Physical Modeling of Biosensors Based on Organic Electrochemical Transistors

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Abstract

Organic electronics, based on conductive polymers and organic small molecules has a continuous development since the end of 1980s. Conducting polymers have been used in a wide range of electronic devices such as transducers and sensors for chemical detection of different types of analytes. One of the most promising categories of semiconductor-based sensors is organic electrochemical transistor (OECT).
OECTs consist of three electrodes (Source, Drain and Gate) and two active layers: electrolyte and conductive polymer (Figure 1). In conductive polymer layer, the current modulation is generated by a dedoping effect produced by the positive ion penetration from electrolyte, followed by its recombination with negative conductive polymer ion. Since the amount of positive charge carriers in the conductive polymer is decreased, current between source and drain electrodes also decreases. This kind of current variations is dependent on the electrolyte concentration and gate voltage.
Despite the fact that OECT attracts a lot of attention in the last years, appropriate physical and chemical coupled models to describe precisely the interaction between ionic and electronic charge carriers haven't been yet developed. To understand the working mechanism of OECT devices, it is absolutely necessary to use modeling [1,2]. In full OECT models, the combination of three processes should be considered:
1) Movement of ions in electrolyte and polymer layers (electrochemical process)
2) Recombination of the electronic and ionic charge carriers in the polymer
3) Transport of the charge carriers (holes) inside the polymer
The numerical model (1D or 2D finite elements approach), which is performed with COMSOL Multiphysics® software, allows to understand the influence of different parameters on the charge carriers distribution and doping-dedoping proses in the polymer layer. Simulation of electrolyte ion transport is performed with AC/DC Module (Electrostatics interface) and Chemical Reaction Engineering Module (Transport of Diluted Species interface). Simulation of the charge carrier distribution and potential profile in the polymer layer is performed with the Semiconductor Module. It is also possible to use the Electrochemistry Module (Secondary or Tertiary Current Distribution interafce).
As a result, a complete numerical model will lead to deep understanding of all the processes inside OECT with the further device optimization and building more efficient and sensitive biosensor. This project receives funding from the European Community's Seventh Framework Program under Grant Agreement n° 607896.

Reference

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transistors. Advanced Functional Materials, 2007. 17(17): p. 3538-3544, (2007)
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Figures used in the abstract

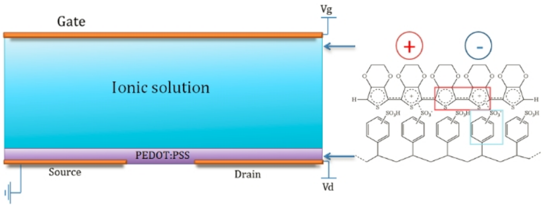

Figure 1: Organic electrochemical transistor structure.