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Short communication

Modification of the sheet resistance of ink jet printed polymer conducting films by changing the plastic substrate

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Abstract

The ink jet printing technology is a relatively novel technique in development of organic electronic devices. The technique consists of working out depositions of organic layers by a piezo-based ink jet printer. In this work polymer conducting films deposited by ink jet printing technique on different plastic substrates has been demonstrated. The poly(3,4-ethylenedioxythiofene)/poly(4-styrenesulfonate) [PEDOT/PSS] and glycerol-modified PEDOT/PSS [G-PEDOT/PSS] were used like conducting inks to be applied on polyester and polyethylene terephthalate (PET) substrates. By means of the change of substrate associated to the deposition number or type of polymer ink used for printing of the conducting films, the sheet resistance can be modified. Such a behavior suggests that plastic substrate fulfills an important role for the changing of sheet resistance of the PEDOT/PSS and G-PEDOT/PSS films made by ink jet printing technique. Films obtained from this technique on different plastic substrates might represent a significant step toward the development and improvement of organic electronic devices.

Keywords: Sheet resistance; Ink jet printed polymer conducting films; Plastic substrate

1. Introduction

Organic electronic devices are attracting considerable attention due to their potential low cost, easy processing advantages and very rapid progress in the last years [1–3]. The manufacturing of these devices has made use of a wide variety of processing methods including soft lithography, thermal evaporation, spin coating, dipping coating, layer by layer, self-assembled and printing techniques [4–12].

With regard to most known printing techniques, screen-printing, micro-contacting printing and ink jet printing, the latter has caught more and more attention because of its unique characteristics. These include, low material wastages, adaptable, simplicity, compatibility with a lot of substrates, non-contact, large-area patterning and low cost. Ink jet printing holds the promise of being a low cost manufacturing process without the need to employ complex microlithography, in special, photolithographic patterning and other capital intensive processing like it is the case with amorphous and crystalline semiconductor devices [14–16].

Ink jet printing technique has already been used in the microfabrication conducting polymer devices [19], polymer light emitting devices (PLEDs) [20], organic thin film transistors (OTFTs) [10,13] and more recently organic RC filter circuits [17,18]. During the manufacturing steps of these devices, the uniformity degree of the polymer film is an important issue to determine the sheet resistance. When the film uniformity is very poor, the resistivity would be greatly increase and even a large discontinuousness could happen [10,13,17,18].

In this study, it is reported the effects of different plastic substrates on the sheet resistance of polymer conducting films

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printed by a commercial ink jet printer with PEDOT/PSS and G-PEDOT/PSS used like conducting inks.

2. Preparation

Two type of polymer conducting inks, PEDOT/PSS bought from Bayer AG (German) and glycerol-modified PEDOT/PSS (hereafter, refer like G-PEDOT/PSS) were used for manufacturing of the conducting films.

PEDOT/PSS is a type of optically transparent polythiofene of sky blue color. It has been used to various applications, such as hole injecting layer of PLEDs, photodiodes, and electrode material of OTFTs, because of its high stability and relative conductivity after drying [21,22]. Recent works have shown that the resistivity of PEDOT/PSS can be decreased without any loss in its optical characteristics through addition a small amount of a polyalcohol such as glycerol. This conductivity gain and optic transparency maintenance are potential characteristics of G-PEDOT/PSS to improve organic devices efficiency [21,22]. The chemical structure of PEDOT/PSS and glycerol are shown in Fig. 1.

Into the printing process of PEDOT/PSS and G-PEDOT/PSS films, the solution viscosity must be considered. Since a solution with high viscosity is not easy to be injected through the tiny nozzles and able to clog them [17,18,23].

It was used 2.0 ml of PEDOT/PSS diluted in 9.0 ml of water to obtain the optimized solution of PEDOT/PSS. Adding 0.25 ml of glycerol in the same solution was obtained the solution of G-PEDOT/PSS in order to both of them can be used like conducting inks for commercial ink jet printers that inject ink droplets of approximately 4.0 pl.

The ink jet printer used in the experiments was a commercially available EPSON Stylus C20SX with 720 by 720 dpi resolution and the configuration for the printing setup was set at "transparent paper". This printer brand ejects ink droplets from the piezoelectric mode of pressure generation; therefore it does not apply thermal load to the polymer inks. The main modification to the ink jet printer was to load the ink cartridges with PEDOT/PSS and G-PEDOT/PSS solutions to print the conducting films.

For films conception, some layers of PEDOT/PSS or G-PEDOT/PSS were printed on the substrate without using a protective atmosphere. The substrate material consisted of two types of plastic: polyester and polyethylene terephthalate (PET) that were carefully cleaned in advance for printing of the films. Each printed layer is dried in a stove at 100 °C for about 2 min. This annealing treatment after printing helps to make a more continuous film. However, for G-PEDOT/PSS films printed on the polyester substrate, it was to verify the presence of glycerol on the post-annealing film surface. So, the ones were placed again in the stove at 50 °C to remove completely the alcohol.

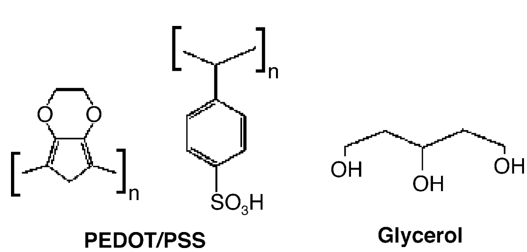

Fig. 1. The chemical structure of PEDOT/PSS and glycerol.

In summary, it was manufactured using four different samples of conducting films on each plastic substrate, two of them using five and ten layers of PEDOT/PSS and the last ones changing from PEDOT/PSS to G-PEDOT/PSS like conducting ink. For each sample, three more identical samples were prepared.

3. Results and discussion

The sheet resistance was measured using the four-point probe technique Keithey 230 current source and Keithey 296 multimeter was used to eliminate the contact resistance. Each sample was subjected to three measurements in order to verify the reproducibility of the sheet resistance and to obtain more consistent results.

In Table 1 is listed the average value of the sheet resistance on the samples. From comparison of the films manufactured using PEDOT/PSS in Table 1, it suggests that no matter what type of plastic substrate is used, the values of sheet resistance are close for five or ten depositions. Now with regard to G-PEDOT/PSS, the results show that the best plastic substrate to print conducting films to get a lower sheet resistance is the polyester, in either case, five or ten depositions. It can also be noticed the expressive gain in conductivity whenever the film is made of 10 layers of G-PEDOT/PSS on the polyester in comparison to PET substrate. These results indicate that the most significant decrease in resistivity is induced by addition of a small amount of glycerol in PEDOT/PSS blend and using polyester like substrate material.

In order to investigate the reasons why the glycerol and polyester substrate help to increase the conductivity of the conducting films made by ink jet printing technique some additional parameters had to be analyzed. At first, KRÜSS

Table 1
Sheet electrical resistance of the polymer film on polyester and PET substrates with five and ten depositions

Plastic substrate	Conducting ink	Deposition number	Resistance (MΩ/m)
Polyester	PEDOT/PSS	5	4.1 ± 0.1
PET	PEDOT/PSS	5	4.4 ± 0.1
Polyester	PEDOT/PSS	10	1.8 ± 0.1
PET	PEDOT/PSS	10	1.8 ± 0.1
Polyester	G-PEDOT/PSS	5	1.15 ± 0.09
PET	G-PEDOT/PSS	5	4.3 ± 0.2
Polyester	G-PEDOT/PSS	10	0.0134 ± 0.0007
PET	G-PEDOT/PSS	10	0.62 ± 0.02