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Fabrication of Printed Organic Thin-Film Transistors using Roll Printing

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1. Introduction

Many of the early demonstrations of organic thin-film transistors (OTFTs) and circuits made use of a variety of conventional device fabrication techniques. However, these methods have disadvantages such as incompatible organic materials, complex and high temperature process, unpatterning in rough, nonplanar, or curved substrates [1, 2].

More recently, number of techniques and processes including unconventional lithography, non-impact printing (NIP), and traditional printing have been introduced for the fabrication of OTFT circuits, flexible displays, low-cost printed electronics, and printed electro-mechanical systems (PEMS) that aim specifically at reducing the fabrication process and cost [1-4].

To fabricate a high-resolution and large-area printed OTFT, we are developing a high-resolution roll printing technique based on transferring a pattern from patterned hard-engraved plate to flexible plastic substrates by nanoparticle silver (Ag) inks gravure or flexo printing process. This method is an attempt to enhance the accuracy of traditional printing to a precision comparable with optical photolithography, creating a low-cost, large-area, and high-resolution patterning process.

2. Fabrication of Roll Printed OTFT

Printed organic thin-film transistors (OTFTs) for use as a switching and driving device in a flexible display and plastic electronics were fabricated by roll printing at near room temperature. The printed OTFTs was used in the fabrication of a roll printed gate, source and drain electrodes with three types of low-resistance silver (Ag) pastes, coated parylene and tipped polyvinylphenol (PVP) as polymeric gate dielectrics, and soluble processed bis(triisopropyl-silylethynyl) pentacene (TIPS-pentacene) as organic semiconductors on on flexible, transparent poly(ethylenenaphthalate) (PEN), polyethyleneterephthalate (PET), and polycarbonate (PC) plastic substrates. To fabricate a high-resolution and large-area printed OTFT, we fabricated screen mask patterns onto a metal meshed substrate which dimensions 300 × 300 mm. The channel lengths of the unit element was split between 30 and 70 μm, and line width between 200 μm and 2 mm on the 150×150 mm pattern mask with the mask designed for 40 elements of different channel lengths and line widths to be placed. The electrodes of the printed OTFTs were fabricated with both gravure and flexo printing. The printed electrodes in printed OTFTs used the gravure type roll-printing process, which consisted of; wraping a flexible substrate whose surface was hydrophilic treated with plasma on a rubber roll; pouring Ag paste into the feeder of the plate surface; blading to make the paste inking into the engraved pattern using the doctor blade, and; forming a gate electrode by forwarding and rotating the roll covered with substrate.

Fig. 1 shows the fabricating process of the printed OTFTs using flexo printing, where the pattern was formed by inserting a plastic substrate between the rubber roll and the sub-roll. The conditions for forming the electrode consisted of a doctoring speed of 16 m/min and a patterning speed of 24 m/min. The printed OTFT was fabricated with the same method as the gravure printing process.

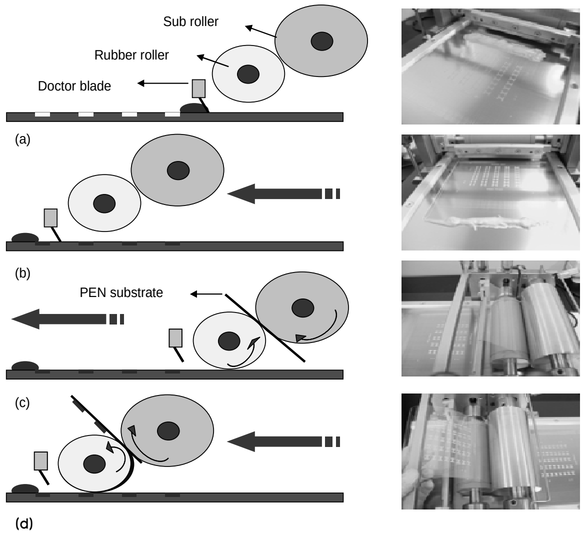
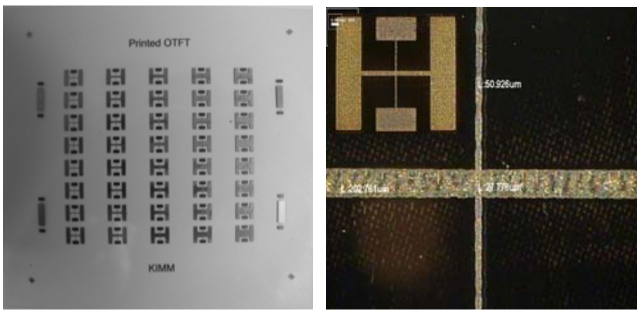


