Design and Fabrication of All Organic Field Effect Transistor

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Abstract

All organic field effect transistor consist of poly-3-hexyloxythiophene, undoped poly-3,3”-didecyl-2,2’,5’,2”-terthiophene and polypyrrole has been successfully developed. Poly-3-hexyloxythiophene was applied as gate material. Undoped poly-3,3”-didecyl-2,2’,5’,2”-terthiophene was used as insulating layer and polypyrrole was applied as source-drain material. The multilayer polymers were deposited onto gold source-drain and gate electrodes by electropolymerization method. The spaces between the gold electrodes were 50 μm. The transistor shows a current amplification upon increasing gate voltages. Good conductivity stability upon increasing gate voltages was observed. Overall the field effect transistor has properties that similar to inorganic field effect transistor.

KEYWORDS: organic field effect transistor, alkylthiophene, alkoxythiophene, electropolymerization

I. INTRODUCTION

Poly-3-hexylthiophene has been applied as a gate material in planar field effect transistors and Schottky barrier diode that produce a charge mobility higher than found in the metal oxide transistors [1]. Poly-3-octylthiophene applied as planar field effect transistor show an ideal diode properties in the dark [2]. Quarterthiophene, monohexylquarter-thiophene, dihexyl-quarterthiophene and dihexylsexithiophene applied as gate materials on field effect transistor produce high charge mobility that linear to the long of the alkyl side chains [3]. Poly-3,3”-didodecyl-2,2’,5’,2”-terthiophene and Poly-3,3”-dipentoxy-2,2’,5’,2”-ter-thiophene polycrystalline film applied in thin film transistor showlinear response to applied to measure ethanol and 1-hexanol vapors in the 200-2000 ppm ranges [4].

The aims of this experiments are to investigate the characteristics of the organic field effect transistors based on polypyrrole, poly-3-hexyloxythiophene and poly-3,3”-didecyl-2,2’,5’,2”-terthiophene source-drain and gate materials. The insulating layer material used was undoped poly-3,3”-didecyl-2,2’,5’,2”-terthiophene.

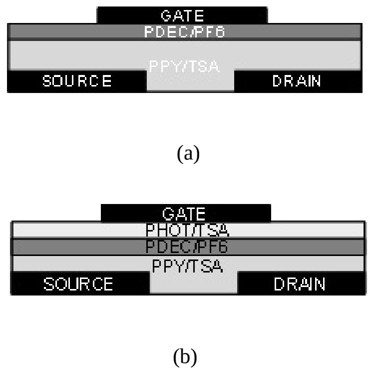

FIG. 1: FET configurations for PPY/TSA source-drain material and (a) PDEC/PF6 (b) PDEC/PF6-PHOT/TSA gate materials.

II. EXPERIMENT

Field effect transistor configuration used in this experiment is described in figure 1. The polymer source-drain was set to a high resistance state by dedoping the polymer film. The source-drain semiconductors used were polypyrrole and poly-3,3”-didecyl-2,2’,5’,2”-terthiophene. The insulating layer used was undoped poly-3,3”-didecyl-2,2’,5’,2”-terthiophene. Gate materials used were polyethylene dioxythiophene (PEDOT), poly-3,3”-didecyl-2,2’,5’,2”-terthiophene and polypyrrole. The source drain electrode distances were 50μm.

The source-drain voltages and source-drain currents were measured using μLab III EcoChimie Potentiostat with maximum-minimum voltage $\pm$5V. The gate voltages were generated from DC output of commercial power supply. The source-drain voltage was maintained at -1V. The gate voltage applied were 0V, $\pm$5V, $\pm$10V and $\pm$15V.

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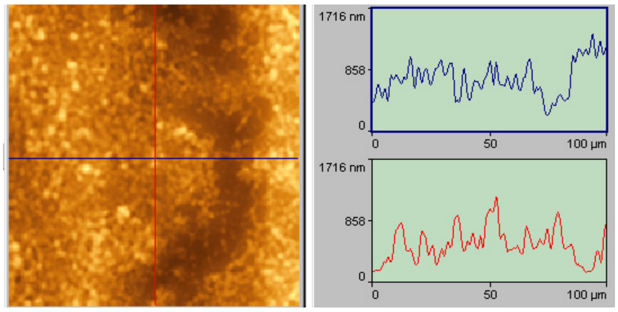
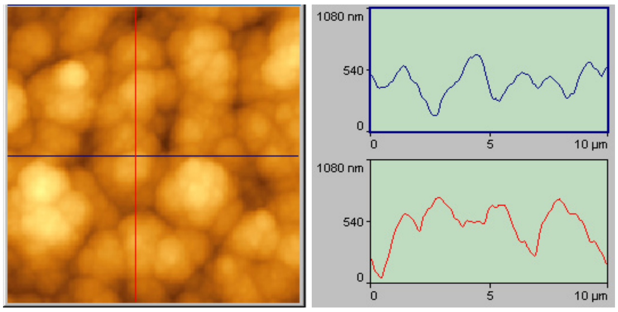


(a) (b)

FIG. 2: Film morphology of PPY/TSA on PDEC/PF6 at $100\mu^2$.



(a) (b)

FIG. 3: Film morphology of PPY/TSA on PDEC/PF6 at $10\mu^2$.

