Electrolyte-Gated Transistors using n-type organic molecular semiconductors: the case of PCBM as Channel Material

Tian Lan,[1] Jonathan Sayago,[1] Fabio Cicoira,[2] and Clara Santato[1*]
[1]École Polytechnique de Montréal, Département de Génie Physique, C.P. 6079, Succ. Centre Ville, Montréal, Québec H3C-3A7, Canada
[2]École Polytechnique de Montréal, Département de Génie Chimique, C.P. 6079, Succ. Centre Ville, Montréal, Québec H3C-3A7, Canada
*corresponding author: clara.santato@polymtl.ca

Abstracts:

Electrolyte-gated transistors (EGTs) using electrolytes as the gating medium are of interest since the exceptionally high capacitance of the electrical double layer forming at the electrolyte/transistor channel interface permits current modulations of several orders of magnitude, at relatively low gate voltages, sub 2V [1]. Electrolyte gating is a powerful approach to produce large charge carrier densities (ca 1014 cm^{-2}) in semiconductors. Room temperature ionic liquids (RTILs) show great potential as gating media for their physico-chemical properties, such as negligible volatility, electrochemical stability windows up to ca 5 V, ionic conductivity up to 10 $mS \cdot cm^{-1}$ [2]. N-type organic transistors are of relevance for organic p-n junctions, bipolar transistors and complementary integrated circuits for flexible, large-area, and low-cost electronic applications [3]. In this work, we will report on EGTs with RTILs based on bis(trifluoromethylsulfonyl)imide ([TFSI]) anions and 1-ethyl-3-methylimidazolium ([EMIM]) cations as the gating medium and phenyl-C61-butyric acid methyl ester (PCBM) as the n-type organic molecular semiconducting channel material. Cyclic voltammetries in transistor configuration (where the working electrode is the channel material included between the source and drain electrodes and the reference is a high surface area gate electrode) were recorded to bridge the gap between the redox properties of PCBM films, characterized by a certain supramolecular organization, and the modulation of the film electrical conductance. Drain-source voltages, V_{ds}, as low as 100mV and gate-source voltages, V_{gs}, within the range 0~1.25 V, 0~1.7 V, 0~1.9 V were explored. We observed typical transistor behavior for our PCBM EGTs with I_{ds}/I_{gs} and ON/OFF ratios of around 10, ON/OFF ratios increasing with the increase of the gate voltage range. A correlation has been established between the redox peaks observed in the cyclic voltammetry with the morphology/structure of the films as deduced by Atomic Force Microscopy and XRD obtained at glancing angles and the corresponding transistor behavior.

References:

[1]Se Hyun Kim, Kihyon Hong, Wei Xie, Keun Hyung Lee, Sipei Zhang, Timothy P. Lodge, and C. Daniel Frisbi, Advanced Materials, **13**, (2012), 1822–1846.
[2]M. Galiński, A. Lewandowski, and I. Stępniak, Electrochim. Acta, **26**, (2006), 5567-5580.
[3]Shinji Ando, Ryo Murakami, Jun-ichi Nishida, Hirokazu Tada, Youji Inoue, Shizuo Tokito, and Yoshiro Yamashita, J. AM. CHEM. SOC. **43**, (2005), 14996-14997.