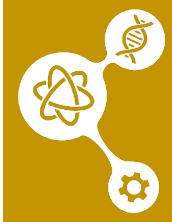
Academic year 2026/2027

Teaching Guide: MATERIALS SCIENCE



FACULTAD DE CIENCIAS QUÍMICAS

1. IDENTIFICATION

Degree	Bachelor's Degree in Chemical Engineering			Code	801536
Course	Materials Science			ECTS	6
Subject Area	Materials Science				
Module	Industrial Engineering				
Type	Compulsory	Year	First	Semester	First
Responsible Department	Chemical and Materials Engineering				

Coordinator

Activity	Lecturer	Email	Office
Coordination	SONIA MATO DÍAZ	msmatodi@ucm.es	QA-131N

Morning Group

Activity	Lecturer	Email	Office
Theory/Seminars/Tutorials	SONIA MATO DÍAZ	msmatodi@ucm.es	QA-131N
Laboratory	SONIA MATO DÍAZ	msmatodi@ucm.es	QA-131N
Laboratory	ISABEL LASANTA CARRASCO	milasant@ucm.es	QA-131C

Afternoon Group

Activity	Lecturer	Email	Office
Theory/Seminars/Tutorials	GUSTAVO GARCÍA MARTÍN	gusgarci@ucm.es	QA-131L
Theory/Seminars/Tutorials	JUAN CORNIDE ARCE	jcornide@ucm.es	QB-419
Laboratory	GUSTAVO GARCÍA MARTÍN	gusgarci@ucm.es	QA-131L
Laboratory	MARTA MOHEDANO SÁNCHEZ	mmohedan@ucm.es	QA-131G

QA Laboratory (Basement Floor)

Group	Semester	Lecturer	Email	Office
A1	1st	SONIA MATO DÍAZ	msmatodi@ucm.es	QA-131N
A2	1st	SONIA MATO DÍAZ	msmatodi@ucm.es	QA-131N
A3	1st	ISABEL LASANTA CARRASCO	milasant@ucm.es	QA-131C
A4	1st	ISABEL LASANTA CARRASCO	milasant@ucm.es	QA-131C
B1	1st	GUSTAVO GARCÍA MARTÍN	gusgarci@ucm.es	QA-131L
B2	1st	GUSTAVO GARCÍA MARTÍN	gusgarci@ucm.es	QA-131L

B3	1st	MARTA MOHEDANO SÁNCHEZ	mmohedan@ucm.es	QA-131G
B4	1st	MARTA MOHEDANO SÁNCHEZ	mmohedan@ucm.es	QA-131G

2. OBJECTIVES

General Objective

To know and understand the scientific foundations of the world of materials and the interrelationships between structure, properties, processing, and applications.

Specific Objectives

- To know all those properties of materials that add technological and industrial value and the physicochemical basis behind them.
- To know which materials are of technological and industrial interest and why they are important. To be able to relate their properties of technological interest to their microstructure.

3. PRIOR KNOWLEDGE AND RECOMMENDATIONS

Prior Knowledge

Basic knowledge of chemistry, physics, and mathematics is required.

Recommendations

Students are recommended to have a basic level of English that enables them to use bibliography in English, search for information, and communicate in writing and orally in that language. Students are also advised to be familiar with computer tools and programs for solving complex problems.

4. CONTENTS

Brief description of the contents

Theoretical contents

Introduction. Classification of materials: Metallic, Ceramic, Polymeric, and Composite materials. Defects in the structure of materials. Slip phenomena. Structural characteristics. Phase diagrams. Solid solutions. Phase transformations. Solidification. Solid-state transformations. Mechanical properties of materials. Materials of technological interest: Metallic, Ceramic, Polymeric, and Composite materials. Corrosion and degradation of materials. Behaviour and inspection of materials.

Practical contents

Characterization of materials: microstructural and mechanical characterization. Non-destructive inspection testing.

Syllabus

Unit 1: Introduction. Classification of Materials

1.1. Brief historical perspective
1.2. Classification of materials
1.3. General properties according to their classification
1.4. Relationship between structure, properties, and processing
1.5. Materials selection

Unit 2: Crystal structure of metals and their defects

2.1. Concept of crystal. Crystallographic planes and directions
2.2. Crystal structures of materials
2.3. Imperfections in crystalline solids
  2.3.1. Point defects
  2.3.2. Line defects
  2.3.3. Surface defects
  2.3.4. Interaction of dislocations with defects

Unit 3: Structure of alloys and phase diagrams

3.1. Concepts and definitions
3.2. Interstitial solid solutions
3.3. Substitutional solid solutions. Hume-Rothery rules
3.4. Intermetallic compounds and intermediate phases
3.5. Binary isomorphous systems
3.6. Binary eutectic systems
3.7. Peritectic and peritectoid reactions
3.8. Eutectoid reaction. The Fe-C system

