Fabrication of An Organic Thin-Film Transistor Array by Wettability Patterning for Liquid Crystal Displays

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Abstract

We demonstrate a novel selective patterning process of a semiconducting polymer for channel regions to fabricate an array of organic thin-film transistors (OTFTs). This process is applicable for various organic films over large area. A reflective liquid crystal display based on the OTFT array was produced using the selective patterning through a wettability control.

1. Introduction

Organic thin-film transistors (OTFTs) have emerged as one of the promising candidates to build their potential for electronic applications, such as flat panel displays, electronic papers, and smart cards so far [1–5]. In contrast to traditional silicon-based devices, the fabrication of the OTFTs in backplane electronics allows for relatively simple processes on a variety of substrates at low temperature in a cost-effective manner. To date, many soluble polymeric materials have been used to meet the growing demands of fabricating the OTFTs as driving elements for next-generation organic displays [6–8]. Although several soluble semiconducting polymers have been utilized for the OTFTs due to high mobility, in particular, they suffer from the limited patterning capability in large area. Therefore, we address the patterning issue on the fabrication of the polymeric OTFT in the active channel regions.

In our work, the selective wettability patterning of a semiconducting polymer, poly(9-9-dioctyfluorene-*co*-bithiophene) (F8T2), is examined to understand the underlying physical origin. In addition, as a prototype, a reflective liquid crystal display (LCD) based on an array of polymeric 30 × 30 OTFTs is demonstrated.

2. Selective wettability patterning

The key concept in our approach is to generate the selective wettability on a substrate for a soluble semiconducting polymer film in large area produced through a spin-casting process. The fluorine based polymer layer, CYTOP (Asahi Glass, Japan), was laser-ablated by the ultraviolet light (UV) exposure as shown in Fig. 1. Since the bare CYTOP has no absorption band in the deep UV wavelength, the TDUR-P015 (Tokyo Ohka Kogyo) was prepared as a photo-absorption buffer layer below the CYTOP in order to carry out the laser ablation of exposed areas at the 248 nm wavelength [9–11].

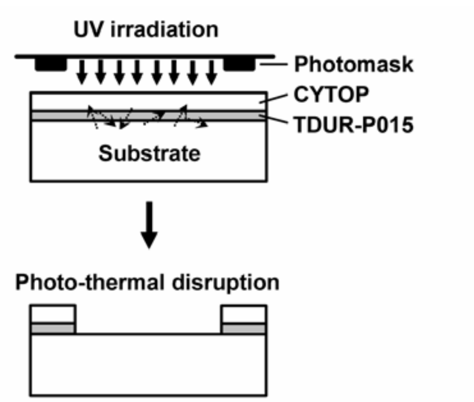


Fig. 1. Schematic diagram of the selective wettability process on a substrate by the UV irradiation.

