COURSE DATA

DATA SUBJECT

Code: 43305
Name: Optoelectronic materials and devices
Cycle: Master's Degree
ECTS Credits: 6
Academic year: 2025-26

STUDY (S)

Degree	Center	Acad. year	Period
2150 - Master's degree in Advanced Physics	Facultat de Física	1	First quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
2150 - Master's degree in Advanced Physics	Optoelectronics	ELECTIVES

COORDINATION

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SUMMARY

The content of the subject is related to the different aspects of the technology of optoelectronic materials and devices based on them, and is organized into three blocks:

PART 1: CRYSTAL GROWTH, AND STRUCTURAL AND MORPHOLOGICAL CHARACTERIZATION

1. Crystal growth: Physical, chemical and technological fundamentals.

2. Methods for crystal growth of bulk materials, thin layers and nanostructures.

3. Structural and morphological characterization.

PART 2: MICROELECTRONIC TECHNOLOGY AND ENGINEERING OF THE BANDGAP

4. Device manufacturing techniques: lithography, positive and negative resins, wet and dry etching.

5. Bandgap engineering in semiconductor heterostructures for optoelectronic devices.

PART 3: OPTOTELECTRONIC DEVICES

6. Electroluminescent diodes (LEDs) in visible and NIR.

7. Laser diode technology.

8. Technology of photodetectors and photovoltaic devices.

PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

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

OTHER REQUIREMENTS

To follow up the contents of the module a basic background in Physics of Solids (band theory, lattice vibrations, electrical properties) is needed, as well as a basic but more specific knowledge in Physics of Semiconductors (statistical of carriers, carriers out of equilibrium and optical properties) and in basic electronic devices (p-n diode, for example).

COMPETENCES / LEARNING OUTCOMES

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Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.

Comprender cómo se modifican las propiedades optoelectrónicas de los materiales en
medios nanoestructurados y su influencia en dispositivos optoelectrónicos/fotónicos.

Comprender de una forma sistemática el campo de estudio de la Física y el dominio de las habilidades y métodos de investigación relacionados con dicho campo.

Comprender el funcionamiento de los dispositivos optoelectrónicos a partir de las propiedades de los materiales y la estructura del dispositivo, así como conocer los avances recientes en el campo.

Comprender las bases físicas de las propiedades de los materiales que determinan sus aplicaciones optoelectrónicas.

Comprender las técnicas más habituales de preparación, crecimiento y caracterización de materiales optoelectrónicos en monocristal, capa delgada o nanoestrucutura.

Concebir, diseñar, poner en práctica y adoptar un proceso sustancial de investigación con seriedad académica.

Elaborar una memoria clara y concisa de los resultados de su trabajo y de las conclusiones obtenidas en el área de la Física.

Evaluar la validez de un modelo o teoría propuesto por otros miembros de la comunidad científica.

Exponer y defender públicamente el desarrollo, resultados y conclusiones de su trabajo en el área de la Física.

Poseer la capacidad para el desarrollo de una aptitud crítica ante el aprendizaje que le lleve a plantearse nuevos problemas desde perspectivas no convencionales.

Realizar un análisis crítico, evaluación y síntesis de ideas nuevas y complejas en el área de la Física.

Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.

Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.

Ser capaz de seleccionar los materiales y diseñar (aspectos más básicos) un dispositivos optoelectrónico que permita abordar una aplicación o problema planteado.

Students should demonstrate self-directed learning skills for continued academic growth.

Students should possess and understand foundational knowledge that enables original thinking and research in the field.

DESCRIPTION OF CONTENTS

1. Crystal growth: Physical, chemical and technological fundamentals

In this firth topic, the physical-chemical and technological bases of crystal growth are analyzed, with special emphasis on semiconductor materials. It begins with a review of these concepts based on the students' previous knowledge in their corresponding degree studies, with special emphasis on phase diagrams, fluid dynamics, chemical potentials, supersaturation and superfusion states, coupling of crystal networks, surface energy, etc. Next, the basic elements of a crystal growth laboratory are analyzed and how this equipment affects the fundamentals previously presented.

2. Methods for crystal growth of bulk materials, thin layers and nanostructures

In this second topic, several methods for the growth of crystalline materials in volume are described in more detail: Czocralskii method, Bridgman method, THM, PVD, CVD, hydrothermal, solid phase recrystallization, among others. Other options are also studied for the growth of crystalline layers on different substrates, such as vacuum evaporation, sputtering, the use of different types of beams and laser ablation, liquid phase epitaxy (LPE), phase epitaxy vapor (CVD, Mist-CVD and MOCVD) and the spray pyrolysis method. In all cases, the characteristics of the method and the variables that allow control of the properties of the cultivated material are analyzed.

