Freie Universität Bozen
Libera Università di Bolzano
Università Liedia de Bulsan

Syllabus
Course description

Course title	Plastic and Molecular Optoelectronics
Course code	46087
Scientific sector	FIS/01
Degree	PhD in Advanced Systems Engineering
Semester	2
Year	1
Academic year	2024/2025
Credits	3
Modular	No

Total lecturing hours	36
Attendance	Strongly recommended
Prerequisites	Classical mechanics and thermodynamics (Physics I), Electromagnetism (Physics II). Calculus I and II.
Course page	

Specific educational objectives	The student should understand the basic principles of organic, carbon-based semiconductors and apply them to the understanding and design of organic semiconductors devices, with emphasis on optoelectronic ones, such as organic light-emitting diodes (OLEDs) and light-emitting electrochemical cells (LECs), as well as organic photovoltaic diodes (PVDs).

Lecturer	Professor Franco Cacialli Office: Building B1, Room 03.16, NOI e-mail: franco.cacialli@unibz.it tel. 0471 017119 https://www.unibz.it/en/faculties/engineering/academic-staff/person/47601-franco-cacialli
Scientific sector of the lecturer	FIS/01
Teaching language	English
Office hours	Previous appointment via email
List of topics covered	**1) Introduction -** a. Inorganic semiconductors b. Organic semiconducting (macro)molecules i. π-orbitals and conjugation ii. Excitations: excitons and polarons iii. Exciton spin: singlets and triplets iv. Synopsis electronic and optical processes

	v. Optical properties: a few examples 1. E_G (Energy Gap) vs. molecular weight 2. Electron-phonon coupling: vibrational structure and thermochromism 3. Förster transfer and Site-Selective Photoluminescence Spectroscopy vi. Summary of optical properties **2) Organic light-emitting diodes** a. Structure b. Fundamental processes i. Charge injection ii. Charge transport iii. Exciton formation 1. Mutual capture 2. Exciton characteristics (binding energy, spin-multiplicity, capture cross-section) iv. Exciton decay 1. Radiative and non-radiative decay 2. Exciton lifetime 3. Efficiency c. Characterisation of OLEDs i. Relevant performance parameters ii. Characterising metal-semiconductor contacts: electroabsorption measurements as a non-invasive tool for the study of the energy level line-up in finished devices d. Practical implementations i. Anodes ii. Cathodes iii. Active materials 1. Singlet emitters 2. Triplet emitters – enhanced spin-orbit coupling via doping with heavy metals/rare-earth ligands

	3. Blends: achieving the best of all worlds iv. Fabrication technology: solution processability e. State-of-the-art devices and future prospects 1. Thermally activated delayed fluorescence (TADF) 2. Aggregation-induced emission (AIE) 3. Flexible electronics and "tattoo-electronics" **3) Organic photovoltaic diodes (PVDs) -** a. Fundamental process i. Exciton absorption ii. Exciton dissociation iii. Charge collection b. Characterisation of PVDs i. Relevant performance parameters c. Examples of polymer-based PVDs i. Type II heterojunctions ii. Multi-layers vs. bulk heterojunctions iii. Fullerene and non-fullerene acceptors d. State-of-the-art devices and future prospects **4) Supramolecular structures -** a. Introduction to secondary (non covalent) interactions and their role in organic solids b. Insulated molecular wires, IMWs and threaded molecular wires (TMWs). c. Other types (dendrons). **5) Near-infrared (NIR) emitting + absorbing materials** a. Overview i. Motivation ii. Inorganic or hybrid emitters / absorbers iii. Phosphorescent emitters b. Challenges: the energy gap "rule" c. Materials not leveraging triplet-assisted photophysics

	d. Current state-of-the-art
Teaching format	The lessons are divided into theoretical classroom lessons and exercises on the blackboard.

Learning outcomes	1. Knowledge and understanding Knowledge and understanding of: - the fundamental physical and chemical properties fof organic semiconductors (OS) - Understanding basic operation of organic light-emitting diodes (OLEDs) - Understanding basic operation of light-emitting electrochemical cells (LECs) - Understanding basic operation of organic solar cells 2. Applying knowledge and understanding 3. Ability to apply knowledge for solving given problems, including solving them with numerical data, approximating significant numbers, and taking care of the notation of units. Making judgements 4. Ability to judge plausibility of results. Communication skills 5. Maturing of technical-scientific terminology. Ability to learn 6. Learning skills to independently study and apply methods of physics for specific applications beyond topics covered in this lecture.

Assessment

Formative assessment

Form	Length /duration	ILOs assessed
In-class exercises	Continuously as part of course-accompanying exercises	1-6

Summative assessment

Form	Length /duration	ILOs assessed
Written	120 minutes	1-6

Assessment language	English
Evaluation criteria and criteria for awarding marks	The exam includes a written (2 hours) and an oral component. The written exam (2 hours) will include 4 questions of either qualitative/semi-quantitative nature as well as

	numerical or symbolic problems on topics covered in the lectures. The grading will be based on: - The correctness of the approach and the mathematical steps of the solution, the calculation of numerical results and the correct use of physical quantities and units. - The correctness of the provided answers and of the presented, as well as the terminology used. To pass the exam the final grade must be greater or equal to 18. If the final score is greater than 30, a "cum laude" grade is awarded. The student can have access to the exam with pen, pencil and a portable calculator. A short list of constants is provided to the students along with the text of the exam. Depending on the outcome of the written exam students may be invited, at the discretion of the examiner(s), to an oral exam that may include questions on the program covered in the lectures (including those of the written part of the exam) and may lead to an increase <u>or a reduction</u> of the grade of the written component. Students should also be able provide proof of identity (e.g. Campus card, ID card, passport) before the start of the exam.

Required readings	Course handouts
Supplementary readings	[1] Electronic Processes in Organic Crystals and Polymers, M Pope, C Swenberg, Oxford University Press, 2nd ed., Oxford, 1999 [2] *Organic Light-Emitting Devices*, K Müllen and U Scherf eds., Wiley-VCH, Weinheim, 2006 *Organic Electronics: Foundations to Applications*, SR Forrest, Oxford University Press, Oxford, 2020