PHYSICAL CHARACTERIZATION OF MATERIALS WITH LABORATORY

Master in Sustainable Materials

CONTACT INFORMATION

Professor/Instructor: Anna Vedda
University/Company/Institution: University of Milano - Bicocca
E-mail Address: anna.vedda@unimib.it
Webpage: www.unimib.it

COURSE CONTENT AND INTENDED LEARNING OUTCOMES (ILOs):

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;
- Address the ideation of materials with sustainable character through the subtitution of critical elements in existing systems, or through the formulation of novel solutions;
- Design a strategy for the experimental characterization of material properties in relation to their applications;
- Acquire a proactive and responsible attitude during laboratory activities;
- Collaborate in a constructive way with class mates during laboratory activities.

Aligning with the EIT OLOs:

1 = peripherally relevant to the course content; 2 = highly relevant to course content.

- ☐ EIT OLO 1 - Making value judgments and sustainability competencies
- ☐ EIT OLO 2 - Entrepreneurship skills and competencies
- ☐ EIT OLO 3 - Creativity skills and competencies
- ☐ EIT OLO 4 - Innovation skills and competencies
- ☑ EIT OLO 5 - Research skills and competencies – 2
- ☑ EIT OLO 6 - Intellectual transforming skills and competencies – 2
- ☑ EIT OLO 7 - Leadership skills and competencies – 2

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Description of how the course covers the EIT OLO(s) and EIT Thematic Areas

The lessons are focused on the understanding of 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 in 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 (**OLO 5**). During the laboratory group working part, the students are invited to address a specific research problem (**OLO 6**) and to find original solutions in a mature and collaborative way (**OLO 7**). Moreover, a few seminars are given by the teacher on complementary topics, including two seminars on 1. Sustainability of materials for optical applications and 2. Applications of luminescent nanomaterials in medical imaging and therapy (**OLO 5**). The course falls into the **EIT Thematic Area No. 5**: "Substitution of critical and toxic materials in products and for optimal performance".

ASSESSMENT METHODS AND GRADING SYSTEM

The final assessment consists in an oral examination in which different abilities are evaluated. In particular, the student is asked to:

- Demonstrate a well-grounded knowledge in the field of spectroscopy and about experimental tools that can be employed to investigate the interactions between electromagnetic radiation and several material classes *(Content-based assessment*, also evaluating **OLO 5**).
- Prove the ability to design experimental strategies for the characterization of materials for specific purposes *(Competence-based assessment,* also evaluating **OLO 6**).
- Prove the ability to consider in a critical way the research work undertaken during the laboratory activities, discussing the appropriateness of the experimental approach, the relevance of the obtained results, and their possible perspectives in future applications *(Impact-based assessment,* also evaluating **OLO 7**).

The grades in the Italian university system are expressed out of **30.** The passing grade is **18/30**.

ASSESSMENT METHOD	WEIGHT ON FINAL GRADE
Class participation	0%
Lab / on-the-field task	0%
Written output(s) (essay, position papers, case study, final exam etc.)	0%
Oral exam (consisting in discussion about topics of the lessons and about the report prepared at the end of the laboratory task)	100%

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

COURSE SESSIONS

Suggested pre-course reading materials: Fundamentals of electromagnetism and of structure of matter

Session 1	INTRODUCTION TO THE COURSE
Content	• Outline of the contents and of the assessment methods
Readings	Slides uploaded in the web page of the course
Assignment	None

Session 2	INTERACTION OF ELECTROMAGNETIC RADIATION WITH MATERIALS IN THE LINEAR RESPONSE REGIME
Content	• Solution of the electromagnetic wave equation in a material • Dielectric function and refractive index • Lorentz and Drude models • Kramers-Kronig relations
Readings	F. Wooten, *"Optical properties of solids"*, Academic Press
Content	• Response to e.m. 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
Assignment	Group discussions

Session 3	DISPERSION PHENOMENA AS INSTRUMENTS FOR MATERIALS CHARACTERIZATION
Content	• 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
Assignment	Group solutions of specific problems

Session 4	INVESTIGATION OF MATERIALS THROUGH RESONANCE PHENOMENA
Content	• 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
Assignment	Group solutions of specific problems

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

Session 5	INTRODUCTION TO NON LINEAR RESPONSE OF MATERIALS TO E.M. RADIATION
Content	• Introduction to non linear response • Second and third order non linearity • Electro-optic and Kerr effects • Origin of non linearity in materials
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
Assignment	Group discussions

Session 6	THEMATIC SEMINARS
Content	• Seminar on materials sustainability • Seminar of medical applications if nanomaterials
Readings	Slides of the teacher uploaded in the web page of the course
Assignment	Group discussions on the topics of the seminars

Session 7	EXPERIMENTAL ACTIVITIES
Content	Execution of one experimental activity in a research laboratory of the department: • 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 XRF (X-ray Fluorescence) analysis on Cultural Heritage materials • Optical band gap determination by UV-Vis diffuse reflectance measurements • Polarized optical spectroscopy - a tool for studying the optical properties of solid-state materials • Mechanical Properties and Rheology of Polymeric Materials • Principles and Applications of Electron Microscopy for the Investigation of Nanomaterials
Readings	Materials provided by tutors on the specific activity performed
Assignment	Preparation of a written report on the experimental activity performed

Session 8	FINAL EXAM
Date - hours	JUN 2021, JUL 2021 2nd week, JUL 2021 4th week, SEP 2021, OCT 2021
Content	Oral interview (with presentation of quantitative analyses, equations, graphs, and schematic drawing and modelling. Discussion about the written report of the laboratory activities. Duration: about 45 min)

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation