ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

43000603 - CaracterizaciÓn Microestrtuctural

DEGREE PROGRAMME

04AN - Master Universitario En Ingenieria De Materiales

ACADEMIC YEAR & SEMESTER

2023/24 - Semester 1

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	43000603 - Caracterización Microestrtuctural
No of credits	6 ECTS
Type	Compulsory
Academic year ot the programme	First year
Semester of tuition	Semester 1
Tuition period	September-January
Tuition languages	English
Degree programme	04AN - Master Universitario en Ingenieria de Materiales
Centre	04 - Escuela Tecnica Superior De Ingenieros De Caminos, Canales Y Puertos
Academic year	2023-24

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Raquel Gonzalez Arrabal (Subject coordinator)	IFN/ETSII	raquel.gonzalez.arrabal@upm.es	Sin horario. to agree with the teacher via e-mail
Marta Clement Lorenzo	B-309	marta.clement@upm.es	Sin horario. to agree with the teacher via e-mail

Jimena Olivares Roza	B-307	jimena.olivares@upm.es	Sin horario. to agree with the teacher via e-mail

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

The subject - recommended (passed), are not defined.

3.2. Other recommended learning outcomes

- Solid state physics

- Materials science

4. Skills and learning outcomes *

4.1. Skills to be learned

CB06 - 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

CB07 - 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

CB09 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CB10 - 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.

CE1 - Capacidad para aplicar los fundamentos científicos del comportamiento físico y químico de los materiales para relacionar causalmente sus propiedades fundamentales físicas y químicas con su comportamiento

macroscópico y el de los productos con ellos realizados / Ability to apply the scientific foundations of the physical and chemical behavior of materials to correlate their fundamental physical and chemical properties with their macroscopic behavior and that of the products made with them.

CE2 - Uso de equipos y técnicas experimentales de caracterización de materiales (micro y macroestructura, comportamientos mecánico, eléctrico, y óptico) para identificar y analizar los diversos tipos de materiales / Use of equipment and experimental techniques for the characterization of materials (micro and macrostructure, mechanical, electrical, and optical behavior) to identify and analyze the various types of materials.

CE4 - Autonomía para adquirir, analizar, actualizar y aplicar nuevos conocimientos, modelos y técnicas experimentales y numéricas en relación con la composición y estructura de los materiales, su caracterización física y química, sus procesos de fabricación, su utilización y aplicación científica y tecnológica, y su reciclado, reutilización y eliminación / Autonomy to acquire, analyze, update and apply new knowledge, models and experimental and numerical techniques related to the composition and structure of materials, their physical and chemical characterization, their manufacturing processes, their use and scientific and technological application, and their recycling, reuse and disposal

CE8 - Aplicación del método científico para la resolución de problemas y la generación de conocimiento / Application of the scientific method to solve problems and generate knowledge

CE9 - Capacidad de realizar un trabajo o proyecto individual integrando y relacionando las competencias adquiridas en las distintas asignaturas del máster, junto con la capacidad de defenderlo en público ante un tribunal universitario experto en el tema del trabajo / Ability to carry out an individual job or project integrating and relating the skills acquired in the different subjects of the master's degree, together with the ability to defend it in public before an expert university panel on the topic of the job

CG4 - Creatividad: Los alumnos son capaces de resolver de forma nueva, original y aportando valor, situaciones o problemas en el ámbito de la ingeniería de materiales / Creativity: Students are able to solve situations or problems in the field of materials engineering in a new, original way and adding value.

CG8 - Resolución de problemas: Los estudiantes son capaces de reconocer, describir, organizar y analizar los elementos constitutivos de un problema para idear estrategias que permitan obtener, de forma razonada, una solución contrastada y acorde a ciertos criterios preestablecidos / Problem solving: Students are able to recognize, describe, organize and analyze the constitutive elements of a problem to devise strategies that allow obtaining, in a reasoned way, a contrasting solution and according to certain pre-established criteria.

