Inkjet-printed narrow silver line on plastic substrate for high resolution flexible electronics

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Abstract

We demonstrated narrow and good aspect-ratio inkjet-printed silver lines with multi-time over-printing methods. By using this strategy, narrow silver lines were obtained with 200 nm thickness and their width and gap between printed lines of uniform narrow silver lines were 30 μm and 17 μm, respectively. It also had good conductivity, sheet resistacne of 0.36 Ω/□ and specific resistance of 8μΩ·cm. In current stress test, narrow silver line with 30 μm width was able to a current flow up to 50 mA (2.1A/cm^2). Using surface treatment on poly-arylate substrate with UVO_3, we obtained clean-edge narrow line without any edge waviness.

1. Introduction

Today, there are increasing demands of drop-on-drop inkjet printing for the fabrication method of electronics because of low-temperature, non-vacuum and maskless process which is important in implementing ultra-low-cost, flexible, large-area electronic devices. Therefore, many research groups have studied solution-based inkjet printing materials and process conditions optimization for electrodes, insulators and semiconductors for ultra-low cost organic thin-film transistors (OTFTs) [1-5]. However, inkjet-printing method has critical disadvantage for high resolution electronics application such as source/drain pattering of TFT in comparison with photolithography method because of nozzle size, surface tension and viscosity of limited ink materials that can be printed. In addtion, non-uniform metal electrodes can affect to devcie properties [6] and high conductivy and electrical reliability should be guarantted for electrical device applications. To overcome these problems, we optimized silver ink jetting and curing condition on flexible poly-arylate substrate, and adopted muti-printing method for high performance narrow silver lines. For uniform narrow silver line, surface treatment was carried out using UVO_3 to control surface energy of the substrate for hydrophobic silver ink.

2. Experimental

Narrow silver lines were fabricated on flexible poly-arylate substrates with 200 μm thickness which cleaned using isopropylalchol and deionized water rinsing for 5mins sequentially. To obtain high resolution silver lines, we used Silver ink from INKTEC corp. (IJ-TEC-010), an inkjet printer from DIMATIX corp. (DMP-2800 series) with 1 picoliter volume ink cartridge. Silver lines were inkjet-printed on the substrate at 60°C and annealed at 150°C for 30 minutes in oven under atmospheric environment. Nozzle diameter of 1pl cartridge is 9 μm and corresponding drop size is about 25 μm. The substrate was maintained at 60°C during the printing process, because the printed layer showed shinier appearance and better morphology in comparison with those printed at room temperature. For uniformity and low resistance of narrow line, we carried out multi-time over printing and surface treatment using UVO_3 exposure for maximum 30mins to increase surface energy for hydrophobic silver ink. Thickness, width and surface profiles of narrow silver lines were measured using TENCOR Alpha-step 500 and atomic force microscope (AFM), and surface energy of substrates was extracted using Phoenix 300 from SEO corp. To measure resistance and current flow capacity of silver line, HP 4155C semiconductor parameter analyzer was used.

3. Results and discussion

From these optimized conditions, we demonstrated uniform and clean-edge inkjet printing narrow silver line with 200 nm thickness, 30 μm line width and 17 μm gap between printed silver lines on poly-arylate substrate (fig.1). After UVO_3 exposure treatment for 10mins, poly-arylate surface energy was increased from 40mJ to 50mJ and we obtained clean-edge narrow silver line without any waviness comparing with narrow silver line on untreated poly-arylate substrate because hydrophobic silver ink did not spread on hydrophilic substrate surface. Because of fast solvent evaporation of silver ink when it was droped on the 60°C substrate, muti-printing method was required for good surface properties although line width was increased about 5 µm (fig.2). From figure.3, sheet resistance and corresponding specific resistivity of 3-time-print narrow silver lines were 0.36 Ω/□ and up to 8µΩ·cm, respectively. These results were highly competitive in electrical resistance comparing narrow line results using 10pl cartridge with line width of 61 µm. Moreover, in 3-time-print narrow silver line, maxium current flow capacity up to 50 mA (2.1A/cm^2) was also suitable for electronic applications. These results are much better than recently published works from other groups because their width and height of 5-time-print narrow silver lines were 40 µm and 250 nm, respectively [7].

