Characteristics of Organic Thin Film Transistors with UV-treated Surface of Synthesized Gate Insulator

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Abstract

In this study, we report that the characteristics of OTFTs can be improved by the UV exposure of the surface of the synthesized photo-reactive gate insulator, and be optimized by controlling the exposure time. As a gate dielectric, the modified PVP was prepared by substituting hydroxyl group in PVP with cinnamoyl group. The synthesis details and the effects of the modified PVP on the device performance are discussed.

1. Introduction

Organic thin-film transistors (OTFTs) have received a lot of attention during the past several years. A variety of materials has been used in the last two decades for the development of the organic and polymer thin-film transistor structures to achieve the performance of OTFTs comparable to those of inorganic TFTs, such as those made of amorphous or poly-crystalline silicon [1]. The advancement of organic electronics for applications in solar-energy conversion, printed circuitry, displays, and solid-state lighting depends on the optimization of a variety of organic-semiconductor interfaces with other materials [2,3]. In particular, organic-semiconductor/insulator (OSC/I) interface is one of critical factors to the performance of OTFTs. Structural and electrostatic disorder in the first few layers of the organic semiconductor next to the insulator (i.e., in the OSC/I interfacial region) can lower the OTFT on-current, reduce the switching speed, and increase the threshold voltage [4]. Pentacene is one of promising organic semiconductors for the application in OTFTs due to enhanced qualities such as superior field effect mobility, good semiconducting behavior, and environmental stability [5, 6]. In general, it is well known that a vertical alignment of pentacene molecules to the substrate for OTFTs can provide a strong π-π* overlap and increase the electrical conductivity in the direction of perpendicular to long-axis. Therefore, some surface treatments of gate insulators, such as rubbing, photo-alignment and self-assembled monolayer (SAM) deposition, are necessary for aligning pentacene molecules on a gate insulator surface in a certain direction with high order. And it has been reported that those treatments contribute to improve the performance of OTFTs [7].

In this work, the electrical characteristics of pentacene-based OTFTs with the photo-reactive polymer as a gate insulator were investigated by using a photo-alignment method. The UV exposure of the photo-reactive insulator, prior to the deposition of organic semiconductor, modifies the surface properties of the insulator, and a preferential orientation of deposited pentacene molecules and the improvement of OTFT characteristics can be obtained. The synthesis details and the effects of the modified Poly(4-vinylphenol) (PVP) on the device performance are discussed.

2. Experimental

In order to synthesize the photo-reactive polymeric insulator, PVP and cinnamoyl chloride were dissolved in ethyl acetate (EA) in three neck flask equipped with a stirrer at 0℃. Triethyl amime (TEA) was then added used dropping funnel over a period of 30 min with constant stirring and cooling. The reaction mixture was stirred for 1hr at O℃ and consecutively for 12hr at room temperature. The precipitation was filtered off and the solvent in the filtrate was removed using a rotary evaporator. The synthesis process of photo-reactive polymeric insulator (PC) is shown in Fig 1.

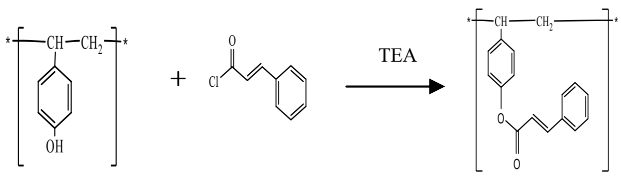


Fig 1. The synthesis process of PC.

In the fabrication of OTFTs, Al was thermally evaporated through the first shadow mask onto a glass substrate as a gate electrode and its thickness was about 1200Å. In order to evaluate the virtue of the chemically modified PVP, four kinds of OTFTs were fabricated with different UV-exposure times in the channel direction. PC dissolved in chloroform was spin-coated onto a glass substrate and consecutively baked at 40℃ for 10min and then at 70℃ for 1hr. Before the deposition of pentacene, the insulator surface of devices was exposed to UV in the direction of channel for no-exposure, 20 min, 30 min, 40 min, respectively. UV-exposure is used super high-pressure mercury lamp (Ushio Model USH-250D). And pentacene, as an organic semiconductor, was thermally evaporated through the second shadow mask onto the insulator-coated substrate at a rate of 1.0Å/s and its thickness was about 600Å. Then, 400Å-thick gold layer was thermally evaporated through the electroplating mask for source and drain electrodes. All the evaporation processes were carried out at a base pressure of about 10^{-6} Torr. The channel length and width of the fabricated OTFTs were 90 ㎛ and 200 ㎛, respectively.

3. Results and discussion

Atomic force microscopy (AFM) images of the pentacene molecules on the UV exposed PC are shown in Fig 2. Grain sizes are almost the same regardless of the UV-treatment condition on the gate insulator, but structural packing of pentacene molecules is increased as the UV-exposure time increases up to 30 minutes. However, as the UV exposure time exceeds 40 minutes, molecular packing intensity decreased.

The X-ray diffraction (XRD) spectra of deposited pentacene layers for different UV-exposure times are compared in Fig 3. The (001) reflection peak is decreased with the UV-exposure time for the first 30 minutes, which is due to the packing density increase, but as the UV-exposure time increases up to 30 minutes, it increased.