Fig. 1 Fabrication of printed electrodes in printed OTFTs using flexo printing: (a) pured Ag paste onto engrave plate (b)spread and inking on plate using doctor blade, (c) inserted plastic substrate between sub roll and rubber roll, and (d) roll printed electrode on plastic substrate.

3. Results and Discussion

The printed electrodes of organic thin-film transistors (OTFTs) were fabricated by roll printing using patterned hard-engraved plate with various channel lengths on flexible PEN, PET, and PC plastic substrates. The roll printed OTFT corresponds to channel lengths between 16 to 62 μm (designed L=30 to 70 μm) and line widths between 211 and

1995 μm (designed W=200 to 2000 μm) for Ag paste source and drain contact electrodes, with various gate electrode patterns on the 150×150 mm plastic substrates. The roll printed OTFT with PVP as polymeric dielectrics were formed using coating or dispensing respectively. The TIPS-pentacene as organic semiconductors were ink-jet printing. The roll printed OTFT was characterized in air and the following parameters were obtained: a mobility as high as 0.08 (±0.02) cm^2/Vs, an on/off current ratio of 10^4 and a subthreshold slope of 2.53 V/decade.



(a) (b)

Fig. 2 Images of fabrication of roll printed OTFTs: (a) printed OTFT fabrication on the 150×150 mm plastic substrate and (b) with gate width W=57 μm, source and drain channel length L=27 μm (width W=202 μm).

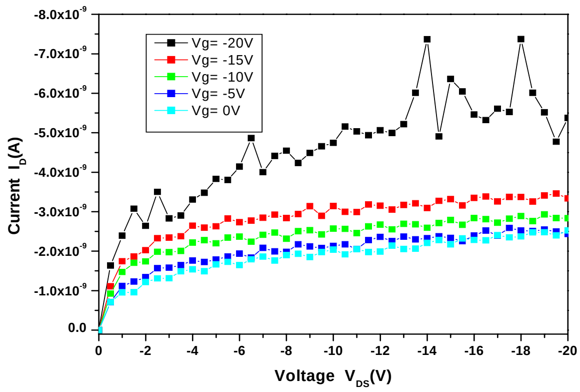


Fig. 3 Drain current I_{DS} versus drain voltage V_{DS} output characteristics of roll printed OTFT in the gravure printing

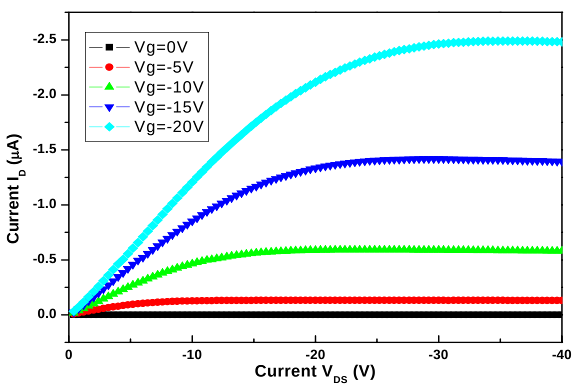


Fig. 4 Drain current I_{DS} versus drain voltage V_{DS} output characteristics of roll printed OTFT in the flexo printing

4. Conclusions

The printed OTFTs using screen printing and soluble process, made it possible to fabricate a printed OTFT with a channel length as small as to 16 μm on the 150×150 mm PEN, PET and PC substrates without pattern defects, which had been hardly patterning in the previous traditional printing. The number of steps in the fabrication process was reduced by 20 steps compared with conventional fabrication techniques, and there were no need to carry out UV exposure, development, or removal processes. Since the fabrication of the printed OTFT devices was carry out at near room temperature, it was possible to minimize dimensional distortion and to provide better alignment in the printing process for a large area, thus preventing performance degradation.

Acknowledgements

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