CG9 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

4.2. Learning outcomes

RA39 - HCC1 - Ability to logically and critically apply the bases of the scientific method in materials science and engineering

RA4 - Que los estudiantes sepan comunicar sus conclusiones (y los conocimientos y razones últimas que las sustentan) a públicos especializados y no especializados de un modo claro y sin ambigüedades

RA19 - The student should be able to perform an optimized characterization of a wide variety of materials by means of well chosen characterization technique.

RA2 - Ser capaz de aprender y actualizar autónomamente nuevos conocimientos y técnicas

RA1 - Saber comunicar conocimientos, procedimientos, resultados o técnicas relacionadas con el comportamiento y el uso de materiales

RA26 - Saber utilizar y aplicar las técnicas y modelos matemáticos de simulación para predecir el comportamiento y evolución de los materiales. Saber evaluar su seguridad, durabilidad e integridad estructural y la de los componentes fabricados con ellos

RA15 - Know, understand and correlate the behavior of materials under different environments with their structure, properties, processing and applications.

RA20 - The student should be able to choose the appropriate characterization technique for different needs of materials research

RA22 - Ser creativo, ejecutando el trabajo con responsabilidad y respeto a los demás

RA27 - Conocer, comprender y saber aplicar los fundamentos científicos del comportamiento de los materiales

RA8 - RA32 - Conocer, comprender y saber aplicar los fundamentos científicos del comportamiento de los materiales

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

Materials characterization is the process of studying and understanding the physical and chemical properties and defects of the materials. It is an essential part of materials science and engineering analysis and offers a large number of important advantages for research and industry.
Materials characterization is a complex process which usually requires the combination of different techniques. Typical probes to determine the materials properties are: ions, electrons, photons, neutrons, positrons.

In order to properly characterize the materials, we need:
? To identify the properties to be analysed.
? To choose the right characterization technique

In this lecture we are going to learn, the capabilities and limitations of diverse characterization techniques and how to choose the selected technique to characterize the required property. Finally, we are going to review significant examples in which materials characterization has contributed to develop advanced materials.

Objectives:

1) Learn the fundamentals of the techniques.

2) Identify the field of applications of each technique within materials science.

3) Become familiar with instrumentation and experimental set-ups

4) Learn the way to look for the optimal experimental conditions in each particular case.

5) Data analysis.

5.2. Syllabus

1. Introduction

2. Radition-Matter interaction

   2.1. Fundamentals of radiation-matter interaction, stopping power definition, straggling and beam spread,

   2.2. Computational calculations of stopping powers and radiation-induced damage

3. Elemental characterization by means of Rutherford Backscattering Spectrometry (RBS) and Elastic Recoil Detection (ERDA)

