



ЦЕНТЪР ЗА ОБУЧЕНИЕ – БАН

1000 София
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Basic Information:

Course Title: Optical properties of organic / inorganic hybrid materials and structures

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Total Teaching Hours: 30

Annotation (up to 150 words)

The aim of the course is to introduce students to the fundamentals of thin-film optics and the methods of optical modeling of homogeneous and heterogeneous media. The program covers Maxwell's equations for linear media, the laws of reflection and refraction, Snell's invariant, Fresnel equations, amplitude and energy transmission and reflection coefficients of a thin film and a film/substrate system, matrix representation, and multilayer systems. The course also examines the effective medium theories of Maxwell–Garnett, Lorentz–Lorenz, and Bruggeman, which are widely used for the optical modeling of hybrid structures. Particular attention is given to the advantages and limitations of the different theories and their fields of application. The course concludes with two examples related to the modeling of the optical behavior of thin films and hybrid materials consisting of a matrix with embedded nanoparticles.

Course content (brief description by topics or modules)

Module 1: Maxwell's equations; Electromagnetic fields in linear media; Telegraph and wave equations; Plane monochromatic waves in dielectrics and conductors; Wave polarization; Light dispersion; Lorentz classical theory of dispersion in dielectrics; Dispersion in metals; Plasma frequency.

Module 2: Relationship between the classical electrodynamic and quantum-mechanical descriptions of light–matter interaction; Wemple–DiDomenico single-oscillator model; Modified Lorentz oscillator model; Sellmeier and Cauchy dispersion models.

Module 3: Laws of reflection and refraction; Fresnel equations; Amplitude and energy transmission and reflection coefficients of a thin film; Matrix formalism; Clausius–Mossotti equation; Effective medium theory; Maxwell–Garnett and Bruggeman models.

Module 4: Examples of determining optical parameters and free volume in thin films from their transmission and reflection spectra; Determination of the refractive index and density of nanoparticles embedded in an organic matrix.

Teaching and assessment methods

Teaching, consultations; written and oral examination.



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Competencies acquired as a result of training (3–5 points)

- Understanding the interaction between light and matter
- Mathematical modeling of the optical properties of thin-film systems and multilayer coatings
- Modeling of composite and hybrid materials using effective medium theories
- Application of the acquired knowledge through two specific examples

Literature:

- Hiroyuki Fujiwara, Spectroscopic ellipsometry, Principle and applications, Jonh Wiley & Sons, Ltd, 2007, pp 13-48
- S. Wemple and M. DiDomenico, “Behavior of the electronic dielectric constants in covalent and ionic materials”, Phys. Rev. B 3, 1338-1350, (1971).
- D. E. Aspnes, “Optical properties of thin films”, Thin Solid Films, 89 (1982) 249-262
- D. Stroud, “The effective medium approximations: Some recent developments”, Superlattices and Microstructures, Vol. 23, No. 3/4, 1998
- M. M. Braun, L. Pilo, “Effective optical properties of non-absorbing nanoporous thin films”, Thin Solid Films 496 (2006) 505 – 514
- T. Babeva, R. Todorov, S. Mintova, T. Yovcheva, I. Naydenova and V Toal, “Optical properties of silica-MFI doped acrylamide-based photopolymer”, J. Opt. A: Pure Appl. Opt. 11, 024015, (2009).
- Konstantinov, Tz. Babeva and S. Kitova, “Analysis of errors in thin-film optical parameters derived from spectrophotometric measurements at normal light incidence”, Appl. Opt. 37, 4260-4267, (1998).

Additional information (optional) (e.g., special requirements, laboratory equipment, prior knowledge)

The course is intended for young researchers, specialists, and PhD students in physics and chemistry. Prior background in optics is not mandatory, but it is recommended.