Triple Layer Passivation for Organic Thin-Film Transistors

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Abstract

Passivation of organic thin-film transistors (OTFTs) using organic and metal thin-film was presented. Parylene-C and titanium were used as an organic and metal layer, respectively. With the proposed passivation method the degradation of electric parameters of OTFTs was relieved compared with non-passivated devices. Several electric parameters such as on/off current, field-effect mobility, and threshold voltage were shown.

1. Introduction

Electrical performance of OTFTs has improved dramatically over the last decade [1], [2]. Now their performance is comparable to amorphous silicon thin-film transistors (a-Si:H TFTs) [3]~[6]. This implies that circuits using OTFTs can be materialized for RFID tags, smart cards, pixel arrays for displays, or electronic papers. However, the stability issue which is essential for these usages is one of the challenging difficulties which OTFT researchers are faced with.

In this study, effects of triple layer passivation for OTFTs in terms of electrical parameters are investigated.

2. Experiment

Devices used in this study were bottom contact type (BC) OTFTs (Fig. 1) and the width and length of the devices were 1000 ㎛ and 25 ㎛, respectively. Substrate was 2 ㎝×2 ㎝ size of p-type Si and it also served as a common gate electrode. Thermally grown 1000 Å silicon dioxide was used as a gate insulator. S/D electrodes were formed on top of SiO_2 film. To define S/D electrodes, photolithography, Au evaporation, and lift-off process were applied successively. A 300 Å thick Au layer was evaporated on top of photo-resist patterned Si substrate at the base vacuum of about 10^{-6} torr for S/D electrode formation. Pentacene, which was employed as an active layer, was evaporated using thermal evaporator system at the deposition rate of about 1 Å/sec at 80 ℃. Such process gave the thickness of pentacene of 500 Å.

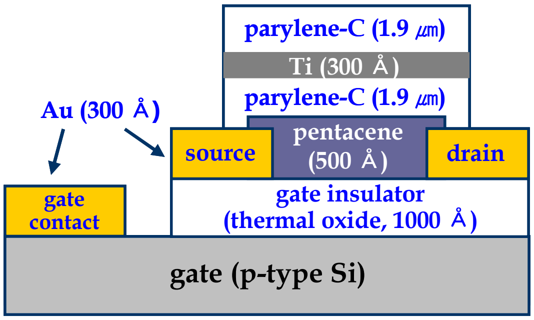


Fig. 1 Schematic of passivated bottom-contact type organic thin-film transistors (OTFTs).

The pentacene source for thermal evaporation had been purchased from Aldrich and used without purification. Triple passivation layer consisting of parylene-C, Ti thin-film, and parylene-C was employed to retard the degradation of electric performance of OTFTs. To make probing pads, the passivation layer on the area of gate contact and S/D electrodes had to be removed. The two parylene layers and the Ti layer were removed by O_2 plasma etching and HF wet etching, respectively. The manufacturing processes of control devices were

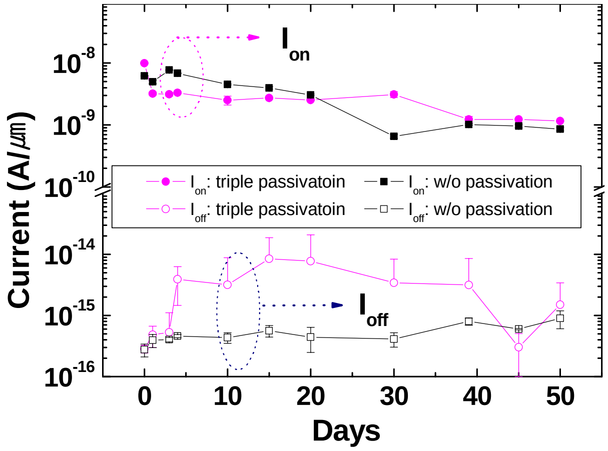


Fig. 2 On/off-current change with time. On-current of triple layer devices and controlled devices crossed on day 30.

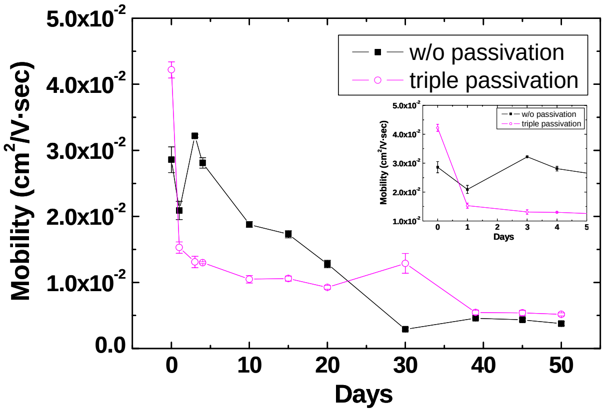


Fig. 3 The mobility decrease of passivated devices was smaller than that of control devices. Field-effect mobility decreased suddenly between day o and day 1, though.

identical with triple layer passivation devices except the parylene-Ti-parylene passivation layer.

3. Results and Discussions

Electrical analysis was performed repeatedly (12 times) for 50 days. OTFT devices were kept in a laboratory whose condition was air, dark, ambient temperature and humidity. The electrical parameters were determined using semiconductor parameter analyzer (Agilent 4156C). In each measurement, four OTFTs having the same gate length and width were measured to get average and standard deviation.

On/off-current change with time is shown in Fig. 2. On current of passivated and non-passivated devices (control devices) crossed when the measurement was carried out on day 30. Fig. 3 illustrates the field-effect mobility change of the two types of devices. The mobility also crossed on day 30. It can be found that the mobility decrease rate of triple layer passivation devices was smaller than that of controlled devices.

