

Investigation of the Sensing Mechanism of Dual-gate Low-voltage Organic transistor for Pressure Sensing by Quantitative Analysis

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Organic pressure sensors have received much attention because their mechanical flexibility and low cost of manufacturing^{1,2}. However, there is a need to reduce the operation voltage of the OFETs used in these sensors. Recently, we developed a low-voltage dual-gate organic transistor for pressure sensing³ in which we assumed that the change in threshold voltage (V_{th}) and drain current (I_D) was due to the charges generated on the piezoelectric layer when compressed. However, the quantitative investigation for these changes in electrical output observed has been lacking. Here, we show a quantitative analysis that describes the sensing mechanism of the pressure sensor.

30 nm Al gate electrode was vacuum evaporated on a clean glass substrate. On the Al electrode, 300 nm thick poly (vinyl cinnamate) layer was spin coated and crosslinked then annealed to form the gate dielectric. The source and drain contacts were formed by evaporating 50 nm Ag electrodes through a shadow mask. To complete the fabrication of the OFET device, a blend of TIPS-pentacene and Polystyrene was spin coated on the Ag electrodes, then annealed for 30 mins. The dual-gate OFET based pressure sensor was completed by laminating a film of polarized polyvinylidene fluoride and its fluorinated co-polymer trifluoroethylene (P(VDF-TrFE)) on the OFET. To complete the fabrication process for a dual-gate OFET, 1 μm of CYTOP layer was deposited on the semiconducting layer then annealed on a hot plate for 20 mins at 100 °C. Finally, a 50 nm top-gate Al electrode was evaporated on the CYTOP layer through a shadow mask.

Figure 1a shows the shift in transfer curves at different pressure loads, while Fig.1b shows a relationship between the pressure load and V_{th} . An increase in the pressure load causes a linear shift in V_{th} . The quantity of charges/voltage (Q) generated on a polarized P(VDF-TrFE) sensor is proportional to the applied force (F) and they are approximately related as $Q = d_{33}F$ with d_{33} as the piezoelectric constant. To estimate d_{33} , the equation $Q/A_1V = d_{33}F/A_2V$ was deduced from the equation, $Q = d_{33}F$ where, A_2 is the area of the sensing layer (1 cm^2). The value of 996819 Pa/V was obtained from the slope of pressure against V_{th} graph in Fig. 1b. This value is substituted into the equation, given that pressure is equal to F/A_2 .

On the other hand, the shift in transfer curves and V_{th} shift observed when we applied the top-gate voltage (V_{TG}) on the dual-gate OFET (Fig.1c and d). We estimated the amount of charges depleted per unit area (Q/A_1) by multiplying the capacitance of CYTOP (C_{cytop} , 1.9 nF/ cm^2) to V_{TG} ⁵ which was reduced by application of V_{TG} . Figure 1e shows relationship of Q/A_1 against V_{th} . In order to quantify the charges depleted in the channel of the OFET by the pressure sensor, we used the results from the slope of Fig. 1e. We obtained the amount of depleted charges per unit V_{th} shift as 7.9 nC/ cm^2V . By inserting these values into the equation, d_{33} was calculated to be 79 pC/N. This shows that the charges are linearly depleted. This value is consistent with directly measured value of d_{33} (53 pC/N). From this result, we therefore concluded that the sensing mechanism was due to the effect of induced charges or voltage from the deformed piezoelectric layer on the mobile charge carriers in the bottom channel of the OFET. More details and analysis will be explained in the presentation.

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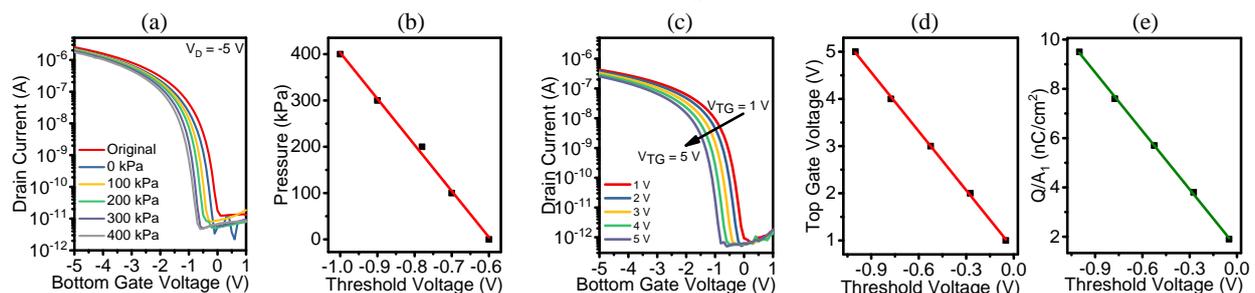


Fig. 1 (a). Transfer curve shift corresponding to pressure load (b). Graph of pressure load against V_{th} . (c) shift of transfer characteristics of OFET with respect to top-gate voltage. (d) Graph of top gate voltage against threshold voltage OFET corresponding to top-gate voltage (e) graph of charge per unit area against threshold voltage.