Electrophoretic Display employing OTFT-Backplane on plastic substrate

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Abstract

We fabricated a flexible OTFT(organic thin film transistor) backplane for the electrophoretic display. The backplane was composed of 128 × 96 pixels on the Polyethylene Naphthalate substrate in which each pixel had one OTFT. The OTFTs employed bottom contact structure and used the cross-linked polyvinylphenol for gate insulator and pentacene for active layer

1. Introduction

Recently, the reflective paper-like displays include several types such as an electrophoretic display (EPD) utilizing microencapsulated TiO_2 nano-particles, a twisting ball display, and a cholesteric liquid crystal display[1-5]. And than, EPD with lightweight and flexibility has stimulated much interest due to potential commercialization in the filed of information displays including electronic-newspapers and electronic-books.

The objective of this work is to implement a backplane using OTFTs for active-matrix-addressed EPD on plastic substrate.

E-ink Corp is a leader of EPD panel. Recently, Sony released LIBRIe(800 × 600) a electronic book in 2004 and Sony Reader in 2006 CES. iRex in Netherlands exhibited e-book reader Iliad ER0100(1024 × 768) based on E-ink technology, and Jinke Hanlin Corp. released V8 e-book reader(800 × 600) in 2006 CES. Philips is a major company in the field of roll display and demonstrated a prototype of roll display (readius 320 × 240) with 5 inch size. Also Plastic Logic Inc. reported a EPD activated by OTFT-backplane.

In this work we developed a design methodology and fabrication processes for OTFT-backplane for EPD panel on PEN substrate.

2. Experiment

A EPD can display black & white image by direction of the electric field. Also it has the memory characteristic in itself which can keep prior condition[6-9]. So EPD backplane needs a pixel circuit having a switching device to eliminate the cross talk which is produced by leakage current (Fig 1). The resolution of the OTFT backplane we design is 128 × 96 and the size of the display is 2.5inch. The pitch of a pixel is 400um × 400um and is designed by the minimum feature size of 10um. It is composed of an OTFT and a pixel electrode and the W/L of the OTFT is 5. The aperture ratio of a pixel is 74%.

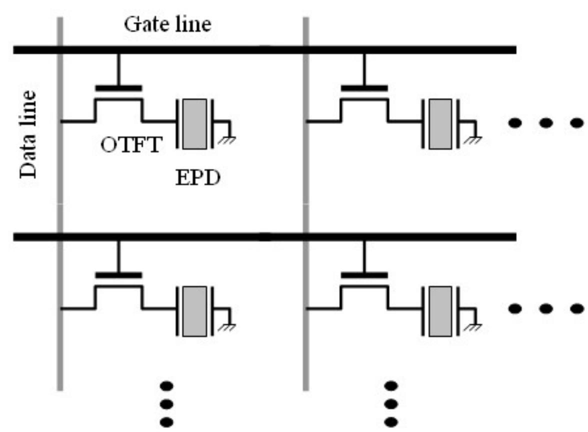
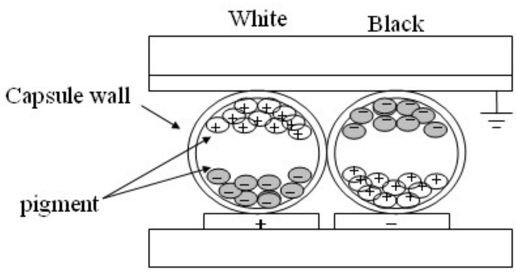


Figure 1. The structure of a pixel consisted of EPD and OTFT

The OTFT used at backplane is designed by bottom contact structure. To ensure the uniformity of a Backplane's characteristic, a uniformity of the pattern is important. Usually, the performance of OTFT with Top contact structure is more excellent than OTFT with Bottom structure[10]. But it is difficult to form an uniform microscopic pattern. So for the uniform formation of microscopic pattern, we use the Bottom contact structure, which is produced by photolithography. And we can acquire the uniformity of performance. In figure 2, we shows device structure of frontplane and OTFT backplane.