III. RESULTS AND DISCUSSION

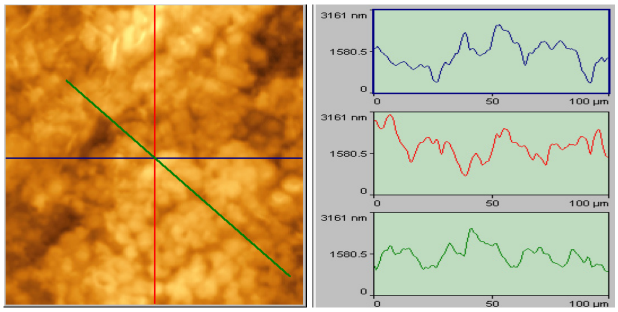
A. Polypyrrole Gate Material

Polypyrrole deposited on to poly-3,3”-didecyl-2,2’,5’,2”-terthiophene produced a rough and flat film, figure 2. The gap between source-drain gold electrodes was well covered, a characteristic that was not observed when only polypyrrole was used as base layer. The nodules at $10\mu m^2$ film were uniform, figure 3.

B. Poly-3-Hexyloxythiophene and Poly-3,3”-Didecyl-2,2’,5’,2”-Terthiophene Gate Materials

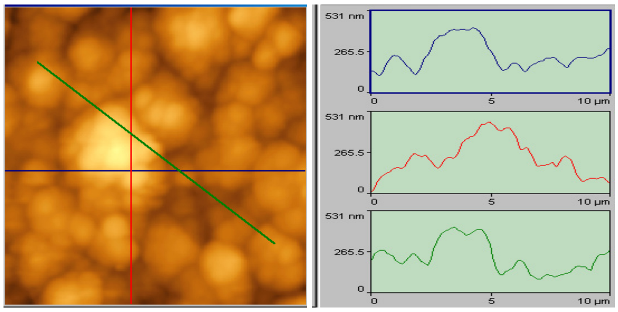
Electrochemical deposition of poly-3-hexyloxythiophene on poly-3,3”-didecyl-2,2’,5’,2”-terthiophene produces a nodular film, figure 4. The film morphology was different compared to poly-3-hexyloxythiophene stand-alone film that produce stem like, flat films. Poly-3-hexyloxythiophene on poly-3,3”-didecyl-2,2’,5’,2”-terthiophene at 10m2 shows non-uniform nodular film, figure 5.

Noisy source-drain currents were observed when undoped poly-3,3”-didecyl-2,2’,5’,2”-terthiophene used as gate material, figure 6. A good sensitivity to ethanol was observed at -1V source-drain voltage. The sensitivity of transistor to pentanol increase as gate voltages increased as shown in figure 7. The source-drain currents-voltage were similar to inorganic



(a) (b)

FIG. 4: Film morphology of poly-3-hexylthiophene on poly-3,3”-didecyl-2,2’,5’,2”-terthiophene at $100\mu^2$.



(a) (b)

FIG. 5: Film morphology of poly-3-hexylthiophene on poly-3,3”-didecyl-2,2’,5’,2”-terthiophene at $10\mu^2$.

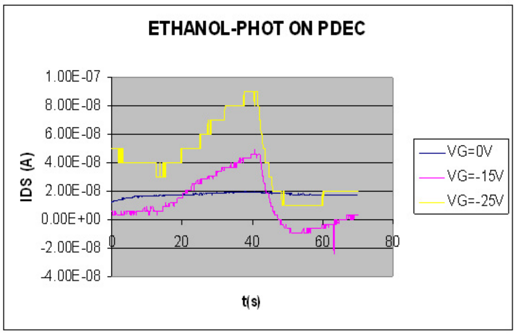


FIG. 6: PHOT/TSA gate material on PPY/TSA source-drain material for dry air and ethanol measurement

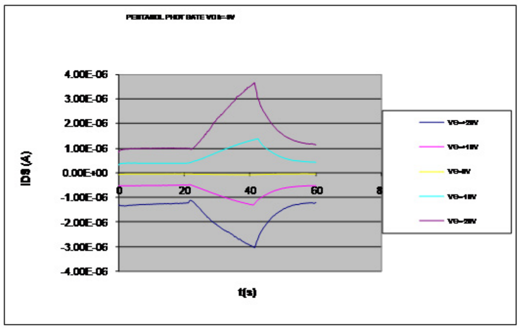


FIG. 7: IDS vs. VDS for PPY/TSA gate on PHOT/TSA source-drain material for pentanol measurement

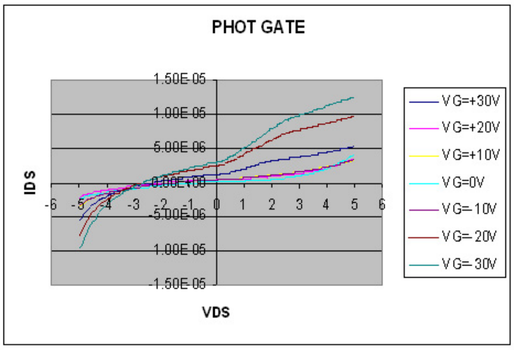


FIG. 8: FET characteristic of PHOT/TSA on PDEC/PF6

field effect transistor characteristics which contain linear and saturated region at various gate voltage applied, as shown in figure 8.

The on/off voltage and threshold voltage for both transistor configurations were at about -10 V.

IV. CONCLUSION

All organic transistors consist of undoped poly-3,3”- didecyl -2,2’,5’,2”-terthiophene show a current amplification upon increasing gate voltage. Polypyrrole source-drain material shows better stability with increasing gate voltage.

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