A 160 ppi All-printed Organic TFT Backplane for Flexible Electrophoretic Displays

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Abstracts
We have demonstrated a 160 ppi all-printed OTFT backplane for flexible EPDs. To achieve such a high-resolution backplane, we have developed a surface energy controlled ink-jet printing with UV irradiation on novel polyimide for Ag electrode and several printing processes for OSC and pixel electrode on plastic substrate. A short channel length less than 5 µm was successfully fabricated.

1. Introduction

There is an increasing interest in flexible display for its lightness and robustness. Printing technology is suitable for low-cost, large-area and high-throughput manufacturing process. Organic semiconductor (OSC) is one of promising materials that can be suitable for printing process on flexible substrate. Several printing methods such as screen printing [1] and ink-jet printing [2, 3] have been developed to fabricate organic thin film transistors (OTFTs). On the other hand, the resolution of these conventional printing is lower than that of photolithography. But recently, higher resolution such as 80 ppi of advanced printing process was reported [7, 8]. We developed a surface energy controlled ink-jet printing with UV irradiation, which produced higher resolution of electrode than conventional printing method without wet processes such as development and etching [4]. We also reported the amorphous polymers OSC with high solubility and high air stability, which is suitable for printing process [5, 6]. In this work, we demonstrate 80 ppi and 160 ppi all-printed OTFT for electrophoretic displays (EPDs) with these technologies and several printing methods.

2. Fabrication of OTFT backplane

Fig.1 shows a schematic cross-section of all-printed OTFT backplane with bottom-gate structure on plastic substrate. The gate electrode and source/drain (S/D) electrode were fabricated using Ag nanoparticles ink by the surface energy controlled ink-jet printing method. The gate insulator is a novel polyimide film fabricated by spin coating. Amorphous polymers OSC consisting of stilbene polymer with triarylamine unit and long-chain alkyl group was fabricated by ink-jet printing. Triarylamine unit is for high air stability and high mobility; long-chain alkyl group is for high solubility.

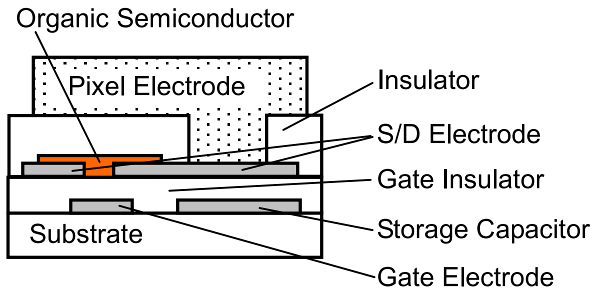

Fig.1 Schematic cross-section of the all-printed OTFT backplane.

Fig.2 shows a schematic of the surface energy controlled ink-jet printing process. The novel polyimide film was fabricated on the plastic substrate by spin coating, whose surface had low surface energy after post bake. After ultraviolet (UV) irradiation through a photo mask from the front side of the substrate, the high surface energy area corresponding to electrode pattern and the low surface energy area were formed on the novel polyimide film surface (Fig.2b). In the high surface energy area water-based Ag nanoparticles ink was ink-jetted and spread over the edge of the area (Fig.2c). Electrode thickness and profile were controlled with ink-jet conditions such as drop size and volume per unit line. Typical electrode thickness was 100 nm and its conductivity was 16 $\mu\Omega$cm after post-annealing. Minimum space width was up to 2 μm (designed), typically up to 5 μm.

Fig.3 shows an optical micrograph of a 160 ppi (pixel size 159 μm $\times$ 159 μm) all-printed OTFT array on flexible substrates after organic semiconductor fabrication. Fabricated by the surface energy controlled ink-jet printing with UV irradiation, it is shown that a minimum width of the electrode was 20 μm, channel length was 5 μm as examples. We used the appropriate solvent of polymer OSC and optimized ink-jet conditions. OSC profile was like a coffee stain and separated with each others at 159 μm pitch without any bank structure. After OSC printing, insulator and pixel electrode were fabricated by screen printing.

All-printed OTFT backplane with 80 ppi resolution had 10 μm channel length (L) with 500×400 pixels, 8 inch diagonal. One with 160 ppi resolution had 5 μm channel length with 432×288 pixels, 3.2 inch diagonal.

3. Integration of 160ppi OTFT backplane and EPDs

For demonstration of flexible EPDs, electrophoretic sheet was laminated with a 160 ppi all-printing OTFT backplane on plastic substrate. As shown in Fig.4, Japanese characters were driven by OTFT backplane. 10-point figure pattern was successfully displayed. The voltages of select line and data line were 30 Vpp and 27 Vpp, respectively.

4. Conclusions

We have succeeded in fabricating a 160 ppi all-printed OTFT backplane for flexible EPDs. To achieve such a high resolution backplane on plastic substrate, we have developed the surface energy controlled ink-jet printing with UV irradiation for Ag electrodes with a short channel length less than 5 μm, and developed several printing processes.

Acknowledgments

The authors would like to thank Ricoh Advanced Technology R&D Center for providing the organic semiconductor materials and other members of the development team for their support.

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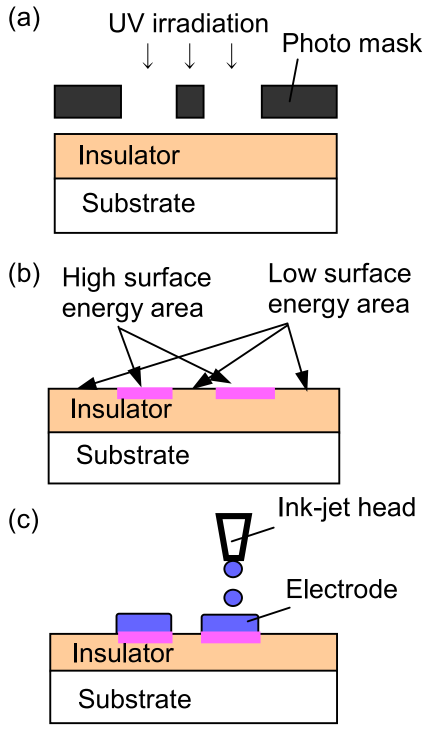

Fig. 2 Schematic of the surface energy controlled ink-jet printing process (a) UV irradiation, (b) Formation of areas with different surface energy, (c) Fabrication of electrodes by ink-jet printing.

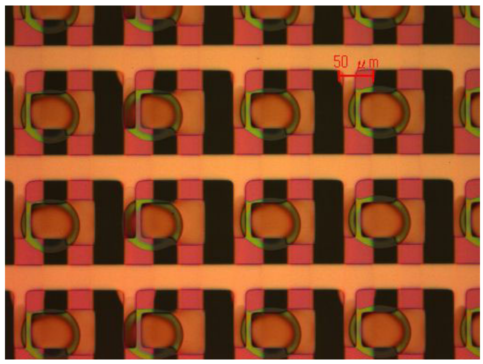

Fig. 3 Optical micrograph of a 160 ppi all-printed OTFT array on flexible substrates after organic semiconductor fabrication (L=5 μm).

Fig. 4 A 160 ppi EPD driven by all-printed OTFT backplane on flexible substrates.