Unit 4: Diffusion

4.1. Concept and diffusion mechanisms
4.2. Fick's laws
4.4. Factors influencing solid-state diffusion

Unit 5: Solidification

5.1. Concept and thermodynamic considerations
5.2. Homogeneous and heterogeneous nucleation
5.3. Solidification of pure metals.
5.4. Solidification of alloys.
5.5. Microstructure of an ingot. Defects: segregation and porosity

Unit 6: Mechanical properties of materials

6.1. Concept of stress and strain
6.2. Tensile test and stress-strain diagram.
6.3. Elastic behaviour
6.4. Plastic behaviour. Slip phenomena. Schmid's law
6.5. Hardness test
6.6. Impact fracture test

Unit 7: Solid-state transformations

7.1. Concepts and definitions
7.2. Diffusional transformations without phase change. Recrystallization
7.3. Diffusional transformations with phase change
7.4. Diffusionless transformations. Martensitic transformation
7.5. Heat treatments in steels: IT and CT diagrams
7.6. Hardening processes

Unit 8: Metallic materials

8.1. Classification
8.2. Ferrous alloys
  8.2.1. Carbon steels
  8.2.2. Alloy steels. Stainless steels
8.3. Non-ferrous alloys
  8.3.1. Copper and its alloys
  8.3.2. Aluminium and its alloys
  8.3.3. Other light alloys

8.4. Corrosion of metallic materials
8.4.1. Electrochemical corrosion
8.4.2. Passivation
8.4.3. High-temperature corrosion

Unit 9: Polymeric materials

9.1. Definition and classification
9.2. Molecular structure and crystallinity
9.3. Characteristics of thermoplastic polymers, thermosetting polymers, and elastomers
9.4. Mechanical and thermal behaviour according to their classification

Unit 10: Ceramic materials

10.1. Crystalline ceramics
10.2. Amorphous ceramics
10.3. Mechanical and thermal behaviour

Unit 11: Composite materials

11.1. Definition and classification
11.2. Reinforcements and matrices
11.3. Fibre-reinforced composite materials
11.4. Particle-reinforced composite materials
11.5. Structural composite materials

Seminars:

Crystal structures and defects
Equilibrium diagrams
Stress-strain diagram: Determination of mechanical properties
Heat treatments: Kinetic diagrams

Laboratories:

Hardness testing and heat treatments in steels
Microstructural characterization of metallic alloys
Non-destructive testing

5. COMPETENCES

General

CG1	Use concepts from basic and technological subjects that enable autonomous learning of new methods and theories and the ability to address new situations.
CG5	Perform calculations, measurements, valuations, expert assessments, studies and reports in the relevant field of knowledge.
CG6	Use standards and regulations related to the relevant field of knowledge.
CG1-MII3	Apply the fundamentals of materials science.
CG1-MII8	Apply the principles of strength of materials.

Specific

CE9-B1	Relate the technologically relevant properties of materials to their atomic, molecular and crystalline structure.
CE9-B2	Recognise all material properties that add technological and industrial value, particularly in relation to chemical engineering.
CE9-B3	Recognise which materials are relevant to industrial engineering and why they are important, and relate their properties to their atomic, molecular and crystalline structure.
CE9-B4	Apply theoretical and practical knowledge of materials to solving problems in chemical engineering.
CE14-B1	Distinguish between different materials and choose the most suitable ones according to the required technological performance.

Transversal

CT2-II1	Demonstrate capacity for analysis and synthesis in Industrial Engineering.
CT3-II1	Organise and plan documents and projects in the field of Engineering.
CT5-II1	Consult, use and analyse bibliographic sources.
CT5-II2	Use bibliography, specialised databases and resources accessible through the Internet.
CT6-II1	Use computer programs to calculate, design, simulate, approximate and predict.
CT7-II1	Work in a team.
CT9-II1	Demonstrate professional ethical commitment.
CT10-II1	Integrate acquired knowledge and apply it to solving problems in Industrial Engineering.
CT11-II1	Learn autonomously.
CT13-II1	Demonstrate initiative and creativity in solving new situations.

6. LEARNING OUTCOMES

- Recognize which materials are of interest in engineering and relate the properties of materials to their atomic, molecular, and crystalline structure.
- Describe and interpret the importance of crystalline imperfections in the behaviour of metallic materials and recognize the importance of dislocations in slip phenomena.
- Use equilibrium diagrams as the basis for understanding the microstructural transformations that occur in alloys.
- Recognize the importance of diffusion and of nucleation and growth processes in solidification and in solid-state transformations of materials.
- Recognize the importance of the mechanical behaviour of materials and the causes that lead to their fracture in service.
- Describe and interpret the tests used to measure the mechanical properties employed in selecting materials according to their applications.
- Understand the importance of solid-state transformations for modifying microstructure and use time-temperature-transformation diagrams to predict microconstituents in steels.
- Classify metallic alloys and recognize their main characteristics.
- Know the main characteristics of ceramic materials, polymers, and composite materials.

