

Fabrication of Organic Thin-Film Transistors with Polymer Gate Insulators on Plastic Substrate

Seong Deok Ahn*, Seung Youl Kang, Ji Young Oh, In Kyu You,

Gi Heon Kim, Kyu Ha Baek, Chul Am Kim and Kyung Soo Suh

Electronics and Telecommunications Research Institute, Daejeon, 305-350 KOREA

Phone: +82-42-860-1581, E-mail: lovesky@etri.re.kr

Abstract

Active layer patterned OTFT was obtained on a plastic substrate using the optimal growth condition of pentacene thin films as active layer and parylene thin films as passivation layer. Traditional photolithography was performed to use a dry etch to pattern the material stack. The pentacene thin film and parylene thin film were deposited onto a plastic substrate using PC-OVD and CVD, respectively.

1. Introduction

In recent years there has been growing interest in the field of organic thin film transistors (OTFTs) on plastic for organic electronics such as smart cards, low cost identification (ID) tags, and flexible displays.[1] OTFT offer advantages compared to traditional field-effect transistors, like mechanical flexibility and weight reduction.[2] Pentacene, a polyacene, consists of five linear benzene rings and has demonstrated the highest electron and hole mobility of organic small molecules. The material exhibits a strong tendency to form highly ordered films which depend on the growth conditions and the substrate. Pentacene thin film have been fabricated by solution precipitation,[3] organic molecular beam deposition,[4] vacuum thermal evaporation,[5] organic vapor phase deposition,[6] all having compared performance.

However, many unresolved problems still remain in OTFT processing for more advanced organic-based integrated circuits such as display applications. A very important one problem is a difficulty in the organic active layer using photolithography and etching. It is known that the conventional photolithography process cannot be applied to organic materials. Several approaches have been proposed in the literature for patterning organic semiconductors. The Jackson group made a pentacene TFT using a poly(vinyl alcohol) (PVA) passivation layer.[7] The Jang group made a OTFT using the selective growth

of pentacene thin films between and on Cr/Au source and drain contacts.[8]

For this work, we developed the technology to enable photolithography patterning of pentacene between source and drain contact of an OTFT. Also, we have grown the pentacene thin film with new deposition technique such as pressure control organic vapor deposition (PC-OVD). PC-OVD proceeds by the sublimed source materials into hot inert gas flow that transports the vapors toward a substrate where condensation of the organic occurs. Opposite the substrate in the reactor, the gas inlet is configured as showerhead from in one surface.

2. Results

Figure 1 shows a schematic diagram of the PC-OVD reactor used to grow the pentacene thin film. As received pentacene, obtained from Aldrich Chemical Co., is used without additional purification. The source material, pentacene, was evaporated at a temperature of about 300°C and its deposition temperature was 10°C. The reactor is regulated to have a pressure of 1 torr using N₂. Compared to the thermal evaporation, this method minimizes material waste and achieves uniform deposition of pentacene thin film on 5 inch wafer.

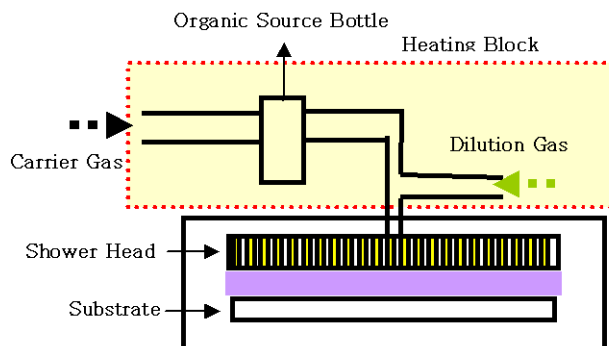


Figure 1. Schematic diagram of the PC-OVD reactor.

The pentacene TFTs were fabricated a bottom-contact structure. Cr/Al/Cr and Ti/Au were used for the gate and the source/drain metals, respectively, and they were deposited by sputtering and e-beam evaporation methods, respectively. For OTFT with an organic gate insulator, J1 was deposited onto the patterned gate metal by spin coating from solution. The gates were planarized by the spin-coated J1 at a thickness about 300 nm. After pentacene deposition, the parylene thin film as the passivation layer was deposited. Parylene coatings are very well suited to this process. The material is deposited onto the pentacene surface at the room temperature and polymerizes during the deposition process into a solvent-resistant, chemically inert film. The passivation layer protects pentacene against any attack with the solvents used for the photolithographic process.

Figure 2 shows the optical image of a mask align keys in an OTFT array on Poly-carbonate (PC) substrate. It is not observed the misalign in the mask align keys.

