COURSE DATA

DATA SUBJECT

Code: 46991
Name: Smart materials with advanced functionalities
Cycle: Master's Degree
ECTS Credits: 8
Academic year: 2025-26

STUDY (S)

Degree	Center	Acad. year	Period
2278 - Master in Advanced Materials	Facultat de Química	1	Second quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
2278 - Master in Advanced Materials	Materiales inteligentes con funcionalidades avanzadas	COMPULSORY

COORDINATION

CORONADO MIRALLES EUGENIO

SUMMARY

This course will be taught, together with the module MA5, intensively during 3 weeks in May and each year at a different university. The course will be taught in English.

This course aims to train students in the most relevant aspects of advanced characterization and modeling of materials and devices. Likewise, the main concepts of materials design with advanced functionality (particularly materials that respond to external stimuli) will be explained, serving as a basis for developing applications primarily in four specific areas: Information and Communications Technologies, Health, Mobility, and Habitat and Environment.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

Previous knowledge of chemistry, physics or materials science as taught in the degrees indicated in the recommended entry profile to the master's degree is required. Previous knowledge of materials science as taught in the Introduction Module (MA1) is required.

COMPETENCES / LEARNING OUTCOMES

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Acquire knowledge of the components, molecules and materials that are fundamental for the design and fabrication of quantum devices.

Analyse the design of nanomaterials for their application in advanced imaging diagnostic techniques and theranostic techniques.

Capacity for learning, responsibility and decision-making: Act autonomously in learning, make informed decisions in different contexts, issue judgements based on experimentation and analysis and transfer knowledge to new situations.

Categorise the use of advanced materials for environmental remediation: water, soil and air treatment. Also consider concepts such as biodegradation.

Creative and entrepreneurial skills: Propose creative and innovative solutions to complex situations or problems within the field of knowledge to respond to diverse professional and social needs.

Critically analyse, evaluate and synthesise new ideas to solve problems in complex or unfamiliar environments within broader contexts in the different areas of impact and application of materials.

Critical thinking, ethical commitment and professional responsibility: Demonstrate critical and self-critical reasoning in the field of the degree, considering aspects such as professional ethics, moral value and the social implications of the different

Describe the functioning of functional nanosystems as materials with antimicrobial and antifungal capabilities.

Design smart nanomaterials to solve problems in the field of the biomedical sciences by applying the principles of controlled release of species of interest.

Emotional intelligence: Understand and regulate one's own emotions and those of others to interact and participate effectively and constructively in social and professional life.

Evaluate the lifetime of advanced materials by applying the concept of circular economy to starting products, preparation processes, usage and recycling.

Gender perspective: Know and understand, within the area of the degree, inequalities based on sex and gender in society; integrate different needs and preferences based on sex and gender into the design of solutions and problem-solving.

Have the knowledge and skills necessary to pursue future doctoral studies in the field of materials.

Identify the different response mechanisms of functional bionanomaterials to exogenous and endogenous stimuli.

Interpret the performance of nanosystems in biomedical applications for the controlled release of drugs of interest.

Predict and rationalise properties related to spin-polarised transport in devices.

Relate the type of advanced material to the best methods of production, manufacturing and processing of the final device.

Social commitment and sustainability: Contribute to the design, development and implementation of solutions that respond to social demands, considering the Sustainable Development Goals as a reference.

Students from one area of knowledge (e.g. physics) should be capable of communicating and interacting scientifically with peers from other areas of knowledge (e.g. chemistry) in the analysis and resolution of common problems.

Teamwork and leadership: Collaborate effectively in work teams, taking on responsibilities and leadership roles and contributing to collective improvement and development.

Understand the fundamentals and necessary elements for the design of memristors to be used in neuromorphic computing.

Understand the main applications of materials in quantum technologies and neuromorphic computing.

Understand the main characterisation techniques needed to evaluate the biological activity of the functional nanosystems designed.

Understand the main techniques for the construction and characterisation of the properties of optoelectronic and spintronic devices.

Understand the most relevant applications of 2D materials.

Understand the structure property relationship in different advanced stimuli-responsive materials and distinguish their fields of application.

Understand the transport mechanisms that control the operation of both optoelectronic and spintronic devices.

DESCRIPTION OF CONTENTS

U4.1. Advanced Characterization and Modeling of Materials/Devices

- Nanoscale characterization of materials under operating conditions/in situ/in operand integrated into electronic/electrochemical devices.
- Multi-scale simulation of material/device properties using high-performance computational techniques. Correlation of the chemical composition and nano/microstructure of the material with its properties.

U4.2. Functional Materials for ICTs

- Materials design for electronics and molecular spintronics. Integration of molecular nanostructures into (opto)electronic devices (OFETs, OLEDs, spin valves, etc.). Study of their properties. Basic concepts of coherent electron transport in molecular nanodevices. Experimental techniques for measuring quantum transport and theoretical modeling. Basic concepts of spin transport in molecular spintronic devices.

