FACULTAD DE
CIENCIAS QUÍMICAS

# MATERIALS SCIENCE

COURSE GUIDE

BSc Chemistry

Academic Year 2026-2027

UNIVERSIDAD
COMPLUTENSE
MADRID

# 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:** | CONSUELO GÓMEZ DE CASTRO |
| | **Department:** | Ingeniería Química y de Materiales |
| | **Office:** | QB-418 |
| | **e-mail:** | cgcastro@ucm.es |

| **Group E** | | |
|---|---|---|
| **Theory Seminars Tutorials** | **Lecturers:** | GERMÁN ALCALÁ PENADÉS & NOEMÍ ENCINAS GARCÍA |
| | **Department:** | Chemical and Materials Engineering |
| | **Office:** | QA-131 J & QA-131 C |
| | **e-mail:** | galcalap@ucm.es & nencinas@ucm.es |
| **Laboratory** | **Lecturers:** | NOEMÍ ENCINAS GARCÍA & GUSTAVO GARCÍA MARTÍN |
| | **Department:** | Chemical and Materials Engineering |
| | **Office:** | QA-131 C & QA-131 L |
| | **e-mail:** | nencinas@ucm.es & gusgarci@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 fundaments 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. Aluminium and its alloys
  8.3.2. 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 fundaments 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 three sessions of four 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. The final grade will be calculated as the weighted average of the assessed activities. However, in order to pass the course, it will be necessary to achieve the minimum mark established for each of them. If this requirement is not met, the final grade will be the weighted average obtained, with a maximum of 4.5 out of 10. 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 partial exam of the first five subjects, which will be released if a minimum mark of 5 is obtained, and a final exam at the end of the term.
The final exam will comprise two parts. It is a requisite obtaining a minimum mark of 5 over 10 on each part. Furthermore, an average mark of 5 over 10 in the global of the exam is needed.
Students who did not pass the final exam will have a new test comprising the whole syllabus in the extraordinary call.

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, CT12MF2.

- **LABORATORY SESSIONS: 20%**

The laboratory sessions are mandatory.

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.

A minimum mark of 5 over 10 in the lab sessions will be compulsory. If a final 5 over 10 mark is achieved in the lab, it will not be necessary to repeat the activity in case of repeating the subject just for next year.
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 | 1st Week | 5th Week |
| | Seminars | 3 | 1 | | |
| | Planned Tutorial | 1 | 1 | 5th Week | |
| **SECTION II** | | | | | |
| **Units 4 to 7** | Theory Classes | 12 | 1 | 5th Week | 11th Week |
| | Seminars | 4 | 1 | | |
| | Planned Tutorial | 1 | 1 | 10th Week | |
| **SECTION III** | | | | | |
| **Units 8 to 11** | Theory Classes | 10 | 1 | 12th Week | 15th Week |
| | Seminars | 1 | 1 | | |
| | Planned Tutorial | 2 | 1 | 13 y 14th 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.<br>Formulation of questions and doubts. | Assessment of the answers given to questions related to theoretical concepts. | 30 | 45 | 75 | |
| **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.<br>Encouragement for creative discussion. | Asking questions and answering those proposed by the lecturer.<br>Discussing with the lecturer concept and method difficulties encountered when studying the subject. | Active participation of the student.<br>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. | Learn the materials laboratory security rules and handle the characteristic tools. Understand and discuss experimental results.<br>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.<br>Structure, results discussion and | 12 | 9 | 21 | 20% |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Guidance on the results discussion and report's preparation. | | conclusions presented in 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 | 70% |
| **P: In-class; NP: Self-study; C: Evaluation** | | | | | | | | |