   3.1. Fundamentals of RBS and of Non-RBS

   3.2. Design of experiments and data analysis

   3.3. Examples of applications in different fields

4. Elemental characterization by means of Nuclear reaction Analysis (NRA)

   4.1. Fundamentals of NRA and RNRA

   4.2. Design of experiments and data analysis

   4.3. Examples of applications in different fields

5. Particle-induced X-ray Emission (PIXE)

   5.1. Fundamentals

   5.2. Examples of applications in different fields.

6. Optical microscopy and Profilometry

7. Electron microscopy: imaging and spectroscopy

   7.1. Transmission electron microscopy (TEM)

   7.2. Scanning Electron Microscopy (SEM)

8. Atom probe microscopy

   8.1. Atomic force microscopy (AFM)

   8.2. Scanning tunnel microscopy (STM)

9. X-ray difraction (XRD)

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Chapter 1.- Introduction** Duration: 01:40 Lecture **Chapter 2.- Radiation-Matter interaction** Duration: 01:40 Lecture			
2	**Chapter 2.- Radiation-Matter interaction** Duration: 01:40 Problem-solving class **Chapter 2.- Radiation-Matter interaction** Duration: 01:40 Problem-solving class			
3	**Chapter 3.- Elemental characterization by means of Rutherford Backscattering Spectrometry (RBS) and Elastic Recoil Detection (ERDA)** Duration: 01:40 Lecture **Chapter 3.- Elemental characterization by means of Rutherford Backscattering Spectrometry (RBS) and Elastic Recoil Detection (ERDA)** Duration: 01:40 Cooperative activities			**Computer simulations delivery. Neither in person nor face to face** Individual work Continuous assessment Not Presential Duration: 00:00 **Deliverables. Neither in person nor face to face** Individual work Final examination Not Presential Duration: 00:00
4	**Chapter 3.- Elemental characterization by means of Rutherford Backscattering Spectrometry (RBS) and Elastic Recoil** Duration: 01:40 Laboratory assignments	**Visit to the Centro de Microanalisis de Materiales (CMAM/UAM) (if possible)** Duration: 01:40 Additional activities		**Visit to the Centro de Microanalisis de Materiales (CMAM/UAM) (if possible)** Other assessment Continuous assessment Presential Duration: 01:40
5	**Chapter 4.- Elemental characterization by means of Nuclear reaction Analysis (NRA)** Duration: 01:40 Lecture **Chapter 4.- Elemental characterization by means of Nuclear reaction Analysis (NRA)** Duration: 01:40 Lecture			**Computer simulations delivery. Neither in person nor face to face** Individual work Continuous assessment Not Presential Duration: 00:00 **Deliverables. Neither in person nor face to face** Individual work Final examination Not Presential Duration: 00:00

6	**Chapter 4.- Elemental characterization by means of Nuclear reaction Analysis (NRA)** Duration: 01:40 Cooperative activities			
7	**Chapter 4.- Elemental characterization by means of Nuclear reaction Analysis (NRA)** Duration: 01:40 Cooperative activities **Chapter 4.- Elemental characterization by means of Nuclear reaction Analysis (NRA)** Duration: 01:40 Laboratory assignments			
8	**Chapter 5.- Particle-induced X-ray Emission (PIXE)** Duration: 01:40 Cooperative activities **Chapter 6.- Optical microscopy and profilometry** Duration: 01:40 Lecture			**Computer simulations delivery. Neither in person nor face to face.** Individual work Continuous assessment Not Presential Duration: 00:00 **Deliverables. Neither in person nor face to face.** Individual work Final examination Not Presential Duration: 00:00
9	**Chapter 7.- Transmission electron microscopy (TEM)** Duration: 01:40 Lecture **Chapter 7.- Scanning electron microscopy (SEM** Duration: 01:40 Lecture			
10	**Chapter 8.- Scanning tunnel microscopy (STM)** Duration: 01:40 Lecture			
11	**Chapter 8.- Atomic fornce microscopy (AFM)** Duration: 01:40 Lecture **Chapter 8.- Microscopy. Data handling** Duration: 01:40 Problem-solving class			**Microscopy Deliverable. Neither in person nor face to face.** Individual work Continuous assessment Not Presential Duration: 00:00 **Deliverables. Neither in person nor face to face.** Individual work Final examination Not Presential Duration: 00:00

12		**Lab session. Not recoverable** Duration: 01:40 Laboratory assignments **Lab session. Not recoverable** Duration: 01:40 Laboratory assignments		**Practical session Not recoverable** Other assessment Continuous assessment Presential Duration: 01:40 **Practical session Not recoverable** Other assessment Continuous assessment Presential Duration: 01:40
13	**Chapter 9.- X-ray diffraction** Duration: 01:40 Lecture **Chapter 9.- X-ray diffraction** Duration: 01:40 Lecture	**Laboratory Session** Duration: 01:40 Laboratory assignments		
14				
15		**TEM visit. Not recoverable** Duration: 01:40 Additional activities **AM XRD visit. Not recoverable** Duration: 01:40 Additional activities		**Visit to UCM facilities Not recoverable** Other assessment Continuous assessment Presential Duration: 01:40 **Visit to XRD facilities Non recoverable** Other assessment Continuous assessment Presential Duration: 01:40 **XRD Deliverable. Neither in person nor face to face.** Individual work Continuous assessment Not Presential Duration: 00:00 **Deliverables. Neither in person nor face to face.** Individual work Final examination Not Presential Duration: 00:00
16	**Chapter 9.- X-ray diffraction** Duration: 01:40 Lecture **Chapter 9.- X-ray data handling** Duration: 01:40 Problem-solving class			
17				**Written exam** Written test Continuous assessment Presential Duration: 01:40

