ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

43000604 - Propiedades De Materiales

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	43000604 - Propiedades de Materiales
No of credits	4.5 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 *
Javier Martinez Rodrigo	C-200	javier.martinez@upm.es	M - 13:00 - 14:00 Tu - 13:00 - 14:00
Jose Maria Ulloa Herrero	C-200	josem.ulloa@upm.es	W - 13:00 - 14:00 Th - 13:00 - 14:00
Elena Maria Tejado Garrido			Tu - 11:00 - 13:00 W - 11:00 - 13:00 Th - 11:00 - 13:00 Students can always ask for a

(Subject coordinator)	Materials Dept.	elena.tejado@upm.es	more convenient date by contacting via email to elena.tejado@upm.es
Sandra Tarancon Roman	Materials Dept.	sandra.tarancon@upm.es	Tu - 12:00 - 14:00 Th - 12:00 - 14:00

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

2.3. External faculty

Name and surname	Email	Institution
Yu Kyoung Ryu Cho	y.ryu@upm.es	ETSITelecomunicacion

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

- User level Word, Excel and PowerPoint software

- Basic Mechanical Properties; Fracture mechanics

- Basic Optics, Electricity and Magnetism; Semiconductor Physics; Quantum Physics; Instrumentation; Optoelectronics

- Basic knowledge of Materials Science and Engineering: structure of materials, properties, applications

4. Skills and learning outcomes *

4.1. Skills to be learned

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

CG1 - Uso de la lengua inglesa: Los alumnos son capaces de transmitir conocimientos y expresar ideas y argumentos de manera clara, rigurosa y convincente, tanto de forma oral como escrita, adaptándose a las características de la situación y de la audiencia / Use of the English Language: Students are able to transmit knowledge and express ideas and arguments in a clear, rigorous and convincing manner, both orally and in writing, adapting to the characteristics of the situation and the audience .

CG2 - Liderazgo: Los estudiantes son capaces de dirigir y coordinar personas para que trabajen con entusiasmo en la consecución de objetivos en pro del bien común / Leadership: Students are capable of directing and coordinating people so that they work enthusiastically to achieve objectives for the common good.

CG3 - Trabajo en equipo: Los alumnos desarrollan la capacidad para trabajar en equipo, integrarse y colaborar de forma activa en la consecución de objetivos comunes / Teamwork: Students develop the ability to work as a team, integrate and actively collaborate in achieving common goals.

CG7 - Uso de las TIC: Los alumnos son capaces de aplicar conocimientos tecnológicos necesarios de manera que les permitan desenvolverse cómodamente y afrontar los retos que la sociedad les va a imponer en su quehacer profesional empleando la informática / Use of ICT: Students are able to apply the necessary technological knowledge in a way that allows them to function comfortably and face the challenges that society is going to impose on them in their professional work using computers.

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 - Análisis y Síntesis: Los alumnos son capaces de reconocer y describir los elementos constitutivos de una realidad, y de proceder a organizar la información significativa según criterios preestablecidos adecuados a un propósito / Analysis and Synthesis: Students are able to recognize and describe the constituent elements of a reality, and to proceed to organize significant information according to pre-established criteria suitable for a purpose.

4.2. Learning outcomes

RA17 - Knowledge and understanding of the most common techniques for the characterization of materials properties (electrical, optical, thermal and mechanical)

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

RA16 - Knowledge and understanding of the electrical, optical, thermal and mechanical properties of materials

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

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

* 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

This subject focuses on the most widely used experimental approaches for electrical, optical, thermal, and mechanical characterization of materials, providing background, insights on the correct usage of the respective techniques, and the interpretation of the results.

With a focus on practical applications, this course will expand the knowledge of functional and structural properties and characterization of materials that students might have acquired in Materials Science subjects (compulsory in many degrees). To do so, Masterclasses combined with Problems and Laboratory practices are scheduled. Through it, the student will be able to find the most suitable testing technique for the required material and/or application, they will learn the physical fundamentals of the different techniques and the working principles of the instruments involved.

In addition, they will practically learn to use some of these characterisation systems in the laboratory. At the end of the work, they will be able to analyse and interpret the measurements corresponding to the different techniques using the appropriate computer tools.

Through laboratory work and report writing, students should develop their skills in collaboration and written communication of scientific results.

Objectives

1. Understand the principles, capabilities, and limitations of some of the most important materials characterisation methods.

