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Enhancement in the Reliability of *a*-InZnO TFT by Fluorine-Doped Polysilsesquioxane Passivation with Spray Pyrolysis

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ABSTRACT

We report the effect of inorganic-organic passivation deposited by spray pyrolysis technique on enhancing the stability of a-InZnO thin-film transistors. We achieved better device stability by incorporating spray coated fluorine-doped passivation layer which protects the channel layer from atmospheric effects.

1 INTRODUCTION

Amorphous oxide semiconductors (AOS) thin-film transistors (TFTs) are widely studied as it exhibits excellent electrical performance, wide bandgap, and low leakage current which suits the demand of advanced electronic device applications [1]. Even though there are many reports on high-performance AOS TFTs, the reliability is still one of the main challenges in the case of current-driven organic light-emitting diode display particularly due to its electrical instability and back-channel interaction with atmospheric gasses [2].

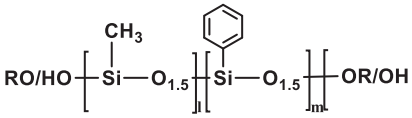

Fig. 1. Chemical structure of fluorine-doped polysilsesquioxane (PSQ:F) passivation.

In this work, the utilization of inorganic-organic fluorine-doped polysilsesquioxane (PSQ:F) was explored as a passivation layer for solution-processed amorphous Indium Zinc Oxide (*a*-IZO) TFTs. PSQ material is composed of Si-O polymer backbone with methyl and phenyl as the organic groups as shown in Fig. 1. The presence of organic groups helps in improving the hydrophobicity as well as flexibility of the PSQ polymer. Other than that, fluorine additive that was incorporated in PSQ material can increase the carrier concentration and passivate trap sites in the AOS channel [3].

There are many reported methods to deposit passivation layers for AOS TFTs such as sputtering, atomic layer deposition, and PECVD. However, these deposition methods may require longer fabrication time and need to be performed in a vacuum environment. Conversely, solution-processed deposition method offers vacuum-free, scalable deposition with a low fabrication cost. Herein, we report the deposition of inorganic-organic PSQ:F passivation layer based on spraying the 5% V/V solid content solution onto preheated substrates as illustrated in Fig. 2 [4].

2 EXPERIMENT

50 nm nominal thickness of *a*-IZO layers were deposited through spin coating process. This active *a*-IZO was pre-baked at 150ºC and post-baked at 300ºC for one hour. Photolithography was performed to pattern the *a*-IZO channel before deposition of Ti/Au as source and drain electrodes. Then, the unpassivated *a*-IZO TFTs were annealed at 300ºC for 2 hours as the post-annealing process. Consequently, 300 nm PSQ:F film was deposited as a passivation layer spray coating (SP) methods as in Fig. 2 (a). Spray coated film was deposited for 2 s at a pressure of 0.05 MPa. The distance between the spray nozzle and the substrate was maintained at 15 cm to uniformly coat the preheated substrate. Subsequently, the film was cured at 300˚C for 1 h. Contact holes were then fabricated through a dry etching process with a mixture of $Ar/O_2/CF_4$ gasses. Finally, the passivated *a*-IZO TFTs as in Fig 2(b) was annealed at 300ºC for two hours. All annealing processes were performed in a controlled environment.

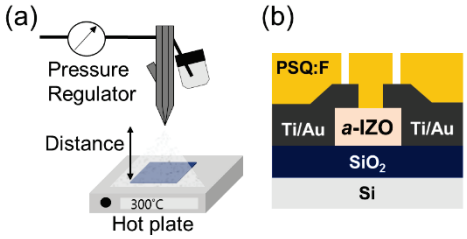

Fig. 2. (a) The set-up of PSQ:F passivation deposition by spray coating (SP) and (b) structure of SP F-PSQ passivated *a*-IZO TFT.

3 RESULTS

The electrical characteristics of *a*-IZO TFTs were extracted at drain voltage (V_d) of 0.1V as in Fig. 3. Unpassivated *a*-IZO TFTs recorded mobility of 5.11 ± 0.26 $cm^2V^{-1}s^{-1}$ with a threshold voltage (V_{th}) at -6.5 ± 0.13

V and subthreshold swing (*SS*) of 0.83 ± 0.27 $Vdec^{-1}$. Meanwhile, SP PSQ:F passivated sample recorded μ of 4.55 ± 0.13 $cm^2V^{-1}s^{-1}$ with V_{th} of -2.1 ± 0.38 V and SS of 0.54 ± 0.15 $Vdec^{-1}$.