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
3	Computer simulations delivery. Neither in person nor face to face	Individual work	No Presential	00:00	5.5%	4 / 10	CE9 CG4 CG8 CG9 CB10 CB06 CB07 CE1 CE4 CE8 CB09
4	Visit to the Centro de Microanalisis de Materiales (CMAM/UAM) (if possible)	Other assessment	Face-to-face	01:40	2.5%	/ 10	CE2 CB06
5	Computer simulations delivery. Neither in person nor face to face	Individual work	No Presential	00:00	6%	4 / 10	CB06 CB07 CE2 CE9 CG4 CG8 CG9 CB10 CE1 CE4 CE8 CB09
8	Computer simulations delivery. Neither in person nor face to face.	Individual work	No Presential	00:00	6%	4 / 10	CB06 CB07 CE2 CE9 CG4 CG8 CG9 CB10 CE1 CE4 CE8 CB09

11	Microscopy Deliverable. Neither in person nor face to face.	Individual work	No Presential	00:00	5%	4 / 10	CB07 CE2 CE9 CG4 CG8 CB06 CG9 CB10 CE1 CE8 CB09
12	Practical session Not recoverable	Other assessment	Face-to-face	01:40	2.5%	/ 10	CB10 CE1 CE8 CB06 CE2
12	Practical session Not recoverable	Other assessment	Face-to-face	01:40	2.5%	/ 10	CB10 CE1 CE8 CB06 CE2
15	Visit to UCM facilities Not recoverable	Other assessment	Face-to-face	01:40	2.5%	/ 10	CE2 CB06 CB07
15	Visit to XRD facilities Non recoverable	Other assessment	Face-to-face	01:40	2.5%	/ 10	CB06 CB07 CE2
15	XRD Deliverable. Neither in person nor face to face.	Individual work	No Presential	00:00	5%	4 / 10	CB06 CB07 CE2 CE9 CG4 CG8 CG9 CB10 CE1 CE4 CE8 CB09
17	Written exam	Written test	Face-to-face	01:40	60%	4 / 10	CE9 CG8 CE8

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills

3	Deliverables. Neither in person nor face to face	Individual work	No Presential	00:00	5.5%	4 / 10	CE2 CE9 CG4 CG8 CG9 CB10 CE1 CE4 CE8 CB09 CB06 CB07
5	Deliverables. Neither in person nor face to face	Individual work	No Presential	00:00	6%	4 / 10	
8	Deliverables. Neither in person nor face to face.	Individual work	No Presential	00:00	6%	4 / 10	CB06 CB07 CE2 CE9 CG4 CG8 CG9 CB10 CE1 CE4 CE8 CB09
11	Deliverables. Neither in person nor face to face.	Individual work	No Presential	00:00	5%	4 / 10	
15	Deliverables. Neither in person nor face to face.	Individual work	No Presential	00:00	5%	4 / 10	CB06 CB07 CE2 CE9 CG4 CG8 CG9 CB10 CE1 CE4 CE8 CB09

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Deliverables. Neither in person nor face to face.	Individual work	Face-to-face	00:00	30%	4 / 10	CB06 CB07 CE2 CE9 CG4 CG8 CG9 CB10 CE1 CE4 CE8 CB09
Written exam	Written test	Face-to-face	01:40	70%	4 / 10	CE8 CG8 CE1

7.2. Assessment criteria

- **Note**

This subject involves mandatory practical activities that must be taken during the schol period as tehy require dedicated means that are only available at that time. If they are not taken during the school period, the maximum grade in the global evaluation cannot be achieved.