2. Becoming familiar with instrumentation and experimental setups.

3. Learning how to use some standard characterisation systems.

4. Learning how to analyse and interpret the measurements.

5.2. Syllabus

1. Part 1: Electrical characterization

    1.1. - Basic Concepts

    1.2. Contact resistance

    1.3. Electrical characterization I (doping and transport)

    1.4. Electrical characterization II (defects)

    1.5. Micro and Nano electrical characterization

    1.6. Laboratory I: Nano characterization of electronic devices

2. Part 2. Optical characterization

    2.1. Basic concepts

    2.2. Instrumentation

    2.3. Absorption, FTIR spectroscopy, photocurrent

    2.4. Photoluminescence (PL) Spontaneous emission, direct

    2.5. Electroluminescence (EL), Cathodoluminescence (CL), Thermoluninescence (TL)

    2.6. Laboratory II: Measuring the PL spectrum of quantum wells, quantum wires and quantum dots.

3. Part 3. Thermal characterization techniques

    3.1. Basic concepts

        3.1.1. Thermal transport properties, such as thermal conductivity, thermal diffusivity, or specific heat capacity, characterizing the ability of materials to conduct, transfer, store and release heat. Basic thermal properties and thermal transitions of materials

    3.2. Thermal conductivity and specific heat capacity

        3.2.1. Introduction, History and Description. Methods to Measure Thermal Conductivity. Factors Affecting. Applications of Thermal Conductivity

    3.3. Thermal expansion and thermomechanical analysis

    3.4. Thermogravimetric methods, Differential Thermal Analysis (DTA), and Differential Scanning Calorimetry (DSC)

        3.4.1. Fundamentals. Working methods. Study of thermal transitions and processes by DSC. Case studies.

    3.5. Thermal shock tests

3.5.1. Introduction. Fundamentals. Thermal shock: origin and influence on the microstructure. Evaluation of the thermal shock in materials: general response of brittle materials. Case examples: Refractory ceramics and advance refractory materials

3.6. Laboratory IV: Measuring the thermal conductivity and heat capacity

3.6.1. The students will measure the thermal conductivity of several materials with the laser-flash-method.

4. Part 4. Mechanical characterization

4.1. Introduction

4.1.1. Fundamentals of mechanical characterization, General structure of a mechanical test system. Research and bibliographic resources, general remarks.

4.2. Universal mechanical testing machines

4.2.1. Load bearing elements, joints, ball joints, load transfer devices, clamps Response time Extensometers and force measurement. Data acquisition. Sources of error.

4.3. Tensile, compression, bending tests.

4.3.1. Fundamentals. Sequential Description. Mechanical strength. Ductility. Influence of different test variables: deformation rate, temperature, grain size.

4.4. Hardness and nanoindentation tests

4.5. Tribology tests

4.5.1. Introduction. Origins and history of tribology. Fundamentals of tribology: surfaces in contact, friction, lubrication, and wear. Definition of the Tribo-test. Standard tests. Case studies.

4.6. Laboratory V: Mechanical characterization of engineering materials

4.6.1. The students will perform tensile tests on different materials, evaluating the effect of deformation and temperature on the obtained results. Hardness and fracture toughness will also be evaluated by means of indentation.

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Master class** Duration: 04:00 Lecture			
2	**Master class** Duration: 04:00 Lecture			
3		**Laboratory I** Duration: 04:00 Laboratory assignments		
4		**Laboratory I** Duration: 04:00 Laboratory assignments		
5	**Master class** Duration: 04:00 Lecture			**Report lab I** Group work Continuous assessment Presential Duration: 00:00
6	**Master class** Duration: 04:00 Lecture			
7		**Laboratory II** Duration: 04:00 Laboratory assignments		**Exercises** Individual work Continuous assessment Presential Duration: 01:00
8		**Laboratory II** Duration: 04:00 Laboratory assignments		**Partial Exam 1** Written test Continuous assessment Presential Duration: 00:50
9	**Master class** Duration: 04:00 Lecture			**Report lab II** Group work Continuous assessment Presential Duration: 00:00
10	**Master class** Duration: 04:00 Lecture			
11		**Laboratory III** Duration: 04:00 Laboratory assignments		

12	**Master class** Duration: 04:00 Lecture			
13	**Master class** Duration: 02:00 Lecture **Coursework 1: Tensile and bending tests** Duration: 02:00 Problem-solving class			
14	**Master class** Duration: 04:00 Lecture			
15	**Master class** Duration: 02:00 Lecture **Coursework 2: Hardness tests** Duration: 02:00 Problem-solving class			
16		**Laboratory IV** Duration: 04:00 Laboratory assignments		**Partial Exam 2** Online test Continuous assessment Presential Duration: 00:50
17				**Ordinary Exam** Written test Final examination Not Presential Duration: 02:00 **Report lab III and IV** Group work Continuous assessment Presential Duration: 00:00

