UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Semiconductors Physics

2425-1-F1701Q118

Aims

The main objective of the course is to provide an overview of the subject and a solid background for further specialization in the area of nanoelectronics, spintronics, optoelectronics, quantum technologies, sensors, energy harvesting and production, and neuroelectronics. After a summary of technologically relevant materials and their properties and a reminder of solid-state physics concepts, such as crystal structure, lattice vibrations and band structure, semiconductor specific topics such as effective mass and its experimental determination, k dot p perturbation method, point defects and their structural, thermodynamic and electronic properties, charge statistic in intrinsic and extrinsic semiconductors, optical properties, charge transport, semiconductors in equilibrium and non-equilibrium conditions will be presented as the core of the course.

For the interested reader some additional topics (nanoelectronic, spintronics, 2D materials for example) are included to offer an overview of some highlights in semiconductor physics current trends and stimulate further reading. To follow efficiently the course pre-existing knowledge in quantum mechanics and solid-state physics is necessary.

Contents

Semiconductor physics: electronic, optical, and transport properties.

Detailed program

ELECTRONIC STRUCTURE

Band structure, effective mass and its experimental determination k dot p method: conduction band, valence band,

spin-orbit interaction,

Point defects: structure, thermodynamics, vibrational properties, electronic properties, dopants; intrinsic defects; impurities; complex defects.

"Shallow" defects: effective mass theory. Mott transition. High concentration effects.

"Deep" defects: Green’s function approach.

Introduction to some experimental techniques for the study of defects: electron spin resonance (EPR), deep level transient spectroscopy (DLTS).

STATISTICAL DISTRIBUTIONS

Statistics; thermodynamics; density of states; distribution of holes and electrons; intrinsic and extrinsic semiconductors, chemical potential and Fermi level.

OPTICAL PROPERTIES

Photon-electron interaction; band-band absorption; excitons; absorption of free carriers; reflectivity; impurities. Optical spectroscopy of impurities and dopants (Raman, Photoluminescence, Photoionization).

TRANSPORT PROPERTIES

Macroscopic quantities characterizing charge transport. Boltzmann equation; distribution function; charge transport; scattering processes, relaxation time approximation. Hall effect, magnetoresistance, effects of high electric field (hot carriers), negative differential resistance, Gunn effect. Semiconductors in equilibrium and non-equilibrium. Recombination of charges, drift and diffusion. Spin-dependent transport.

NANOSTRUCTURES

Two-, one-, and zero-dimensional structures and related electronic properties, quantum hall effect, 2D systems (graphene, silicene, dicalcogenides of transition metals).

Prerequisites

Quantum Mechanics. Solid State Physics.

Teaching form

30 two-hour lectures, in person, traditional lectures

Textbook and teaching resource

- M. Balkanski and R.F. Wallis, Semiconductor Physics and Applications (Oxford) [Ch.: 1, 2, 3(1,4,5,6,7), 4, 5, 6, 8, 10(1,2,3,4,8), 20(4)]

- M. Grundmann, The Physics of Semiconductors: An Introduction Including Devices and Nanophysics, Springer

- Karl W. Böer and Udo W. Pohl, Semiconductor Physics, Springer

- Teacher's notes and slides

- Additional materials for specific topics

Semester

II semester (Feb.- June).

Assessment method

The examination is oral and consists of two or three questions related to the topics covered in which a quantitative illustration accompanied by diagrams, equations, and numerical data is required. In particular, the following skills will be assessed: understanding of the physics described in the course and the related mathematical formalism
The evaluation criteria are related to demonstrate a clear understanding of the physical content of the topic and its physical-mathematical treatment.

Office hours

By appointment.

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | CLEAN WATER AND SANITATION | AFFORDABLE AND CLEAN ENERGY | SUSTAINABLE CITIES AND COMMUNITIES | RESPONSIBLE CONSUMPTION AND PRODUCTION