Extended Abstracts of the 2007 International Conference on Solid State Devices and Materials, Tsukuba, 2007, pp. 1100-1101

H-9-3

Fabrication of Soluble Semiconductor Thin Film Transistor with Printed Electrodes using h-PDMS Stamp

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1. Introduction

More recently, the different methods of solution processing used for the fabrication of organic thin film transistor(OTFT) include spin-coating, ink-jetting, screen printing, dip casting, and microcontact printing [1]. Also, OTFT is required to reduce the operating voltage less than 5V for active matrix organic light emitting diode(AMOLED), a plastic chip for inventory tags and smart cards [2]. And then, when fabricating OTFT on flexible substrate, substrates warpage, surface roughness, and layer-by-layer registration methods should be considered, and the several problems such as optical characteristics deterioration caused by exceeding the maximum process temperature, incoherent pattern alignment by shrinkage and transformation, and loosening of the adhesion between organic and inorganic materials should be solved to improve the performance [3].

In this study, we were tried methods with decrease the channel length and the thickness of gate dielectric layer using microcontact printing and direct printing processes at an all room temperature, and will be used as a switching device of flexible displays. The gate electrode of OTFT was fabricated using microcontact printing, and source and drain electrodes were fabricated using direct printing process with h-PDMS stamp. The OTFT with dielectric layer was formed using special coating system, and organic semiconductor layer was ink-jet printing process.

2. Fabrication of Printed OTFT

The PDMS stamp used in microcontact printing could be categorized into a soft PDMS(s-PDMS) stamp and a h-PDMS stamp, according to a mold materials, a pattern size, and a fabrication method [4, 5]. The s-PDMS stamp was fabricated by mixing Sylgard 184A (silicone elastomer base) with Sylgard 184B (silicone elastomer curing agent) at a ratio of 10:1. And then, fabrication process of the h-PDMS stamp for the high fidelity pattern form of a nano size is similar to that of the s-PDMS stamp, and it was fabricated by using VDT-731((vinylmethylsiloxane) (dimethylsiloxane) copolymer) with characteristics of Sylgard 184A, SIP 6831.1 (platinum-divinyltetramethyl-disiloxane complex in xylene), a reaction catalyst, Fluka 87927, an adhesion fortifier and HMS-301 ((vinylmethylsiloxane) (dimethylsiloxane) copolymer) with characteristics of Sylgard 184B as mold materials. As to the plastic substrate for fabricating printed OTFT, we deposited 150nm of ITO(indium tin oxide) as etching layer using e-beam deposition device maintained below 50℃ inside the chamber, and inked hexadecanethiols(HDT) self-assembled monolayer(SAM) solution up to h-PDMS stamp, transferred into poly(ethylenenaphthalate)(PEN) substrates through microcontact printing, and formed single layers. Also, selectively etched ITO using LCE-12K solution and fabricated gate electrode. On the fabricated gate electrodes, organic dielectric layers of 500nm, 600nm, 700nm, and 900nm were formed by parylene-C with high permittivity at room temperature using specialized deposition coater. The patterned organic dielectric layer was selectively etched using O_2 plasma. And on the parylene-C organic dielectric layer, we made 5μm, 10μm, and 20μm of channel lengths and carried out patterning of source and drain electrodes using the h-PDMS stamp, and then it was contacted physically, and an ink injection hole was created in the h-PDMS stamp. The source and drain electrodes were formed by the direct printing process wherein conductive Ag ink was injected. And on the contact electrodes, we were deposited organic semiconductor layer using e-beam deposition whereby the vacuum deposition is carried out 100nm thickness under the condition of keeping at 0.05nm/sec, and ink-jet printing of poly(3-hexylthiopene-2,5-dily(P3HT), poly(3,3-didodecyl quarter thiophene(ADS12PQT) by using ink-jet system [1, 6]. Fig. 1 show fabrication process of printed OTFT using microcontact printing and direct printing process. During the printed OTFT fabricating process, in order to keep the flatness, we used film photoresist as adhesion layer and thin glass as rigid layer adhered to PEN substrate. Fig. 2(a) shows the results of printed OTFT fabrication using microcontact printing and direct printing processes, and optic microscope image of printed OTFT with channel lengths were 5μm, 10μm, and 20μm, where the line width and the pattern space were different. In Fig. 2(b) shows the source and drain electrodes with a channel length of 20μm fabricated with conductive Ag ink and with semiconductor layer.

The electrical characterization of the printed OTFTs was carried out in air using an Keithley semiconductor parameter analyzer. Figs. 3 and 4 show the measurement results of the transfer characteristics and output characteristics of the printed OTFT. As a result of conducting the OTFT fabricated with the proposed process, the performance showed that the on/off current ratio was 1.26×10^3 and that the off current was 1.26×10^{-10}A.