Figure 4 shows all-inkjet-printed gate and source/drain narrow line silver electrodes which are isolated by inkjet-printed poly(4-vinylphenol) (PVP) gate dielectric layer. Details of all-printed organic thin-film transistors (OTFTs) and their performance will be reported at conference.

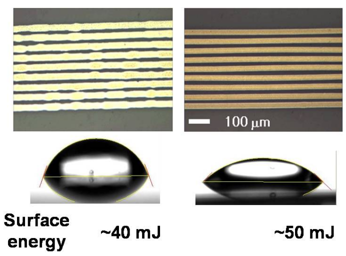
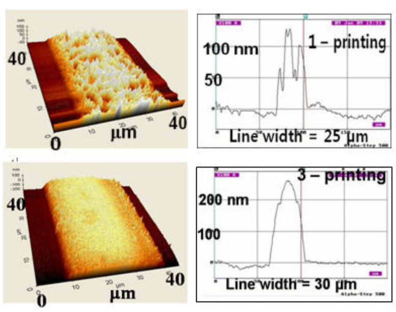
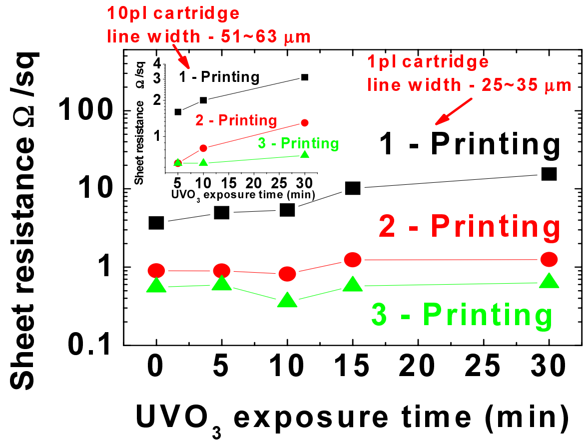


Fig.1. Surface treatment result using UVO_3 exposure on poly-arylate.

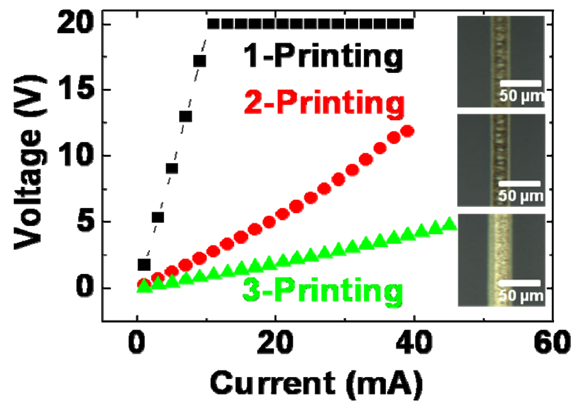


(a) (b)

Fig.2. (a) AFM and (b) alpha-step images of 1 and 3-time-print narrow silver lines with 25 and 30 µm line width



(a)



(b)

Fig.3. (a) Sheet resistance of multi-time over printed narrow silver lines on poly-arylate substrate with different UVO_3 exposure time (Narrow lines results using 10pl cartridge are also include in inset) (b) Current flow capacity of muti-time over printed narrow silver lines

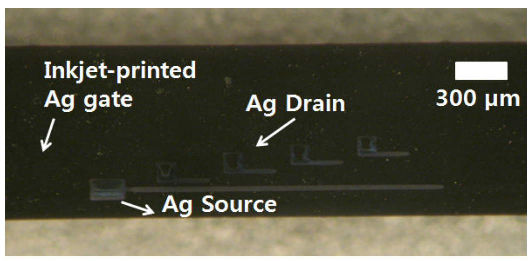


Fig.4. Narrow silver line for source/drain of inkjet-printed OTFTs application

4. Summary

In this paper, we reported high resolution and uniform conductive silver line formation on flexible substrate, and the effect of surface treatment to produce narrow inkjet-printed silver lines with clean-edge and good aspect-ratio, which are very important for high resolution printed electronics applications. By using carefully optimized inkjetting and curing conditions, uniform narrow silver line with 30 μm line width and 17 μm gap between printed lines was obtained. Especially, muti-printed silver lines showed high electrical conductivity and reliability for printed electronic applications, for example, RFID tags or OTFTs.

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6. Reference

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