UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Physical Characterization of Materials With Laboratory

2122-1-F5302Q005

Aims

The course aims at the understanding of the fundamental concepts of the response of materials to electromagnetic radiation, together with the description of selected experimental techniques. The course includes lessons and an experimental activity carried out in small groups in the research laboratories of the Department; in this experimental part, students have the opportunity to become familiar with modern experimental techniques useful for the investigation of materials, and to apply the concepts learned during the lessons.

At the end of the course, the student will be able to:

- Understand material requirements for specific functionalities in which interaction with electromagnetic radiation is implied;
- Design a strategy for the experimental characterization of material properties in relation to their applications;
- Acquire a proactive and responsible attitude during laboratory activities.

Contents

The lessons address the broad field of spectroscopy, intended as the general interaction of electromagnetic radiation with materials, and on its very extended applications. Fundamental aspects are treated alongside experimental approaches that can be adopted in different frequency ranges. Classical techniques and advanced tools are proposed both during lessons and during the laboratory part. Students acquire solid competences and skills in such topics, becoming able to apply them also in cross-disciplinary contexts. During the laboratory part, the students are invited to address a specific research problem and to find original solutions in a mature and

collaborative way. Moreover, a few seminars are given by the professor on complementary topics.

Detailed program

LESSONS

SECTION 1: INTRODUCTION

- Outline of the contents and of assessment methods

Readings:

Slides uploaded in the e-learning page of the course

SECTION 2 : INTERACTION OF ELECTROMAGNETIC RADIATION WITH MATERIALS IN THE LINEAR RESPONSE REGIME

- Solution of the electromagnetic wave equation in a material
- Dielectric function and refractive index
- Lorentz and Drude models
- Kramers-Kronig relations
- Response to electromagnetic radiation of real materials (metals, semiconductors and insulators)

Readings:

F. Wooten, *“Optical properties of solids”,* Academic Press

J. G. Solé, L.E. Bausà, D. Jaque, *“Optical spectroscopy of Inorganic Solids”,* Wiley

SECTION 3 : DISPERSION PHENOMENA AS INSTRUMENTS FOR MATERIALS CHARACTERIZATION

- Dispersion and elastic scattering
- Inelastic scattering (Brillouin and Raman)

Readings:

J. G. Solé, L.E. Bausà, D. Jaque, *"Optical spectroscopy of Inorganic Solids"*, Wiley

H. Kuzmany, *"Solid State Spectroscopy"*, Springer

SECTION 4 : INVESTIGATION OF MATERIALS THROUGH RESONANCE PHENOMENA

- Impedance spectroscopy
- Electron spin resonance
- Optical absorption
- Steady state and time resolved luminescence
- Specific topics: Anti-Stokes luminescence, optical cooling

Readings:

J. G. Solé, L.E. Bausà, D. Jaque, *"Optical spectroscopy of Inorganic Solids"*, Wiley

J.C. De Mello, *"An Improved Experimental Determination of External Photoluminescence Quantum Efficiency*", Advanced Materials vol. 9, 230 (1997)

G. Blasse and B.C. Grabmaier, *"Luminescent materials",* Springer Verlag

A.V. Chadwick and M. Terenzi, *"Defects in solids: Modern techniques"*, NATO ASI Series B: Physics, vol. 147, Plenum Press, 1986

SECTION 5 : INTRODUCTION TO NON LINEAR RESPONSE OF MATERIALS TO ELECTROMAGNETIC RADIATION

- Fundamentals of the non linear response
- Second and third order non linearity
- Electro-optic and Kerr effects
- Origin of non linearity in materials (crystals, glasses, polymers)

Readings:

B.E.A. Saleh and M.C. Teich, "*Fundamentals of Photonics*", Wiley

R. Feynman, *"Lectures on Physics*" vol. 1, part 2, Inter European Editions

SECTION 6 : THEMATIC SEMINARS

- Materials sustainability
- Medical applications of nanomaterials

Readings:

Slides of the professor uploaded in the web page of the course

EXPERIMENTAL ACTIVITIES

The students will be divided into small groups and they will work under the supervision of different tutors. Each group will be asked to perform one experimental activity among the following topics:

- Atomistic simulation of epitaxial growth
- Raman spectroscopy of group IV semiconductors
- Optical spectroscopy of nanostructures (2 groups)
- Materials characterization by electron spin resonance technique (2 groups)
- Material characterization by radio- and thermo-luminescence
- Qualitative and quantitative X-ray Fluorescence analysis on cultural heritage materials
- Optical band gap determination by UV-Vis diffuse reflectance measurements
- Polarized optical spectroscopy
- Mechanical properties and rheology of polymeric materials
- Contact angle measurements for the characterization of surface wetting properties
- Principles and applications of electron microscopy for the investigation of nanomaterials

All groups are required to prepare of a written report on the experimental activity performed

Readings:

Texts provided by tutors on the specific activity performed

Prerequisites

Fundamentals of the structure of matter acquired during the bachelor course.

Teaching form

Lessons and lab activities. Course attendance is mandatory for the experimental part, and strongly suggested for the lessons.

Textbook and teaching resource

F. Wooten, "*Optical properties of solids*", Academic Press

J. G. Solé, L.E. Bausà, D. Jaque, "*Optical spectroscopy of Inorganic Solids*", Wiley

H. Kuzmany, "*Solid State Spectroscopy*", Springer

B.E.A. Saleh and M.C. Teich, "*Fundamentals of Photonics*", Wiley

R. Feynman, *"Lectures on Physics*" vol. 1, part 2, Inter European Editions

J.C. De Mello, *"An Improved Experimental Determination of External Photoluminescence Quantum Efficiency*", Advanced Materials vol. 9, 230 (1997)

G. Blasse and B.C. Grabmaier, *"Luminescent materials",* Springer Verlag

A.V. Chadwick and M. Terenzi, *"Defects in solids: Modern techniques"*, NATO ASI Series B: Physics, vol. 147, Plenum Press, 1986

Slides provided by the professor

Semester

The course has an annual duration. Lessons are given from October to March, while the period for the lab part can be chosen along the whole year, upon agreement with the professors responsible for each group.

Assessment method

The exam is in the form of an oral interview (duration about 45 min). It consists of:

- a discussion about the topics treated during the lessons with presentation of quantitative analyses, equations, graphs, schemes;

- a discussion on the experimental activity carried out in the laboratory, also on the basis of the written report.

Students are requested to send the report to the professor by e-mail in word or pdf format at least one week before the exam.

Office hours

8 - 18

Appointments between professor and students can be agreed by e-mail.