Titulación

Master en Ingeniería de Materiales

Functional Materials at Macro and Micro/Nanometer Scales,

24-11-2014

Department (Faculty)
Ingeniería Electrónica (ETSI de Telecomunicación)

Subject	Code
Properties of functional materials in bulk, micro and nanoscale	43000334

ECTS	Type	Year/Semester	Schedule	Language
5		1/2	Spring Semester	English

Objectives

The main objective of this course will be to acquire fundamental knowledge on the properties of functional materials at different levels of volume (size); from bulk material (3D) to micro and nanoscale structures (2D, 1D and 0D). Special emphasis will be given to structural, transport (electrical conductivity) and optical properties. Specific characterization techniques will be described to analyze the mentioned properties. Finally, examples of nanostructures at the different scales (3D,2D,1D, and 0D), as well as on their fabrication methods, will be addressed.

Prerequirements

None

Previous knowledge recommended

Basic Optics; Electricity and Magnetism; Structure of Materials; Semiconductor Physics; Quantum Physics.

Coordination with other subjects

Generic Competencies

CG1, Use of English language
CG2, Capacity for teamwork
CG3, Spoken and written communication skills
CG4, Use of Communication and Information technologies
CG7, Planning and organizational capacity
CG9, Capacity of interdisciplinary work

Specific Competencies

CE1, Knowledge of the structure of materials and the techniques for their characterization and analysis
CE5, Capacity for autonomous learning
CE6, Capacity for designing, assessment, selection, and manufacture of materials

Contents

0. Introduction.

Why micro and nano scale matters? Examples of recent technology: data storage, optical and magnetic memories, electrical and optical communications, cheap light generation, single photon sources, etc.

1. Material properties (3D): structural, thermal, electrical and optical.

1.1 Classification of solids: amorphous, polycrystalline, crystalline.
1.2 Structure of materials. Unit cell. Bravais lattices. Miller indices. Reciprocal lattice. Brillouin Zone.
1.3 Crystal structure and electrons in solids. Energy Bands.
1.4 Lattice vibrations. Thermal conductivity.
1.5 Electrical properties. Conductors: Drude Model. Semiconductors: Electron-hole transport. Scattering processes. Mobility. Gunn effect.
1.6 Optical properties: Direct vs. Indirect band-gap. Recombination processes. Lifetime.
1.7 Properties of Semiconductors. Alloys, lattice mismatch, strain, defects. Heterostructure formation, electron affinity (HEMT, QW, p-n junction, Schottky barrier).

2. Materials Characterization (3D): XRD, SEM, PL, CL, Raman, Hall.

2.1 Morphology and structure (shape, lattice and defects): SEM, AFM, TEM
2.2 Crystal properties (crystal unit cell): XRD
2.3 Thermal properties (phonon dynamics): Raman spectroscopy
2.4 Electrical properties (electrons/ion or electron/hole transport): Hall effect
2.5 Optical properties (electron-hole recombination dynamics): PL, CL

3. Nanoscale Science and Engineering.

3.1 Two dimensional structures: Quantum Wells. Band structure. Energy levels. Sub-bands. Density of states. Electrical and optical properties. Quantum stark effect.
3.2 One dimensional structures: Quantum Wires. Band structure. Energy levels. Sub-bands. Density of states. Electrical and optical properties.
3.3 Zero dimensional structures: Quantum Dots: Band structure. Energy levels. Sub-bands. Density of states. Electrical and optical properties.

4. Fabrication and Characterization of Micro and Nanostructured Materials.

4.1 Nanostructures grown by self-assembly method.
4.2 Ordered and top-down approaches to grow nanostructures. Selectivity.
4.3 Nanolithography: e-beam, nanoimprint, colloidal. Assessment by AFM, STM, TEM, and SEM microscopy.
4.4 Applications and examples (nanoFETs, nanoLEDs, QD-lasers, sensors).

Classes and Evaluation

The course will be taught mainly by master classes both theoretical and practical.
Interaction between student and professor and student-student will be enhanced by discussions and homework sets. The continuous evaluation will include two partial exams and individual exercises, with the following distribution in the final grade:

- 1st partial exam: 45% of the final grade.
- 2nd partial exam: 45% of the final grade.
- Homework sets: 10% of the final grade.

Office hours

Office hours give students the opportunity to ask in-depth questions and to explore points of confusion or interest that cannot be fully addressed in class.
The progress of the students will be monitored with individual assignments (homework sets).

Bibliography

- Physics of Semiconductor Devices
  S.M. Sze
  John Willey & Sons.

- Nanoscale Physics for Materials Science
  T. Tsurumi, H. Hirayama, M. Vacha, T. Taniyama
  CRC Press, 2009

- Optical Properties of Solids
  M. Fox
  Oxford Master Series in Condensed Matter Physics
  Oxford University Press, 2001

Teaching Staff

Instructors: Enrique Calleja Pardo (coordinator)
M.A. Sanchez Garcia
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