A PEDOT:PSS Process on Textiles for Health Monitoring

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Abstract:

Wearable electronic textiles are good candidates for achieving low cost, flexible, and light-weight health monitoring devices. The integration of biocompatible organic polymers, such as poly(3,4-ethylenedioxythiophene):polystyrene sulfonate (PEDOT:PSS), and ionic gels with textiles allows for the development of conformable and high performance electronics for cutaneous applications. For these reasons, we developed a fabrication process for PEDOT:PSS based electrodes. Such electrodes were used for recording electrocardiography (ECG) activity and for developing an electrochromatographic display of such activity. An ionic liquid gel was used to aid in the electrochemical doping and de-doping of the PEDOT:PSS electrodes. Color changes on the electrochromatographic display were analyzed via optical spectroscopy. The PEDOT:PSS electrodes were also used as capacitive pressure sensors, with polydimethylsiloxane (PDMS) as dielectric, for physiotherapeutic applications. Results obtained using this process pave the way for technology that can be further integrated on an electronic textile glove that can perform several health monitoring tasks at once.

Introduction:

There is an increasing interest for combining the capabilities of electronics with textiles. This emerging field of research provides new tools for a variety of applications such as in the medical field. Detection of electrical activity of the heart by external electrodes, also referred to as electrocardiography (ECG), is a method used by physicians to investigate heart rhythm. This test can help physicians detect anomalies in the functions of the heart. To perform ECG testing, two or more metal electrodes are placed directly on top of skin. However, such metal electrodes can be expensive and, as they lack flexibility, do not conform well with skin. Having textile-based electrodes could allow for improved ECG testing as the flexibility of the textile enables to follow the movement of most human body parts. Furthermore, in this work we seek to expand the applications of textile-based electrodes to be used as capacitive sensors to detect changes in pressure. This technology can provide crucial information in the field of physiotherapy regarding pressure applied on patients.

Device Fabrication:

All materials used in this process are biocompatible, which allows for applications in direct contact with skin. The textile electrodes were constructed by patterning the conductive polymer on polyester-based fabric. A negative polyimide master was used to define the desired pattern. On such master, a layer of PDMS was deposited by spin coating. The polyimide master was then placed on top of textile, with the PDMS in direct contact with the fabric (see Figure 1).

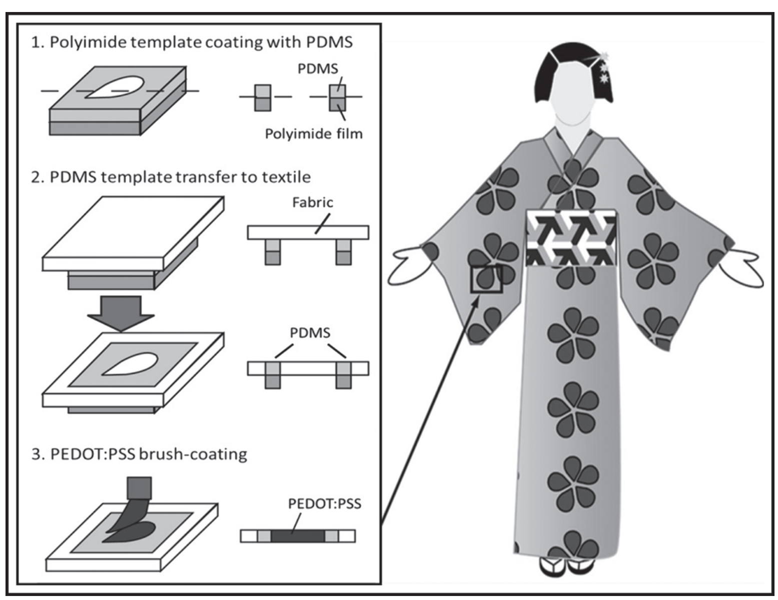

Figure 1: Patterning process.

