

**Microscopy Lab and Material Characterisation  
Techniques (year-long)**

Code: 103307  
ECTS Credits: 6

Degree	Type	Year	Semester
2501922 Nanoscience and Nanotechnology	OB	2	A

## Contact

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## Use of Languages

Principal working language: catalan (cat)  
Some groups entirely in English: No  
Some groups entirely in Catalan: Yes  
Some groups entirely in Spanish: No

## Teachers

Gemma Garcia Alonso  
Ignacio Ramón Mata Martínez

## Prerequisites

NONE

## Objectives and Contextualisation

Objectives:

- Introduction to electronic microscopy and SPM
- Theoretical foundations and description of the technical equipment in SEM, TEM, STM and AFM microscopes.
- Analysis of surface morphology and microstructure, at the atomic scale, of different materials using microscopes.
- Fundamentals of the crystallographic structure of different materials. Introduction to structural analysis through X-ray diffraction.
- Introduction to the concepts of ideal surfaces and real surfaces. Surface treatments and their applications.
- Introduction to vacuum technology and its application in nanotechnologies

## 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 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.
- Interpret the data obtained by means of experimental measures, including the use of computer tools, identify and understand their meanings in relation to appropriate chemical, physical or biological theories.
- 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.
- 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. Apply the concepts related with microscopy techniques to characterise materials, devices and systems on a nanoscale.
4. Be ethically committed.
5. Characterise crystalline surfaces by AFM/STM with atomic resolution
6. Communicate orally and in writing in one's own language.
7. Correctly handle the materials and products used to prepare samples.
8. Correctly use microscopy techniques to recognise surfaces, materials, nanomaterials, devices and microorganisms in studies in the field of nanoscience and nanotechnology
9. Critically evaluate experimental results and deduce their meaning.
10. Describe the concepts related with microscopy techniques.
11. Determine crystalline planes using TEM
12. Distinguish the different microscopy techniques (optical, SEM, TEM and local probe microscopies), describing their operation, applications and limitations.
13. Draft reports on the subject in English.
14. Follow correct protocols for preparing samples
15. Follow correctly the safety protocols for laboratories with ambient controlled and white rooms.
16. Functionalise surfaces and characterise them using microscopy techniques
17. Handle the different instruments related with microscopy techniques.
18. Identify the microscopy technique used by means of sample images.
19. Identify the situations in which the different methodologies studied can help to resolve problematic situations and know how to select the best techniques.
20. Interpret and rationalise the results obtained from diffraction studies.
21. Interpret and rationalise the results obtained from studies using different microscopy techniques.
22. Lead and coordinate work groups.
23. Learn autonomously.
24. Manage the organisation and planning of tasks.

25. Obtain, manage, analyse, synthesise and present information, including the use of digital and computerised media.
26. Operate with a certain degree of autonomy.
27. Perform bibliographic searches for scientific documents.
28. Perform studies to characterise different samples by means of microscopy techniques
29. Prepare samples for study with microscopy techniques.
30. Propose creative ideas and solutions.
31. Reason in a critical manner
32. Recognise the correct terms for topics related to methodologies and experimentation in nanoscience and nanotechnology.
33. Recognise the physical basics of optical microscopy, electronic microscopy and local probe microscopy.
34. Resolve problems and make decisions.
35. Resolve problems with the help of the provided complementary bibliography.
36. Show motivation for quality.
37. Understand texts and bibliographies in English on each of the techniques, methodologies, tools and instruments in the subject area.
38. Use computer tools for the development, manipulation and automation of instrumentation and control systems.
39. Use suitable software for each microscopy technique to obtain optimum experimental results
40. Work correctly with the formulas, chemical equations and magnitudes used in chemistry.

## Content

### - Atomic Force Microscopy. AFM.

Theory. Introduction to the foundations of the AFM microscope. Modes of work, lateral and vertical resolution, convolution concept. Advantages and limitations.

Laboratory Practice. Observation of surfaces of different materials, study of topography, roughness, defects, ordering.

### - Scanning Tunneling Microscopy - STM.

Theory: Introduction of the tunnel effect. Piezoelectric Materials. Foundations of STM microscopy. Modes of work, advantages and limitations.

Laboratory Practice. Use of a teaching STM Equipment. Analysis and interpretation of surface images obtained with graphite, gold and molybdenum disulfide samples.

### - Electronic Microscopy. SEM / TEM.

Theory. Introduction to electron microscopies. Applications in the field of materials science and nanotechnology. Visit to the microscopy service of UAB.

Virtual Practice. Virtual practice Analysis of the surface microstructure of different materials using SEM/TEM microscopes. Interpretation of the data.

### - Surfaces and surface treatments.

Theory: Introduction to the concepts of ideal surface, functionalization, surface treatments. Concepts of wettability, hydrophobicity and hydrophilicity.

Laboratory Practice. Physical and chemical treatments of various surfaces, observation and discussion of the effects of the treatment on the wettability of the surfaces.

### - Vacuum technology.

Theory: Definition of vacuum and its applications. Concepts of kinetic theory of gases, residual gases, Mean Free path, formation time of a monolayer, pumping rate, conductance.

Online practice: Videos and exercises about the use and familiarization with an experimental laboratory of medium vacuum set-up

### - X-ray diffraction.

Theory: introduction to crystallography. Reticular theory. Crystalline structures. Miller index. Geometry Bragg-Brentano. X-ray diffraction.

