Course Guide

Sceneries 1, 2, 3:

MATERIALS SCIENCE

CHEMISTRY DEGREE

COMPLUTENSE UNIVERSITY OF MADRID

ACADEMIC YEAR 2021-2022

SCENARIO 1. FACE TO FACE

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
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Group E		
Theory **Seminars** **Tutorials** **Laboratory**	**Lecturers:** **Department:** **Office:** **e-mail:**	GERMÁN ALCALÁ PENADÉS & NOEMÍ ENCINAS GARCÍA Chemical and Materials Engineering QA-131 M & QA-131 C galcalap@ucm.es & nencinas@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. 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 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 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, CT12MF2.

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	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	5	1		
	Planned Tutorial	1	1	10th Week	
SECTION III					
Units 8 to 11	Theory Classes	10	1	12th Week	15th Week
	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. 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								

SCENARIO 2. MIXED

VIII.- METHODOLOGY

- **Theoretical classes and seminars** will be given by the lecturer as usual like in Scenario 1, covering the same contents. Following the principle of *maximum attendance* approved by the rector's office of the UCM, the sessions will be followed face-to-face by the students in the classroom, up to the capacity limit keeping social distance. The rest of students will follow the session virtually either in their place of residence or in public classrooms provided with screens at the faculty announced at the Virtual Campus. In case of classrooms without camera, face-to-face rotatory turns will be stablished according to the students DNI number. This procedure could be modified by the lecturer along the term if convenient to adjust the classroom capacity to the students' attendance.

  - The teaching material used will be the same classroom slides used in Scenario 1, which will be available in the Virtual Campus UCM, as well as the videos related to the topic and other materials considered as relevant by the lecturer. All this material will be available in advance for the students in the Virtual Campus.
  - The telematic means used to make possible the virtual sessions for the student non attending physically the classroom will be the following platforms: Microsoft Teams available in the VC, Google Meet or Zoom. The lecturer will keep a session of these platforms open to maintain fluid and direct contact with the students attending virtually, allowing the possibility of simultaneous slide projection, and of following the traditional explanations given using the blackboard.

- The planned **laboratory sessions** will take place with a face-to-face attendance of at least 60%, which allows maintaining the needed social distance. According to the particularities of each activity, attendance may be slightly modified if possible. The experimental teaching organization is based on the following facets:
  - A test resolution is planned before each session starts.
  - Each practical session will be structured in three sections: theoretical and practical introduction, experimental procedure, and results management and data processing.
  - The experimental procedure will take place in a face-to-face manner. When this is not possible it is planned the use of recorded material and commercial videos.
  - The other two parts will be given according to any of the following cases, or combinations among them:
    (a) Classroom attendance, keeping large social distance.
    (b) Synchronous virtual sessions.
    (c) Asynchronous virtual sessions.
  - The teaching material used will be the same than in Scenario 1, as well as written manuals, numerical results, charts and/or PowerPoint presentation with explanations.
  - All the material will be available in advance for the students in the Virtual Campus.

- **Individual Tutorials**
  They will take place by means of videoconferences and/or email.

- **Students' attendance**
  In the teaching taking place in a face-to-face manner the lecturer will follow the traditional methods. In the virtual teaching the monitoring of the student's attendance will be done using different techniques chosen by the lecturer: using the session activity registry (Microsoft Teams), the participant's names (Google meet), signature sheet in the VC as a questionnaire, analyses of downloads carried out by the students in the VC, etc.

X.- EVALUACIÓN

Face-to-face exams will take place like in Scenario 1.

SCENARIO 3. ONLINE

VIII.- METHODOLOGY

- **Theory classes and seminars** will be given in combining synchronous (in the official time schedule) and asynchronous sessions.
  - The teaching material used will comprise class presentation mad available in the Virtual Campus UCM, also used in Scenarios 1 and 2, PowerPoint presentations including voice recording with the appropriate explanations like in a face-to-face class, videos related to the subject, and any other material considered as relevant or interesting by the lecturers of the subject. Like in the previous Scenarios, all this material will be available online in advance in the Virtual Campus.
  - The telematic means used will be the platforms already mentioned in Scenario 2: Microsoft Teams through the VC, Google Meet or Zoom.

- **The laboratory sessions** will take place like in Scenario 2, but the face-to-face experimental procedure will be replaced by several possible alternatives: written material describing in detail the procedures, recordings of the experimental activities and y videos of similar experiments making sure the acquisition of the skills and competences.

- **Individual tutorials** will take place like in Scenario 2.

- **Students' attendance**
  Like described in Scenario 2 for the virtual teaching.

X.- ASSESSMENT PROCEDURE

DESCRIPTION OF THE ASSESSMENT PROTOCOL

- **Student's identification**:

Several minutes before de beginning of the exam, the students must submit a commitment document in their handwriting and scanned in PDF format, accepting the rules to be assessed. The text of this document, made by the Department of Chemical and Materials Engineering, will be available online in the Virtual Campus. This document should make known in writing: name and surnames, signature, location and a copy of the student's DNI. The identification of the student attending the test will be done by means of: (i) registry in the Virtual Campus to visualize the questions of the exam, (ii) video image through Google Meet or Microsoft Teams (using either the computer or the mobile phone's camera), (iii) commitment document, and (iv) possible telematic verification along the test by the lecturer.

- **Type of exam**:

The exam will be design in the Virtual Campus (Moodle) by means of the Assignment activity, in this way each student can have access to a different exam. The test duration cannot exceed two hours.

- **Monitoring of students during the test**:

During the test, the students must have a connected camera (either of the computer or the mobile) to make possible the lecturer surveillance of the commitment signed by the student to be assessed individually and using the allowed means.

- **Exam review:**

The students who wish to review their exam will contact the lecturers of their group by email and a timetable will be stablished for individual review by Microsoft Teams/Google Meet. The student will keep a copy of the PDF files sent as the answers to the exam to make the review process smoother. Additionally, the lecturer can ask the student an interactive discussion and revision of the exam within the timeframe stablished for review as notified in the VC.

- **Methods used for the documentation/recording of the evaluation procedure for their future visualization and evidence:**

The lecturer will keep copies of the files (in the specified electronic format) with the answers submitted by the student, and the pertinent partial assessments. Additionally, if considered opportune, there will be access to the recording of the exam session, with the limits stablished by the UCM, for its revision if necessary. This recording, in case of taking place, will be kept with the pertinent security means in computers of the UCM, and will be deleted once the review period is over.