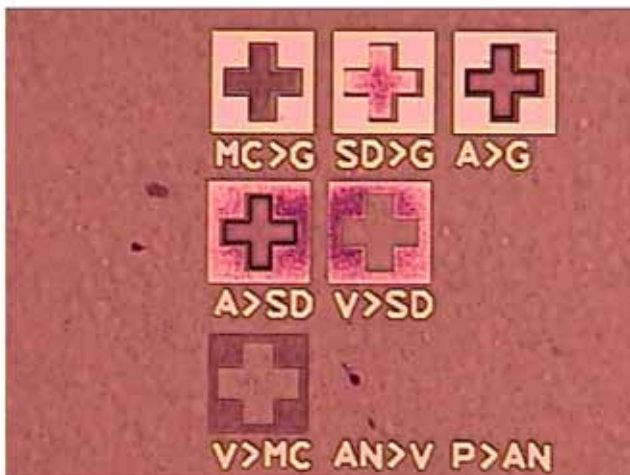


Figure 2. the optical image of a mask align keys in an OTFT array PC substrate.

Figure 3 and 4 show the transfer (a), output (b), and mobility characteristics (C) of a pentacene TFT after passivation and active patterning, respectively. We observed that the mobility was not change after active patterning.

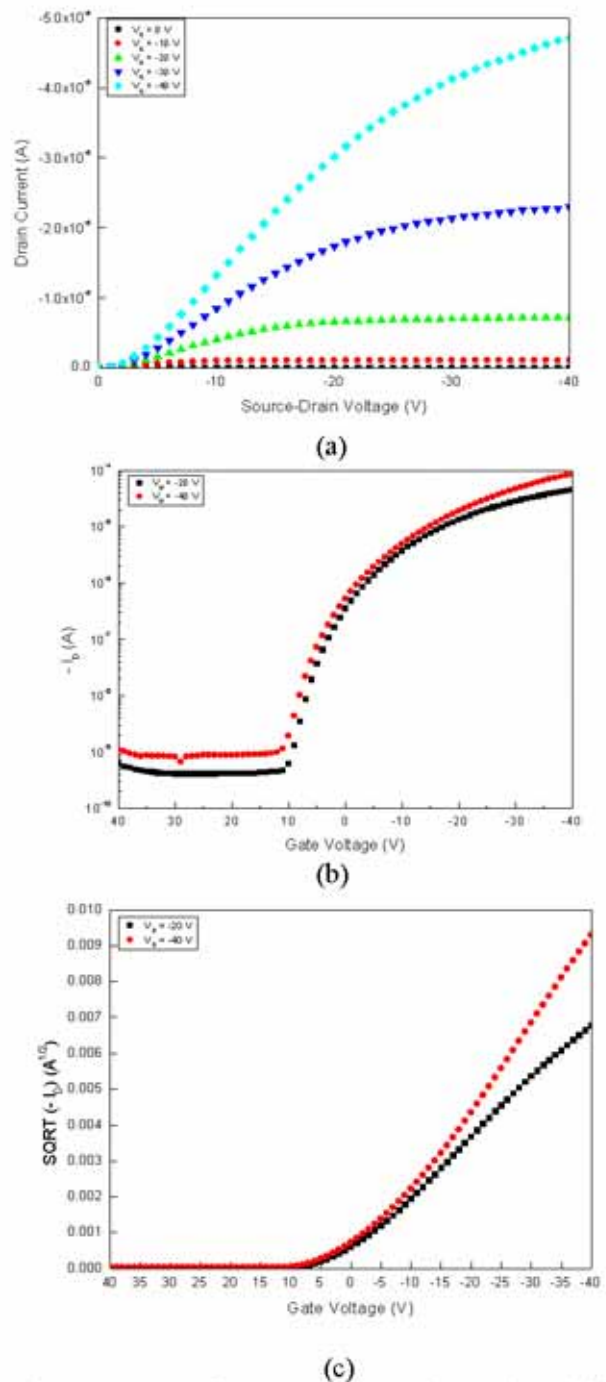


Figure 3. Transfer (a), output (b), and mobility characteristics (C) of a pentacene TFT after passivation.

