Hydrogel-Mediated Direct Writing of Conducting Polymer Films

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Introduction

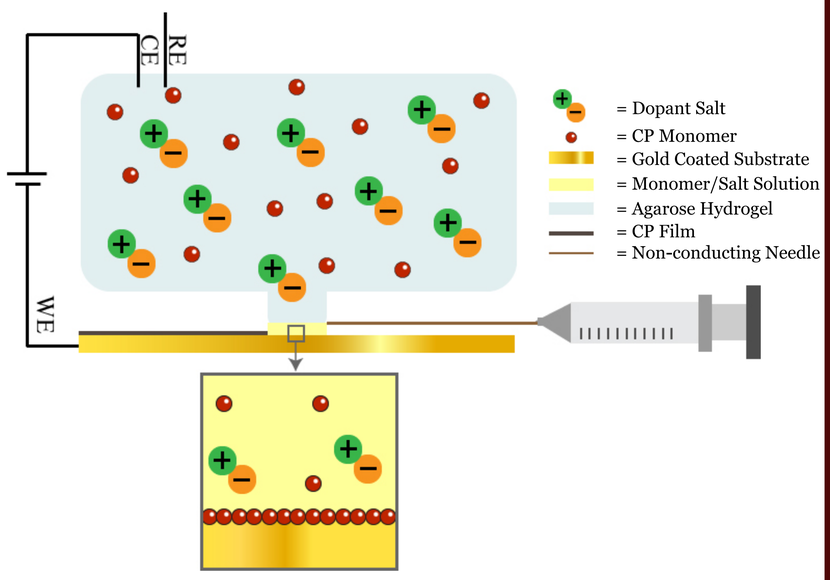
- Conducting polymers (CP) are a unique material in that they can facilitate electron flow like metals, but they are soft materials like polymers. As a result, CP's have been utilized in implantable bioelectronics.
- Typical fabrication of conducting polymers is electrodeposition that done within a liquid solution, and provides a large film of CP, therefore not allowing the fabrication of complex structures.
- In this work, we develop and characterize a methodology for depositing CP through a hydrogel "pen" to recreate the process of 3D printing. By instituting finer control over the morphology and shape of CP's, advancements in applications such as directed neurite outgrowth and bioelectronic incorporation can be made.

Materials & Methods

Fabrication of Loaded Hydrogel Pen

- A mixture of Agarose powder in a solution of pyrrole (Py) and poly(sodium-p-styrenesulfonate) (PSS) is heated, and then poured into a polydimethylsiloxane (PDMS) mold containing negative features that result in a matrix of hydrogel posts.
- Excess posts are cut away using a scalpel, and the one remaining is to be used as the "pen".

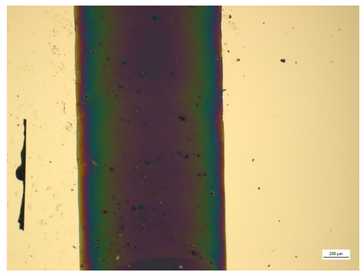
Method for Direct Writing of Conducting Polymer

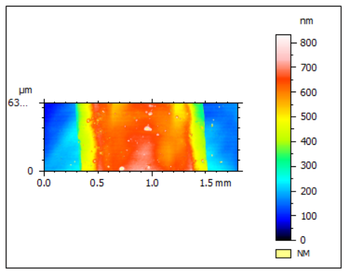


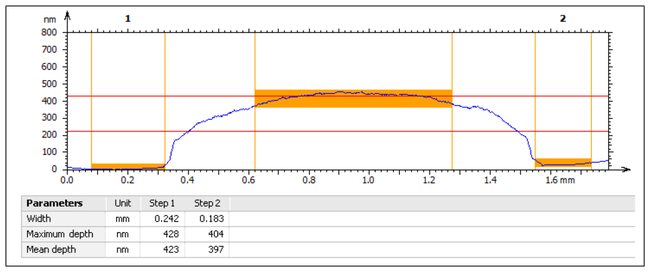
Results and Discussion

1 Pass Substrate Optical and Confocal Data Samples

- Optical and Confocal microscopy data of a 1 pass line are shown.
- Results show that straight line of Polypyrrole (PPy) can be fabricated.
- Z-stack analysis shows slight peak in height towards center of PPy line.

