Extended Abstracts of the 2009 International Conference on Solid State Devices and Materials, Sendai, 2009, pp1182-1183

Organic TFT-driven Flexible Displays

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1. Introduction

Because of the weak Van der Waals interaction between organic molecules, mechanically flexible films of organic semiconductor and organic dielectric can be made at low temperature typically below 150°C. Therefore organic TFTs (OTFTs) can be directly fabricated on a flexible substrate such a plastic and a thin metal foil, providing a lot of advantages over a conventional glass substrate, such as their mechanical robustness, flexibility, lightweight and lower cost. In addition, many organic materials can be dissolved in organic solvents and organic thin films can be easily formed or patterned by using a solution or a printing process without use of vacuum equipments. With these advantages, OTFTs have been being expected to achieve attractive novel applications, such as flexible displays [1-4], electric papers [5-7], low-cost RF-ID tags [8] and large-area sensors [9].

We have demonstrated OTFT-driven-flexible AM-TN-LCD[1], AM-polymer-dispersed-LCD driven by solution-processed OTFTs[2], flexible OTFT-driven full-color AM-OLEDs [3,4] and printed flexible OTFT-driven-AM-electrophoretic display(EPD)[5,7]. In this paper, we will present material, process and device technologies to achieve these demonstrations with mainly focusing on the OTFT-driven AM-OLED and AM-EPD.

2. OTFT-driven AM-OLED

Pixel Structure and Integration

For a pixel circuit, we have employed the conventional 2T-1C circuit in an OTFT-driven AM-OLED as shown in Fig 1.

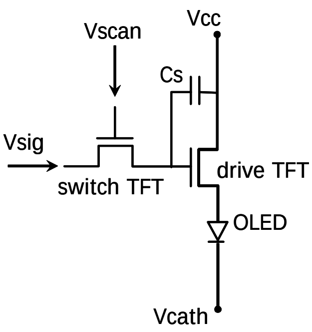

Fig. 1 2T-1C pixel circuit of AM-OLED

A stacked top-emission structure is used and the schematic cross-sectional view of a pixel is shown in Fig.2. In a backplane, bottom-gate pentacene TFTs with channel length of

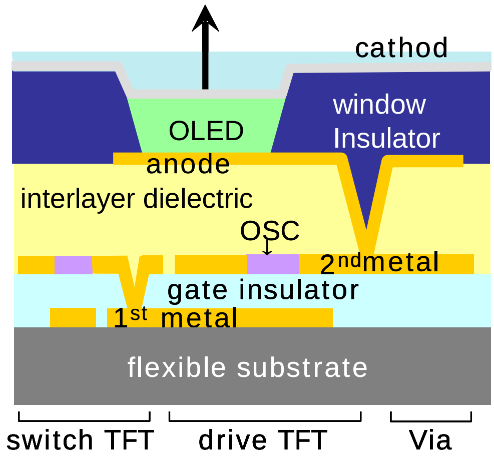

Fig. 2 Schematic cross-section of the top-emission OTFT-driven OLED display

5 μm are used for a switch and drive TFTs. In OTFTs, gold or cupper electrodes are used for source/drain (S/D) electrodes. We made a layer of gate insulator by spin-coating a solution of poly(4-vinylphenol) (PVP) and cross-linker. Polycrystalline pentacene have been deposited by thermal evaporation as a semiconductor layer. Solution-processed polymer dielectric is used as an interlayer dielectric. An OLED layer has been made by thermal evaporation with a shadow mask. The maximum process temperature is 150 C. The pentacene TFT shows apparent mobility of 0.1 cm^2/Vs and on/off ratio > 10^6.

An optical microscope image of the pixel is shown in Fig. 3. The OTFT backplane is designed for a top-emission 2.5-inch full-color 160 (data lines) × RGB × 120 (scan lines) AM-OLED display with a resolution of 80 ppi, in which the dimensions of the main pixel are 318 μm × 318 μm..

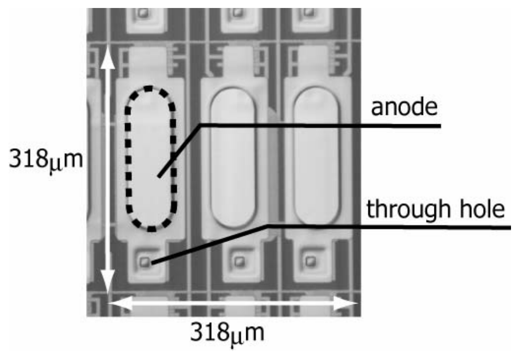

Fig. 3 Optical microscope image of a pixel

Demonstration

Fig. 4 shows a photograph of the display under bending condition is shown in Fig. 6. The panel clearly displayed moving images at a frame rate of 60 Hz even after 10,000 times bending with radius of 4 cm for 25 hours. The display achieved a maximum brightness of over 200 cd/m^2 with a contrast of over 1000:1 within a signal-voltage range of 12 V[4].

Fig. 4 Photograph of OTFT-driven 2.5-in QQVGA flexible AM-OLED

3. Printed OTFT-driven AM-EPD

Pixel Structure and Integration

Fig. 5 shows a schematic cross-sectional view of a field-shielded OTFT pixel we have developed to drive an EPD. We have originally developed soluble small-molecule organic semiconductor, *peri*-xanthenoxanthene (PXX) derivative which shows high mobility 0.4 cm^2/Vs and high thermal stability [10]. This PXX was patterned by inkjet printing method and encapsulated by screen printing of a fluoropolymer.

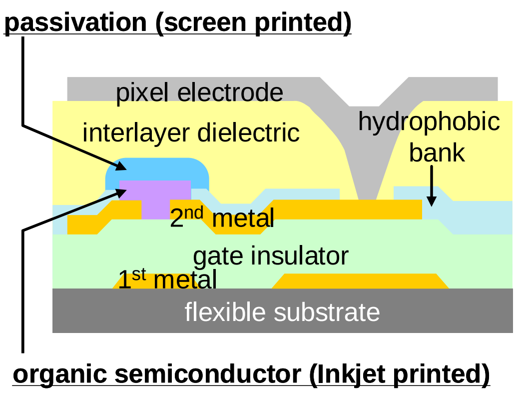

Fig.5 Schematic cross-section of the backplane for a OTFT-driven EPD.

Demonstration

We completed a flexible EPD after lamination with E Ink imaging film on the backplane we developed. The size of this display is 4.8 inch diagonal. The number of pixel and resolution is VGA(640×480) and 169 dpi with pixel size of 150 μm × 150 μm Fig. 6 shows a 16-bit grayscale image of our OTFT-driven EPD. The voltages applied to the data line and the scan line were 30 V_{p-p} and 40 V_{p-p}, respectively.

Fig. 6 Photograph of printed OTFT-driven 4.8-VGA flexible AM-EPD.

4. Summary

We have developed and demonstrated an OTFT-driven flexible AM-OLED and a printed OTFT-driven AM-EPD. Their low-temperature process, great mechanical flexibility and potential of manufacturing by printing process are expected to be promising for future flexible display.

Acknowledgements

The author would like to thank E Ink Corporation for their technical support regarding E Ink imaging film.

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