3. Structural and morphological characterization

In the third topic, the characterization of the structural and morphological properties of the materials is addressed. It begins by describing what the interaction of radiation with matter is like. Next, different characterization techniques are generally analyzed depending on the type of beam, both for X-rays (XRD, XFR, HRXRD) and electrons (SEM, TEM, HRTEM). The structural and morphological information that can be obtained is described and How the different measurement techniques are applied depending on the material, whether it is polycrystalline, in volume, in the form of a layer or nanostructures.

4. Microelectronics Technology

In this topic we explain different processes carried out on semiconductor wafers: layer deposition, silicon oxidation, diffusion of impurities, definition of apertures by lithography techniques (optics, electron beam) and material removal (chemical and plasma attack)

5. Bandgap engineering

Most current emitting optoelectronic devices are based on semiconductor heterostructures and nanostructures. They are defined by the difference between the lattice parameters and the band gaps of the materials involved (III-V semiconductors and their alloys, for example), as well as the relative alignment of their valence bands. These aspects will determine heterostructures with a potential profile that can eventually be exploited to confine the carriers and determine their wave function and intersubband and interband optical transitions. Semiconductor hetero-junction, metal-semiconductor junction and metal-oxide-semiconductor junction.

6. Electroluminescent diodes (LED) in visible and NIR.

This topic starts from the basic concept of an electroluminescent diode (Fundamentals of Optoelectronics subject) to review its historical evolution, highlighting the materials and most used structures. Due to its importance, the cases of the GaN LED, its impact on lighting, and new concepts will be discussed

7. Technology of laser diodes

The basic concept of a lateral emission laser diode (Fabry-Pérot resonator) is defined, as well as the quantities that define its operation: optical confinement, gain, threshold current, temperature parameter... as well as the balance equations that allow determining the optical power of laser emission. Different types of lateral emission lasers will be discussed as well as the VCSEL diode.

8. Technology of Photodetectors and photovoltaic devices.

The most basic cases of photodetector devices will be examined, such as the case of p-n and p-i-n photoconductors and photodiodes, in order to review other more complex architectures, such as the case of CCD and CMOS devices

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	36,00
Seminar	3,00
Laboratory	4,00
Total hours	**43,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	7,00
Individual or group project	10,00
Independent study and work	30,00
Preparation of lessons	20,00
Preparation for assessment activities	20,00
Resolution of case studies	20,00
Total hours	**107,00**

TEACHING METHODOLOGY

MD1 - Standar theory lecture

MD3 - Problems solving

MD4 - Problems

MD5 - Seminars.

MD6 - Visit to external scientific facilities and companies

MD7 - Addressed debate or discussion.

EVALUATION

SE1 - Written exams on theory and practical classes: based on the learning results and the specific objectives of each subject.

SE3 - Continuous evaluation of the student in theory and practical classes: participatory assistance and carrying out exercises in the classroom.

SE5 - Evaluation of non-face-to-face activities related to theory and practical classes: reports and/or practical reports delivered.

To determine the final grade, the grades obtained from the different evaluation methods will be weighted depending on the amount of subject evaluated in each case.

This evaluation system will be used for both the first and second call.

REFERENCES

- Crystal Growth Processes, J.C. Brice, Ed. Wiley, 1986.
- Fundamentos de electrónica física y microelectrónica", J.M. Albella, J.M. Martínez-Duart, Ed. Addison-Wesley/U.A. Madrid (1996).
- Physics of semiconductor devices, S.N. Sze, Ed. John Wiley, 1981 y ediciones posteriores
- Physics of Optoelectronic Devices, S. L. Chuang, Ed. Wiley, 1995
- Quantum Wells, Wires and Dots, Paul Harrison, Ed. Wiley, 2007
- Semiconductor laser physics, W.W. Chow, S.W. Koch, M. Sargent, Ed. Springer-Verlag (1994).
- Photonics and laser: an introduction, Richard S. Quimby, Jjhon Wiley & sons, 2006
- Fundamentals of Semiconductor Fabrication, G.S. May & S.M. Sze, Ed. Wiley, 2003