COURSE DATA

Data Subject	
Code	34277
Name	Semiconductor physics
Cycle	Grade
ECTS Credits	6.0
Academic year	2020 - 2021

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	4	First term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	16 - Complements of Physics	Optional

Coordination

Name	Department
MARTINEZ PASTOR, JUAN PASCUAL	175 - Applied Physics and Electromagnetism
SEGURA GARCIA DEL RIO, ALFREDO	175 - Applied Physics and Electromagnetism

SUMMARY

Semiconductor Physics is an optional subject that is taught in the second semester of the fourth year of the Degree in Physics and consists of 6 ETCS credits, of which 4.5 are theoretical and 1.5 are laboratory experiments.

The aim of this subject is to provide students with an introduction to the basic properties of semiconductors (electronic structure, electron and hole statistics, carrier scattering, generation and recombination of non-equilibrium carriers, optical properties) and to show how these properties are modified in low dimensionality structures (quantum wells, wires and dots) and determine the characteristics, efficiency and limitations of electronic and optoelectronic 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

Mechanics and Waves, Electromagnetism, Optics, Quantum Physics, Quantum Mechanics, Solid State Physics, Statistical Physics.

COMPETENCES (RD 1393/2007) // LEARNING OUTCOMES (RD 822/2021)

1105 - Degree in Physics

- Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.
- To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.
- Ability to collect and interpret relevant data in order to make judgements.
- Capacity to communicate information, ideas, problems and solutions to a specialist and a general audience.
- Developing learning skills so as to undertake further studies with a high degree of autonomy.
- Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .
- Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.
- Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.
- Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.
- Literature Search: be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.

- Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.
- Cultura General en Física: Haberse familiarizado con los aspectos más importantes de la materia, y con enfoques que abarcan y relacionan diferentes áreas de la física.

LEARNING OUTCOMES (RD 1393/2007) // NO CONTENT (RD 822/2021)

- Knowledge of the basic parameters of the electronic structure of a semiconductor.
- Knowledge of the statistics of electrons and voids and the role of acceptor and donor impurities.
- Knowledge of the basic transport phenomena in intrinsic and extrinsic semiconductors.
- Understanding of the behavior of non-equilibrium carriers the role they play in electronic devices.
- Understanding of the relationship between the electronic structure and the optical properties of a semiconductor.
- Understanding of the modification of the electronic structure in systems of low dimensionality with respect to that of the bulkmaterial.
- Understanding of the basic physics of the p-n junction and the relationship between its electronic structure and its characteristics and applications.
- Understanding of the band schemes of the different types of heterojunctions and the use of these schemes to determine its characteristics and applications.
- Basic understanding of the physical foundations of light detection by semiconductor devices.
- Basic understanding of the light emission by LEDs and semiconductor lasers.

DESCRIPTION OF CONTENTS

1. Crystal structures and electronic structure of semiconductors

Crystal structure of some semiconductors. Band structures of semiconductors IV, III-V and II-VI. Basic parameters of the electronic structure: forbidden band and effective masses. Direct and indirect semiconductors.

2. Electron and hole statistics and transport properties

After introducing the concept of density of and using the Fermi-Dirac statistics in an intrinsic semiconductor, it will be shown how the electron and hole concentration is determined by the temperature, the bandgap and the effective masses. Changes produced by doping with donor and acceptor impurities will be studied,. Doping is needed to control the Fermi level and design and produce electronic devices. A very simple model, the Drude model, will be used to introduce the transport parameters. Then, in a second step a simple version of the Boltzmann equation will be presented, showing how it can be used to treat more complex transport problems, such as carrier diffusion or the thermoelectric effect.

3. Carrier scattering and non-equilibrium carriers

After introducing the concepts of scattering probability and relaxation time the carrier scattering mechanisms by ionized impurities and lattice vibrations are studied. The temperature dependence of carrier mobility is discussed. The concepts of carrier generation and recombination introduced as well as the difference between carrier diffusion and drift. Using these ideas, the Einstein relation and the diffusion equation are deduced and discussed.

