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Efficient electrolyte-gated field-effect transistor based on solution-proceed small molecule semiconductor

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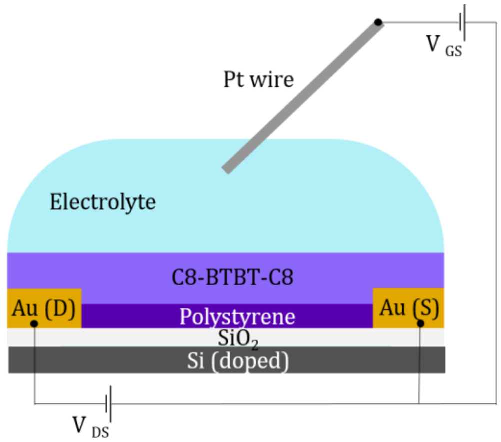
Electrolyte-gated organic field-effect transistors (EGOFET) are intensively investigated type of electronic devices, which is widely used as a platform for low-power biosensors [1]. The advantages of such biosensors is their very high sensitivity (down to single-molecule level [2]) as well as opportunity of creation of small and flexible devices, which are suitable for point-of-care applications. To reach high sensitivity of the sensor an EGOFET should have high transconductance [3], which is defined at constant V_{DS} as (1):

$$g_m = \partial I_{DS} / \partial V_{GS} \tag{1}$$

Stability in aqueous environment is the other important parameter of EGOFET as the electrical performance of the device could be negatively affected by ions injection. Highly crystalline materials based on small molecule semiconductors meet both requirements. 2,7-dioctyl[1]benzothieno[3,2-b][1]benzothiophene (C8-BTBT-C8) is solution-proceed semiconductor that is often exploited as a high-performance material for OFETs. Yet there are only a few examples of C8-BTBT-C8 application in aqueous environment [3,4].

In this work we aimed to develop a high-performance and stable in aqueous environment EGOFET that can be obtained by a simple and scalable solution-proceed technique. A blend of C8-BTBT-C8 and polymer dielectric, polystyrene, was used to suppress molecule aggregation and to induce the formation of flat crystals [5]. As a result of phase microsegregation, the polymer dielectric is located at the boundary with the substrate, while the semiconductor forms the top layer in contact with the electrolyte (Figure 1). Doctor Blade technique deposition was chosen as a well-controlled and scalable approach. The procedure for deposition of a smooth semiconductor layer in solution was developed and optimized. Among the varied deposition parameters were temperature and blade coating speed, which affected the size of C8-BTBT-C8 2D crystals obtained.

Fig. 1. Scheme of electrolyte-gated organic field-effect transistor based on C8-BTBT-C8/polystyrene blend.



We took electrical measurements in deionized water as electrolyte using both saturation (V_{DS} = -0.5 V) and linear (V_{DS} = -0.1 V) regime to measure transfer characteristics. The best parameters was extracted from the transfer curve in Figure 2: V_{th} = 0.03 V, $I_{on/off}$ = 900, g_m = 205 µS. To estimate efficiency of the EGOFET we used the following parameter (2):

$$\mu C_{eff} = g_m/(W/L \times V_{DS}) \tag{2}$$

It allows comparing the performance of devices described in different papers, with various architecture and voltage ranges. In our work, μC_{eff} was up to 0.622 µS V^{-1} in linear regime. This value could be assumed as rather high according to the data published earlier [3]. All devices show low hysteresis during the measurements. The EGOFETs showed very stable operation during continues 1 h measurements.

The approach developed could be used to manufacture EGOFET by printing techniques. The devices obtained with the method described could be utilized for both biosensor and neuromorphic devices applications.

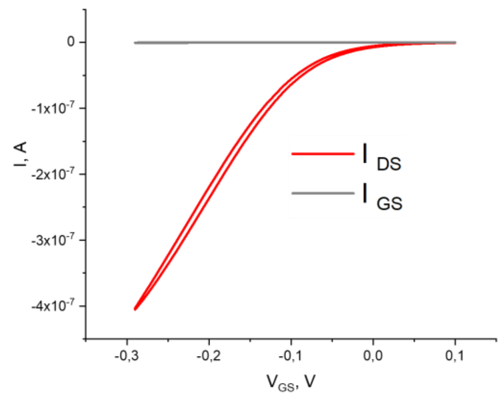


Fig. 2. Transfer characteristics of the EGOFET device recorded at V_{DS} = -0.1 V.

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