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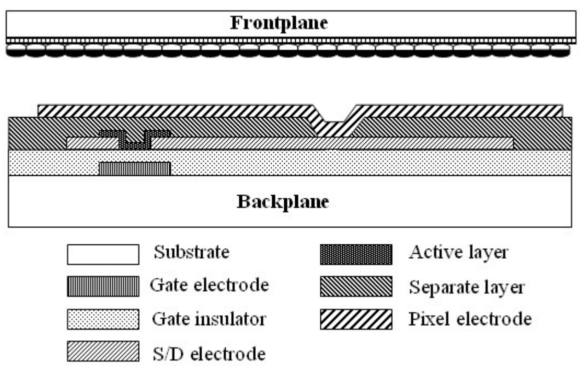


b)

Figure 2. a) Schematic illustration of Frontplane (microcapsule-type electrophoretic display : MC-EPD), b)The cross-sectional illustration of the device structures.

The OTFT array has six layers of thin film and is fabricated by the four photolithography processes and the two shadow mask processes.

The backplane size was 2.5inch in diagonal. First, the row electrode (gate electrode : Al) are formed by lift-off process on the PEN substrate. For a good lift-off process, chlorobenzene was applied after exposure. Next, PVP is spread by spin coating on the gate electrode. The PVP organic gate material consisted of PVP polymer and cross-link agent (CLA), and Propylene glycol monomethyl ether acetate (PGMEA) as a solvent. We found that the optimum ratio of components was 10wt% of PVP mixed with 5wt% of CLA in 100wt% of PGMEA[11]. The CLA was activated by thermal heating After PVP cirrhosis, we patterned the PVP by using photolithography and O_2 Plasma etching. Next, we made S/D (Source/Drain) electrode(Au) by lift-off process. The pentacene active layer was formed by thermal evaporation (Effusion cell) with the deposition rate of 0.3A/s and the thickness of 45nm through shadow mask. The substrate temperature was maintained at 80°C during the process[12]. For combining it with the EPD Frontplane, a separate layer was inserted to protect the activity layer. Finally, the pixel electrodes (Al) was deposited by shadow mask.

In figure3, we presented the complete OTFT backplane.

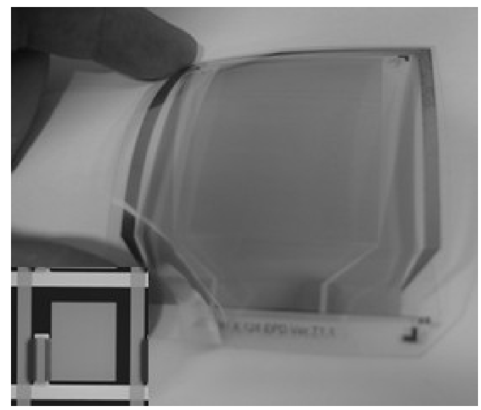
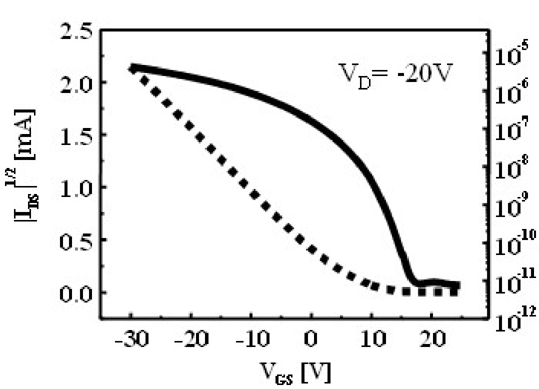


Figure 3. The picture of flexible OTFT-backplane fabricated on PEN substrate; the insert show an enlarged pixel.

In figure 4 the measured transfer and output curve of the OTFTs are presented. From several locations from the backplane OTFTs were characterized to check the uniformity. The OTFTs produced the field effect mobility of 0.21 ± 0.02 cm^2/V.sec, off state current 0.056 ± 0.014 pA/um, threshold voltage 7.42 ± 0.59 V, and the Ion/Ioff current ratio of 4.8 ± 1.36 × 10^5.



