



Course Guide

MATERIALS SCIENCE



CHEMISTRY DEGREE
COMPLUTENSE UNIVERSITY OF MADRID
ACADEMIC YEAR 2022-2023



I.- IDENTIFICATION

COURSE NAME:	Materials Science
CREDITS (ECTS):	6
CHARACTER:	Mandatory
SUBJECT:	Materials Science
MODULE:	Fundamental
DEGREE:	Bachelor in Chemistry
SEMESTER/TERM:	First term (second year)
DEPARTMENT/S:	Chemical and Materials Engineering

LECTURERS:

Coordinator	Lecturer: GERMÁN ALCALÁ PENADÉS Department: Chemical and Materials Engineering Office: QA-131 M e-mail: galcalap@ucm.es
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Group E	
Theory Seminars Tutorials	Lecturers: GERMÁN ALCALÁ PENADÉS & NOEMÍ ENCINAS GARCÍA Department: Chemical and Materials Engineering Office: QA-131 M & QA-131 C e-mail: galcalap@ucm.es & nencinas@ucm.es
Laboratory	Lecturers: NOEMÍ ENCINAS GARCÍA & FELISA GONZÁLEZ GONZÁLEZ Department: Chemical and Materials Engineering Office: QA-131 C & QA-232 e-mail: nencinas@ucm.es & fgonzalezg@ucm.es



II.- OBJECTIVES

■ GENERAL OBJECTIVE

Acquiring the knowledge and understanding of the scientific fundamentals of the world of materials, as well as the correlation among structure, properties, processing procedures and applications.

■ SPECIFIC OBJECTIVES:

- Learn all those materials properties providing technological and industrial value, as well as understanding the chemical and the physical fundamentals of these properties.
- Learn which are the materials of technological and industrial interest, and why are they important. Learn to relate the technological interest properties with the materials microstructure.

III.- PREVIOUS KNOWLEDGE AND RECOMMENDATIONS

■ PREVIOUS KNOWLEDGE:

Basic knowledge of chemistry, physics, mathematics, and geology.

■ RECOMMENDATIONS:

It is recommended that the student has successfully passed the basic subjects of *General Chemistry* and *Geology*.

IV.- CONTENTS

■ BRIEF DESCRIPTION:

Theoretical contents

Types of materials. Description. General properties. Microstructure flaws. Sliding mechanisms. Phase diagrams. Solid solutions. Diffusion. Phase transformations. Solidification. Solid state transformations. Materials mechanical properties. Elastic and plastic behaviour. Fracture. Materials processing. Moulding and forming. Materials with technological interest: metals, ceramics, polymers, composites, and other materials. Applications.

■ SYLLABUS:

Unit 1: Introduction. Materials classification

- 1.1. Brief historical review
- 1.2. Materials Classification
- 1.3. General properties
- 1.4. Correlation among structure, properties, processing procedures

Unit 2: Crystalline structure of materials, and flaws

- 2.1. Crystalline structure of metals
- 2.2. Flaws in solid materials
- 2.3. Sliding phenomena

Unit 3: Alloys' structure and phase diagrams



- 3.1. Concepts and definitions
- 3.2. Interstitial solid solutions
- 3.3. Substitutional solid solutions. Hume-Rothery rule
- 3.4. Intermetallic compounds and intermediated phases
- 3.5. Isomorphic binary systems
- 3.6. Eutectic binary systems
- 3.7. Equilibrium diagrams with intermediated phases or compounds
- 3.8. Eutectoid reaction. The iron-carbon system

Unit 4: Mechanical properties of materials

- 4.1. Stress and strain concept
- 4.2. Stress-strain diagram
- 4.3. Elastic behaviour
- 4.4. Plastic behaviour
- 4.5. Hardness
- 4.6. Fracture and impact tests

Unit 5: Diffusion

- 5.1. Concepts and definitions
- 5.2. Diffusion mechanisms
- 5.3. Diffusion equations. Fick's laws
- 5.4. Factors affecting diffusion

Unit 6: Solidification

- 6.1. Homogeneous and heterogeneous nucleation
- 6.2. Pure metals solidification. Thermal undercooling
- 6.3. Alloys' solidification. Constitutional Undercooling
- 6.4. Ingot' solidification and flaws: segregation y porosity

