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	**Bio-compatible and bio-resorbable photonics and optoelectronics**
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 PhD project aims to develop innovative bio-compatible and bio-resorbable photonic and optoelectronic devices, utilizing advanced organic and hybrid semiconductor materials. Such devices include, as illustrative but non-exhaustive examples, light-emitting diodes (LEDs) and photovoltaic diodes (PVDs).

Such devices will be designed for applications in the general areas of biomedical devices (e.g., in so-called "theranostics", which combines therapeutic and diagnostic functionalities), and in what we identify as "environmental applications". Here we define *environmental applications* as applications that are *distributed* within a certain *environment* (natural, industrial, urban or "built-environment" …), and that require, therefore, the capability of collecting, processing, storing, and/or transmitting information. Notable examples are all the subsets of internet-of-things (IoT), or environmental sensing applications, that will require distributed and stand-alone power generation/storage and signal reception/transmission capabilities, among others.

The emphasis and focus will be on creating sustainable and biodegradable solutions to reduce electronic waste and enhance the biocompatibility of all devices.

II. Objectives:

1- Development of bio-resorbable hybrid/organic light-emitting diodes (HOLEDs)

- To design and fabricate HOLEDs that incorporate bio-resorbable materials as substrates (e.g., silk or cellulose derivatives), active layers, and electrodes (e.g., *indium gallium zinc oxide*-based ones). These devices will be characterized for their optical/optoelectronic properties (e.g., emission spectra, emission efficiency, luminance and current vs. voltage characteristics), as well as for their biodegradability in water and, more generally, in physiological media. This includes optimizing the materials for efficient light emission and detection, as well as ensuring their safe degradation within biological environments.

2- **Development of bio-resorbable hybrid/organic photovoltaic diodes/photodetectors (HOPVDs)**
   - To design and fabricate HOPVDs that incorporate bio-degradable and bio-compatible materials. This aim will leverage and optimise key information obtained in the pursuit of objective 1.

3- **Proof of principle integration prototype**
   - To investigate the potential integration of the bio-degrable/bio-resorbable HOLEDs and/or HOPVDs with (commercially-sourced) environmental sensors (with emphasis on mountain and/or agricultural environments)
   - Fabrication of a simple prototype incorporating a (commercial) temperature sensor, and HOPVDs and HOLEDs developed in this project for power generation and signal transmission to a *data collection tower* within suitable range.

III. Methodology:

- **Material selection and synthesis**:
  - ✓ Collaborate with material scientists to select and synthesize bio-compatible and bio-resorbable materials suitable for photonic applications.
  - ✓ Utilize advanced organic semiconductors and bio-compatible substrate materials (such as silk and cellulose derivatives).
- **Device fabrication**:
  - ✓ Fabricate OLEDs, photodetectors, and other photonic devices using the selected materials.
  - ✓ Employ techniques such as solution processing, printing, and thin-film deposition to fabricate the devices.
- **Characterization and testing**:
  - ✓ Characterize the optical and electronic properties of the fabricated devices using spectroscopy, photoluminescence, and electrical measurements.
  - ✓ Test the biodegradability and biocompatibility of the devices in simulated biological environments.
- **Optimization**:
  - ✓ Optimize the device structures and material compositions to enhance performance, focusing on parameters such as efficiency, stability, and biodegradability.
  - ✓ Conduct iterative testing and modification cycles to achieve the desired performance.

IV. Expected outcomes:

- **Innovative bio-resorbable photonic devices:**
  - ✓ Development of OLEDs and photodetectors that are both bio-compatible and bio-resorbable, suitable for medical applications.
- **Enhanced biocompatibility:**
  - ✓ Integration of advanced bio-compatible materials that improve the safety and efficacy of photonic devices in biomedical applications.
- **Sustainability and environmental impact:**

- ✓ Creation of sustainable photonic devices that contribute to reducing electronic waste through their biodegradable nature.

- **Scientific contributions:**
  - ✓ Publication of research findings in high-impact journals and presentations at international conferences.
- **Potential applications:**
  - ✓ Implementation of the developed devices in theranostic applications, including in-vivo and in-situ monitoring of chemotherapeutic drugs and other biomedical uses.