Printed Electrodes on Soft Materials for Wearable Electronic Devices

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Introduction

Electrodes deposited on soft materials have a wide range of applications due to their unique properties and have already shown promise in the consumer market [1]. Current piezoresistive sensors suffer from variables such as mechanical noise and a complicated fabrication process. Furthermore, while Polydimethylsiloxane (PDMS) is a suitable candidate for medical sensing applications, it is also hydrophobic. By implementing inkjet printing alongside chemical treatment, these problems can be solved.

Goals of this research are to:

- Develop an efficient method of inkjet printing electrodes on soft materials.
- Increase PDMS wettability for deposition via chemical treatment.

Figure 1: Inkjet-printed lettering on a small scale.


Figure 2: A respiratory acoustic sensor using thin-film electrode technology [2]

Materials and Methods

Substrate Fabrication

Polyvinyl Alcohol (PVA) is mixed into DI water to achieve a 1:50 ratio solution (by volume) of PVA to water. The solution is spin coated onto a silicon wafer, then sintered. Polydimethylsiloxane (PDMS) is then made at a 10:1 ratio between base and curing agent to be used as a substrate. Once prepared, the PDMS is spin coated on top of the layer of PVA upon the silicon wafer. The PDMS upon the wafer is then sintered, and subsequently cooled. After cooling, the wafer is placed in an ultra-sonification bath to dissolve the PVA layer. Lastly, the PVA layer dissolves, and the PDMS layer detaches from the wafer.

Substrate Treatment

The PDMS substrate sheet is then put through chemical treatment to achieve hydrophilicity. By incubating in a solution of 3-mercaptopropyl-trimethoxy-silane (MPTMS) and Ethanol, the PDMS substrate gains a MPTMS layer upon it to allow for printing. The timing of the incubation is directly proportional to the hydrophilicity of the PDMS and is currently the focus of experimentation. Hydrophilicity is determined via contact angle.

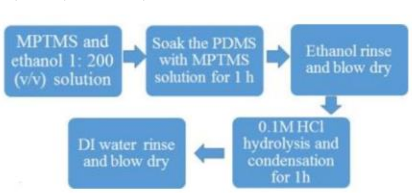

Figure 3: The substrate treatment process [3]

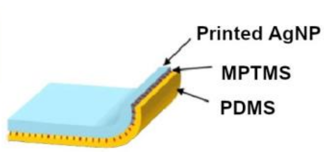

Figure 4: Layers PDMS substrate after treatment and printing

Inkjet Printing

After chemical treatment, the PDMS substrate sheet is ready to be printed on in the inkjet printer. Silver nanoparticles (AgNP) are printed onto the PDMS sheet by using a Dimatix materials printer 2831 (DMP-2831). The DMP-2831 accepts any custom pattern for printing, and a "subsampling" technique, visualized in figure 5, is used for printing effectiveness. By breaking up an original print pattern into separate patterns which, when combined, complete the original pattern, the chances for printing error is significantly reduced.

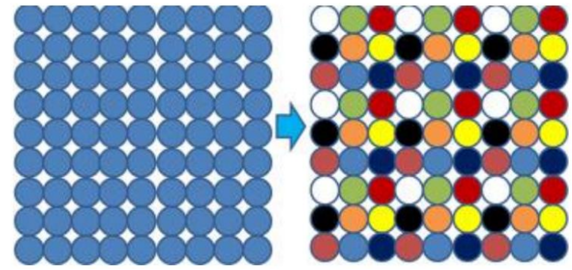
Figure 5: Simple diagram of the subsampling technique [3]

Results

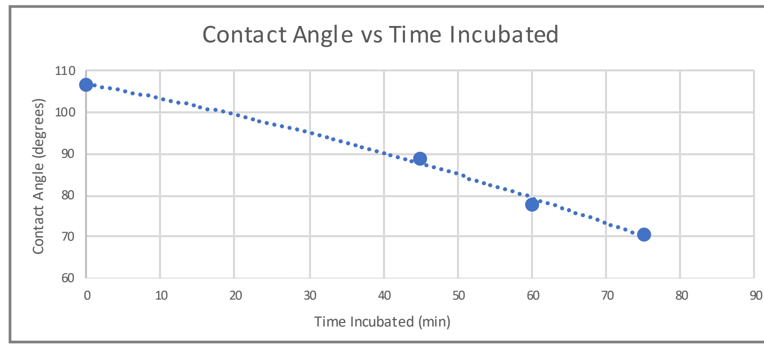

Figure 6: Graph of contact angle between PDMS and AgNP dependent on incubation times.

A contact angle less than 90 degrees is considered hydrophilic, and after 45 minutes does the PDMS gain this property. The MPTMS chemical treatment is a success.

Conclusion

- Higher incubation timings result in a lower contact angle between the AgNP and the treated PDMS.
- Current chemical treatment will certainly allow for inkjet printing of AgNP on treated PDMS.
- More experimentation will be required to find the most effective incubation timing for inkjet printing.

Future Work

The successful treatment of the PDMS will allow for further experimentation with inkjet printing. Using AgNP as the electrode, a circuit may be printed onto treated PDMS, which will give the electrode the piezoresistive property. The resistance of the circuit will change in proportion to its force, allowing for the development of an acoustic-based sensor.

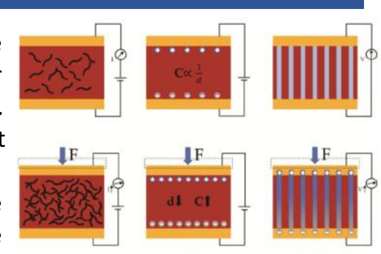

Figure 7: A simple diagram of a piezoresistive, capacitive, and piezoelectric sensor. [4]

References

[1] J. Heikenfeld *et al.*, doi: 10.1039/C7LC00914C
[2] Kang *et al.*, doi: 10.1038/s41746-022-00691-w
[3] J. Wu *et al.,* doi: 10.1109/ICSENS.2014.6985197
[4] W. Chen and X. Yan, doi: 10.1016/j.jmst.2019.11.010