Unit 7: Solid state transformation

- 7.1. Concepts and definitions
- 7.2. Diffusional transformations without phase change. Recrystallisation
- 7.3. Diffusional transformations with phase change
- 7.4. Adiffusional transformations. Martensitic transformation
- 7.5. Thermal treatments in Fe-C alloys: TI and TC diagrams
- 7.6. Hardening procedures

Unit 8: Metallic materials

- 8.1. Classification
- 8.2. Iron alloys
 - 8.2.1. Carbon steels
 - 8.2.2. Alloyed steels. Stainless steels
 - 8.2.3. Cast iron
- 8.3. Non-iron alloys
 - 8.3.1. Copper and its alloys
 - 8.3.2. Aluminium and its alloys
 - 8.3.3. Other light alloys

Unit 9: Polymeric materials

- 9.1. Structure and classification



- 9.2. Crystallinity. Parameter affecting crystallinity
- 9.3. Thermal behaviour. Glass transition
- 9.4. Mechanic behaviour
- 9.5. Thermoplastics polymers
- 9.6. Thermostable polymers and elastomers

Unit 10: Ceramic materials

- 10.1. Crystalline ceramics
- 10.2. Glassy ceramics
- 10.3. Mechanical and thermal behaviour
- 10.4. Traditional ceramics
- 10.5. Advanced ceramics

Unit 11: Composite materials

- 11.1. Definition and classification
- 11.2. Reinforcements y matrixes
- 11.3. Fibre reinforced composites
- 11.4. Particle reinforced composites
- 11.5. Structural composites

SEMINARS

Number of vacancies calculation
Equilibrium diagrams
Diffusion equations solutions
Mechanical properties determining
TTT Diagrams

PRACTICAL

Solidification microstructures: monophasic materials, eutectics
Microstructures of solid-state transformations: copper and aluminium alloys, and steels.
Tensile test, hardness y toughness

V.- COMPETENCES

■ GENERAL:

- **CG1-MF1:** Recognize the everyday life chemical processes.
- **CG2-MF1:** Relate chemistry with other disciplines.
- **CG3-MF1:** Continue studying multidisciplinary areas.
- **CG5-MF1:** Prove knowledge and understanding of the essential facts, concepts, principles, and theories related to chemistry.
- **CG6-MF1:** Analise and solve qualitative and quantitative problems.
- **CG7-MF1:** Recognize and analyse new problems and establish strategies to solve them.
- **CG8-MF1:** Review scientific and technic information efficiently.



- **CG9-MF1:** Prove knowledge about laboratory equipment and practical skills.
- **CG10-MF1:** Use chemical products in a safe way.
- **CG10-MF2:** Recognize and evaluate risks when using chemical substances and in laboratory procedures.
- **CG11-MF1:** Use standard chemical equipment.
- **CG12-MF1:** Understand the data obtained in the laboratory.
- **CG13-MF1:** Recognize and implement good scientific procedures related to tests and experimentation.

■ **SPECIFIC:**

- **CE33-MFCQ:** Relate materials properties to their atomic and molecular structure.
- **CE33-MFCQ2:** Describe all those materials properties providing technological and industrial value, as well as the chemical and physical fundamentals making them possible.
- **CE34-MFCQ1:** Explain which are the materials with technological and industrial value and its importance.
- **CE34-MFCQ2:** Develop skills characterizing materials.

■ **GENERIC:**

- **CT1-MF1:** Produce scientific and technical reports.
- **CT2-MF1:** Cooperate with other students by means of teamwork.
- **CT3-MF1:** Apply critical and auto-critical reasoning.
- **CT5-MF1:** Use chemical information, bibliography, and specialized databases.
- **CT6-MF1:** Identify the importance of chemistry in the industrial, environmental, and social context.
- **CT7-MF1:** Use tools and software to process experimental results.
- **CT11-MF1:** Develop autonomous learning.
- **CT12-MF1:** Recognize the current energy problems and their importance.
- **CT12-MF2:** Develop sensitivity about environmental issues.

VI.- LEARNING OUTCOMES

Once the students have passed this subject, they must be able of:

1. Identify the importance Materials Science and Engineering in various areas of social, economic, technical, and scientific interest.
2. Describe their general properties and classify those materials with technological interest.
3. Identify the basic features in the relation among processing-structure-properties-behaviour in metallic, ceramic, polymers and composite materials.
4. Describe the usual structures of metallic, ceramic and polymers materials.
5. Calculate parameters of importance in crystalline structures (linear density, planar density, atomic packing factor, etc.).
6. Recognize and understand the importance of crystalline imperfections to obtain reasoned and coherent information about the behaviour of metallic materials.
7. Calculate vacancies concentration as a function of temperature in metallic materials.