- Design of molecules and functional materials for quantum information technologies. Basic concepts: quantum bits, quantum gates, quantum devices based on spin quantum bits. Advanced characterization techniques.
- Design of functional materials with memristive properties for neuromorphic computing.

U4.3. Materials for biomedical applications

- Design of functional molecules and nanomaterials that respond to exogenous stimuli (light, temperature, magnetic or electric fields, etc.) or endogenous stimuli (pH, presence of small molecules or biomolecules, presence of radicals, reducing medium, etc.).
- Incorporation into organic or inorganic nanosystems for biomedical applications: controlled release, implants, artificial organs, biomaterials, materials for advanced therapies, antimicrobial and antifungal materials, or materials with applications in in vitro molecular diagnostics or imaging (probes, biomarkers, biosensors, etc.).

U4.4. Multifunctional materials and devices for sustainable mobility, habitat, and the environment

- Mobility: design and integration of smart multifunctional materials into structural health monitoring systems for components; design of multifunctional products related to energy management for mobility (battery architecture, hydrogen tanks, vehicle-integrated solar cells); design of new lightweight multifunctional materials for transportation.

- Habitat and environment: ceramic products with new functionalities (electronic, biological, etc.); design of porous materials for the environment, catalysis, and electronics; generation of smart structures for energy applications; new smart materials for energy management in buildings; polymers with advanced functionalities (biopolymers with active, sensory, and intelligent behavior and controlled biodegradation; polymers based on dynamic chemistry); sustainability in processes and products through the recycling and recovery of both industrial and natural waste.

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	48,00
Classroom practices	33,00
Total hours	**81,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	0,00
Independent study and work	0,00
Preparation of lessons	9,00
Preparation for assessment activities	42,00
Resolution of case studies	68,00

	Total hours	119,00

TEACHING METHODOLOGY

The main training activities and face-to-face teaching methodologies will be the **theoretical classes** and the **seminars**. During the seminars, the theoretical contents of the modules will be worked on in a practical way. Among the methodologies used in the seminars are the discussion of articles, debate and guided discussion, discussion of practical cases and resolution of problems and questions and visits to laboratories and scientific facilities of the university where the classes are held that year.

These training activities will be carried out intensively each year at a different university, which will be attended by students and teaching staff from all the universities. Through this mobility between the participating universities, students will be able to benefit from the knowledge of various renowned professors and researchers distributed throughout the territory. Given that these modules deal with advanced and specific concepts, the inter-university nature of the master's degree means that students will be able to count on expert lecturers in each of the subjects covered at all the universities.

After the theory classes, students will have to solve a series of **questions and problems** posed by each of the lecturers of these modules, through this work, students will develop and assimilate the concepts studied during the face-to-face classes.

The resolution of these questions involves a great deal of individual work by the students, as well as the pooling with the rest of the students, and they will also have the participation of the teaching staff to resolve any doubts. During the seminar hours, guidelines will have been given for the resolution of the questions and initial doubts will have been resolved. In the weeks following the intensive classes, group **tutoring sessions** will be carried out in online, synchronous and interactive mode. During these sessions, guidance will be offered to students and doubts will be resolved about the questionnaire, once students have started working on it, as well as about the preparation of the exam.

Students will also be able to contact the professors individually at any time to resolve any doubts they may have.

This combination encourages direct interaction between students and teachers as well as the autonomous work of students, which allows them to deepen their knowledge of the topics covered and apply what they have learnt autonomously.

EVALUATION

SE3- Active participation in face-to-face activities: 10%
SE1- Written exam on basic subject content: 90%

SE3- Active participation in face-to-face activities: Continuous assessment of students based on their involvement and commitment to the teaching-learning process. Their participation in debates and discussions, as well as in solving simple problems related to the module content, will be taken into account. Students' level of interest, understanding and analytical ability of the content taught, as well as their ability to formulate relevant questions and comments and respond to questions and problems posed by the professor will be assessed.

SE1- Written exam on basic subject content: Students' achievement of the various learning outcomes will be assessed through an individual final written exam. The degree of mastery of the fundamental concepts taught during the theoretical classes and intensive seminars, as well as the students' independent work through solving questions posed by the professors, will be taken into account.

Exams may include different types of questions, such as short answers, short essays, and problem-solving, in order to assess both the knowledge acquired and the students' analytical, synthesizing, and argumentative skills.

Each student will take the exam, in person, at their university of enrollment. It will be a common exam for all participating universities, ensuring equal conditions for all students and facilitating a controlled and reliable assessment.

Attendance at training activities is mandatory. To pass the module, students must have attended all in-person training activities and regulated tutorials, except in duly justified cases.

REFERENCES