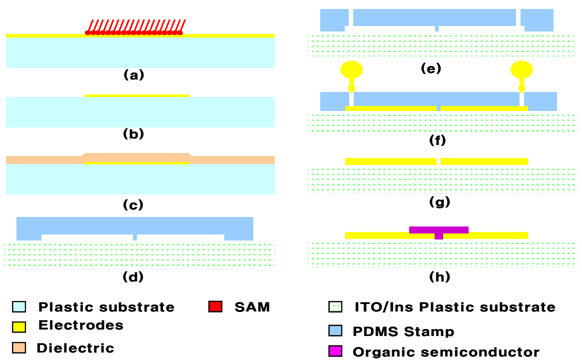
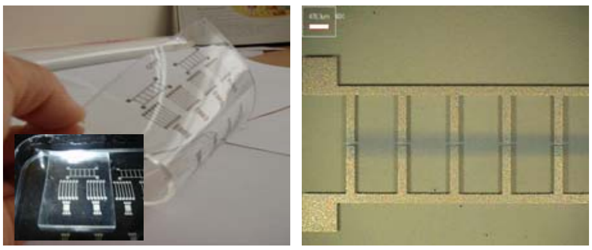


Fig. 1 Schematic procedures for microcontact printing and direct printing processes of OTFT: (a) Inked SAM solution on ITO deposited PEN substrate, (b) fabricated gate electrode, (c) deposited and patterned parylene dielectric layer, (d) physical laminated on ITO and parylene formed PEN substrate, (e) fabricated injection hole, (f) injected conductive Ag ink with viscosity as 4cps(at 22℃) and resistance as 0.084Ω(at sq/mil(25㎛)), (g) fabricated source and drain electrode, and (h) jetting organic semiconductor.



(a) (b)

Fig. 2 Results of OTFT fabrication in: (a) 5" size h-PDMS stamp with channel lengths of 5μm, 10μm, and 20μm(width=500um), (b) printed source/drain electrodes on ITO and parylene formed PEN substrate using conductive Ag ink, and ink jetting semiconductor

3. Conclusions

Microcontact printing and direct printing processes using SAM and h-PDMS stamp made it possible to fabricate printed OTFT with channel lengths down to 5um size, and reduced the fabrication process by 20steps compared with photolithography, there was no need for exposure, develop, and remove process. Since this study fabricated an OTFT with organic dielectric layer, electrode, and organic semiconductor layer carried out at room temperature, there was no appeared such as pattern shrinkage, pattern transformation and bending problem. The printed OTFT was fabricated through the microcontact printing and direct printing processes, special coating system, and ink-jet printing in room temperature, so that it was possible to improve electric field mobility, to decrease contact resistance, to increase close packing of molecules by using SAM compared with traditional printing processes.

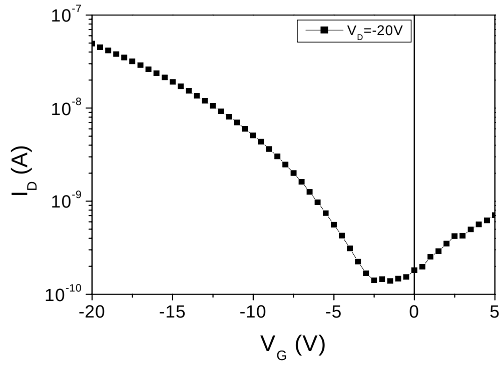


Fig. 3 I_D-V_G transfer characteristics of printed OTFT*(collaboration with J.B. Koo, ETRI)*

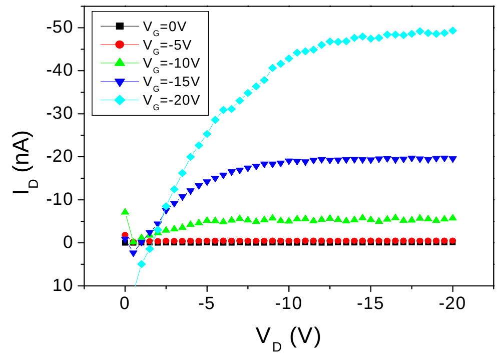


Fig. 4 I_D-V_D output characteristics of printed OTFT*(collaboration with J.B. Koo, ETRI)*

Acknowledgements

This Research was supported by a grant(M102KN01001) from Center for Nanoscale Mechatronics & Manufacturing, one of the 21st Century Frontier Research Programs, which are supported by Ministry of Science and Technology, Korea. And, one of the authors (Jeongdai Jo) would like to acknowledge the financial support provided by Japan Society for the Promotion of Science and Korea Science and Engineering Foundation through the dissertation Ph.D program.

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