UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Physics of Soft Matter Nanostructures

2526-1-FSM02Q015

Aims

The course aims to provide students with the fundamental physics of nanostructures based on organic molecular materials, focusing on those of interest for optoelectronic applications.

Knowledge and understanding
At the end of the course the student knows:
• the main concepts of the physics of the interactions between atoms, molecules, and macroscopic bodies
• the main effects of Van der Waals interactions in the opto-electronic properties of organic semiconductor solids
• the key deposition techniques of organic semiconductor films
• the key applications of organic electronics

Applying knowledge and understanding
At the end of the course the student is able to:
• identify the dominant type of force governing the interaction between different molecules, particles, or surfaces
• apply the concept of excitonic dimer to predict the effect on intermolecular forces in a given organic semiconductor solid
• recognise the most suitable methods to deposit a specific organic semiconductor material (and the possible challenges involved)
• describe the key excitonic processes involved in a specific application of organic electronics

Making judgements
At the end of the course the student is able to:
• choose the right function to quantify the strength of the interaction between molecules, particles, or surfaces
• identify the common aspects, approximations, and limitations in the functions derived during classes

Communication skills
At the end of the course, the student will be able to effectively convey the acquired knowledge orally, using the appropriate scientific language.

Learning skills
Although the course primarily covers the fundamental physical aspects of intermolecular forces and their impact on material properties, students will also develop an understanding of soft matter processes that are of interest to various disciplines, such as chemistry and biology.

Contents

Starting from a detailed description of the forces between molecules, particles, and surfaces, the course will then focus on a class of nanostructured solids based on molecules that are held together by weak Van der Waals interactions, i.e., organic (molecular) crystalline thin films.
In particular, the course will deal with organic nanostructures (mostly thin films) exhibiting semiconducting properties. Key topics will be the growth/deposition methods and related physics; photo-physics of molecular aggregates and crystalline thin films (excitons, energy/charge transfer).
The main characterization methods and applications related to each topic will be discussed.

Detailed program

Intermolecular Forces (IF): Interactions between atoms & molecules:

- Introduction: Historical overview; thermodynamics & statistics of IFs;
- Strong IF: Covalent and Coulomb (Ionic) Interactions;
- Interactions involving the Polarity and the Polarization of molecules;
- Van der Waals Forces;
- Repulsive forces, Total Intermolecular Pair Potentials;
- Special interactions: Hydrogen-Bonding, Hydrophobic & Hydrofilic Interactions.

Forces between Particles & Surfaces:

- Similarities and Differences between Intermolecular & Interparticle/Intersurface Forces;
- Van der Waals Forces between Particles & Surfaces;
- Colloids & Nanoparticles: Electrostatic Interactions between Surfaces in Liquids;
- Adhesion and Wetting.

Organic (Molecular) Crystalline Thin Films:

- Frenkel excitons in molecular crystals;
- Main mechanisms of energy transfer;
- Charge transfer;
- Triplet excitons.

Thin film deposition/growth techniques and characterization:

- Solution vs. Vacuum techniques;
- Vacuum techniques;
- Examples of characterization (optical properties, morphology);
- Examples of applications (LEDs, transistors, solar cells).

Prerequisites

For the first part of the course on intermolecular and surface forces, a basic knowledge of chemistry, thermodynamics and electromagnetism is needed. For the second part, a good knowledge of quantum physics and fundamentals of solid-state physics would be beneficial but not mandatory.

Teaching form

The course consists of 24 two-hour lectures, in person (Delivered Didactics).

Textbook and teaching resource

- Slides and selected scientific papers/reviews (supplied by the teacher);
- J.N. Israelachvili – Intermolecular & Surface Forces;
- M. Pope & C.E. Svenberg – Electronic processes in organic crystals and polymers;
- J.A. Venables – Introduction to Surface and Thin Film Processes;
- H. Lüth - Solid Surfaces, Interfaces and Thin Films.

Semester

First semester

Assessment method

Oral exam, which will be divided in two parts.
In the first one, counting for 60% of the final mark, the student will be interviewed on a specific topic selected among those covered in the course. The teacher will inform each student (via the e-learning platform) of the assigned topic 24 hours before the exam.
In the second part, counting for 40% of the final mark, the general preparation of the student on the remaining contents of the course will be assessed. Namely, the student will have to answer two/three questions regarding other topics in the program, possibly but not necessarily related to the topic assigned in the first part of the interview.

Office hours

Monday to Friday upon e-mail request

Sustainable Development Goals

QUALITY EDUCATION | AFFORDABLE AND CLEAN ENERGY