Fabrication of ultra thin film transistor base on poly(3-hexylthiophene)/F-4 TCNQ Langmuir-Blodgett film

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1 Introduction

Organic films of few nanometers (a monolayer) are expectations as being useful components in many practical and commercial applications which are sensors, detectors, displays and FET [1-3]. An organic film can be deposited on a solid substrate using various techniques such as thermal evaporation, sputtering, molecular beam epitaxy, adsorption from solution, Langmuir-Blodgett (LB) technique etc.[4] The LB-technique is one of techniques for preparing such thin films as it enables (1) the control of the monolayer thickness, (2) homogeneous deposition of the monolayer over large areas and (3) fabrication multilayer structures with varying layer composition, (4) monolayers can be deposited on almost any kind of solid substrate . We fabricated thin film transistor (TFT) using LB techniques. Semiconductor layers consist of RR-P3HT and F-4TCNQ. A mixture of P3HT and F-4 TCNQ spread from a chloroform on water surface forms a stable monolayer. Bottom contact device was fabricated on Si wafer which was patterned by normal photolithography process

2.1 Experimental and Results

Chrome and gold layer were deposited on top of the thermally grown 300nm thick SiO_2 layer using thermal evaporation with the thickness of 5nm and 50nm, respectively. Deposition rate was about 0.1nm/sec at the pressure of $1x10^{-6}$ Torr. The source and drain electrode were patterned using a normal photolithography process (Fig.1).

Regio-regular P3HT was purchased from Aldrich. HPLC grade chloroform was used as the solvent for dissolving the P3HT/ F-4TCNQ (Fig. 2). A Langmuir trough (KSV2000) was employed for the preparation of the films. The sub-phase was ultrapure water. A series of spreading solutions with different ratios of P3HT / F-4TCNQ were prepared to investigate the composition dependence of the Langmuir films. After the solvent had evaporated completely (>30 min), the spreading molecules at the air/water interface were compressed at a barrier speed of 10 mm/min, and the surface-pressure-area (π-*A*) isotherm was recorded. LB films. P3HT / F-4TCNQ were deposited from the air/water interface by vertical dipping onto a patterned Si wafer.

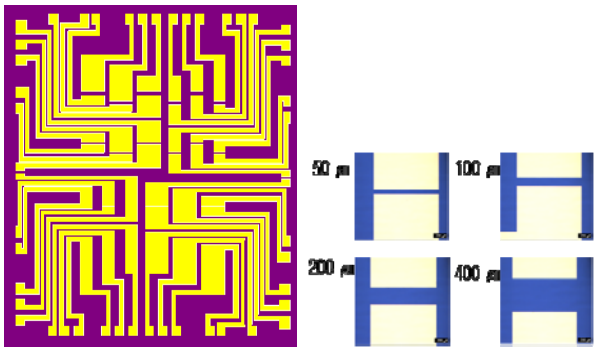

Fig.1 Photo mask of source/drain electrode. Optical microscopy image of the fabricated transistors with channel lengths

