UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Materials Physics With Laboratory

2122-3-E2701Q045

Aims

Provide the student with the basis for understanding the physical properties of materials and their measurement.

Contents

Introduction to the physics of materials: mechanical, elastic, electronic and magnetic properties.

Detailed program

LABORATORY OF PHYSICS OF MATERIALS

The laboratory consists of a series of experiences with a duration of two or three afternoons each, focusing mainly on the properties of semiconductor materials. The purpose of the experiences is mostly to develop a critical sense and autonomy in the process of measuring the physical properties of the materials. Experiences include:

- the Hall measurement of electrical and doping properties of semiconductors;
- voltage-current characteristics of a p-n junction;
- measurement of absorption and reflection properties;
- measurement of the efficiency of photovoltaic cells as a function of the wavelength of the incident light;
- life time measurements of photo-excited carriers.

PHYSICS OF MATERIALS

Crystal Structures

- General Description of Crystal Structures
- Some Important Crystal Structures
- Cubic Structures
- Close-Packed Structures
- Structures of Covalently Bonded Solids
- Crystal Structure Determination
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X-Ray Diffraction

- Bragg Theory
- Lattice Planes and Miller Indices
- General Diffraction Theory
- The Reciprocal Lattice
- The Meaning of the Reciprocal Lattice
- X-Ray Diffraction from Periodic Structures
- The Ewald Construction
- Relation Between Bragg and Laue Theory

Bonding in Solids

- Attractive and Repulsive Forces
- Ionic Bonding
- Covalent Bonding
- Metallic Bonding
- Hydrogen Bonding
- van derWaals Bonding

Mechanical Properties

- Elastic Deformation
- Macroscopic Picture
- Elastic Constants
- Poisson’s Ratio
- Relation between Elastic Constants
- Microscopic Picture
- Plastic Deformation
- Estimate of the Yield Stress
- Point Defects and Dislocations
- The Role of Defects in Plastic Deformation
- Fracture

Thermal Properties of the Lattice

- Lattice Vibrations
- A Simple Harmonic Oscillator
- An Infinite Chain of Atoms
- One Atom Per Unit Cell
- The First Brillouin Zone
- Two Atoms per Unit Cell
- A Finite Chain of Atoms
- Quantized Vibrations, Phonons
- Three-Dimensional Solids
- Generalization to Three Dimensions
- Estimate of the Vibrational Frequencies from the Elastic Constants
- Heat Capacity of the Lattice
- ClassicalTheory and Experimental Results
- Einstein Model
- Debye Model
- Thermal Conductivity
- Thermal Expansion
- Allotropic Phase Transitions and Melting

Electronic Properties of Metals: Classical Approach

- Basic Assumptions of the Drude Model
- Results from the Drude Model
- DC Electrical Conductivity
- Hall Effect
- Optical Reflectivity of Metals
- TheWiedemann–Franz Law
- Shortcomings of the Drude Model

Electronic Properties of Solids: Quantum Mechanical Approach

- The Idea of Energy Bands
- Free Electron Model
- The Quantum Mechanical Eigenstates
- Electronic Heat Capacity
- The Wiedemann–Franz Law
- The General Form of the Electronic States
- Nearly Free Electron Model
- Energy Bands in Real Solids
- Transport Properties

Semiconductors

- Intrinsic Semiconductors
- Temperature Dependence of the Carrier Density
- Doped Semiconductors

- n and p Doping
- Carrier Density
- Conductivity of Semiconductors
- Semiconductor Devices
- The pn Junction
- Transistors
- Optoelectronic Devices

Magnetism

- Macroscopic Description
- Quantum Mechanical Description of Magnetism
- Paramagnetism and Diamagnetism in Atoms
- Weak Magnetism in Solids
- Diamagnetic Contributions
- Contribution from the Atoms
- Contribution from the Free Electrons
- Paramagnetic Contributions
- Curie Paramagnetism
- Pauli Paramagnetism
- Magnetic Ordering
- Magnetic Ordering and the Exchange Interaction
- Magnetic Ordering for Localized Spins
- Magnetic Ordering in a Band Picture
- Ferromagnetic Domains
- Hysteresis

Dielectrics

- Macroscopic Description
- Microscopic Polarization
- The Local Field
- Frequency Dependence of the Dielectric Constant
- Excitation of Lattice Vibrations
- Electronic Transitions
- Impurities in Dielectrics
- Ferroelectricity
- Piezoelectricity
- Dielectric Breakdown

Prerequisites

Good knowledge of General Physics and techniques of integral and differential calculus. Basic knowledge of Quantum Physics.

Teaching form

Lectures

Textbook and teaching resource

- Solid State Physics: An Introduction, di Philip Hofmann (Main reference book)
- Principi di Fisica dei Semiconduttori di Mario Guzzi (Semiconductor book)
- Notes from the lecturer.

Semester

I Semester

Assessment method

The Physics examination of the Materials with the Laboratory is divided into oral tests, with the compilation of a laboratory report. The Materials Physics course with Laboratory is composed of 14 CFU. The exam is divided into three modules, one relative to the laboratory and two modules dedicated to theory. These three modules can be passed either simultaneously or separately.

The laboratory module includes the evaluation of a report on one of the practical experiences of the laboratory. The mark on the report is based on the correctness, completeness and clarity of the exposure of the measurements. The oral test instead analyzes the knowledge of all the demonstrations that the student carried out in the laboratory. For this module it is not necessary to have a thorough knowledge of the theory, which is instead the object of the other modules, but it is sufficient to know the minimum notions of physics of the materials necessary for understanding the experiment. These minimum notions are those reported in the laboratory sheets related to the experiences carried out. Obviously, it is assumed that the arguments of the laboratories of previous years are known. This module mainly analyzes the understanding of the experiment methodology, the understanding of the instrumentation (for example the operation, instrumental limits, procedures), and the analysis of data (uncertainties, processing, presentation). This module weighs about 3/14 in the final mark.

The two modules of Physics of Materials are instead focused on the theory of physics of materials and have a greater relative weight equal to 5/14 and 6/14. The details of the subdivision of the two modules are reported in the e-learning section.

Office hours

at the end of the lessons or by appointment