- **Progressive assessment:**

1. Computer simulations delivery. (17.5 % final mark), pass mark (4/10)
2. Attendance to practical session. Compulsory and not recoverable (5% final mark)
3. Attendance to visits. Compulsory and not recoverable (7.5% final mark)

4. Microscopy delivery (5% final mark), pass mark (4/10)
5. XRD delivery (5% final mark), pass mark (4/10)
6. Written exam (60%final mark), pass mark (4/10)

- **Second opportunity exam**

1. Deliverys (27.5 % final mark), pass mark (4/10)
2. Written exam (72.5 % final mark), pass mark (4/10)

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
J. F. Ziegler, M. D. Ziegler, J. Biersack: The Stopping and Range of Ions in Solids. 2. Handbook of Modern Ion Beam Mateials Analysis, Yongqiang Wang and Michael Nastasi, Materials Research Society, ISBN 978-1-60511-215-1.	Bibliography	
Rutherford Backscattering Spectrometry (RBS), M. Mayer, http://users.ictp.it/~pub_off/lectures/lns022/Mayer_1/Mayer_1.pdf	Web resource	
Nuclear Reaction Analysis (NRA), M. Mayer, http://users.ictp.it/~pub_off/lectures/lns022/Mayer_2/Mayer_2.ps	Web resource	
L.C. Feldman, J.W. Mayer: Fundamentals of Surface and Thin Film Analysis, North-Holland (1986)	Bibliography	
Stopping and Range of Ions in Matter (SRIM)	Others	SRIM is a collection of software packages which calculate many features of the transport of ions in matter.

SIMNRA	Others	SIMNRA is a Simulation Program for the Analysis of NRA, RBS and ERDA
http://mse.iastate.edu/microscopy/home.html	Web resource	
R. Haynes B.Met., Ph.D., C.Eng., F.I.M., M.Inst.P. "Optical Microscopy of Materials", Springer (1984)	Bibliography	
P. Eaton and P. West "Atomic force microscopy", Oxford Press (2010)	Bibliography	
http://www.mrl.ucsb.edu/mrl/centralfacilities/xray/xray-basics/index.html	Web resource	
B.D. Cullity, "Elements of X-ray diffraction"	Bibliography	
B. K. Vainshtein, E. Feigl and J.A. Spink, "Structure Analysis by Electron Diffraction", Pergamon Press (1964)	Bibliography	
L. Reimer, H. Kohl, "Transmission Electron Microscopy: Physics of Image Formation" Springer Verlag (2008)	Bibliography	
L. Reimer, "Scanning electron microscopy: physics of image formation and microanalysis", Springer-Verlag (1985/1998).	Bibliography	
Research laboratories of GMME-UPM	Equipment	Clean room with several characterization techniques
CAI X-ray diffraction	Equipment	X-Ray diffraction service at UCM
Ion beam center CMAM/UAM	Equipment	The main facility of CMAM is a 5MV terminal voltage tandem accelerator using the Cockroft-Walton power supply system. CMAM operates six beamlines for material analysis and modification

9. Other information

9.1. Other information about the subject

- This course invests a significant time and effort to demonstration activities. Several external laboratories will be visited to see and learn practical aspects of the different characterization techniques.
- The schedule is based on an a priori planning of the subject; it might be modified during the academic year, according to the number of enrolled students. Both teaching and assessment activities may be turned into on-line activities if required by the health situation.
- Communication between students and lecturers will take place by email. The students are encouraged to send an email to the coordinator or any specific lecturer for any concern related to the module. As far as possible, the lecturers will answer with the least possible delay.
- On-line teaching (if necessary) will take place through Zoom or Teams platforms.

The subject works on some of the following sustainable development goals

- **SDG 7: Ensure access to affordable, reliable, sustainable and modern energy for all.**

Target 7.3 double the global rate of improvement in energy efficiency

- **SDG 9: Industry, Innovation and Infrastructure**

Target 9.5 Enhance scientific research, upgrade the technological capabilities of industrial sectors in all countries, in particular developing countries, including, by 2030, encouraging innovation and substantially increasing the number of research and development workers per 1 million people and public and private research and development spending.

- **SDG 13: Climate change**

Target 13.3. Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning