Organic Electronics 14 (2013) 1218–1224

Contents lists available at SciVerse ScienceDirect

Organic Electronics

journal homepage: www.elsevier.com/locate/orgel

A printed OTFT-backplane for AMOLED display

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ARTICLE INFO

Article history:
Available online 4 March 2013

Keywords:
OTFT
OLED
Printing electronics
TIPS-pentacene
Inkjet
Printing

ABSTRACT

An AMOLED panel driven by an OTFT-backplane is an attractive display because OTFTs and OLEDs use organic materials with unique characteristics such as low temperature and solution processing ability, and thus are able to implement the key features of future displays. In this study we applied some printing technologies to fabricate an OTFT-backplane for AMOLEDs. Screen printing combined with photolithography with Ag ink was used for the gate electrodes and scan bus lines and contact pads. Ag metal lines with a width of 20 μm and thickness of 60 nm and resistivity of 3.0×10^{-5} Ω cm were achieved. Inkjet printing was applied to deposit TIPS-pentacene as an organic semiconductor. The OTFT-backplane using the Ag gate electrodes and TIPS-pentacene exhibited uniform performance over 17,500 pixels on a 7 in. panel. The mobility was 0.31 ± 0.05 cm^2/V s with a deviation of 17%. The AMOLED panel successfully demonstrated its ability to display patterns.

1. Introduction

Recently the annual growth of the display market is rapidly decreasing, resulting in gradual saturation of the entire market [1]. A major reason is that the flat panel display market has not continuously expanded due to shrinkage of TV demand caused by economic recession and the reduction of panel prices resulted from strong competition among display manufacturers. In order to break this stagnation, new displays are required to create new markets. Many expect that the flexible display will be one of the new future displays because flexibility can meet the various form requirements of future displays that can be installed on any shaped objects, such as rounded domed ceilings, cylindrical columns, large windows and even walls [2–4]. In addition the demand to access information anywhere and anytime in future will require many displays everywhere, and thus the price of display panels should be inexpensive. In conclusion, the key features of future displays can be summarized by flexibility and low price.

Flexible displays manufactured by printing technology can implement these key features [5–7]. From the point of view of device, the organic thin film transistor (OTFT) and organic light emitting diode (OLED) is the most promising combination as the driving transistor and display mode, respectively, to achieve a flexible display in terms of compatibility with a flexible substrate originating from a low temperature process and of solution processing capability for printing. Several articles have reported about AMOLED panel employing OTFT [8–18]. However, we have not found articles on using printing technology for AMOLEDs.

In this paper we applied printing technologies to fabricate AMOLED panels that used OTFTs as the driving devices. In particular, screen printing was used for the gate electrodes of the OTFTs and the scan bus lines and pads of the panels, which occupied most of the area of the substrate and thus needed to be achieved by a simple and cheap process such as screen printing. Additionally, inkjet printing was also used for deposition of the organic semiconductor (OSC) layer to conserve the expensive OSC material because inkjet can jet a tiny amount of OSC solution on a specific channel area only. We investigated the

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http://dx.doi.org/10.1016/j.orgel.2013.02.006

feasibility of printing technologies for the OTFTs-backplane of AMOLED panels.

2. Design and fabrication of AMOLED panel

A pixel consists of 2 OTFTs and 1 capacitor and 1 OLED. The pixel pitch was determined to be 1000 μm × 1000 μm by considering the limitation of the printing technology used in this study. The channel length of the switching (SW) and driving (DR) OTFT was 20 μm and the width was 1040 μm and 1980 μm, respectively. The inter-digitated structure for the source and drain (S/D) electrodes could implement a wide channel in a small area and thus supply sufficient current to the OLED. The area of the OLED was 730 μm × 360 μm, resulting in an aperture ratio of 26.3%. The diagonal length of the panel was 7.4 in. in which 17,500 pixels (=140 × 125) were contained.

