P(EDOT-co-3HT) Organic Electrochemical Transistor Grown by Oxidative Chemical Vapor Deposition

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Organic electrochemical transistor (OECT) is an electronic device with a conjugated polymer as active channel material in direct contact with an electrolyte.[1, 2] The conjugated polymer can support concurrent ionic and electronic conduction. When a gate voltage is applied, OECT allows facile penetration of ions from electrolyte into/out of the bulk of the channel, which modulates the polymer channel's redox state and thus conductivity. This operation mechanism makes the OECT an efficient ion-to-electron transducer capable of amplifying signals with low concentrations at very low electrochemical potentials (below 1 V). By virtue of biocompatibility, easy fabrication, low cost, mechanical flexibility, and notable low operating voltages, OECTs have the great potential as neural recording elements, biosensors, neuromorphic computing components.

In this work, we report high-performance P(EDOT-co-3HT) transistors. The film was deposited on the Si wafers with SiO_2 layer at 140 °C by oxidative chemical vapor deposition (oCVD). PEDOT and all copolymers show a XRD peak at $2\theta \sim 26°$, which corresponds to a face-on stacking orientation (020) with a lattice spacing d~0.34 nm (Fig. 1). The XRD patterns indicate that the homogenous polymer PEDOT, P3HT and their copolymer varies drastically in terms of the crystallinity and π-π interchain stacking orientation. Hall measurements show that the as grown PEDOT and P(EDOT-co-3HT) films have mobility of μ_{PEDOT} = 6.5 cm^2/Vs, $\mu_{copolymer}$ = 12.1 cm^2/Vs, and carrier density of $n_{PEDOT} = 6.5 \times 10^{19}$ cm^{-3}, respectively. The copolymer demonstrated a higher conductivity than PEDOT.

For comparison, OCETs with the same device geometry (W/L=150 μm/200 μm) were fabricated using PEDOT:PSS, oCVD PEDOT and oCVD P(EDOT-co-3HT) thin films with a similar thickness (~170 nm). The transistors were operated with a solution of 0.1M NaCl in DI water as the electrolyte (Fig. 2). The copolymer OECTs exhibit an ON current of 550 μA, higher than that of oCVD PEDOT at the same gate bias. The oCVD copolymer OECTs have demonstrated an ON/OFF ratio of more than 10^4, and the maximum transconductance of 550 μS, very close to that of PEDOT:PSS devices (Fig. 3). The excellent device performance is attributed to the high material quality of oCVD grown copolymer thin films.

[1]P. Gkoupidenis, N. Schaefer, B. Garlan, G. Malliaras, *Adv Mater* **27** (44), 7176 (2015).
[2]Y. van de Burgt, E. Lubberman, E. J. Fuller, S. T. Keene, G. C. Faria, S. Agarwal, M. J. Marinella, A. Alec Talin, and A. Salleo, *Nat Mater* **16** (4), 414–418(2017).

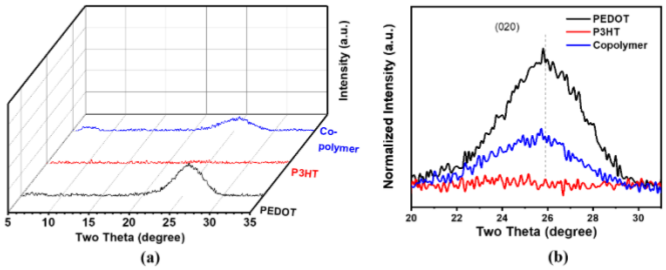

Figure 1: (a) Room temperature XRD pattern for PEDOT, P3HT and copolymers. (b) The XRD patterns with high magnification around the (020) peak.

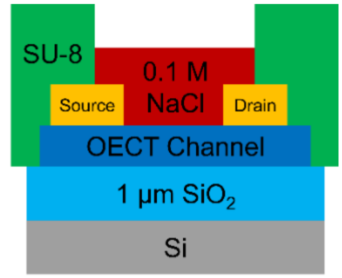

Figure 2: Cross-sectional device structure

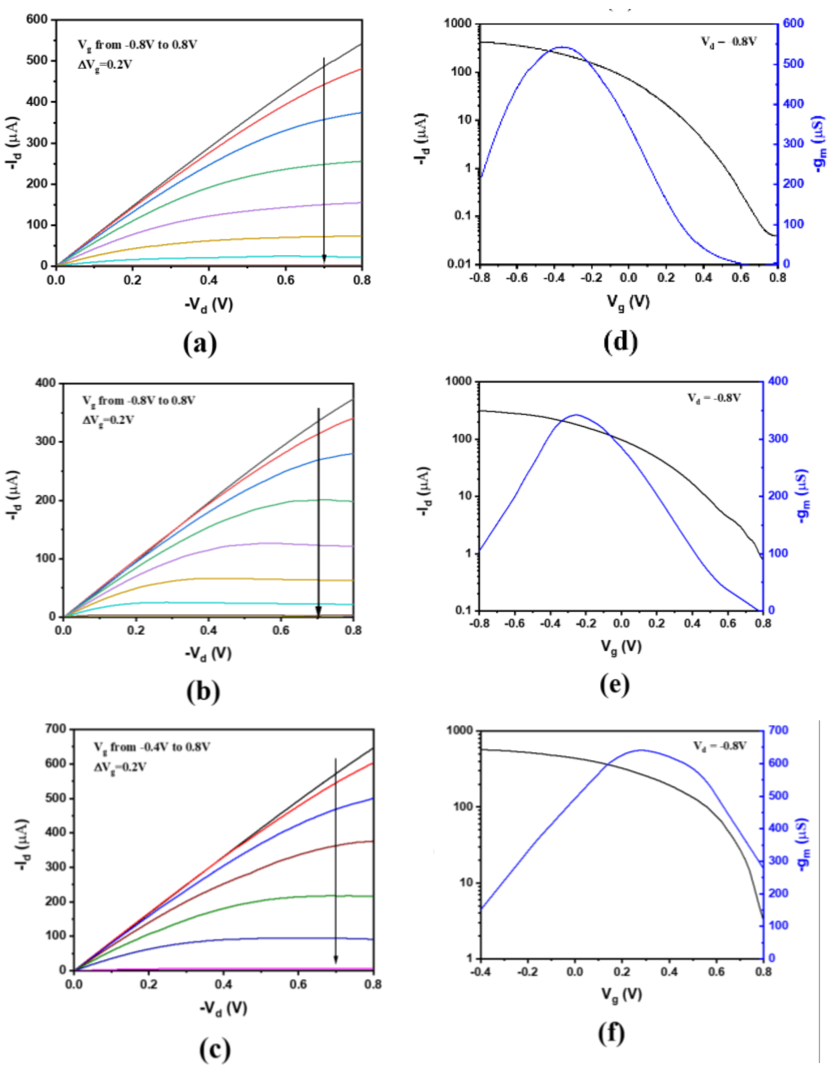

Figure 3: Output and transfer characteristics of (a)(d) oCVD P(EDOT-co-3HT), (b)(e) oCVD PEDOT, and (c)(f) PEDOT:PSS.