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
5	Report lab I	Group work	Face-to-face	00:00	7.5%	5 / 10	CE4 CG3 CG9 CE8 CG1 CG2 CE2
7	Exercises	Individual work	Face-to-face	01:00	5%	5 / 10	CG8 CE8
8	Partial Exam 1	Written test	Face-to-face	00:50	30%	5 / 10	CG9 CE8 CG1 CG8 CE1
9	Report lab II	Group work	Face-to-face	00:00	7.5%	5 / 10	CG2 CE2 CE4 CG3 CG9 CE8 CG1
16	Partial Exam 2	Online test	Face-to-face	00:50	30%	5 / 10	CG7 CG9 CE8 CG1 CG8 CE1
17	Report lab III and IV	Group work	Face-to-face	00:00	20%	5 / 10	CG2 CE2 CG3 CG7 CG9 CE8 CG1

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
17	Ordinary Exam	Written test	No Presential	02:00	100%	5 / 10	CE4 CG8 CE1 CG1

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Extraordinary exam	Written test	Face-to-face	02:00	100%	5 / 10	CG8 CE1 CE4 CG1

7.2. Assessment criteria

The progress of the students will be monitored through individual assignments and laboratory

1) Attendance and active participation in more than 70% of the classes

2) The students will have to deliver several individual exercises, with special emphasis on practical aspects like the analysis of real measurements corresponding to the different techniques. The resolution of the exercises will require the usage of computer tools.

3) They will also make four group reports based on the measurements taken at the laboratory. They will have to analyze and interpret the measurements and answer several questions. Preparation of the reports will require the use of computer tools.

4) There will be 2 partial exams composed of short theoretical questions and practical questions including data analysis. A mark equal to or higher than 4.0 in each exam is required to pass each part of the subject (Parts 1-2 and Parts 3-4)

For both *FINAL* and *PROGRESSIVE* EVALUATION, the final grade is composed based on the following categories:

- Exams determine 60% of the final mark (a mark equal to or higher than 4.0 in the exam is required to pass the subject)
- Laboratory reports determine 30% of the total mark
- Exercises - 10%

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
D.K. Schroder, Semiconductor Material and Device Characterization, 3rd ed., Wiley Interscience, 2006	Bibliography	Part 1. Electrical characterization
Eugene Hecht, Optics, Addison-Wesley, 1990	Bibliography	Part 2. Optical Characterization
Zhang, Sam. Materials characterization techniques. CRC Press. 2009	Bibliography	Part 3. Thermal characterization
Michael E. Brown, Introduction to Thermal Analysis. Techniques and applications, Springer Dordrecht, 2001	Bibliography	Part 3. Thermal characterization
P.J. Haines (Ed.), Thermal Methods of Analysis; Principles, Applications and Problems, Blackie Academic and Professional (Chapman and Hall), London, 1995	Bibliography	Part 3. Thermal characterization
David R. H. Jones, Michael F. Ashby, Engineering Materials 1 (Fourth Edition),Butterworth-Heinemann,2012	Bibliography	Part 4. Mechanical charaterization
William F. Hosford, Mechanical behaviour of materials. Cambridge University Press, 2005	Bibliography	Part 4. Mechanical characerization
Annual Book or ASTM Standards, American Society for Testing and Materials	Bibliography	Part 4. Mechanical characterization

A.C. Fischer-Cripps. Nanoindentation, Springer, 2002	Bibliography	Part 4. Mechanical characterization
Michael R. Lovell, Tribology for Scientists and Engineers, From Basics to Advanced Concepts, Springer, 2013	Bibliography	Part 4. Mechanical characterization
W.R. Runyan and T.J. Shaffner, Semiconductor Measurements and Instrumentation, McGraw-Hill, 1998	Bibliography	Part 1. Electrical characterization
A.C. Diebold, ed., Handbook of Silicon Semiconductor Metrology, Marcel Dekker, New York, 2001	Bibliography	Part 1. Electrical characterization
P. Horowitz and W. Hill, The art of electronics, Cambridge University Press, 2010	Bibliography	Part 1. Electrical characterization
Jacques I. Pankove, Optical Processes in Semiconductors, Dover Publications, 1971	Bibliography	Part 2. Optical characterization
Alex Ryer, Light Measurement Handbook, http://www.intl-light.com/handbook/	Web resource	Part 2. Optical characterization
Lecture notes	Web resource	Lecture notes available on Moodle
Specialized research articles	Bibliography	Specialized scientific and technical articles. References included in each lecture notes.

9. Other information

9.1. Other information about the subject

Although not formally included in the Course Syllabus, this subject will introduce students to national and international policies related to the 2030 Agenda and its 17 accompanying Sustainable Development Goals (SDGs) in a transversal manner, with special attention to the following SDGs:

1. Ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all

2. Achieve gender equality and empower all women and girls.

6. Develop resilient infrastructure, promote inclusive and sustainable industrialization, and encourage innovation

7. Reduce inequalities between and within countries.

9. Ensure sustainable consumption and production patterns

10. Take urgent action to combat climate change and its effects.

Teaching and evaluation activities within the subject will be moved online if necessary for health reasons,