# Surface energy control of ITO substrate for Inkjet printing of PEDOT/PSS

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## Abstract

*Inkjet printing is being considered as an alternative to the conventional lithography in the electronic industry. Surface energy control of substrate is a critical issue in controlling the dimension of microsrtuctures by the inkjet printing. This study introduces the surface energy control of ITO substrate for inkjet printing of PEDOT/PSS*

## 1. Introduction

Poly(3,4-ethylenedioxythiophene)/Poly(styrenesulfonate) (PEDOT/PSS) is a popular conductive polymer that finds widespread use in the fields of polymeric electronics and display applications. Its major advantages lie in the suitability for flexible electrical devices and the relatively simple deposition process capabilities with techniques such as inkjet printing [3]. Especially inkjet printing technologies are many advantages associated with application of devices such as fast and simple process, material reduction and large area patterning capability. The production of various devices, such as polymeric transistor or light emitting diodes, organic solar cell, utilizing inkjet printing has already been demonstrated and PEDOT/PSS layer dramatically enhances the devices performance by function of hole injection layer (HIL). In this latter, we demonstrate this concept of using the inkjet printing technology by application of organic light emitting diodes through the printing method and the surface treatment of substrate.

## 2. Experimental

Table 1 shows the property of conductive polymer ink used in this study. For our study the Baytron P purchased from H. C. Stark was used. It was conductive polymer that hole injection layer in the organic light emitting diodes device. In addition, we blend PEDOT/PSS ink with additional Glycerol and Deionized water (DI water) to improve jetting stability (1). Viscosity and surface tension was measured by using Brookfield DV-Ⅱ+ unit and KRUSS DAS100 unit. Density was calculated through a micro pipette and balance. The substrate was coated with Indium tin oxide (ITO) about 180 nm thicknesses. It was cleaned for 5 minutes in acetone and another 5 minutes in isopropyl alcohol (IPA) using an ultrasonic bath before printing. Piezoelectric drop-on-demand inkjet print heads from Dimatix were employed in the present study. A variety of patterns could be printed using drop-on-demand (DOD) inkjet process [2]. Droplets are jetted as the stage underneath move. The inkjet printing tool includes a cartridge type inkjet head with motorized x-y stage, a fiducial camera for the substrate alignment and drop watcher camera to control the drop shape. The exit diameter of the nozzle is 19um and the corresponding droplet volume is about 10 pl. The spreading and wetting of the ink on the substrate was controlled by the surface energy of substrate and the temperature of printing table. To printing pattern of larger than the deposited droplet diameter on substrate, drop spacing (DS) set a significantly smaller than the deposited droplet diameter. Variable drop spacing and UV/ozone treatment processing time to change the way the surface energy of the substrate was set for pixel type pattern of PEDOT/.PSS ink

**TABLE 1. Property of the ink used in this study**

| Ink | Viscosity (cP) | Density (g/ml) | Surface tension (dyne/cm) |
|---|---|---|---|
| PEDOT/PSS+ Glycerol+DI water (8:1:1 vol%) | 9.4 | 1.0 | 79 |

## 3. Results and discussion

Surface tension of blended PEDOT/PSS ink has been measured 79 dyne/cm at room temperature. High surface tension contributes to reduce the injection of satellite droplet that can occur when jetting. Fig. 1 shows a diameter of deposited droplet on non surface treatment ITO substrate by 80 um drop spacing. It shows PEDOT/PSS droplet diameter approximately 15 um less than typical 50x200un pixel size. Therefore, in order to print the pixel type pattern be required many droplets and this case have no advantage to printing. Fig. 2 shows the effect on the UV/ozone surface treatment of ITO substrate. UV/ozone treatment alters the contact angle of PEDOT/PSS on ITO coated glass, making it more wetting. The simple method of surface energy confirmation through the surface treatment is a contact angle measurement between ink and substrate. In this experiment, improved wetting of PEDOT/PSS ink using UV/ozone treatment. If processing time of UV/ozone treatment has increased on the ITO substrate, the increase in surface energy. As a result, the contact angle is decrease however increase the diameter of deposited droplet. The contact angle between ink and substrate before UV/ozone treatment measured about 82℃ as seen in Fig. 2(a). Fig. 2(c) shows a contact angle has smaller than Fig. 2(a) almost 13 degree after UV/ozone surface treatment for 5 minutes. The surface energy of each 35, 46 and 54 was calculated from the result of contact angle measurement using Formamide, Diiodomethane and

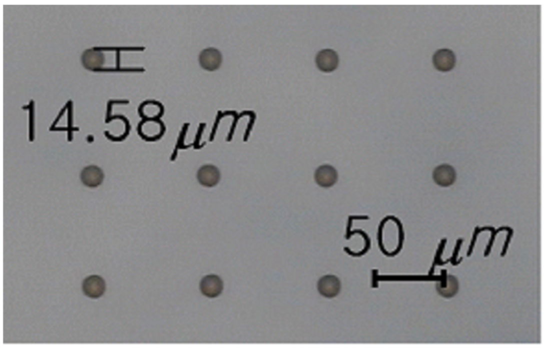
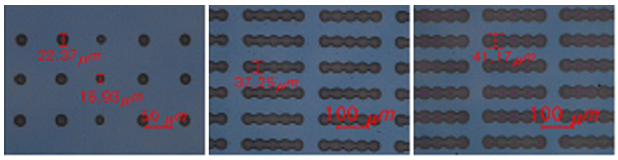