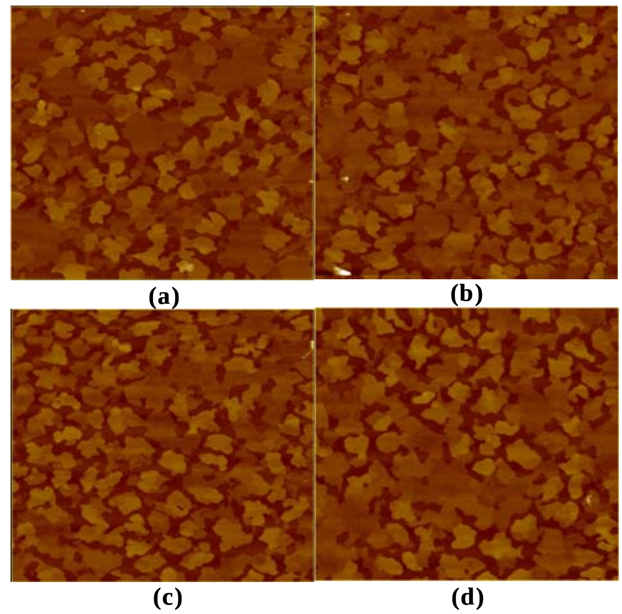


Fig 2. AFM images of 1.5nm deposited pentacene on (a) no-exposure, parallel (b) 20 min, (c) 30 min, (d) 40 min exposure of channel direction treated gate insulator.

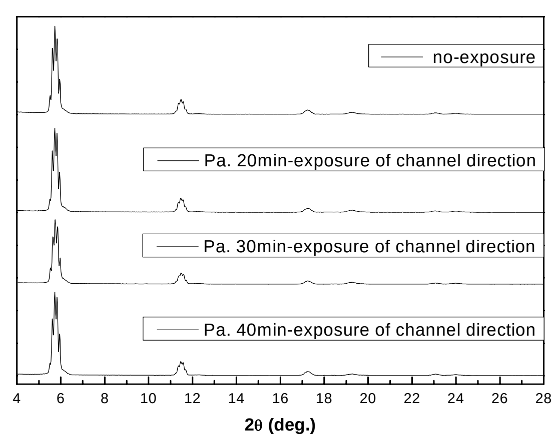
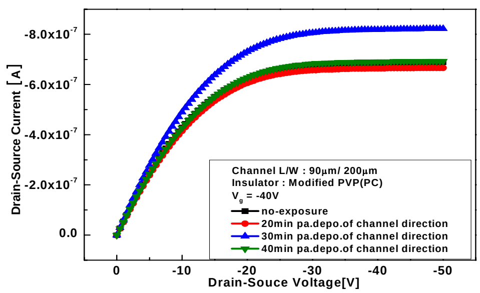
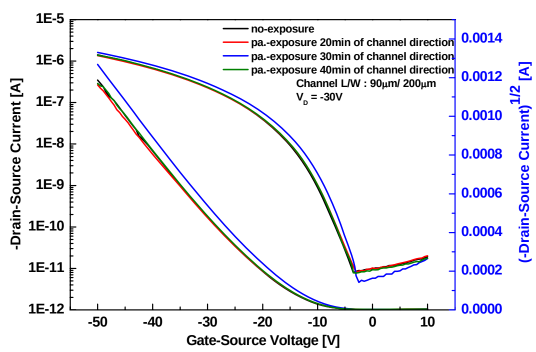


Fig 3. The XRD spectra of deposited pentacene on (a) no-exposure, parallel (b) 20 min, (c) 30 min, (d) 40 min exposure of channel direction treated gate insulator.

The output and transfer characteristics of OTFTs with different UV-exposure times are shown in Fig 4. It is observed that with 30 minute UV-exposure of the insulator surface in the direction parallel to the OTFT channel, the drain current level becomes the highest. The on/off current ratio of the device with the 30 minute UV-exposure in the direction parallel to the channel presents some improvement compared with the OTFT without the UV-exposured insulator. The extracted field effect mobility was about 0.16 ㎠/Vs for the device with the 30-minute UV-exposure in the direction parallel to the channel, and the subthreshold slope was also improved to 1.91V/decade from 2.5V/decade. Comparisons of parameters of four devices are listed in TABLE 1.



(a)



(b)

Fig 3. The output (a) and transfer (b) characteristics of OTFTs with the different UV-exposure times treated gate insulator.

TABLE 1. Summary of values of the various parameters of OTFT devices.

	As-deposit	Pa. UV-exposure 20min of channel direction	Pa. UV-exposure 30min of channel direction	Pa. UV-exposure 40min of channel direction
Threshold Voltage [V]	-18.26	-18.17	**-15.72**	-17.76
Subthreshold Voltage [V/dec]	2.5	2.5	**1.91**	2.5
Mobility [㎠/vs]	0.15	0.14	**0.16**	0.15
On/Off ratio	1.78*10^5	1.67*10^5	**3.5*10^5**	1.78*10^5

4. Summary

Optimization of the OSC/I interface properties is one of the crucial factors for high-performance OTFTs. In this work, the characteristics of OTFTs with the UV-exposed polymeric gate dielectrics synthesized by. With the 30-minute UV-exposure parallel to the channel direction, molecular packing density is the highest, which contributes to the improvement of the OTFT characteristics. And other device parameters such as driving current level, threshold voltage, subthreshold voltage and on/off ratio have also been improved the most for the device with the 30-minute UV-exposure parallel to the channel direction..

5. Acknowledgements

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6. References

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