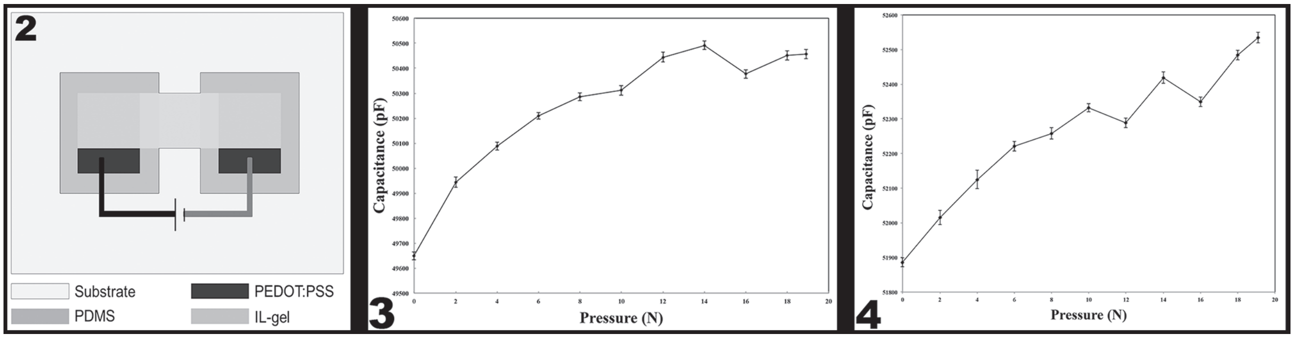

Figure 2, left: *Schematic of ECG display experimental setup.* **Figure 3, middle:** *Pressure sensing characterization. 920 µm thick PDMS layer as dielectric.* **Figure 4, right:** *Pressure sensing characterization. 560 µm thick PDMS layer as dielectric.*

The PDMS was cured onto textile via thermal annealing for ten minutes at 100°C. The polyimide master was then removed from the PDMS surface. The hydrophobic properties of PDMS allowed for confinement of the PEDOT:PSS aqueous solution on textile substrate. Then, PEDOT:PSS solution was paint brushed on textile, and subsequently annealed for five hours at 100°C. The PEDOT:PSS solution was prepared in a 0.80/0.20/0.40/0.01 ratio of PEDOT:PSS aqueous dispersion, ethylene glycol, 4-dodecylbenzenesulfonic acid, and (3-glycidyloxypropyl) trimethoxysilane, respectively. Solution was then mixed, and sonicated for thirty minutes. The films were subsequently baked at 100°C for five hours.

Experimental Procedure:

An ionic liquid gel was used aid in the electrochemical doping and de-doping of the PEDOT:PSS electrodes. The ionic gel consisted of the mixture of ionic liquid 1-ethyl-3-methylimidazolium-ethyl sulfate, 0.1M phosphate buffer solution, poly(ethylene glycol)diacrylate and the photoinitiator 2-hydroxy-2-8-methylpropiophenone at a ratio of 0.12/0.48/0.35/0.05, respectively. Two sets of experiments were arranged for testing the textile electrodes for two applications: electrodes as ECG-signal display, and electrodes as capacitive sensors. On this device, a sine wave of 100 mHz was applied, using potentials ranging from 0.2V to 2V (see Figure 2). This signal promoted ion migration between the electrodes. Because of the elecrochromathographic properties of PEDOT:PSS, we observed changes in color with the naked eye alternating from light blue to dark blue. A glass slide was used as a substrate for the PEDOT:PSS electrodes.

The PEDOT:PSS electrodes were also used as capacitive pressure sensors, with polydimethylsiloxane (PDMS) as dielectric, for physiotherapeutic applications. The capacitor was formed by one layer PEDOT:PSS-textile electrode plates, and one of PDMS on top. The terminal of such textile electrode is connected to the circuit. The second conducting plate was a grounded metal electrode, to allow applied pressure variation. A range of pressures was applied to two capacitors with different dielectric thickness (see Figures 3 and 4). Information regarding capacitance changes on device was obtained from the configuration of the setup of textile-PEDOT:PSS electrodes, capacitance measurement circuit in MCUs, and PC.

Conclusion and Future Work:

We have successfully patterned textile electrodes for health monitoring practices using materials that are all biocompatible and inexpensive. Capacitance changes as a function of pressure were detected, varying with dielectric thickness, agreeing with theory. Textiles as capacitance sensors are promising for physiotherapy applications as we detected pressure changes in the range of 0.1N to 200N, which is the ideal range for such applications. ECG display process needs to be further investigated as the working frequency is not yet reaching 1 Hz, which is a normal ECG frequency. For this reason, we would like to investigate alternative ionic gels that will enable faster doping/de-doping response to match ECG signal frequency, and allow for transferring of process to textiles. Furthermore, future work will focus on optimizing patterning techniques to allow for further integration onto different shapes of substrates such as textile gloves.

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