4. Optical properties of semiconductors

The optical parameters and their relation to the dielectric function are introduced from a simple model of resonant absorption. The fundamental absorption around the gap is studied by distinguishing between the absorption thresholds for direct and indirect semiconductors. The concept of exciton and Einstein's relations between spontaneous and stimulated emission are introducedand applied to photoluminescence.

5. Low dimensionality systems

Quantum wells wires and dots. Electronic states in a 2D system. Density of states in low dimensionality systems. Fermi level in a 2D system. Triangular and square potential wells. Coupled quantum wells superlattices. Quantum wires. Quantum dots.

6. Technology of semiconductors, devices and nanostructures

Synthesis and crystal growth of semiconductors. Epitaxial growth by molecular and metalorganic beam. Manufacture of devices: epitaxy and photolithography. Thin layer techniques Growth of semiconductor nanostructures.

7. P-n junctions

Device band schemes. I (V) and C (V). characteristics. Junction between degenerate semiconductors. The tunnel diode. Heterojunctions. Schottky effect. Metal semiconductor junctions. Structure of the M.O.S . devices: inversion and accumulation. C(V) characteristics.

8. Low dimensionality electronic systems: optical and transport properties

Optical properties of low dimensionality systems: excitons in quantum wells, wires and dots. Transport in low dimensionality systems. Ballistic transport. Tunnel effect devices.

9. Photodetectors and solar cells: bulk and nanostructure devices

The PN diode under illumination. Photodetectors. Photovoltaic spectrum. Solar cells. Efficiency parameters. Maximum efficiency and optimum bandgap value. Efficiency limitations: effect of internal resistance and barrier losses. Types of solar cells. Nanostructured photodetectors and solar cells.

10. Light emission devices: semiconductor LEDS and lasers. Bull and nanostructures

Light mission by a diode. Electroluminescence efficiency. Electroluminescent diode. Physical bases of the semiconductor laser. Population inversion, gain and modes. PN junction lasers: threshold current. Lasers based on semiconductor nanostructures. Quantum emitters and Qbits based on nano structures.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	45,00	100
Laboratory practices	15,00	100
Readings supplementary material	5,00	0
Preparation of evaluation activities	15,00	0
Preparing lectures	30,00	0
Preparation of practical classes and problem	25,00	0
Resolution of case studies	15,00	0
TOTAL	**150,00**	

TEACHING METHODOLOGY

Lectures:
Laying down the foundations of Semiconductor Physics, introducing the fundamental aspects and deriving the electrical and optical properties of semiconductors with a view to understand how they determine the electronic device behavior.

Classes of problems:
Complementary exercises are aimed primarily to understand the orders of magnitude of different physical parameters of a semiconductor and the various figures of merit of electronic devices.

Laboratory sessions:
The labs will be conducted in small groups. Students work together on data collection and discussion of results, in a preliminary analysis.

EVALUATION

Theoretical and practical part:
-Written exams: The theoretical part of the exam will approach the understanding of the properties and physical processes in semiconductors and devices.
Bibliographic work on a particular semiconductor, describing their properties and how are you determining preferred applications.
-Continuous assessment: assessment of the performance of proposed problems during the course.

Laboratory:
-Continuous assessment: Individual control of laboratory work and data processing, results and conclusions of each practice using a questionnaire.
-Final evaluation: exposure of the physical basis, methodology and results of a practice.

At least 30% of the total mark will correspond to a continuous assessment.

REFERENCES

Basic

- "Fundamentos de electrónica física y microelectrónica", J.M. Albella, J.M. Martínez-Duart, Ed. Addison-Wesley/U.A. Madrid, 1996.
- "Physique des semiconducteurs et des composants électroniques", H. Mathieu, Masson, Paris, 1998.

Additional

- "Basic semiconductor Physics", C. Hamaguchi, Springer-Verlag, Berlín 2001
- "Semiconductor physics", K. Seeger, Ed. Springer-Verlag, Berlín, 1982.
- "Física del estado sólido y de semiconductores", J.P. McKelvey, Ed. Limusa, Méjico, 1976.

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

English version is not available