UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Materials Physics With Laboratory

2425-3-E2701Q045

Aims

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

The main training objectives are:

- knowledge and ability to understand the physical properties of materials;
- knowledge and ability to understand the physical properties of materials applied to the main uses;
- autonomy of judgment in the analysis of physical properties and in the setting up of scientific experiments;
- communication skills in the presentation of complex physical theories and in the reporting of scientific experiments;
- ability to learn independently from additional teaching material, manuals and technical specifications of the instrumentation.

Contents

- Material properties (mechanical, vibrational, thermal, electronic, magnetic, dielectric, optical,..)
- Materials (metals, semiconductors, dielectrics, magnets, piezoelectrics,...)
- Solid state devices (photovoltaic cell, LED, thermocouple, transistor, ...).
- Instrumentation of a materials physics laboratory (electrical measurements, optical measurements, ...)

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

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

Bonds 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

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 Break

Prerequisites

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

Teaching form

Physics of Materials Module

28 lessons of 2 hours held in classroom;

Laboratory of Physics of Materials Module

10 lessons of 2 hours and 1 lesson of 1 hour held in classroom;
9 experimental activities of 4 hours held in the laboratory;
Lectures and workshops are held in Italian.

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

First Semester

Assessment method

In summary the tests consist of:

- Interviews on the topics covered in class;
- Interview on the laboratory report;
- Interview on laboratory experiences.
- The details of the tests are described below.
- 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. For these modules, the understanding of physical phenomena, the ability to reduce complex phenomena to simple models, the ability to use mathematical models to quantify the physical properties of materials will be evaluated.

The Laboratory module and the first Materials Physics module are delivered first and therefore can be taken even before the end of the course (ongoing evaluation).

Office hours

At the end of the lectures or by appointment.

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE