams (theory and problems), one at the mid-term and the other at the end, with a weight under the final qualification of 65% (32.5% each). Attendance to these partial exams is mandatory to access to the recovery exam.

Reports corresponding to laboratory practices with a weight on the final qualification of 30%. This note will be taken into account for the final evaluation provided that the student exceeds the qualification of 4.5 as an average of the two partials or as a qualification of the recovery exam.

NOTE: Attendance at the practical sessions and the delivery of the corresponding report are a mandatory condition for the student to be evaluated.

Exercises about theoretical classes: with a weight on the final qualification of 5% (2.5 % for each partial).

NOTE: Attendance at the seminars and doing the exercises about theoretical classes is mandatory for the student to be evaluated.

Exam (theory and problems) for recovery: Attendance to the recovery exam will be recommended if you have obtained a qualification of less than 5 in one of the two partial exams. It will have a weight of 65% of the final qualification. The contents referring to the first partial and the second will be assessed separately. This allows presentation to the recovery of a partial or total contents of the subject. Final qualification of the exams (70% of the final subject qualification) will be the averaging between the two parts of the subject, choosing for each part the best qualification between the partial exam and the recovery exam.

Single assessment modality:

Students who have accepted the single assessment modality will have to take a single final test which will consist of an exam with a theory part and a problem part where they will have to solve a series of exercises similar to those they have worked in the Classroom Practice sessions. On the same day that they take the written test, they must hand in the reports of all the practices sessions (laboratory sessions). This exam and the delivery of all practice reports will take place on the day of the second partial exam set for continuous assessment students by the degree coordination. The written exam (theory and problems) will be delivered on paper and the practicals in PDF format via virtual campus.
The student's final grade will be as follows: the written exam (theory and problems) will have a weight of 70% of the final grade and the practical reports a total of 30%. The grade of the practice reports will be taken into account for the final grade only if the student has passed the grade of 4.5 in the written exam (theory and problems) or in the recovery exam.
If the final grade does not reach 5, the student has another opportunity to pass the subject through the recovery exam that will be held on the date set by the degree coordinator. In this test you can recover 70% of the grade corresponding to the theory and the problems. The laboratory practices part is not recovered.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Partial exams	65%	6	0.24	5, 9, 10, 11, 13, 12, 14, 35, 17, 27, 28, 30, 31
continuous assessment, exercises, quizzes	5%	10	0.4	1, 19, 36, 4, 33, 35, 25, 23, 20, 18, 34, 21, 22, 26, 29, 30, 15, 32, 31, 37
laboratory reports	30%	10	0.4	1, 2, 19, 8, 6, 36, 4, 5, 33, 9, 10, 11, 13, 12, 35, 25, 23, 20, 18, 7, 3, 34, 21, 22, 26, 29, 24, 30, 15, 16, 37

Bibliography

Introduction to Microfabrication / Sami Franssila. ISBN 978-0-470-74983-8, John Wiley & Sons, 2010.

Nuevas Tecnologías en los Dispositivos Electrónicos / A. Godoy et. al: Departamento de Electrónica y Tecnología de Computadores, Universidad de Granada, ISBN: 978-84-691-4090-1, 2008.

Nanofabrication, Nanolithography techniques and their applications / José María de Teresa et al. / Online ISBN: 978-0-7503-2608-7 • Print ISBN: 978-0-7503-2606-3, 2020.

Nanofabrication, Techniques and Principles / Maria Stepanova & Steven Dew / ISBN 978-3-7091-0423-1, Springer, 2012.

Optical Lithography, Here is Why / Burn J. Lin / ISBN 978-0-8194-7560-2 Spie Press, 2010.

Fundamentals of microfabrication and nanotechnology / Marc J. Madou; Boca Raton, FL Taylor & Francis, 2011.

Articles published in research journals. The professors will provide the appropriate information.

Software

All of the software works on windows platform.

Glade software (this is about lithography masks design and it is open access)