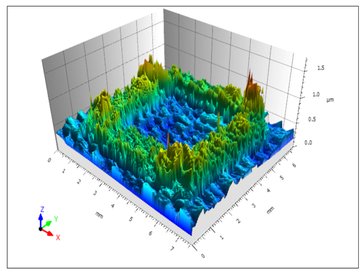


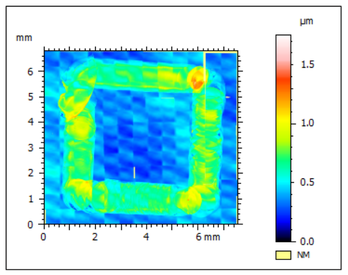


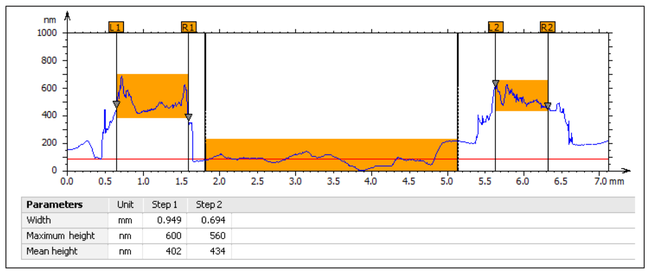


Parameters	Unit	Step 1	Step 2
Width	mm	0.242	0.183
Maximum depth	nm	428	404
Mean depth	nm	423	397

- Confocal microscopy data of a 1 pass square are shown.
- Height map (right) represents a scan taken from left to right.
- Noise is attributed to lower resolution needed to scan larger samples.



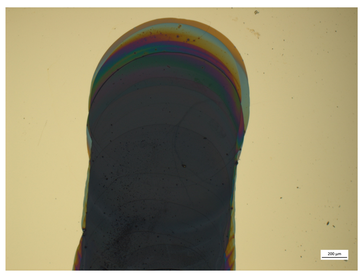


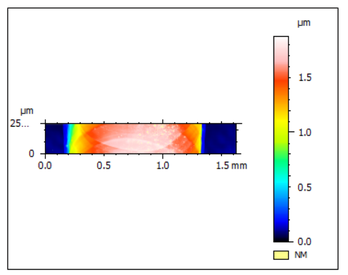


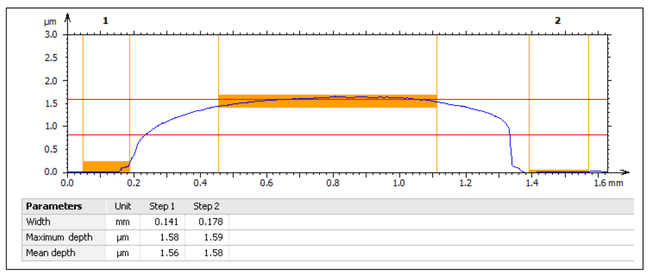
Parameters	Unit	Step 1	Step 2
Width	mm	0.949	0.694
Maximum height	nm	600	560
Mean height	nm	402	434

4 Pass Substrate Optical and Confocal Data Samples

- Optical and Confocal microscopy data of a 4 pass line are shown.
- This data confirms that PPy can built in a "wall", allowing for taller structures and complex shapes to be fabricated in future trials.







Parameters	Unit	Step 1	Step 2
Width	mm	0.141	0.178
Maximum depth	µm	1.58	1.59
Mean depth	µm	1.56	1.58

Step Height Analysis

- Using z-stack analysis, the mean height of each substrate fabricated was calculated.
- The table on the right shows the average height in nanometers across all substrates of a set number of passes, as well as the average height of all passes.
- Identifying this value allows for a more controlled environment during future depositions, resulting in the ability to adjust the stage height accurately as more CP is built up.

Number of Passes	Average Height (nm)
1 Pass, n=5	418 ± 22.8
2 Pass, n=5	816 ± 64.9
4 Pass, n=2	1620 ± 40
5 Pass, n=1	2040 ± 0
Average Pass	408 ± 25.27

Conclusions

- We have developed a novel method for the direct writing of conducting polymers, and characterized properties such as height of PPy generated per pass, and ability of CP to polymerize over previously deposited CP.
- Future studies will focus on fabricating complex 3-D structures, and characterizing depositions at different velocities.

Acknowledgements

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References

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