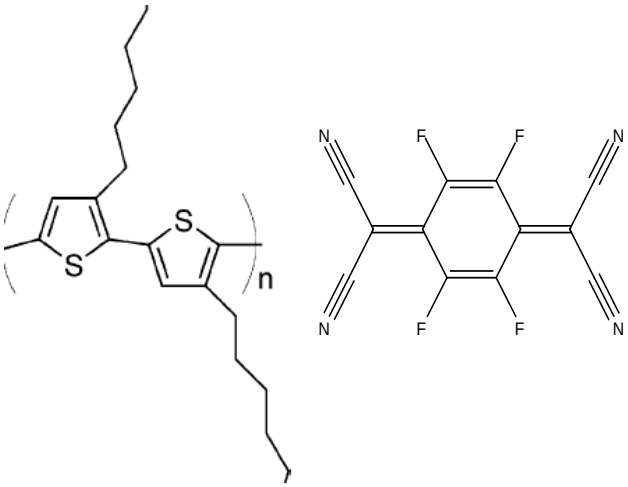

Fig. 2 Chemical structure of the P3HT and F4-TCNQ

The LB deposition was carried out at a dipping rate of 10 mm/min under a constant surface pressure of 25 mN/m. Fig3 shows Isotherms of surface pressure and mean monomeric area of poly(3-hexylthiophene) spread from chloroform solution with concentrations of 0.1 mg/mL, 0.25 mg/mL and 0.5 mg/mL. The formation of a of poly (3-hexylthiophene)LB film was sensitive to preparation conditions for instance spreading solvents and concentrations. The use of concentrated solutions led to aggregations during spreading and the resulting films were visibly inhomogeneous and rigid [5]. Figure 3 shows the isotherms of films prepared with chloroform as the solvent at different concentrations. Compared with the film obtained from a dilute solution (0.1 mg/mL 0.25 mg/mL 1), the film spread from a concentrated solution (0.5 mg/mL) has a lower compressibility and a more drastic transition from an expanded state to a condensed state. Also Fig.4 Show the Surface pressure-area isotherms of of P3HT / F-4TCNQ films The π-A isotherms demonstrate that condensed monolayer can be formed from P3HT / F-4TCNQ mixtures.

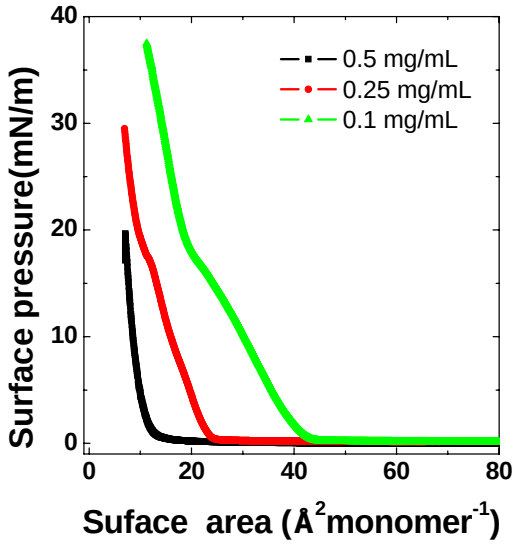

Fig3. Isotherms of surface pressure and mean monomeric area of P3HT spread from chloroform solution with concentrations of 0.1 mg/mL, 0.25 mg/mL and 0.5 mg/mL ,

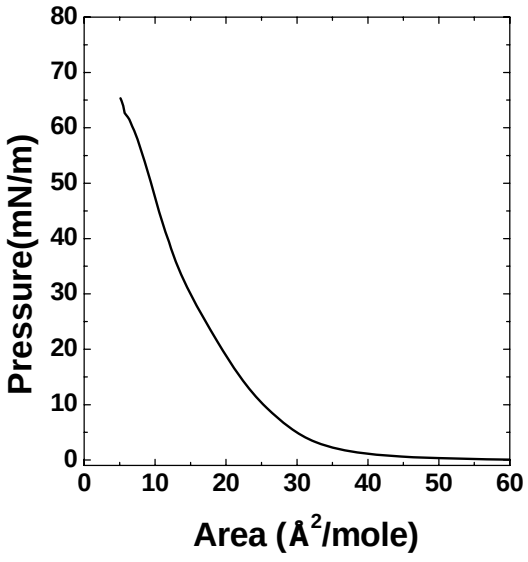

Fig4. Isotherms of surface pressure and mean monomeric area of P3HT/F4TCNQ spread from chloroform solution

