CHARGE TRANSPORT IN GRAPHENE-POLYTHIOPENE BLENDS BY KELVIN PROBE FORCE MICROSCOPY AND FET CHARACTERIZATION

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Graphene incorporation into polymeric matrices has been the subject of intense studies as a route to improve the hosting material properties. Charge carrier mobility in graphene is many orders of magnitudes larger than in silicon, while in organic semiconductors (OS) it is more than two orders of magnitude smaller than in silicon. This causes inferior electrical performances of organic flexible electronics with respect to silicon ones, despite the big advantages of being light-weight, low-cost and easily processable on large scale with respect to silicon electronics.

In order to exploit simultaneously the excellent electronic properties of graphene and the good processability and optoelectronic characteristics of OS, efforts have been devoted to the use of blends of soluble graphene with OS in field-effect transistors (FETs) and solar cells, similarly to previous works on carbon nanotubes-OS blends. To gain a better understanding on the charge transport in graphene-OS blends, we have studied the electrical and morphological properties of a structurally well-defined bicomponent system obtained by physisorption of a p-type organic semiconductor (poly(3- hexylthiophene), P3HT) over a discontinuous layer of atomically thin and thermally reduced graphene oxide (RGO) sheets, previously deposited on electrically insulating SiO_2 substrate

SiO2 substrate. RGO combines good materials properties and excellent processability and is obtained from the thermal reduction of chemically exfoliated graphene oxide (GO), which can be produced with high purity and in large quantities and, being water soluble, is well suited for industrial, large scale applications. Continuous layers formed by microscopic RGO sheets showed roomtemperature mobilities between 2-200 cm^2 $(Vs)^{-1}$ for holes and 0.5-30 cm^2 $(Vs)^{-1}$ for electrons (i.e. approximately 2 orders of magnitude lower than those observed in mechanically exfoliated graphene single sheets, but much higher than the ones of state-of-the-art OS) [1]. Blends of RGO and P3HT are used as the active layer of FETs. By sequentially depositing the two components, the density of RGO sheets can be tuned linearly, thereby modulating their contribution to the charge transport in the transistors, and the onset of charge percolation [2].

The electrical macroscopic properties of the RGO:P3HT blends are studied by fabricating and testing FETs based on different ratios of P3HT and RGO. On a microscopic scale, a thorough characterization of both RGO sheets and RGO:P3HT blends is obtained by means of Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM), optical reflection and fluorescence microscopy and Kelvin Probe Force Microscopy (KPFM). The surface potential of RGO, P3HT and of source-drain contacts is measured on a nanometric scale by KPFM, and correlated with the macroscopic performance of the FETs. KPFM is also used to monitor the potential decay along the channel in the working FETs. From a technological point of view, our results demonstrate that by using grapheneorganic composites FETs with variable geometries and channel lengths up to 60 μm can be fabricated, whose performances and characteristics (effective charge mobility, I_{ON}/I_{OFF} ratio) can be tuned in a simple way by changing the concentration of the GO in the solution spin-coated on the surface. The effective mobility obtained in RGO+P3HT FETs devices is one order of magnitude higher than the mobility measured on P3HT based FETs. This provides unambiguous evidence of the role of graphene to generate percolation pathways for charge migration within the film. Overall, these findings demonstrate that the use of nano-sized graphene sheets as additives for organic electronics devices can allow a robust and versatile control of device properties.

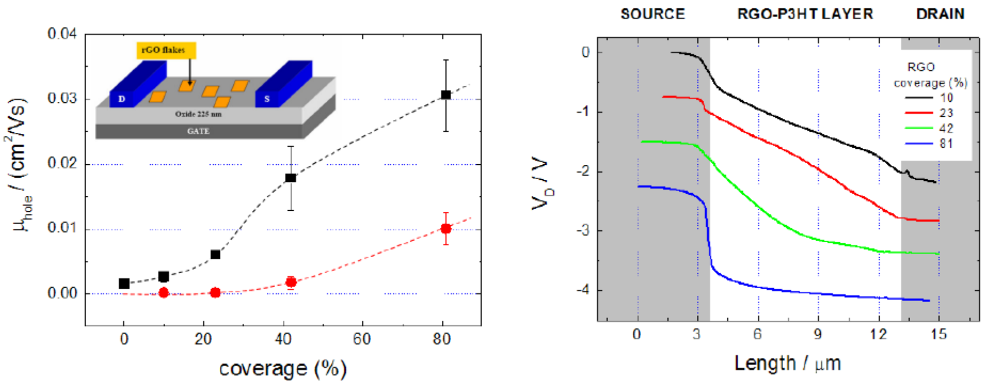

Figure 1: Left Panel: Hole mobility vs. area coverage for RGO (red circle) and RGO+P3HT (black square) FETs devices. Continuous lines are shown as a visual guide. In the inset, a schematic representation of the RGO-P3HT based device. Right Panel: Averaged KPFM profiles taken along the channel of FETs based on RGOP3HT, obtained by GO solutions of increasing concentration. The curves have been shifted for clarity.

References

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