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Stable Polymer Dielectric Film for P3HT TFT by Modified Poly-(Vinyl Phenol) with Polar Functional Group

P.Y. Lo[1, 2], Z. Pei[1], F. Y. Yang[3], Y.R. Peng[1], Y.C. Lin[1], and Y.J. Chan[2]

[1]Electronics and Opto-electronics Research Laboratories, Industrial Technology Research Institute, Hsinchu, 310, TAIWAN, R.O.C. Phone:+886-3-5913858 Fax:+886-3-5820093 E-mail: PYLO@itri.org.tw,
[2]Department of Electrical Engineering, National Central University, Taoyuan 320, TAIWAN, R.O.C.
[3]Materials and Chemical Research Laboratories, Industrial Technology Research Institute, Hsinchu, 310, TAIWAN, R.O.C.

1. Introduction

Organic thin film transistors (TFTs) have received increased attention in last few years [1-5]. For low cost mass production, the semiconductor, dielectric, and conductor layers have to be applied by solution processes [2]. In order to improve the performance of OTFTs, the semiconductor layer must be purified for reducing polydispersity (PDI) value [4] or modified to have better stacking structure [5].Those research are focused on the polymer semiconductor modification, rarely on the properties of dielectric layer [5]. Regarding to the polymer dielectric for organic transistor, poly (vinyl phenol) based pentacene TFT exhibits comparable performance with oxide based TFT [6]. However, PVP is not stable during TFT operation [7]. In this study, an amino-functional group was used to partially replace hydroxyl group in PVP to resist the effect of water in the ambient environment. The material properties of modified PVP (MPVP) film were characterized by nuclear magnetic resonance (NMR), gel permeation chromatography (GPC) and thermo gravimetric analysis (TGA). The performance of MPVP layer been explored in terms of drain current, permittivity of the film and stability of polymer TFT.

2. Experiments

The initial PVP dielectric polymer was purchased from Aldrich (M.W. 20,000) without purification. Powders of PVP were dissolved into propylene glycol monomethyl ether acetate (PGMEA) in 10 wt% in this study. MPVP solution was made by mixing the (3-Aminopropyl-triethoxysilane) to the initial PVP solution in the clean room environment for 2 hr at room temperature. To make polymer TFT, purified P3HT (M.W. 63,611, PDI 1.77) was used as semiconductor layer. Prior to the P3HT coating, part of PVP and MPVP dielectric films were exposures to the ambient environment for 7 hr without any passivation. Platinum was then deposited to form a bottom gate TFT. For current-voltage-capacitance characteristic was measured by a HP 4156A semiconductor analyzer and a HP 4284A LCR meter.

3. Results and Discussion

The leakage current of initial PVP and MPVP are around $1x10^{-9}$ and $7x10^{-8}$ Acm^{-2} at ±20 V respectively. Take thickness and area into account, the permittivity derived from measured capacitance is about 3.03 and 4.7 for PVP and MPVP. For dielectric poses long time ambient storage (22℃, 50%RH), ambient gas such as water and oxygen will be absorbed cause the instability of TFT.

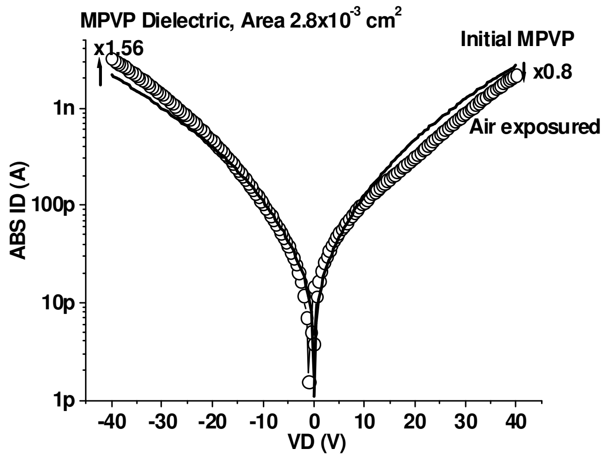

Figure. 1 The leakage current of MPVP with (empty circle) and without (solid line) exposure to the ambient environment.

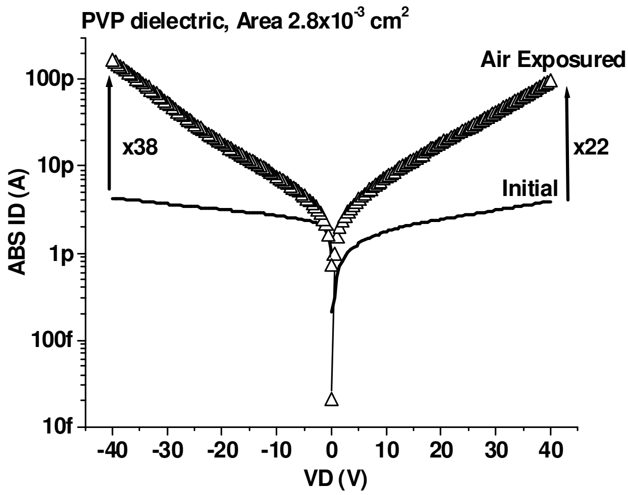

Figure. 2 The leakage current of PVP with (empty circle) and without (solid line) exposure to the ambient environment.

