Ph.D. position: Oxidative molecular layer deposition based conductive and transparent PEDOT thin films as innovative electrodes for opto-electronic applications

Context and Project

Conductive polymers are extremely promising materials for the electronic and optoelectronic devices of the future. They hold the potential to serve as transparent electrodes (TEs), offering significant advancements in strategic applications such as new energies (solar cells), low-power lighting devices (OLEDs), flexible electronic systems, and touch screens. Among these polymers, PEDOT (Poly(3,4-ethylenedioxythiophene)) stands out as the most promising candidate due to its excellent chemical stability, mechanical flexibility, optical transparency, and high electrical conductivity. Our group is actively researching and studying transparent and conductive electrodes based on polymer materials, particularly PEDOT, for various electronics and optoelectronics applications. Recently, our group at the LGC has developed a reliable oxidative Chemical Vapor Deposition (oCVD) process using a simultaneous injection of the monomer (EDOT) and oxidant ($SbCl_5$), and enabling the production of PEDOT thin films of controllable thickness at the nanometer scale. These films are uniform over several tens of cm^2, conformal on complex substrates, with an electrical conductivity of ~500-1600 S/cm and an optical transmittance of ~85-95% at 556 nm. These characteristics are promising, especially when integrated into OLED (organic light-emitting diodes) devices in collaboration with the LAPLACE laboratory[1].

Within this thesis and the framework of an ANR-INNOVATION project, the objective is to develop and investigate a novel approach known as oxidative molecular layer deposition (oMLD) for the synthesis of PEDOT thin films. This approach involves the sequential injection of the monomer and oxidant and allows for the precise growth of high-quality films without the use of solvents and without any pre-treatment or wetting of the substrate surface[2,3]. It is novel since, thus far, only a few groups have recently worked on the oMLD of PEDOT, with a limited implementation of the produced films in applications[4–8]. Additionally, the impact of process parameters on the film structure, as well as its functional (electrical and optical) properties will be explored, aiming for successful integration of the optimized layer in different sets of applications. The integration aspects of this work will be conducted in collaboration with various partners engaged within the ANR project, namely with Prof. R. Hoye from the Department of Chemistry at Oxford University (perovskite solar cells), Dr. E. Carlos from CENIMAT at NOVA University in Lisbon (flexible electronics), and Prof. G. Zissis/Dr. C. Renaud at LAPLACE in Toulouse (OLEDs).

References:

1. *ACS Appl. Polym. Mater.* **5**, 10205-10216 (2023).
2. *J. Mater. Res.* **36**, 2–25 (2021).
3. *Beilstein J. Nanotechnol.* **5**, 1104–1136 (2014).
4. *ACS Appl. Mater. Interfaces* **7**, 3866–3870 (2015).
5. *Chem. Mater.* **26**, 3471–3478 (2014).
6. *ACS Omega* **6**, 17545–17554 (2021).
7. *J. Vac. Sci. Technol. A* **39**, 032413 (2021).
8. *ACS Appl. Mater. Interfaces* **9**, 11116–11125 (2017).

Work requested (Subject Ph.D.)

The goal of this Ph.D. is to further investigate the oMLD process and optimize the deposition of PEDOT thin films for successful integration within optoelectronic applications. Therefore, this Ph.D. will contribute to an in-depth study aimed at improving the properties of PEDOT and exploring its integration into various devices. The correlations between deposition conditions, film characteristics (such as thickness, composition, roughness, and morphology), and properties (including electrical conductivity and optical transparency) will be studied. Additionally, the Ph.D. candidate will have the opportunity to visit different partners depending on the progress of various tasks and will interact with an international consortium of expert researchers within the field. Moreover, the applicant will also have the chance to supervise several internship students.

Location

The Ph.D. will mainly work at the Laboratoire de Génie Chimique Toulouse/Chemical Engineering Research Center of Toulouse within the IRPI department. The applicant will be integrated into a multidisciplinary team and closely interact with surrounding partners (LAPLACE, UMS Castaing, CIRIMAT…). Additionally, they will have the opportunity to perform short stays in Portugal (Lisbon) and/or the United Kingdom (Oxford) as part of the ANR project.

Profile & requested skills

The candidate must have a good ranking (top 25%) in master or engineering school. Ideally, (s)he should have a strong experimental background in chemical engineering, materials sciences/characterization, and/or solid-state physics. We are looking for a highly motivated student of any nationality who is interested to work in an inter-disciplinary group and project. We are looking for hard-working students with high level of autonomy, creativity, and organizational skills. The Ph.D. will start by the 1st of September for **36 months** with a grossly monthly salary of ~2300€. The application deadline is set for **30/04/2024**, and the position will remain open until filled.

Application

Applicants are invited to send a CV and cover letter together with diploma copies and contact details of at least 2 references to:

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