Polyvinyl Alcohol (PVA)/Layered Silicate Nanocomposite Approaches for Organic Passivation Layers in Organic Thin Film Transistors

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ABSTRACT

We have synthesized novel organic passivation materials to protect organic thin film transistors (OTFTs) from H_2O and O_2 using PVA/layered silicate (SWN) nano composite system. Up to 3 wt% of layered silicate to PVA, very homogeneous nanocomposite solution was prepared. Pentacene OTFT device showed no significant initial performance drop after passivation with PVA/layered silicate nanocomposite and even mobility was slightly improved. But PVA only passivated OTFT device showed 25 % of field effect mobility drop after passivation. PVA/layered silicate nanocomposite also formed smooth film layer by spin coating method with surface roughness below 2 nm. We propose layered silicate containing PVA nanocomposite film can be used as good organic passivation layer in OTFT.

Keywords: polyvinyl alcohol, passivation, nanocomposite

1 INTRODUCTION

Organic thin-film transistors (OTFTs) have been demonstrated as promising candidates for flexible displays, smart cards, memory and sensors. These applications with organic electronics offer many advantages, such as light weight, low cost processing, and mechanical flexibility. On the other hand, organic devices also have some significant shortcomings, such as relative low mobility and performance degradation due to moisture (H_2O) and oxygen (O_2) [1,2]. Most of researches have been focused on the mobility improvement and now the mobility of OTFT is almost the same as that of amorphous silicon thin-film transistor (TFT) or even higher. However to realize the real array device such as active matrix display, the passivation of OTFT is the most important process, especially by solution processable materials for all organic devices. Unfortunately there are not so many candidates for organic passivation because organic passivation solution can damage the OTFT device such as organic semiconductor. Most frequently used organic material for OTFT passivation is polyvinyl alcohol (PVA) in water to be safe to organic semiconductor layer by the effect of large difference of surface energy [3].

In our works, we have tried the modification of PVA passivation layer by nanocomposite approach with synthetic smectite clays to improve the barrier property of PVA layer to oxygen and moisture. The standard pentacene OTFT device with top contact configuration for the passivation study is shown in Figure 1. We have traced the electrical performance changes of PVA and PVA nanocomposite system. Surface morphology and composite state were investigated by atomic force microscophy (AFM).

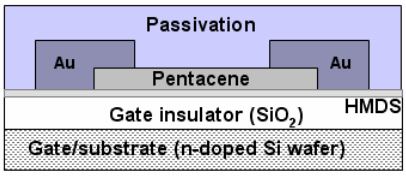

Figure 1. Schematic cross-section of the pentacene organic thin-film transistor (OTFT) with passivation layer.

2 EXPERIMENTAL

2.1 Preparation of PVA/SWN nanocomposite

PVA was purchased from Aldrich and the molecular weight was about 8,000~10,000. PVA was dissolved in H_2O as 10 wt% concentration which was filtered by 0.2 um filter. And then we added layered silicate (SWN) into PVA solution and stirred for 2 hrs at room temperature. The concentration of SWN was varied as 1, 3, 5 and 10 wt% to the amount of PVA. Good homogeneous PVA/SWN nanocomposite solution was found at 3 wt% SWN condition, but insoluble SWN was observed at the concentration above 5wt% of SWN. For the application of passivation layer, very smooth surface roughness is essential, so we used 3 wt% SWN containing PVA solution and made nanocomposite thin film using it by spin coating method.

2.2 Device fabrication

The geometry of pentacene OTFTs for passivation study was top-contact structure. We used heavily doped n-type Si wafer as gate electrode with 60 nm-thick thermally grown SiO_2 layer acting as a gate insulator and cleaned it using the general cleaning process for electronic applications; sonication in detergent, acetone, isopropyl alcohol and

deionized water in that order, for 20 min at room temperature, and then dried it at convection oven. HMDS was spin coated with spinning speed as 3000 rpm on top of the SiO_2 insulator to improve interfacial property between SiO_2 and pentacene organic semiconductor. The baking condition was 120 ^oC for 10 min. A 60-nm-thick layer of pentacene was deposited on top of the HMDS treated SiO_2 through a shadow mask by thermal evaporation at a pressure of $1X10^{-6}$ torr. The evaporation rate of the pentacene was 1Å/s and the substrate temperature was maintained as 90 ^oC during deposition. Pentacene OTFTs were then completed by thermally evaporating a 60-nm-thick source and drain gold electrodes on top of the pentacene layer through a shadow mask with a channel length (L) of 50 μm and width (W) of 1000 μm. Finally we passivated device using PVA/SWN composite solution by spin coating method. The film thickness of passivation layer was about 0.5 um.

