MSE-482

Optical properties of materials

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Cursus	Sem.	Type
Materials Science and Engineering	MA2, MA4	Opt.
Photonics		Opt.

Language of teaching	English
Credits	3
Session	Summer
Semester	Spring
Exam	Written
Workload	90h
Weeks	14
Hours	**3 weekly**
Lecture	2 weekly
Exercises	1 weekly
Number of positions	

Summary

Students will study fundamental principles of light-matter interaction and apply classical and quantum mechanical models for quantitative estimates. Optical phenomena in glasses, organic/inorganic semiconductors, liquid crystals, quantum dots as well as device applications will be treated.

Content

The study of optical properties of materials is a key interdisciplinary field in science and engineering. It is not only a vibrant academic field, but opens the door to innovations of key importance in engineering and industry. This course shall provide an overview of fundamentals and applications and is structured into the following chapters:

1. Interaction of light with matter

This chapter will introduce the Lorentz oscillator model to derive the complex dielectric constant, which is central to understand and simulate optical phenomena. Absorption reflection, transmission, refraction and scattering of light will be treated (Fresnel equations). Particular phenomena such as plasmons, excitons, polaritons will also be discussed. Photoluminescence will be introduced briefly.

2. Optical properties of glasses

Optical transparency, dispersion, temperature dependence of the dielectric function will be treated for different glasses with the aim to understand the propagation of light in fibres for optical fibre communication, nonlinear optics and sensors.

3. Liquid crystals

This important class of materials has given rise to modern display media. Different mesogens and different liquid crystal structures will interact in different ways with polarized light. The most important applications in LCD displays will be discussed.

4. Experimental methods

Some important methods used in the optical characterization of materials will be introduced: Absorption, Fluorescence, specular and diffuse reflection spectroscopy, ellipsometry.

5. Inorganic semiconductors

Absorption and emission in both crystalline and amorphous materials will be studied. Applications in solar cells, photodetectors, LEDs, and lasers will be discussed. Characterization techniques such as electroabsorption as well as time resolved spectroscopy will be treated.

6. Quantum dots

Nanosized objects have impact the optical properties of materials via a confinement effect. Its implication on absorption and fluorescence will be treated. Additionally quantum dots give rise to particular effects such as exciton multiplication. The effect of doping on the optical properties will be treated. Applications in optoelectronics and bioimaging will be discussed.

7. Organic semiconductors

Absorption and emission in organic semiconductors will be treated. The important topic of molecular excitons will be addressed and applications in OLEDs, organic PV, photodetectors and light upconverters will be introduced.

Keywords

Light-matter interaction, complex dielectric function, Fresnel equations, Einstein coefficients, spectroscopy methods, fibre optics, organic and inorganic semiconductors, liquid crystals displays, quantum wells, quandum dots, OLEDs, solar cells, photodetectors

Learning Prerequisites

Required courses

General physics and chemistry

Recommended courses

General knowledge of optics

Important concepts to start the course

Electromagnetic waves, semiconductor physics, molecular materials

Learning Outcomes

- Explain basic optical phenomena in materials
- Derive the complex dielectric function
- Explain the working principle of optoelectronic devices
- Quantify the figures of merit of optical and optoelectronic devices
- Carry out an optical simulation of a thin film device using existing software
- Elaborate and present a solution to a problem

Transversal skills

- Set objectives and design an action plan to reach those objectives.
- Communicate effectively, being understood, including across different languages and cultures.
- Demonstrate the capacity for critical thinking
- Use both general and domain specific IT resources and tools
- Make an oral presentation.

Teaching methods

Ex-cathedra and simulation exercises on Setfos software

Expected student activities

Participate actively during the lectures and exercise lessons

Assessment methods

Written exam

Resources

Bibliography

Mark Fox, Optical Properties of Solids, Oxford University Press, 2nd Edition, Oxford, 2010
Spectroscopy ellipsometry for photovoltaics, Hiro Yuki Fujiwara, Robert W. Collins (Eds.), Springer series in optical sciences, Springer International Publishing, Switzerland, 2018
Springer Handboox of glass, J. David Musgraves, Juejun Hu, Laurent Calvez (Eds.), Springer, Nature, Switzerland, 2019

Ressources en bibliothèque

- Spectroscopy ellipsometry for photovoltaics, Hiro Yuki Fujiwara, Robert W. Collins (Eds.). Vol. 1, Fundamental Principles and Solar Cell Characterization
- Mark Fox, Optical Properties of Solids
- Spectroscopy ellipsometry for photovoltaics, Hiro Yuki Fujiwara, Robert W. Collins (Eds.) Vol. 2, Applications and Optical Data of Solar Cell Materials
- Springer Handboox of glass, J. David Musgraves, Juejun Hu, Laurent Calvez (Eds.)

Notes/Handbook

Handout of course slides and documentation of software for exercises

Moodle Link

- https://go.epfl.ch/MSE-482