The leakage current for both film were shown in figure 1 and 2. MPVP dielectric exhibits only slight leakage current increase after long time exposure. In contrast, PVP dielectric shows poor ambient gas resistance. Besides leakage resistant, function group -NH2 in MPVP can increase the dielectric constant rather than –OH in PVP. Figure 3 shows the dielectric constant of PVP and MPVP. After exposure to ambient, the dielectric constant for both PVP and MPVP further increase. The dielectric constant for MPVP is around 6. The increase of dielectric constant is attributed by the absorption of water interaction with hydroxyl group in the dielectric film.

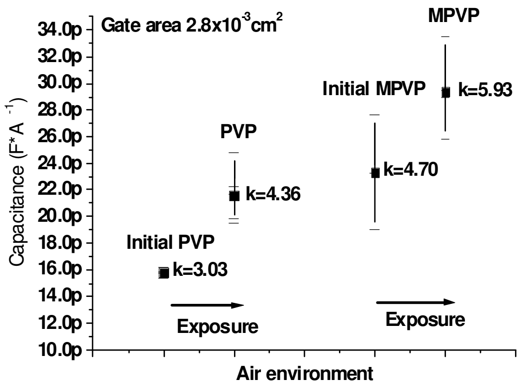

Figure 3. Capacitance of exposured MPVP (PVP) and initial MPVP (PVP) are analyzed. The average value is shown in solid square symbol.

of P3HT only has $2x10^{-3}$ $cm^2V^{-1}s^{-1}$ on MPVP polymer insulator compare with $4x10^{-2}$ $cm^2V^{-1}s^{-1}$ on SiO_2.

The output characteristic of P3HT TFT with MPVP and PVP as dielectric layer was shown in figure 4 and 5, respectively. After exposure to the ambient, the MPVP TFT shows only slightly increased in the drain current keeping good output characteristic. In contrast, the PVP TFT exhibit poor output characteristic even without ambient exposure. The TFT shows extensive source drain leakage current. Exposure to the ambient, the leakage current increased further.

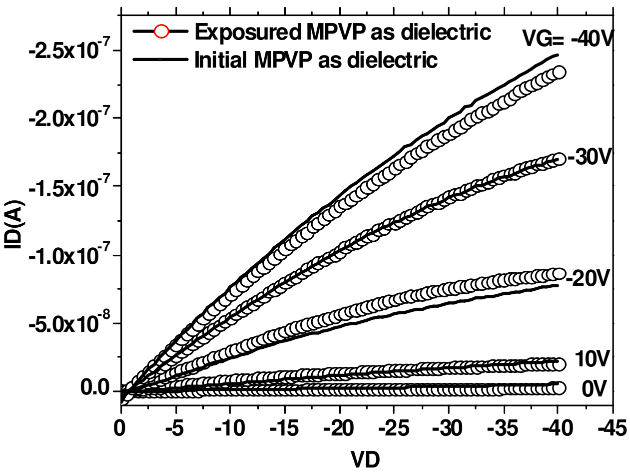

Figure 4. Output characteristic of P3HT TFT with MPVP as dielectric.

The leakage current from source to drain is generated by the P3HT thin layer owing to the poor polymer structure. The hydroxyl groups in PVP cause the surface in poor state for P3HT grown on the PVP surface. The P3HT film structure contains a lot of structure defects. These defects cause leakage current. In contrast to PVP, amino group in MPVP replace the hydroxyl group make the amino group assist P3HT format better structure to suppress the leakage.

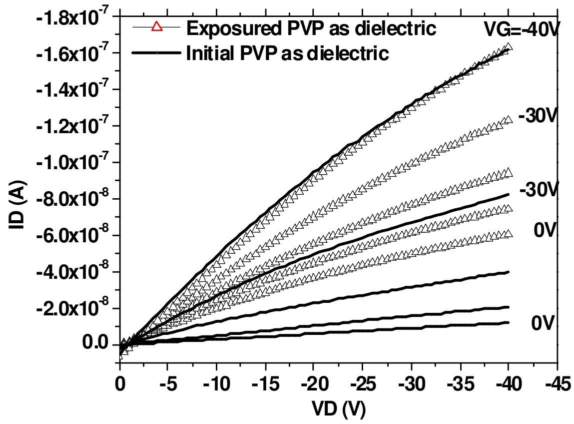

Fig. 5 Output characteristic of P3HT TFT with PVP as dielectric.

4. Conclusions

In summary, a stable, high dielectric constant and low leakage insulator film was reported. The bulk insulator can be modified by replacing hydroxyl group in polymer by a specific functional group. This modification is useful for mass printing production process.

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