The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6212 SEMICONDUCTOR MATERIALS

Credits: **15**

Course Description including Aims

This module describes the basic physical properties (structural, optical, electrical) of semiconductor materials used in the electronic and opto-electronic industries, and in semiconductor based research. The aim is to equip the students with a comprehensive background understanding of the physical, structural, optical, electronic properties of semiconductor materials used in modern electronic and opto-electronic devices.

Course Objectives

On successful completion of this module the students should be able to:

1. Understand the role and used of different semiconductor materials in different types of devices.
2. Understand relevant crystal structures, the reciprocal lattice, and X-ray and electron diffraction.
3. Have knowledge of the role of the crystal structure in defining the thermal, optical, and electrical properties of the semiconductor, and describe the role of defects, dislocations and doping on these properties.
4. Understand the electronic band-structure in defining the electronic properties (e.g. carrier mobilities, intrinsic doping) and optical properties of the semiconductor (e.g. direct and indirect transitions, density of states)
5. Demonstrate an understanding of the different optical transitions and carrier relaxation processes.
6. Gain knowledge on excitonic effects, and the role of free carriers on the band-structure.
7. Understand electrical conduction processes for intrinsic and doped materials and the formation of p-n junctions.
8. Understand the concept of many modern optoelectronic devices, such as LEDs, LASER diodes and photo-detectors, and of solar cells, and how the semiconductor materials and their defects influence these properties.
9. Have knowledge of the effects of quantum confinement on the electronic and optical properties of the semiconductor materials and understand the concepts of quantum dots, wires and wells.
10. Demonstrate practical knowledge of the characterization and analysis of semiconductor materials.

Detailed Syllabus

- Materials of choice – III-V, II-VI, organics, Si, Ge
- Crystal structures, symmetry
- X-ray and electron diffraction
- Reciprocal lattice
- Phonons
- Defects, dislocations, doping
- Electronic band structure
- Optical transitions – direct indirect, Fermi's Golden rule, absorption
- Density of states
- Carrier lifetime and recombination
- Spontaneous emission
- Stimulated emission, gain, and lasing
- Excitons, free carrier effects
- Conductivity as a function temperature, doping, and band-gap
- Conduction – drift and diffusion currents
- The formation of the p-n junction
- Principles of lasing, LASER diodes, photodetectors and solar cells
- Quantum wells, wires, dots. Quantum mechanics and the effects of this quantum confinement on electronic and optical properties.

Recommended Previous Courses

An understanding of basic physics, mathematics and physical electronics, as expected from graduates from Physics, Engineering, Materials, Chemistry, etc.

Assessment

A 3 hour exam 4/6 questions at the end of the year plus 25% based on a report on the structural and optical analysis of a semiconductor material.

Recommended Books

Ashcroft & Mermin,	"Solid State Physics"	Brooks/Cole
Kittel	"Introduction to Solid State Physics"	John Wiley & Sons
Fox	"Optical Properties of Solids"	OUP
Kelly	"Low Dimensional Semiconductors"	OUP
Sze	"Physics of Semiconductor Devices"	Wiley
Phillips	"Crystals, Defects & Microstructures"	CUP

UK-SPEC/IET Learning Outcomes

Outcome	Supporting Statement
SM1p	Students will develop a comprehensive understanding of the underlying scientific principles behind the physical properties of semiconductor materials.
SM2p	The course will introduce mathematic models used to describe materials properties, and the students will learn how to apply these to predict device performance
SM4m	An awareness of the state-of-the-art in the development of semiconductor materials.
SM6m	During the course, the students will be introduced to a wide range of concepts from outside conventional engineering, which underpin the scientific principles discussed. This includes an understanding of the business and societal needs that have driven the development of devices based on "new" compound semiconductors and nano-structures.
SM1fl	An awareness of the state-of-the-art in the development of semiconductor materials.
SM3fl	During the course, the students will be introduced to a wide range of concepts from outside conventional engineering, which underpin the scientific principles discussed. This includes an understanding of the business and societal needs that have driven the development of devices based on new compound semiconductors and nano-structures.
EA1m	The students will be taught the principles of epitaxy and device processing techniques and learn the basic key features (pros/cons) distinguishing related techniques for structuring devices
EA2m	The students will learn how to assess optical spectra and X-ray or electron diffraction patterns and how to derive information on the material type and real-space structures investigated.
EA5m	The students will gain extensive knowledge in the principles of semiconductor materials and be able to apply their knowledge to the development of new materials and structures for devices.
EA2fl	The students will gain extensive knowledge in the principles of semiconductor materials and be able to apply their knowledge to the development of new materials and structures for devices.
EA3fl	The students will be able to apply their knowledge to an unfamiliar problem, defining and executing their own experiments and analysing their data.
D3m	In the laboratory exercise on quantum well structures the students will encounter experimental data with low signal-to-noise ratio on the y-scale and measurement uncertainties on the x-scale which they will have to take into account when drawing conclusions on the real space structure and chemistry.
ET2p/ET2m	Students will develop knowledge of the commercial importance of semiconductor materials. Key future developments and their impact on the industry will also be discussed.
ET2fl	The students will learn about the commercial and societal necessity to shrink optoelectronic devices used for information processing in integrated circuits.
ET4fl	The students will learn about the commercial and societal necessity to make solar cell materials cheaper and more environmentally friendly
EP1fl	At the end of the course the students will have extensive knowledge of a wide range of electronic and opto-electronic materials.
EP2p	The course seeks to describe the current state of the art in terms of electronic and opto-electronic materials. It will also discuss new approaches and emerging trends concerning materials synthesis, characterisation and device

	processing
EP3p/EP3m	The students will develop laboratory skills in the optical and structural characterisation of semiconductor materials.
EP2m	At the end of the course the students will have extensive knowledge of a wide range of electronic and opto-electronic materials.
EP11m	The experimental part consists of PL and XRD measurements conducted in small teams supervised by PDRAs, and the students will have to learn how to splits tasks within a team and how to discuss systematic approaches to problem solving.
EP4fl	The experimental part consists of PL and XRD measurements conducted in small teams supervised by PDRAs, and the students will have to learn how to splits tasks within a team and how to discuss systematic approaches to problem solving.