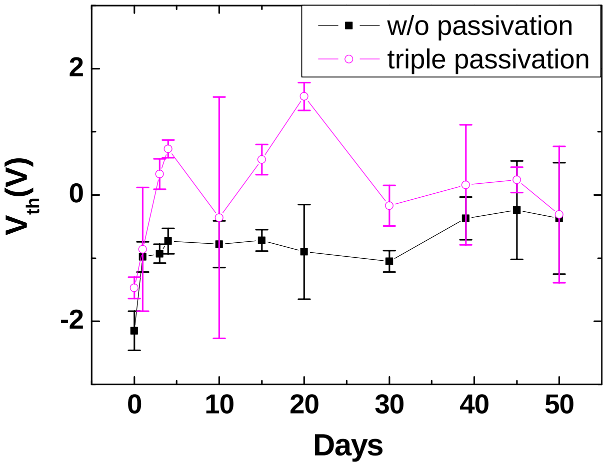
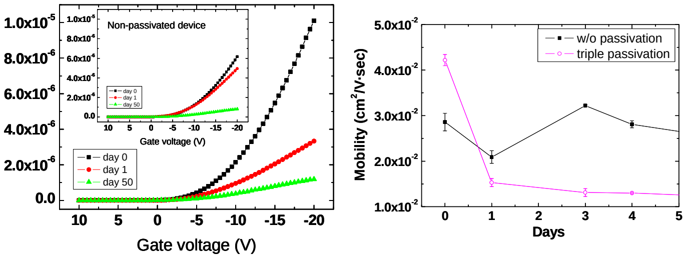


Fig. 4 V_{th} of the controlled devices had negative value and remained near 0 V, but V_{th} of the passivated devices changed around 0 V having positive or negative value alternately.



(a) **(b)**

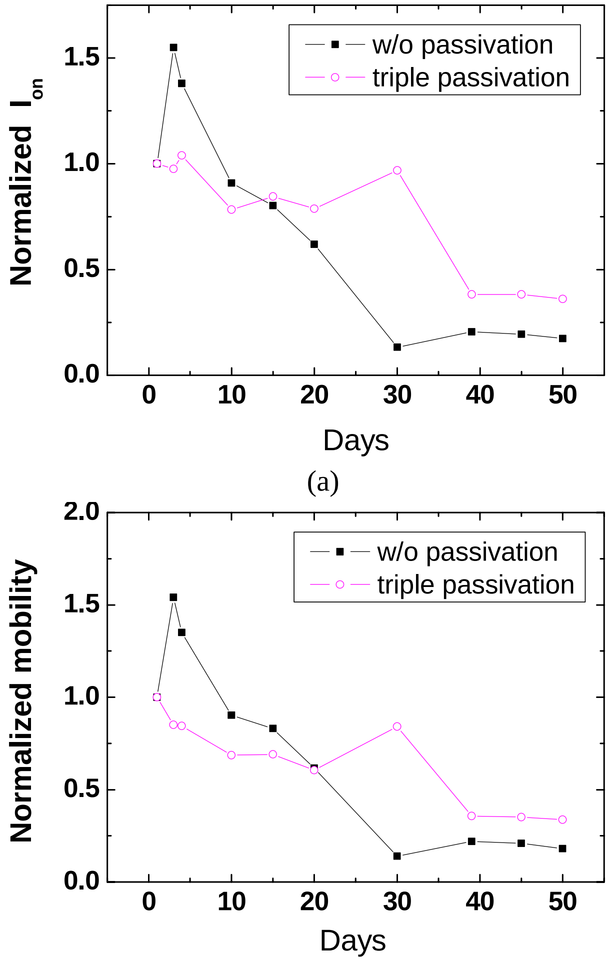
Fig. 5 Between day 0 and day 1, (a) on-current and (b) mobility of the passivated devices decreased by about 68 % and 29 %, respectively.

Fig. 4 depicts the threshold voltage change of the passivated and control devices. The V_{th} of passivated devices fluctuated around positive and negative values while V_{th} of controlled devices stayed near 0 V having negative value.

Between measurement day 0 and day 1, there was an abrupt decrease in mobility and on-current in the case of passivated devices (Fig 3, 5). The reason for these degradations is thought to be due to the following processes after pentacene deposition. Triple layer deposition and pad patterning including photolithography and etch processes were carried out after pentacene deposition and initial measurement (measurement on day 0). The cause of this initial degradation is still under investigation.

In Fig. 6, the initial degradation during passivation and pad patterning processes was excluded and measured data were normalized to show clearly the effect of passivation. The graph shows that the on-currents crossed on the measurement day of 15, and the mobility crossed around day 20. It is thought that the proposed triple layer passivation method will be more effective if the initial degradation is overcome.

Even though all the processes for thin-film deposition and pad patterning were not tuned for its best performance in this experiment, we could see that the triple passivation layer retards the performance degradation of OTFTs. The film thickness of the triple layer can be optimized to maximize the effect of



(a)

(b)

Fig. 6 Normalized value of (a) on-current and (b) field-effect mobility.

passivation. Photolithography and etch processes can be also modified to reduce the initial performance degradation. It seems that there is more room for improvement by modifying and by adopting more appropriate processes for deposition and pad patterning processes.

4. Conclusion

Triple layer passivation consisting of organic and metal films was applied to OTFTs made of pentacene. Repeated measurements for 50 days show that the proposed passivation method can slow down the degradation of electric performances of OTFTs. However, the initial degradation due to deposition processes of triple layer and pad patterning processes still needs to be improved.

5. Acknowledgements

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6. References

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