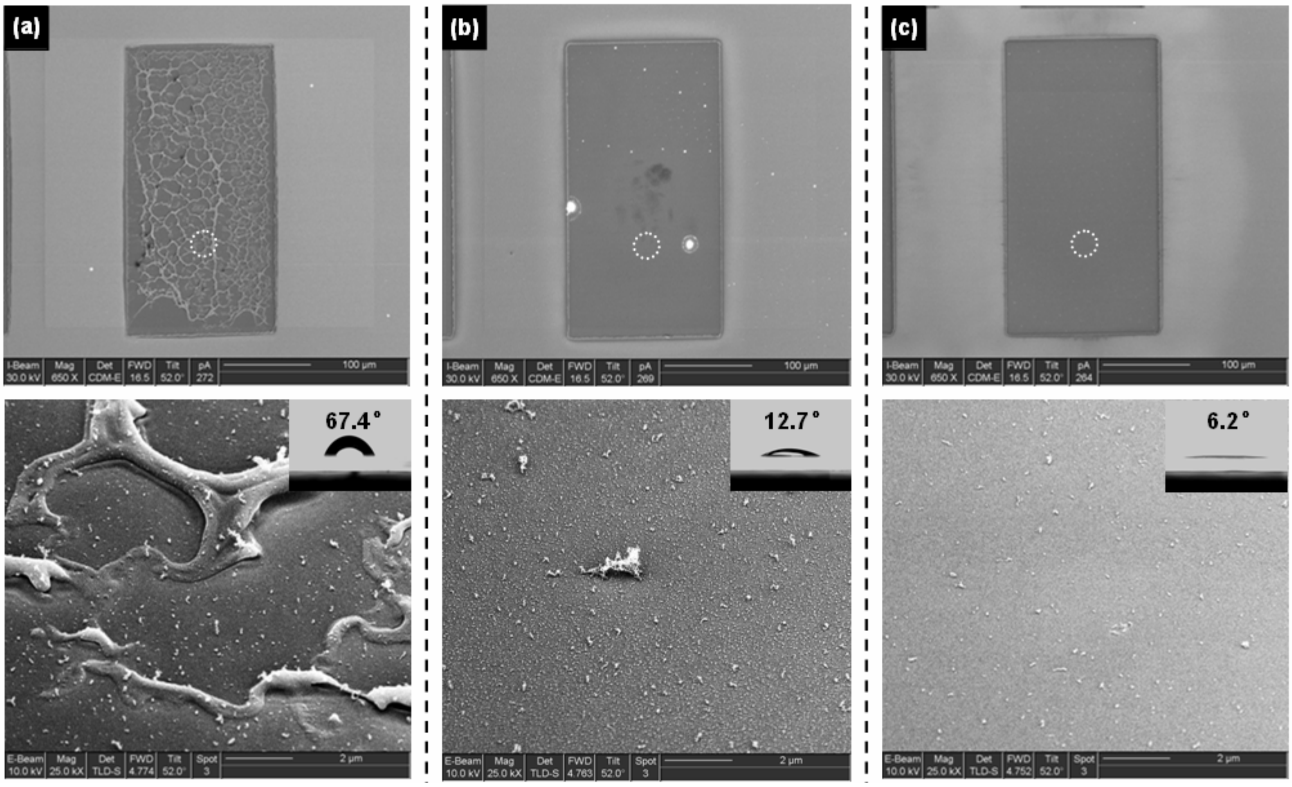


Fig. 2. SEM images and contact angles of the UV-irradiated surfaces. The exposed areas were eliminated by laser ablation. The UV intensities were used (a) 150 mW/cm^2, (b) 300 mW/cm^2, and (c) 450 mW/cm^2.

Let us first examine the wettability change with varying the UV intensity. Figure 2 shows scanning electron microscope (SEM) images and contact angles (θ_{CA}) of the UV-irradiated surfaces together with enlarged images of the exposed areas denoted by dotted circles. In the low UV intensity range (150 mW/cm^2), the exposed area is still hydrophobic due to the remaining CYTOP and the TDUR-P015 as shown in Fig 2(a). However, as the UV intensity increases, the surface becomes hydrophilic ($\theta_{CA} \approx 6.2°$) since the CYTOP layer and the photo-thermally generated TDUR-P015 layer are completely removed. This was supported from the fact that no components of the CYTOP and the TDUR-P015 exist in the characterization of elements weight on the exposed areas. The wettability of organic materials, controlled by the UV intensity, would be useful for patterning the active channels of the OTFTs.

3. Fabrication of the OTFTs and the LCD

We now describe an array of the OTFTs fabricated using a selective wettability patterning technique. The F8T2 film was used as an active organic semiconductor layer for fabricating 30 × 30 OTFTs in an array format. Figure 3 shows the patterns of the F8T2 that were selectively deposited only in hydrophilic regions on the substrate. It should be noted the patterns of the organic semiconducting polymer dissolved in a polar solvent were precisely defined in the active channels in an array through a simple spin-casting process.