- Know the main types of corrosion of metallic materials and the main non-destructive testing methods used to detect defects in materials.

7. WORKLOAD HOURS AND DISTRIBUTION BY ACTIVITY

Activity	In-person (hours)	Independent work (hours)	Credits
Theory classes	31	46,5	3,1
Seminarios	6,5	10	0,66
Tutorials/Directed assignments	2	3	0,2
Laboratories	8	6	0,56
Preparation of assignments and exams	6	31	1,48
Total	**53,5**	**96,5**	**6**

8. METHODOLOGY

Training activities include theory classes, seminar and/or problem-solving classes, preparation and presentation of assignments, and/or directed tutorials.

During the theory sessions, the main objectives of each unit will be clearly presented and the didactic contents will be developed. The lecture notes Powerpoints (in PDF version) and other materials necessary for understanding the course contents will be made available to students on the course Virtual Campus. Part of this material and the recommended bibliography will be in English. For seminars, students will be provided with sets of problems/exercises/diagrams to be completed individually or in groups. In one of the directed tutorials, the required calculation will be carried out using scientific software (Excel).

The practical laboratory sessions will be carried out in two sessions of 4 hours each. At the beginning of each session, the basic foundations of each practical exercise will be explained, and the work will be carried out in groups. One of the practical exercises uses image acquisition and analysis software. At the end of the laboratory period, each group of students must submit the corresponding report, including the results obtained and their discussion.

9. BIBLIOGRAPHY

Basic

- William D. Callister and David G. Rethwisch: "Materials Science and Engineering", Editorial Reverté, 2015. 2nd edition, ISBN 978-84-291-7251-5.
- Callister W.: "*Materials Science and Engineering. An Introduction*". John Wiley & Sons, Inc. 2007, 7th edition. ISBN 978-1118324578
- J.M. Montes, F.G. Cuevas and J. Cintas. "Materials Science and Engineering". Editorial Paraninfo. 2014. ISBN: 9788428330176
- Smith W.: "Foundations of Materials Science and Engineering", McGraw-Hill, 2023, 7th edition. ISBN: 9781456294878.

Additional

- Ashby F., Jones H. "Engineering Materials", Volumes I and II. Ed. Reverté, S.A., 2008. ISBN 978-84-291-7255-3.
- Shackelford, J. F.: "Introduction to Materials Science for Engineers", 7th edition, Prentice-Hall, Inc., 2010. ISBN 9788483226599.

10. EVALUATION PROCEDURE

For the final grade, participation in the different proposed activities is compulsory. Attendance at all directed tutorials and all laboratory sessions is mandatory. Part of these activities will be assessed in English. If scientific software is used, in addition to the corresponding report, the scientific calculation file developed by the students in preparing the results must be submitted. In order to achieve the final assessment, students must have participated in at least 70% of each of the in-person activities.

Students' academic performance and the final grade for the course will be computed on a weighted basis according to the percentages shown for each of the aspects listed below. All grades will be based on an absolute score out of 10 points and in accordance with the scale established in RD 1125/2003. This criterion will be maintained in all evaluation activities.

❖ WRITTEN EXAMS: 80%

Written exams will consist of questions related to the contents taught in theory classes and seminars. A midterm exemption exam covering Units 1 to 4 and a final exam at the end of the semester will be held. Students who do not pass the midterm exam will take an exam covering the whole syllabus in the ordinary exam. Students who pass the midterm exam may choose to sit only the second part of the syllabus. In this case, the exam grade is obtained by applying the following formula:

$$\text{Grade}_{\text{Exam}} = 0.4 \times \text{Grade}_{\text{Midterm}} + 0.6 \times \text{Grade}_{\text{Ordinary}}$$

Competencies assessed: CG1, CG1-MII3, CG1-MII8, CE9-B1, CE9, B2, CE9-B3, CE9-B4, CE14-B1, CT2-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT10-II, CT11-II, CT13-II.

❖ DIRECTED ACTIVITIES (TUTORIALS):10%

The personal effort students make in directed tutorials will be assessed, as well as their active participation in them by promoting discussion of the proposed questions and/or problems. The quality of the work completed will also be taken into account. Part of these activities will be assessed in English (tutorial number two).

Competencies assessed: CG1, CG5, CG1-MII3, CG1-MII8, CE9-B1, CE9-B2, CE9-B3, CE9-B4, CE14-B1, CT2-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT10-II, CT11-II, CT13-II.