**Fig. 1. Printed PEDOT/PSS ink on the ITO substrate; before UV/Ozone treatment.**

Figure 3 shows the characteristic of pattern depend on 40um of drop spacing and various UV/ozone treatment time. The dimensions of the printed pattern are mainly determined by the spreading of the ink after impacting the substrate, which is determined by the substrate's surface chemistry and temperature. 5 droplets are formed a pattern by printing in a single row on the substrate at 40℃ and determine the increment of pattern size as UV/ozone treatment processing time increasing. However, it has winding around the pattern reason of spreading and drop spacing. Fig. 4 shows s pattern shapes depend on 20 um of drop spacing and various UV/ozone treatments processing time. 20 droplets are jetted two lines for one pattern because drop spacing is decreased but the substrate temperature was maintained with the same at 40℃. After patter printing it was cured at 100℃ for 30 minutes in the oven. It was a formed of a rectangular pattern better than Fig. 3.

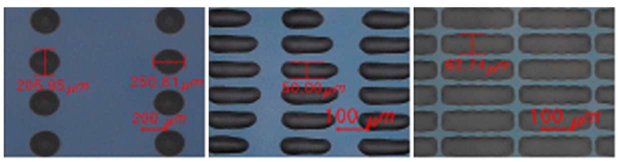
**(a) (b) (c)**

**Fig. 2. Contact angles of PEDOT/PSS ink on the ITO substrate: (a) 82 ° (before UV/Ozone treatment) (b) 50 ° (after 3 min UV/Ozone treatment) and (c) 13 ° (after 5 min UV/Ozone treatment)**



(a) (b) (c)

**Fig. 3. Influence of UV/Ozone treatment on the printed PEDOT/PSS pattern: (a): 0min, (b): 3min and (C): 5min (drop space:40μm)**



**(a) (b) (c)**

**Fig. 4. Influence of UV/Ozone treatment on the printed PEDOT/PSS pattern: (a): 0min, (b): 3min and (C): 5min (drop space: 20μm)**

We could see the impact that formed a pattern such as diameter size of deposited droplet depending on the surface treatment of substrate and drop spacing from the jetting result. Also we confirmed that effective printing ability used of fewer droplets on the UV/ozone treated substrate with 3 and 5minutes compared to the non surface treatment substrate. The increases in surface energy of substrate reduce the merging of adjacent ink. In this experiment, Fig. 4 (c) rectangular pattern printed on the UV/ozone treated substrate at 5 minutes and set a 20 um drop spacing is the most effective implementation of the pixel.

Figure 5 shows a thickness profile of printed pixel type pattern at surface energy of substrate and drop spacing as seen in Fig. 3 and Fig. 4. The thickness of printed pattern is thinner to increase in UV/ozone treatment processing time if the same number of droplet. Typically, the thickness of PEDOT/PSS layer function of hole injection layer for the production of organic light emitting diodes is known as about 50~100nm[2,4]. The thickness of Fig. 3(c) with advantage of pixel type pattern measured approximately 170nm. The minimum overlap area and low contact angle between ink and substrate are needed to achieve thin layer by the wetting and spreading of formulation on the substrate.

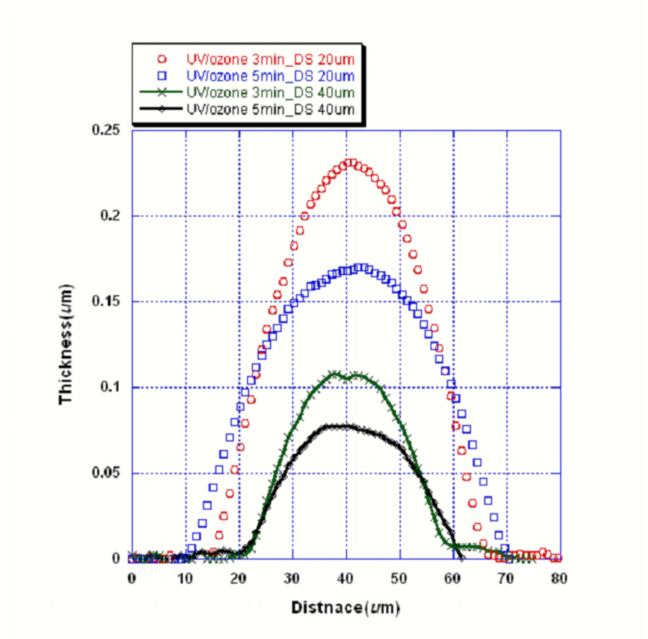



**Fig. 4. Thickness of PEDOT/PSS pattern**

## 4. Summary

In this study, we have printed PEDOT/PSS ink to apply organic light emitting diodes from a commercially available inkjet printer. Control over the thickness and shape of PEDOT/PSS pattern was achieved by using UV/ozone surface treatment and drop spacing. UV/ozone treatment processing time will increase along with the surface energy of substrate and the spreading of deposited PEDOT/PSS ink. In addition, printing methods include drop spacing of ink therefore it can be control the amount of ink. We have demonstrated successfully the concept of applying the inkjet printing technology as an effective tool for the patterning of polymer hole injection layer on the ITO substrate to apply organic light emitting diodes

## 5. References

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