The resolution and the geometrical shape in the patterns are primarily determined by the selective

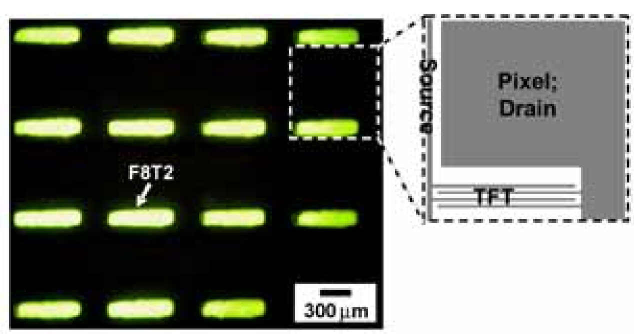
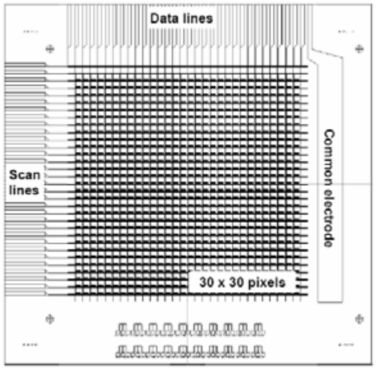
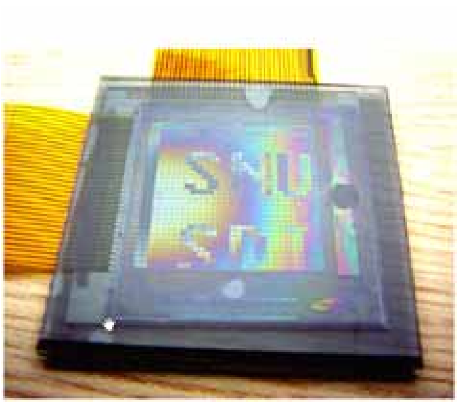


Fig. 3. Fluorescent micrograph of the patterns of the F8T2 produced by the selective dewetting.



(a)



(b)

Fig. 4. (a) Layout of a backplane having 30 × 30 pixels connected with scan and data lines. (b) Image of "SNU-SDI" displayed in a reflective LCD driven with 30 × 30 OTFTs fabricated by the selective wettability patterning technique.

wetting and dewetting properties of an organic semiconductor during the spin-casting process. Our selective wettability concept of patterning the organic semiconductors will not be limited to a particular polymer or substrate pair and will be applicable for other functional organic materials.

As a prototype of displays employing the OTFT array fabricated using the wettability patterning technique, we demonstrate a reflective LCD, whose size is 1.8 inch in diagonal, driven with 30 × 30 OTFTs on the backplane as shown in Fig. 4. The layout of a backplane having 30 × 30 pixels connected with scan and data lines was shown in Fig. 4 (a). The common electrode in the right-hand side was used for driving the LC molecules. This OTFT-based reflective LCD was operated in a normally dark mode. Although the image of "SNU-SDI" in the our first prototype seems poor, no image degradation was observed over several months under ambient conditions, indicating that the 30 × 30 OTFTs have the long-term stability and reliability. The specifications of our display were summarized in Table 1.

Table 1. Specifications of the OFTT based reflective LCD.

	specifications
panel size	1.8 inch
resolution	30 × 30
number of pixels	900
pixel size	900 μm 900 μm
display type	reflective LCD (normally dark mode)
OTFT channel length	20 μm
OTFT channel width	1800 μm
storage capacitor	20 pF
organic semiconductor	F8T2
S/D electrode	MoW
gate insulator	SiO_2
thickness of gate insulator	200 nm
scan voltage	–30 ~ +15 V
data voltage	–5 ~ +5 V
frame rate	30 Hz (1ms; addressing time)

4. Conclusion

We demonstrated a wettability-based patterning technique for soluble semiconducting materials to fabricate the OTFT arrays on an organic display backplane. This technique would be applicable for precise patterning of a variety of functional organic materials for plastic electronics. It was found that the OTFTs used for driving our reflective LCD have the long-term stability and reliability.

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6. References

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