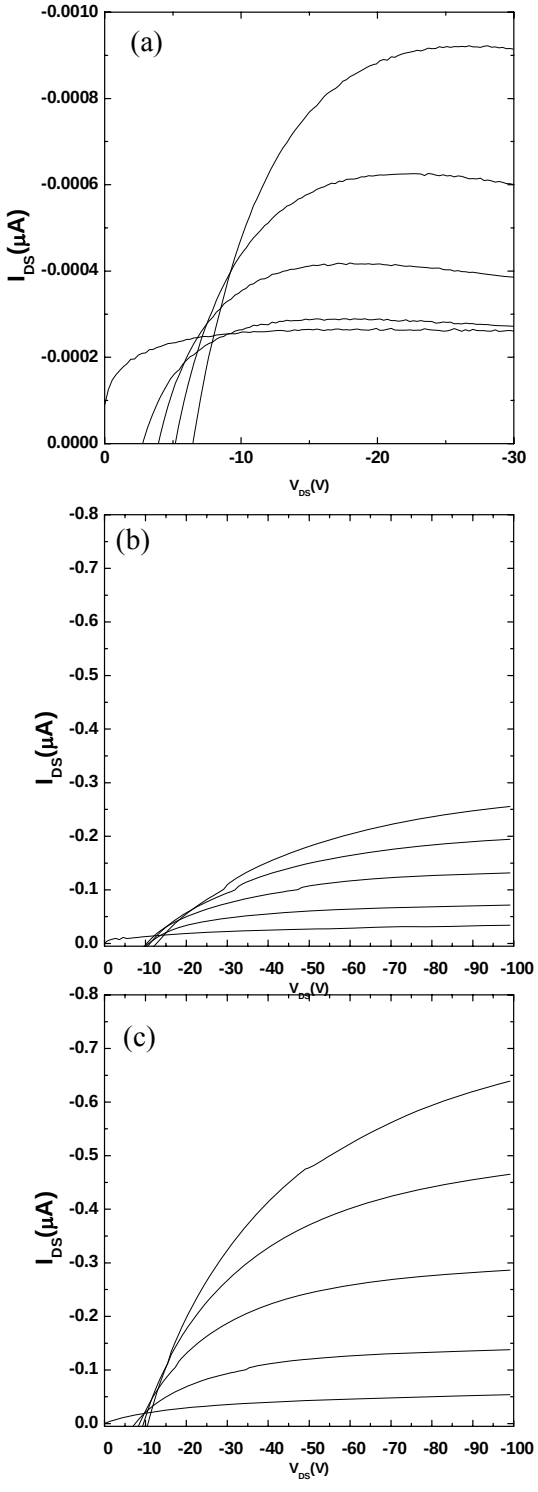

Fig.5 iv curves of the devices as different ratio of F-4 TCNQ (a) pure P3HT (b)2% F4TCNQ (c)6% F4TCNQ

The Fig.5 (a)-(c) shows the iv curves of the devices as different ratio of F-4 TCNQ. The pure P3HT monolayer device showed the field effect mobility (μ_{FET}) of 1 x 10^{-6} $cm^2/V\bullet s$ in the saturation region at Vg= -50V, The field effect mobility measured for P3HT/F-4 TCNQ (2%) was 1 x 10^{-4} cm^2/vs and for P3HT/F-4 TCNQ (6%) was 4 x 10^{-4} cm^2/vs. The output current of P3HT/F-4 TCNQ device is two order higher than that of the pure P3HT device. The mobility of the doped TFTs increases gradually as the F4-TCNQ concentration increases. The number of mobile holes increases as the doping concentration increases. The introduction of F4-TCNQ strongly influence the electrical properties of the P3HT TFTs. It is clear that Charge transfer between the electron acceptor F4-TCNQ and the electron donor P3HT provide mobile holes [6]

Summary

The application of Langmuir-Blodgett(LB) techniques to poly(3-hexylthiophene) (RR-P3HT)/F4-TCNQ offers a unique approach for constructing molecular devices. We fabricated ultra thin film transistor (TFT) using LB techniques. Active layers consist of RR-P3HT and F4-TCNQ. A mixture of P3HT and F4-TCNQ spread from a chloroform on H_2O surface forms a stable monolayer. IV increase gradually as the F4-TCNQ concentration increases.

References

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