Solution-Processed Organic Thin-Film Transistors for Active-Matrix Color Liquid Crystal Displays

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Abstract

A high resolution (diagonal 15 inch, 86ppi) active matrix liquid crystal display (AMLCD) driven by solution-processed organic thin film transistors (OTFTs) were successfully fabricated, where the semi-conductor, gate insulator, and passivaion layers were all formed by organic materials using solution processes. The pixel OTFTs had fine-patterned top-gate structure, and the maximum process temperature was 140°C. The average field-effect mobility of the OTFTs with dimension of W/L=60μm/6μm was 0.3cm^2/Vs and the on/off current ratio was over 10^5, which is enough to drive AMLCDs.

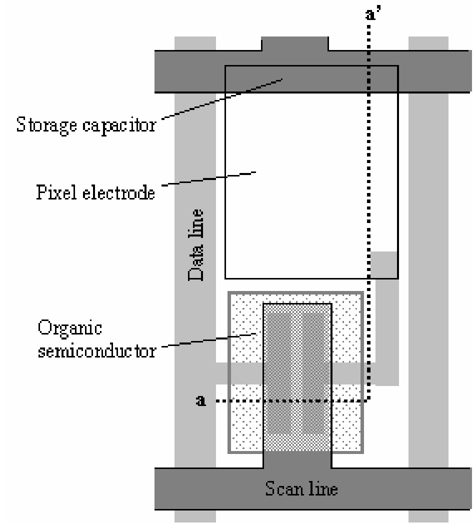
1. Introduction

Organic thin-film transistors (OTFTs) have attracted much attention to the display area. In particular, its low-cost and simple process enable the reduction in the cost of flat panel displays (FPDs) such as active matrix liquid crystal displays (AMLCDs), electrophoretic displays (EPDs), and active matrix organic light-emitting diode (AMOLED) displays. Besides, the expansion of digital broadcasting service and ubiquitous networks demand for flexible display, in which the OTFTs are considered as one of the proper pixel switching devices due to their advantageous low-temperature process and mechanical flexibility. In recent, several groups have demonstrated prototype display panels driven by OTFTs, which include various display modes such as LCD [1]-[3], OLED [4,5], and EPD [6,7]. These results showed the possibilities that the OTFTs can really be used as the pixel TFTs in the display panels. Most OTFT arrays have been made with thermally evaporated pentacene film as the active layer because the pentacene-based OTFT channel has high field-effect mobility as good as that of the a-Si TFTs. However, the vacuum process has the limitation to reduce the fabrication cost. Instead, several solution processes including the printing techniques are thought as more suitable processes to reduce the cost. Recently, many soluble organic semiconductors and organic insulators have been reported, and their performances have steadily improved [8,9]. There have been many efforts to make the display panels with the soluble organic semiconductors, however, few reports have been made on the successful fabrication of high resolution and large area AMLCDs with the soluble organic materials for the TFT active layer and insulating layers.

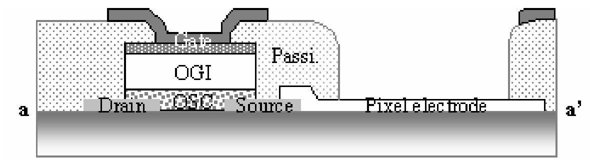
Recently, we have developed a solution-processed 15-inch XGA (86ppi) OTFT array and the full color movie of our solution-processed OTFT-LCD was successfully demonstrated. This panel has the world's highest resolution and is the largest size using solution-processed OTFTs. It is notable that the insulating layers, i.e. the gate insulator and the passivation layers were also made using the solution processes. To obtain the fine-patterned OTFT array structure, we developed new photolithography technique, which minimizes the chemical damage to the active layer. In addition, the double-layered passivation process was developed to minimize the chemical damages to the active layer and the gate insulator during the fabrication process. This passivation structure seems to improve the device performance as well as the device reliability. The average field-effect mobility of our OTFTs with dimension of W/L=60μm/6μm was 0.3cm^2/Vs and the on/off current ratio was over 10^5, which is enough to drive the AMLCD. In this paper, we describe the fabrication procedure of our solution-processed OTFT array and the device characteristics. The microscope image of this array and the photographs of the operating picture are also introduced.

2. Fabrication of OTFT Array

Schematic diagrams of a pixel in the OTFT array are shown in Fig. 1. The pixels were designed to drive the AMLCD with storage capacitor and pixel electrode as shown in the Fig. 1 (a). The OTFT in the pixel has top-gate structure and isolated active region as shown in Fig. 1 (b).



(a)



(b)

Figure 1. (a) Schematic diagram of a pixel in the OTFT array and (b) cross-sectional view taken along the dashed line a-a'.

The OTFT array in this study was fabricated as following steps. At first, Au/Cr source and drain electrodes were thermally evaporated and patterned by wet etch process. Au has a high work function of ~5.1 eV, so that it makes good contact with p-type organic semiconductor. Thin Cr layer with the thickness of ~2 nm was deposited before the deposition of Au electrodes to improve the adhesion of Au onto a glass substrate. Next, transparent pixel electrode, ITO, was formed by sputter and also