8. Recognize the importance of dislocations in the sliding phenomena.
9. Use equilibrium diagrams as the basic knowledge to understand microstructural changes taking place in alloys.
10. Calculate proportion and composition of phases and microconstituents. Apply the lever rule in equilibrium diagrams.
11. Describe the tensile test and calculate its main parameters (elastic modulus, yield stress, ultimate strength, toughness, etc.).
12. Explain the mechanical behaviour of metallic, ceramic, and polymeric materials according to their corresponding structures.
13. Explain the following concepts: elasticity, plasticity, viscoelasticity, viscous flux, slip systems and twinning.
14. Explain and describe the fundamentals of hardness testing.
15. Explain the diffusion processes and how they are affected by parameter such as temperature, structure, and flaws.
16. Apply the 1st and the 2nd Fick's law. Calculate the coefficient and the activation energy for diffusion.
17. Recognize the importance of nucleation and growth phenomena in solidification processes of metallic alloys.
18. Describe the structure and flaws of metallic ingots.
19. Classify and explain the intrinsic characteristics of solid-state phase transformations.
20. Use the Temperature-Time-Transformation diagrams to predict the microconstituents of steels.
21. Identify the different factors inducing hardness in metals and alloys.
22. Learn the classification and uses of metallic alloys for industrial applications.
23. Use optical microscopes and hardness testers in the laboratory.

VII.- WORKING HOURS DISTRIBUTED BY ACTIVITY

Activity	Attendance (hours)	Self-study (hours)	Credits/ hours
Lectures	30	45	3
Seminars / Problem classes	8	12	0,8
Tutorials / Guided work	4	6	0,4
Laboratory	12	9	0,84
Written assignments and exams preparation	6	18	0,96
Total	60	90	6

VIII.- METHODOLOGY

The formative activities are classified in **lectures** (3 credits), **seminars/problem classes** (0,75 credits), **laboratory** (0,84 credits), **tutorials/guided work** (0,4 credits).



In the lectures the main objectives of each unit will be clearly exposed, developing its content and facilitating the student any needed materials to help in its understanding. The materials used in the lectures will be provided to the students in the Virtual Campus and/or the photocopying service of the faculty. In the seminars the students will be provided with problems/exercises/schemes to be developed either individually or in group. In order to boost the autonomous work, the resolution of numerical exercises will be evaluated, work related to industrial applications of materials, bibliographic surveys related to materials science, etc...All these activities will be addressed in the tutorials.

The **laboratory** sessions will take place in four sessions of three hours each. At the beginning of each session the fundamentals of the practical session will be exposed, being developed in groups of 2/3 students. Once the laboratory sessions are over, each group of students must present their report comprising the obtained results and their discussion.

IX.- BIBLIOGRAPHY

■ BASIC:

- Callister W.: *“Materials science and engineering: an introduction”*. 7th edition, John Wiley & Sons, 2007.

■ COMPLEMENTARY:

- Smith W.: *“Foundations of Materials Science and Engineering”*. 5th Edition, McGraw-Hill, 2010.
- Askeland D.: *“The Science and Engineering of Materials”*. 7th edition, Cengage Learning, 2016.
- Shackelford, J.F.: *“Introduction to materials science for engineers”*. 8th edition, Pearson Education Limited, 2016.

X.- ASSESSMENT PROCEDURE

To be evaluated, it is compulsory to take part of the proposed activities, covering at least 70% of the face-to-face activities. The academic performance of the students, and the final grades in this subject will be calculated, in a weighted manner, following the percentages showed in each of the facets gathered in this document. It will be mandatory to successfully pass all the activities related to the laboratory sessions in order to have access to the final evaluation, being the value of these activities 20% of the final mark. All the grades will be based in the absolute punctuation over 10, according to the established scale in the RD 1125/2003 law. This criterion will be maintained in all the calls.

The qualification of the planned activities to evaluate the students in this subject (partial tests, laboratory sessions, tutorials, deliverables, ...) will be announced with time enough in advance before the final test date, so that they can properly plan their preparation to study this and other subjects. In all the cases, a seven-day period will be respected between the mark's publication and the date of the subject final test.