The schematic diagram of the fabrication processes is depicted in Fig. 1. First, an indium zinc oxide (IZO) layer, which was pre-deposited on a glass substrate for the anode electrode of the OLED, was patterned by photolithography and an etching process. Then a silver (Ag) layer for the gate electrodes of the OTFTs and the scan bus lines and the contact pads of the panel were coated by screen printing with Ag ink over the whole area of the substrate and then patterned by photolithography. The process related to screen printing will be described in detail in next subsection. Next, the gate insulator layer using a photo-patternable organic polymer was spin coated and then patterned by photolithography. In this step since the gate dielectric polymer itself was photo-patternable, the several steps for patterning gate dielectric such as photoresist coating and photolithography and etching of gate dielectric, which would be carried out if the conventional non-patternable material were used, could be eliminated. Thus, we could simplify the process steps and avoid the performance degradation of the OTFTs associated with the effects of the photolithography process with a photoresist on the channels [19]. Subsequently, Au was thermally evaporated for the S/D electrodes and data bus lines, which was followed by inkjet printing of TIPS-pentacene for an organic semiconductor layer. Finally, the layers for the OLED and Al for the cathode electrode were continuously deposited by thermal evaporation through a shadow mask. Totally five masks including one shadow mask were used.

In this process two printing technologies were employed screen printing for the gate electrodes and ink jet printing for the organic semiconductor. We will describe the printing processes in detail in the following section.

2.1. Screen printing of the gate electrodes and scan bus lines

In an AMOLED panel, the gate electrode of the SW OTFT is directly connected to a long scan line as shown in Fig. 2 and the requirements are very restrictive in terms of geometric dimensions and resistivity. The small resistance of the gate electrode and scan line is very important to reducing the signal delay along the long scan line. The resistance is expressed by $R = \rho \frac{L}{Wd}$ where ρ is the resistivity, L the length, W the width, and d the thickness of scan line. The length is determined by the panel size, and thus, a large

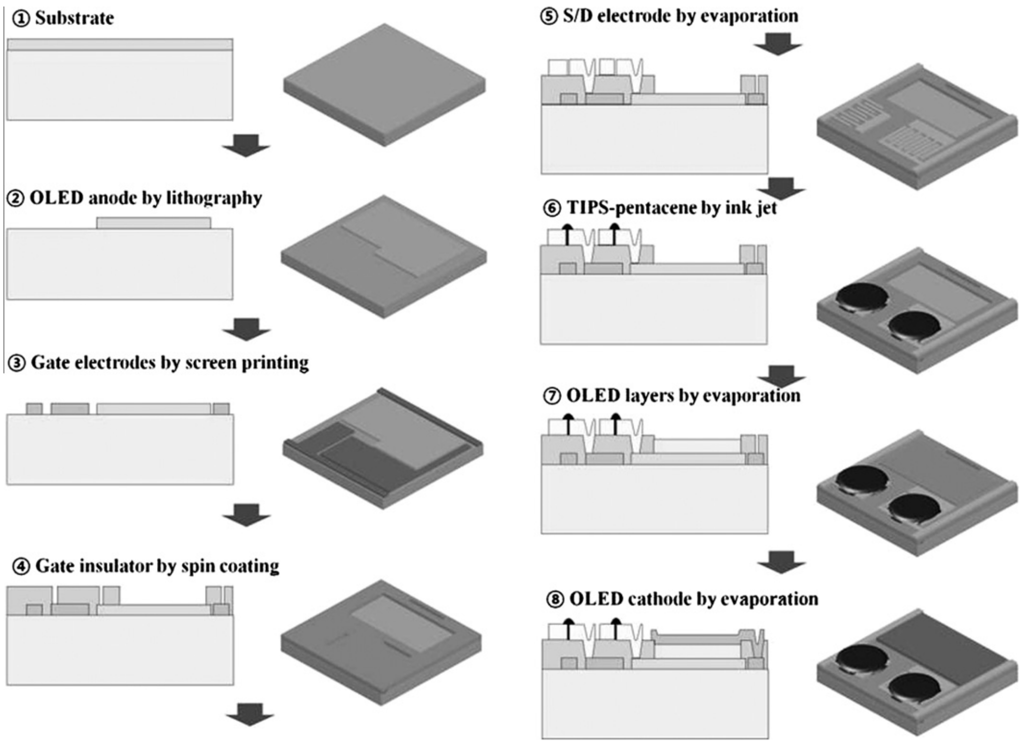

Fig. 1. Schematic diagram of fabrication process of AMOLED panel.