PC practice. Use of the CaRIne Crystallography Program for the study of crystalline structures and obtaining of powder diffraction diagrams. Crystallochemical analysis of structures (link distances, coordination number, etc.).

Use of the PDF database (Powder Diffraction File), of the ICDD (International Center for Diffraction Data) for the identification of phases

Laboratory practice. Use of a teaching diffractometer set-up. Acquisition of monocrystalline diffraction spectra. Analysis of the data. Determination of cell parameters, indexation of peaks.

## Methodology

The course is divided into 21 hours of theory, 6 hours of problems in the classroom and 40 hours of practice (laboratory and online).

Theory: the physicochemical concepts that will be used in the different experimental techniques will be introduced. Exercises will be carried out that will allow a better understanding of the phenomena involved as well as introduce data processing and interpretation.

Classroom Exercises: CaRIne Crystallography free software for solving problems on crystal structures and diffraction. The students will bring their own computer.

Practices: The practical sessions will be carried out in groups or individually to achieve the learning results of the subject.

The student will find in the Moodle classroom of the subject the notes in pdf format, the distribution by groups, the calendar and the scripts of the practices. For the perfect use of the practical hours, the student will have to review the corresponding theory, the practical script and the corresponding complementary documentation (articles, videos, etc.) before each practical session.

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			
Practice laboratory	40	1.6	1, 3, 2, 23, 9, 5, 37, 6, 36, 11, 16, 24, 18, 19, 21, 20, 22, 7, 17, 4, 25, 29, 30, 31, 28, 32, 13, 34, 14, 15, 40, 8, 38, 39
Problem solving	6	0.24	2, 23, 9, 27, 19, 21, 20, 26, 31, 35, 34, 38, 39
Theory lectures	21	0.84	37, 10, 12, 33, 32
tutorized learning	8	0.32	3, 2, 23, 9, 37, 6, 10, 12, 27, 24, 21, 25, 26, 31, 33, 32, 34
Type: Autonomous			
Bibliography research	2	0.08	23, 37, 36, 27
Individual and autonomous Study	16	0.64	23, 37, 36, 27, 24, 21, 20, 25, 26, 30, 31, 32, 35, 34
Practice report redaction	28	1.12	2, 9, 37, 6, 36, 10, 27, 21, 20, 30, 13, 40
Practice guides lectures	22	0.88	24, 32, 14, 15
Problem solving	4	0.16	3, 23, 9, 27, 18, 21, 20, 26, 31, 35, 34

## Assessment

The competences of this subject will be evaluated through different ways, each one with a certain weight in the final grade.

- Theoretical exam: a multiple-choice test will be carried out with a total weight of 30% of the final grade, which will allow evaluating the assimilation of the theoretical concepts studied throughout the course. The minimum mark of the theoretical test to pass the subject will be 3.5. Students will have a second opportunity to pass this minimum, and therefore being able to pass the course, or to improve their final evaluation.
- Deliveries (reports, problems). An evaluation will be carried out for each of the deliveries with the weight specified in the table of training activities.
- Note that before the practical laboratory sessions (AFM, STM, Surfaces and XRD) the student will have an individual and mandatory test prior to the corresponding practice. Passing this test will add 0.5/10 to the final mark of the corresponding practice and failure to pass in due time will mean a penalty of 0.25/10.
- Attendance at all practices and their completion is mandatory. There is no recovery test for the evaluation of the practical activities.

To pass the subject you must have a final grade equal to or greater than 5, as long as you have obtained a minimum of 3.5 on the theoretical exam.

## Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Electron Microscopy Practice Report	10	0	0	3, 2, 23, 9, 6, 36, 10, 11, 12, 24, 18, 19, 21, 22, 4, 25, 26, 29, 31, 33, 13, 40, 8, 39
Exam	30	3	0.12	3, 2, 9, 10, 12, 18, 21, 20, 25, 31, 33
SPM (AFM &STM) Practice reports	20	0	0	1, 3, 2, 23, 5, 37, 6, 36, 10, 12, 27, 24, 18, 21, 22, 7, 17, 25, 26, 29, 30, 31, 28, 33, 32, 35, 14, 40, 8, 38, 39
SurfaceTreatments Practice report	10	0	0	1, 2, 23, 9, 37, 6, 36, 16, 24, 22, 7, 4, 25, 26, 30, 31, 32, 14, 15, 40, 38
Vacuum technology test	10	0	0	1, 2, 9, 37, 6, 36, 24, 22, 4, 25, 31, 32, 35, 34, 15, 40
XRD Carine solved problems	10	0	0	2, 23, 9, 37, 6, 36, 24, 19, 20, 4, 25, 26, 31, 32, 35, 34, 40
XRD Practice report	10	0	0	2, 9, 37, 6, 36, 11, 27, 24, 20, 22, 7, 4, 25, 26, 31, 32, 35, 34, 14, 40

## Bibliography

Bibliografía (llibres virtuals disponible a la biblioteca)

A User's Guide to Vacuum Technology

First published:20 June 2003

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Materials Characterization: Introduction to Microscopic and Spectroscopic Methods, Second Edition

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## **Software**

Carine Crystallography. Data analysis software (Matlab, Excel or similar).