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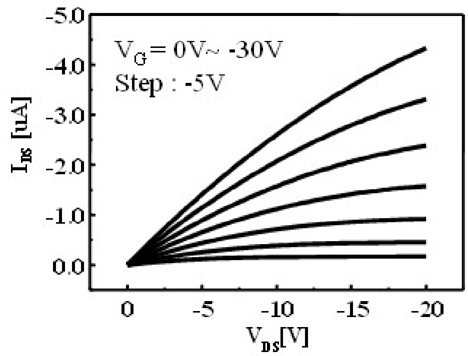

b)

Figure 4. The electrical characteristics of OTFTs in backplane a) the transfer curve of OTFT b) the output curve.

Table 1. Performance of OTFT backplane

Parameter	Value
Mobility(cm^2/v·sec)	0.21 ± 0.02
SS(V/dec)	2.43 ± 0.43
Ion/Ioff	4.8 ± 1.36 × 10^5
VT(V)	7.42 ± 0.59
Off-state current (pA/um)	0.056 ± 0.014

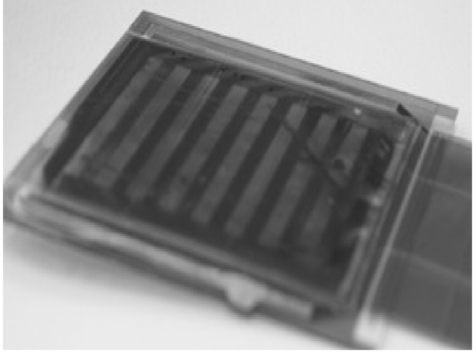

Figure 5. A 128 × 96 array EPD display driven .

To confirm the action of OTFT backplane, we combine the backplane of OTFT with EPD frontplane. The on gate voltage was applied by -15V and off voltage was 10V.

In figure 5 we presented the final EPD panel which displayed a pattern. We found that OTFT-backplane was stable and reliable to operate EPD panel. However, the leakage current through PVP gate is a problem to be solved.

3. Conclusion

We fabricated OTFT-backplane for an active EPD panel. The panel consisted of 128 × 96 pixels and each pixel had one OTFT with the pixel pitch of 400um × 400um. The OTFT produced uniform performance over 2.5inch panel with mobility of 0.21 ± 0.02 cm^2/V.sec, off state current 0.056 ± 0.014 pA/um, threshold voltage 7.42 ± 0.59 V, and the Ion/Ioff current ratio of 4.8 ± 1.36 × 10^5. The AM-EPD panel successfully displayed a pattern.

Acknowledgements

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5. References

[1] B. chomiskey, J. D. Albert, H. Yoshizawa, J. Jacobson, Nature **394** 253 (1998).

[2] A. Henzen, J. van de Kamer, T. Nakamura, T. Tsuji., M. Yasui, M. Pitt, SID'03 Digest 176 (2003).

[3] S. Maeda, S. Hayashi, K. Ichikawa, K. Tanaka, R. Ishikawa, M. Omodan, IDW'03 Digest 1617 (2003).

[4] U. Bach, D. Corr, D. Lupo, F. Pichot, M. Ryan, Adv. Mater. **14** 845 (1996).

[5] L. S. Park, j. W. Park, H. Y. Choi, Y. S. Han, Y. Kwon, H. S. Choi, Current applied physics **6** 644 (2006)

[6] B. Comiskey, J. D. Albert, H. Yoshizawa, J. Jacobson, Nature **394** 253 (1998).

[7] H. E. A. Huitema, G. H. Gelinck, J. B. P. H. van der Putten, K. E. Kuijk, C. M. Hart, E. Cantatore, P. T. Herwig, A. J. J. M. van Breemen, D. M. de Leeuw, Nature **414** 599 (2001).

[8] Y. Chen, J. Au, P. Kazlas, A. Ritenour, H. Gates, M. McCreary, Nature **423** 136 (2003).

[9] D. Voss, Nature **407** 442 (2000).

[10] P. V. Necliudov, S. L. Rumyantsev, M. S. Shur, D. J. Gundlach, T. N. Jackson, JAP **88** 5395 (2000).

[11] H. S. Byun, Y.X. Xu, C. K. Song, Thin solid film **493** 278 (2005).

[12] C. K. Song, M. K. Jung, B. W. Koo, JKPS **39** S271 (2001).