Materials Ink Jet Printing of Electronic Structures

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Abstract

We used poly3,4-ethylenedioxythiophene doped with poly(sterene sulfonate) (PEDOT:PSS), a commercially available conductive polymer, to fabricate electrodes for disposable sensors. We successfully printed the electrodes using an ink jet printer that utilizes piezoelectric nozzles to dispense the polymer. Printing on silicon wafer and photographic paper yielded good quality electrodes. Our goal was to fabricate electrodes that exhibit low resistance on flexible, inexpensive substrates. The first tasks were to optimize the dimension of the electrode pattern, and then optimize the drop spacing used during the printing process in order to obtain continuous films.

We found that the optimum drop spacing is different for different substrates. The optimum drop spacing for printing on paper is 5 μm. At this drop spacing, the resistance of the electrode measured with a voltmeter is around 80 kΩ. To achieve an even lower resistance for electrodes that will be used in devices, the following method was used: one layer of PEDOT: PSS was printed, and then a second layer was printed on top of the first one. The resistance of the two layered electrode was around 30 kΩ.

Introduction

Currently, commercially available sensors are unable to detect small saliva glucose concentrations. When the use of saliva is coupled with inexpensive, disposable polymer-based sensors, it is possible to create a low cost and painless glucose monitor that can lead to a much more widely used sensor [1]. Inkjet printing is a new technology that is used to print conductive polymers. A simple glucose biosensor with micromolar sensitivity utilizes a conducting polymer transistor with a channel made out of PEDOT:PSS and a platinum (Pt) gate electrode [1]. The ink jet printer allows us to print on inexpensive substrates using PEDOT: PSS as the conductive polymer.

The advantages of using the inkjet-print technology for electrodes used in chemical and biological sensors are the high speed and low cost fabrication as well as the possibility of printing onto flexible substrates [2]. Inkjet printing is one of the most promising technologies for several reasons; one of them is the capacity of depositing micro droplets of 2-12 pl on any surface such as plastics, metals, rubber, glass, silicon wafer [3].

Experimental Procedure

Initially, we designed the electrode patterns and then using the ink jet printer, we were able to optimize the parameters of the system

Figure 1: Optical microscope image, PEDOT:PSS on paper at 50 μm drop spacing.

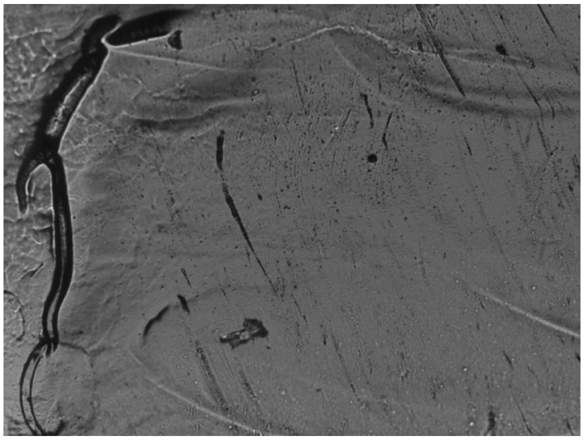

Figure 2: Optical microscope image, PEDOT:PSS on paper at 5 μm drop spacing double layers.

to print PEDOT:PSS electrodes on different substrates (glass slide, Si wafer, and photographic paper). The ideal substrate is inexpensive, flexible, and easy to print on. We predicted that the drops might behave differently on different substrates. In order to obtain continuous films, we changed the drop spacing used during the printing process. The parameter was important because the resistance was affected by drop spacing of the nozzles; large drop spacing could result in a discontinuous film.

Using the molecular vapor deposition (MVD 100) system, we treated the surfaces of the silicon wafer and the glass slide with two chemicals (APTMS and PEG). We investigated whether surface modifications would improve the characteristics of the printed electrodes or not. Photographic paper was used as a substrate to print at different drop spacing, starting with 50 μm to 5 μm single layer printed PEDOT:PSS followed by a double layer printed at 5 μm. We characterized the electrodes printed on photographic paper at 5 μm drop spacing both the single and the double layer by measuring the resistance to see whether we get good quality films. At last we measured the current in order to compare the two final results to see which one performs better.

Results and Conclusions

As a result of performing these experiments, we came to the conclusion that paper is in fact a suitable substrate to print PEDOT: PSS electrodes. Our experiments showed that printing a double layer of PEDOT:PSS on paper exhibits lower resistance and higher current than all the other substrates under investigation. This result proves that inkjet printed PEDOT:PSS electrodes on paper can be of high quality, thus they can be used in devices.

Future Work

Future work includes the use of the PEDOT:PSS electrodes in electrochemical transistors for chemical and biological applications and the study of their behavior and suitability as part of a circuit.

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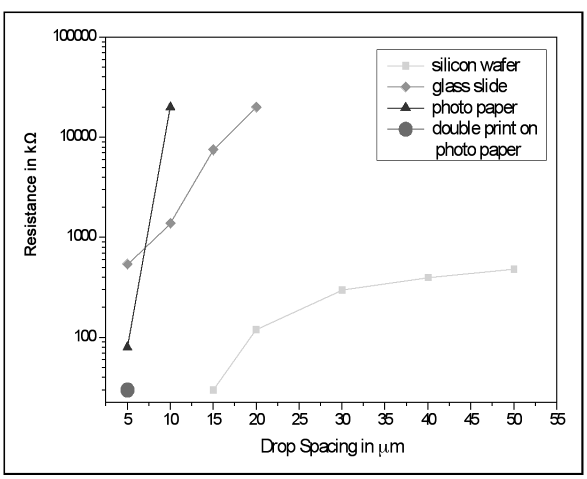

Figure 3: Resistance vs. drop spacing graph with different substrates.

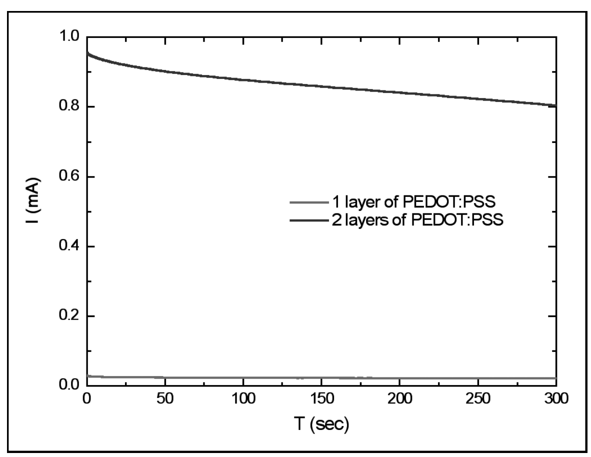

Figure 4: Current vs. time with a drop spacing of 5 μm.