3 RESULTS

Surface morphology of PVA/SWN nanocomposite film. We compared the surface roughness of PVA and PVA/SWN thin film by atomic force microscophy (AFM). Figure 2 show surface AFM images of PVA and PVA/SWN film on top of pentacene OTFT device. There are no significant differences in film morphologies of two films. Both film show good surface smoothness as about 1 nm average surface roughness. Surface roughness of passivation layer is very important factor to prevent failure of the following process in real array device fabrication.

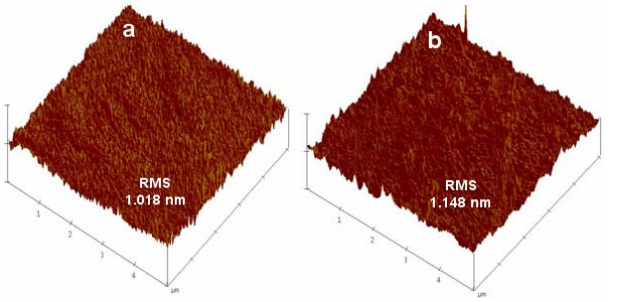

Figure 2. AFM images PVA (a) and PVA/SWN (b) nanocomposite films

Electrical property of pentacene OTFT with passivation. We have prepared three pentacene OTFT devices. One is pentacene only deposited device and others are pentacene OTFTs with PVA and PVA/SWN nanocomposite passivation layer, respectively. Clearly, there are performance differences of each devices, so we selected specific devices that show similar TFT performances as first pentacene deposited state. Figure 3 show the mobility changes as time going of unpassivated, PVA and PVA/SWN nanocomposite passivated devices. After passivation we stored devices in ambient air. All three pentacene OTFT devices show almost similar mobilities as 0.35 ~ 0.37 cm^2/Vs at unpassivated state. But there are significant performance changes after passivation. Normally, optimal state of pentacene is damaged by H_2O based PVA passivation in many other reports, so there should be large initial performance drop after passivation. In our case, similarly, mobility was decreased from 0.35 cm^2/Vs to 0.27 cm^2/Vs. It is almost 25 % performance drop compared to as deposited state device. In the case of unpassivated device, there is also mobility drop from 0.36 to 0.31, it just came from the degradation of device in air as time goes by. Very interestingly, pentacene OTFT device passivated with PVA/SWN nanocomposite exhibited slight performance improvement after passivation. Even up to 50 hrs in ambient air, there is no mobility drop as compared to as pentacene deposited state.

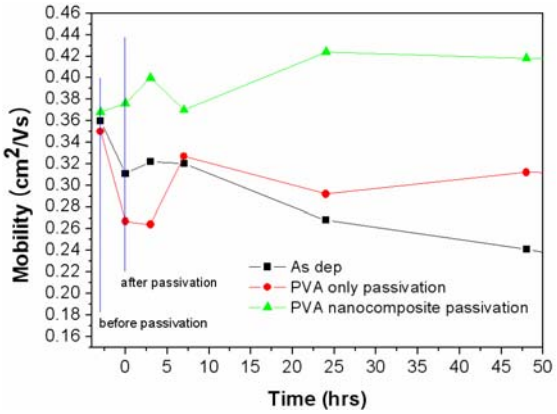

Figure 3. Mobility changes of pentacene OTFTs with and without passivation.

We are doing further deep investigations to know the reason about no performance drop of OTFT device with SWN containing PVA passivation layer. One possible explanation is that layered silicate in PVA nanocomposite acts as barrier toward H_2O and O_2.

4 CONCLUSIONS

We have synthesized new organic passivation layer composed of PVA and layered silicate by nanocomposite approach. General initial performance drop after passivation was not observed and even up to 50 hrs. We propose PVA/layered silicate nanocomposite as promising candidate for passivation layer in OTFT.

REFERENCES

[1] Y. Qiu, Y. Hu, G. Dong, L. Wang, J. Xie, T. Ma, *Appl. Phys. Lett. 83*, 1644, **2003**.
[2] R. Ye, M. Baba, K. Suzuki, Y. Ohishi, K, Mori, *Thin Solid Films*, *464-465*, 437, **2004**.
[3] S.H. Han, J.H. Kim, J. Jang, S.M. Cho, M.H. Oh, S.H. Lee, D. J. Choo, *Appl. Phys. Lett. 88*, 073519, **2006**.