In addition, hysteresis measurements were also performed to study the interface quality of the devices. Unpassivated *a*-IZO TFT recorded large clockwise hysteresis with threshold voltage shift (ΔV_{th}) of 7.7 V between forward and reverse sweep. Incorporation of SP PSQ:F passivation help in improving the hysteresis of IZO TFTs as in Fig. 4(b). Aside from hysteresis measurement, the reliability of the *a*-IZO TFTs was further evaluated through positive bias stress (PBS) test with gate voltage (V_g) of +20 V for 10000 s at a V_d of 5 V. Unpassivated *a*-IZO TFT showed a large positive shift of 3.9 V after the test. In contrast, SP PSQ:F passivated sample showed a more stable device with a smaller ΔV_{th} of 1.0 V.

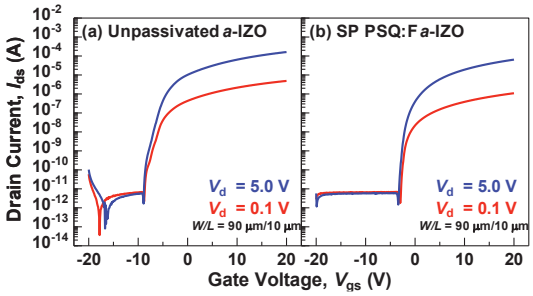

Fig. 3. Transfer curves of (a) unpassivated and (b) SP PSQ:F passivated *a*-IZO TFTs.

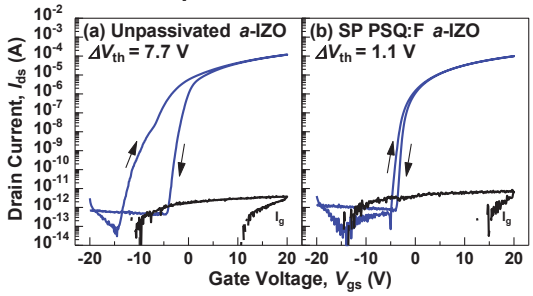

Fig. 4. Hysteresis curves of (a) unpassivated and (b) SP PSQ:F passivated *a*-IZO TFTs.

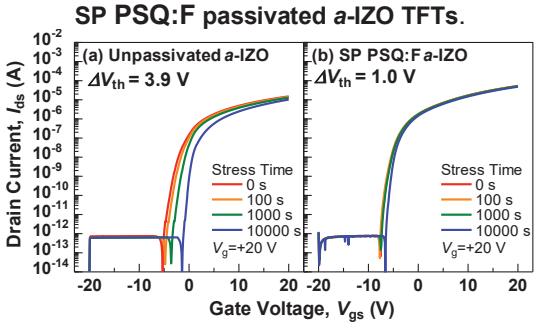

Fig. 5. Evolution of transfer curves (a) unpassivated and (b) SP PSQ:F passivated *a*-IZO TFTs after PBS test.

4 DISCUSSION

Incorporation of SP PSQ:F passivation significantly improves the stability of solution-processed *a*-IZO TFTs which was revealed by the hysteresis measurement. Other than that, PBS test confirmed the instability of unpassivated *a*-IZO TFT which was attributed to the atmospheric gasses or moisture that can easily interact with the exposed backchannel region of the unpassivated *a*-IZO TFT.

Smaller ΔV_{th} for SP PSQ:F passivated sample indicates that SP PSQ:F passivation reduces the number of electrons that can be trapped near channel/gate insulator interface as well as inhibits the adsorption of atmospheric gasses and backchannel interaction. Thus, it resulted in a more stable device which is preferable for an oxide TFT.

5 CONCLUSIONS

This work demonstrates the effect of spray coating PSQ:F passivation for a solution-processed *a*-IZO TFTs. SP PSQ:F passivation exhibited better reliability due to the formation of higher quality film which hindered the interaction of oxide channel and atmospheric gasses. Incorporation of SP PSQ:F passivation reduces the number of electron trapping sites near the interface of channel/gate insulator layers and prevents the interaction of atmospheric gasses or moisture with the exposed backchannel region of *a*-IZO TFTs.

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