❖ LABORATORY PRACTICALS: 10%

Both the students' interest and personal work during the practical sessions will be taken into account, and their attention and care in handling laboratory equipment will also be assessed. The laboratory report will be given significant weight regarding its structure, discussion of results, and conclusions obtained.

Students who completed the practical sessions in previous academic years may request not to repeat them, provided that no more than 3 years have elapsed since they carried out those practical sessions.

Competencies assessed: all general, specific, and transversal competencies.

The final grade is determined using the following formula:

$$Grade_{Final} = 0.8 \times Grade_{Exam} + 0.1 \times Grade_{Laboratory} + 0.1 \times Grade_{Tutorials}$$

To pass the course:

a) It is necessary to obtain an overall grade equal to or higher than 5.
b) In the exam grade ($Grade_{Exam}$), a minimum grade of 4 must be obtained in order to calculate the overall grade.
c) If students complete any of the continuous assessment activities during the course (seminars/tutorials, laboratory, midterm exam), they will be considered to have sat the corresponding exam.

The final grade will be the weighted average of the assessable activities. However, in order to pass the course, the minimum grade established for each of them must be achieved. If this requirement is not met, the final grade will be the weighted average obtained, with a maximum of 4.5 out of 10.

ACTIVITY PLANNING - SCHEDULE

UNIT	ACTIVITY	HOURS	GROUPS	START	END
BLOCK I: Lessons 1 to 3	Theory Classes	11,5	1	Week 1	Week 6
	Problem Classes	3,5	1		
BLOCK II: Lessons 4 to 7	Theory Classes	11,5	1	Week 7	Week 12
	Problem Classes	3	1		
	Scheduled tutorial*	1	2	Week 10	
BLOCK III: Lessons 8 to 11	Theory Classes	8	1	Week 13	Week 15
	Scheduled tutorial*	1	2	Week 14	

* Scheduled tutorials are subject to possible changes according to the complete course planning.

SUMMARY OF ACTIVITIES

TEACHING ACTIVITY	ASSOCIATED COMPETENCIES	TEACHING STAFF ACTIVITY	STUDENT ACTIVITY	ASSESSMENT PROCEDURE	P	NP	TOTAL	C
Theory classes	CG1, CG1-MII3, CG1-MII8, CE9-B1, CE9-B2, CE9-B3, CE9-B4, CE14-B1, CT2-II1, CT5-II1, CT5-II2, CT9-II1, CT11-II, CT13-II	Presentation of theoretical concepts.	Taking notes. Asking questions and raising doubts.	Grading of written answers to questions related to the theoretical concepts explained.	31	46,7	77,5	
Seminarios	CG1, CG5, CG1-MII3, CG1-MII8, CE9-B1, CE9-B2, CE9-B3, CE9-B4, CE14-B1, CT2-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT10-II, CT11-II, CT13-II	Application of theory to solving exercises and problems.	Taking notes. Completing exercises. Asking questions and raising doubts.	Grading of written answers (approach and result) for solving practical exercises and numerical problems.	6,5	10	16,5	**80%**
Tutorials / Directed assignments	CG1, CG5, CG1-MII3, CG1-MII8, CE9-B1, CE9-B2, CE9-B3, CE9-B4, CE14-B1, CT2-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT10-II, CT11-II, CT13-II	Proposal of problems/exercises/diagrams. Preparation and proposal of assignments. Helping students guide their study with explanations and bibliographic recommendations. Encouragement of creative discusión.	Presentation of doubts/questions related to the proposed work. Consulting teaching staff about conceptual and methodological difficulties encountered when studying the subject.	Personal effort developed by students and their active participation. Quality of the work submitted.	2	3	5	**10%**

Laboratories	All general, specific, and transversal competencies	Explanation of the basic foundations of each practical exercise. Explanation of the handling/operation of the equipment. Supervision of students' work. Resolution of issues and questions about the practical exercise. Guidance in the discussion of results and preparation of the report.	Learning the safety rules of materials laboratories and the handling of typical equipment. Learning to interpret and discuss results. Learning to prepare scientific/technical reports.	Students' interest and personal work during the practical sessions. Attention and care in handling laboratory equipment. Structure, discussion of results, and conclusions obtained as presented in the report.	8	6	14	**10%**
Exams	CG1, CG1-MII3, CG1-MII8, CE9-B1, CE9-B2, CE9-B3, CE9-B4, CE14-B1, CT2-II1, CT5-II1, CT5-II2, CT6-II1, CT7-II1, CT9-II1, CT10-II, CT11-II, CT13-II	Preparation, supervision, and correction of the exam. Grading of students.	Preparation and completion.		6	31	37	

P: In-person activities

NP: Non-in-person activities (independent work)

C: Grade