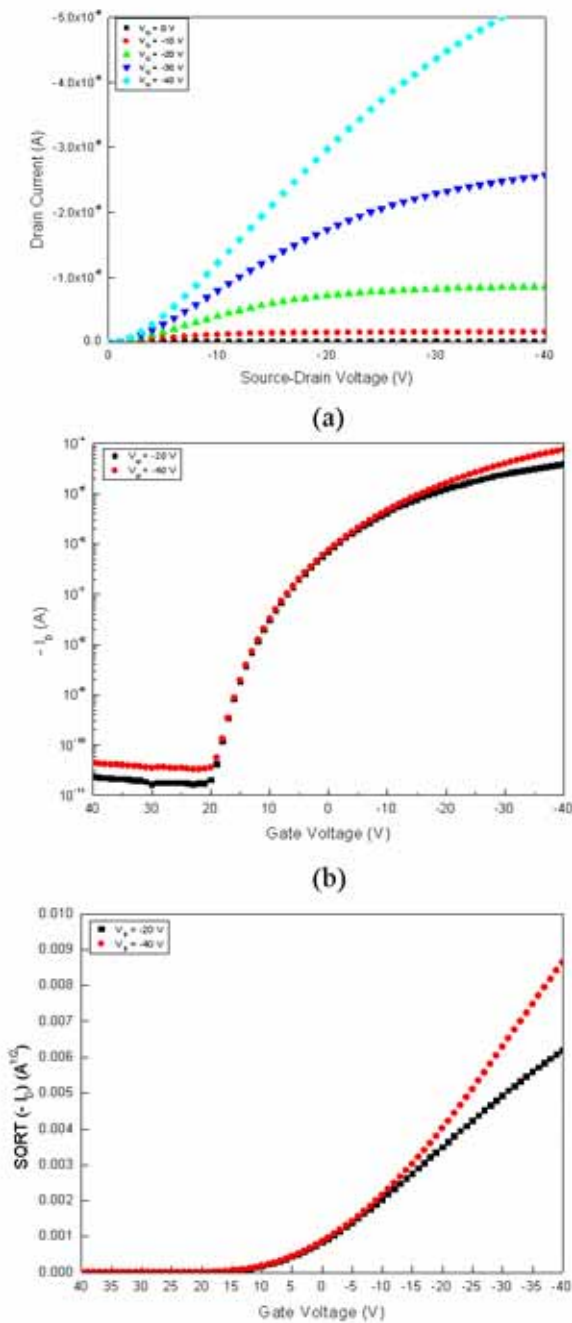


Figure 4. Transfer (a), output (b), and mobility characteristics (C) of a pentacene TFT after active patterning.

Figure 5 shows the photograph of the OTFT array on a plastic substrate.

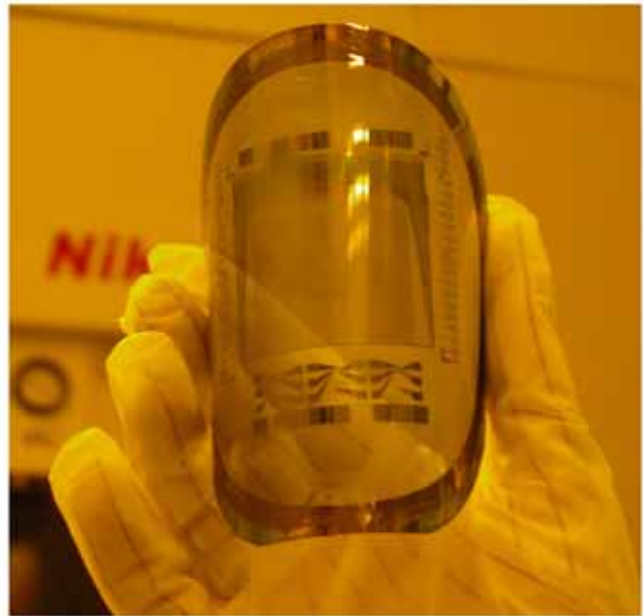


Figure 5. The photograph of the OTFT array on a plastic substrate.

3. Conclusion

We developed the technology to enable photolithography patterning of pentacene between source and drain contact of an OTFT. Also, we have grown the pentacene thin film with new deposition technique such as pressure control organic vapor deposition (PC-OVD). A bottom contact OTFT with the pentacene thin film exhibited a field-effect mobility of $0.1 \text{ cm}^2/\text{Vs}$ and an on/off current ratio of about 10^7 .

4. Acknowledgements

This work was supported by The Korea Ministry of Information and Communications. The authors thank Unitex Co., Ltd for supporting the deposition apparatus and helpful technical assistance.

5. References

- [1] C. D. Dimitrakopoulos and P. R. L. Malenfantols, *Adv. Mater.* 14, 99 (2002).
- [2] C. D. Dimitrakopoulos, S. Purushotaman, J. Kymissis, A. Callegari, and J. M. Shaw, *Science*, 283, 822 (1999).
- [3] A. R. Brown, C. P. Jarrett, D. M. de Leeuw, and M. Matters, *Synth. Met.* 88, 37 (1997).
- [4] C. D. Dimitrakopoulos, A. R. Brown, and A. Pomp, *J. Appl. Phys.* 80, 2501 (1996).

- [5] D. J. Gundlach, Y. Y. Lin, T. N. Jackson, S. F. Nelson, and D. G. Schlom, *IEEE Elec. Dev. Lett.* 18, 87 (1997).
- [6] M. Shtein, H. F. Gossenberger, J. B. Benziger, and S. R. Forrest, *J. Appl. Phys.* 89, 1470 (2001).
- [7] D. J. Gundlach, T. N. Jackson, D. G. Schlom and S. F. Nelson, *Appl. Phys. Lett.* 74, 3302 (1999).
- [8] H. Y. Choi, S. H. Kim and J. Jang, *Adv. Mater.* 16, 732 (2004).