unibz Fakultät für Ingenieurwesen
Facoltà di Ingegneria
Faculty of Engineering

PRIME
PRIntable MatErials for sustainable optoelectronics & photonics

PRIntable MatErials for sustainable optoelectronics & photonics (PRIME)

PhD course	Advanced System Engineering (ASE)
Duration	3 years
Starting date	November 2024
Location	Bolzano-Italy
Project Title	**Electroabsorption spectroscopy of energy-levels line up in organic electronics: optimization of charge injection and extraction**
Supervisor	Prof. Franco Cacialli (franco.cacialli@unibz.it)
Co-supervisor	Dr. Manuela Ciocca (manuela.ciocca@unibz.it)
External supervisor	N/A

I. Project description:

This project will provide an opportunity to gain expertise in the area of organic, printable and hybrid semiconductors which is attracting a burgeoning interest, world-wide, in both condensed matter physics and, especially, optoelectronics and photonics.

The project will make use of an optical probe (the variation of the optical absorption upon application of an electric field) to investigate the internal fields in a variety of structures in which an active layer (e.g., an organic or hybrid semiconductor) is "sandwiched" between different electrodes, as in light-emitting (LEDs) or photovoltaic diodes (PVDs). In LEDs, for example, electrodes need to be chosen with relatively high and low work functions in order to minimise the energy barriers to injection of holes (from the anode), and electrons (from the cathode). It is this difference in work functions that leads to a built-in field across the polymer layer that, in turn, can be monitored via Electro-Absorption (EA). This also means that EA is a powerful means for monitoring the value of energy barriers to charge injection. The project is relevant to the optimisation of efficiency of devices such as LEDs, light-emitting electrochemical cells (LECs) and photovoltaic diodes, PVDs. Findings from these investigations are also relevant to electrodes optimisation in field-effect transistors, FETs.

II. Objectives:

1- Investigation of internal fields in semiconductor structures

- To utilize electro-absorption (EA) spectroscopy to study the internal electric fields in various organic and hybrid semiconductor structures. By monitoring the changes in optical absorption upon the application of an electric field, gain insights into the distribution and magnitude of these internal fields.

2- Optimization of energy barriers for charge injection

- To analyse the work functions of different electrode materials to minimize the energy barriers for hole and electron injection in LEDs and (extraction from) PVDs. This objective aims to improve the charge injection/extraction efficiency, thereby enhancing the overall performance of the devices.

III. Methodology:

- **Electroabsorption spectroscopy**:
  - Set up and calibrate the electro-absorption spectroscopy system to measure variations in optical absorption under applied electric fields.
  - Conduct EA measurements on various semiconductor structures with different electrode configurations.
- **Material selection and device fabrication**:
  - Select suitable organic and hybrid semiconductor materials for the active layers.
  - Fabricate LEDs, light-emitting electrochemical cells (LECs), and PVDs with these materials, ensuring precise control over electrode work functions and layer thicknesses.
- **Data analysis and modelling**:
  - Analyse the EA spectra to determine the internal electric fields and energy barriers within the devices.
  - Develop theoretical models to correlate the observed EA effects with the material properties and device performance.
- **Optimization and testing**:
  - Optimize the electrode materials and device structures based on the EA findings.
  - Perform performance testing on the optimized devices to validate improvements in efficiency and functionality.

IV. Expected outcomes:

- **Enhanced device efficiency** Achieve significant improvements in the efficiency of LEDs, LECs, and PVDs through optimized charge injection and reduced energy barriers.
- **Advanced understanding of internal fields**: Provide detailed insights into the internal electric fields of organic and hybrid semiconductor structures, contributing to the broader knowledge base in optoelectronics.
- **Optimized electrode materials**: Identify and optimize electrode materials that minimize energy barriers and enhance device performance, with potential applications in FETs and other semiconductor devices.
- **Publication and dissemination**: Publication of research findings in high-impact scientific journals and presentations at international conferences to share the advancements and innovations developed during the project.