**■ WRITTEN EXAMS:****70%**

I will consist of questions related to the subject as presented in the theory classes and the seminars. There will be a discharging partial exam of units 1 to 5 and a final exam at the end of the term. Students who did not pass the final exam will have a new test comprising the whole syllabus in the extraordinary call in July.

Assessed competences: CG1-MF1, CG2-MF1, CG3-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CE33-MFCQ1, CE33-MFCQ2, CE34-MFCQ1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT11-MF1, CT12-MF1, CT12-MF2.

■ GUIDED ACTIVITIES:**10%**

Individual work and active participation in tutorials promoting discussion about the proposed questions and/or problems will be valued. The quality of the developed work will also be assessed.

Assessed competences: CG1-MF1, CG2-MF1, CG3-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CE33-MFCQ1, CE33-MFCQ2, CE34-MFCQ1, CT1-MF1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT7-MF1, CT12-MF1, CT12-MF2.

■ LABORATORY SESSIONS:**20%**

Both personal interest and work during the laboratory sessions will be taken into consideration, as well as attention and care while using the laboratory tools. Regarding the laboratory report, a special weight will be given to its structure, and to the elaboration of the results, discussion, and conclusions sections.

Assessed competences: All the general, specific, and generic competences.



ACTIVITY SCHEDULE

SECTION	ACTIVITY	HOURS	GROUPS	START	END
SECTION I					
Units 1 to 3	Theory Classes	8	1	1 st Week	5 th Week
	Seminars	3	1		
	Planned Tutorial	1	1	5 th Week	
SECTION II					
Units 4 to 7	Theory Classes	12	1	5 th Week	11 th Week
	Seminars	5	1		
	Planned Tutorial	1	1	10 th Week	
SECTION III					
Units 8 to 11	Theory Classes	10	1	12 th Week	15 th Week
	Planned Tutorial	2	1	13 y 14 th Week	



SUMMARY OF ACTIVITIES

Teaching activity	Associated competences	Lecturer activity	Student activity	Assessment procedure	P	NP	Total	C
Lectures	CG1-MF1, CG2-MF1, CG3-MF1, CG5-MF1, CE33-MFCQ1, CE33-MFCQ2, CE34-MFCQ1, CT3-MF1, CT5-MF1, CT6-MF1, CT11-MF1, CT12-MF1, CT12-MF2.	Exposition of theoretical concepts.	Taking notes. Formulation of questions and doubts.	Assessment of the answers given to questions related to theoretical concepts.	30	45	75	70%
Problem solving classes/ Seminars	CG1-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CE33-MFCQ1, CE33-MFCQ2, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT11-MF1.	Application of the theory to the resolution of exercises and problems.	Taking notes. Resolution of exercises and questions. Formulation of questions and doubts.	Assessment of the answers (approach and result) given for the resolution of practical exercises and numerical problems.	8	12	20	
Tutorials	CG1-MF1, CG2-MF1, CG3-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CE33-MFCQ1, CE33-MFCQ2, CE34-MFCQ1, CT1-MF1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT7-MF1, CT12-MF1, CT12MF2.	Problems/ exercises/ schemes proposal. Preparation and proposal of activities. Direction and supervision of the study and activities of the students by means of explanations and bibliographic recommendations. Encouragement for creative discussion.	Asking questions and answering those proposed by the lecturer. Discussing with the lecturer concept and method difficulties encountered when studying the subject.	Active participation of the student. Quality of the presented pieces of work.	4	6	10	10%
Laboratory sessions	All the general, specific, and generic competences.	Explanations of the basic fundaments of each activity. Explanation to support the development of skills of laboratory equipment. Student's work supervision. Answering questions related to the laboratory activities. Guidance on the results discussion and	Learn the materials laboratory security rules and handle the characteristic tools. Understand and discuss experimental results. Learn to prepare technical and scientific reports.	Attention and personal work of the student during the sessions. Care when using technical instruments in the laboratory. Structure, results discussion and conclusions presented in	12	9	21	20%



		report's preparation.		the report.				
Examinations	CG1-MF1, CG2-MF1, CG3-MF1, CG5-MF1, CG6-MF1, CG7-MF1, CG8-MF1, CE33-MFCQ1, CE33-MFCQ2, CE34-MFCQ1, CT2-MF1, CT3-MF1, CT5-MF1, CT6-MF1, CT11-MF1, CT12-MF1, CT12-MF2	Exam design. Surveillance and correction. Evaluation of the student.	Exam preparation and examination		6	18	24	
P: In-class; NP: Self-study; C: Evaluation								

