Bringing lab research into the home with paper-based analytical devices

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Project Goal: Design and optimize paper devices for common analytical techniques/assays to use for virtual labs and field work

Paper-based microfluidics allow students to perform chemical analysis – like they would in the lab – in a remote environment. These devices are inexpensive to make, are mobile and easily distributed, and only require small quantities of analytes and reagents, making them excellent for field research and low resource areas.

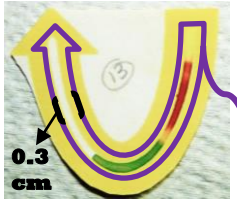
Sensor Translation & Method Development

Laboratory

Colorimetric

Background color, lighting and camera position, device shape/size, wax heating and thickness

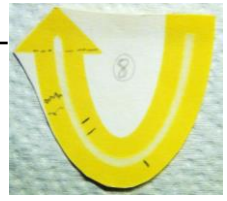
Remote



Microfluidic colorimetric device wax printed on Whatman #2 paper

Results

Sample (µL)	Distance Traveled (cm)	Relative Distance (cm/µL)	% Device filled
10	4.2	0.42	44.21
20	7.0	0.35	73.68
30	8.0	0.27	84.21
40	9.3	0.23	97.89



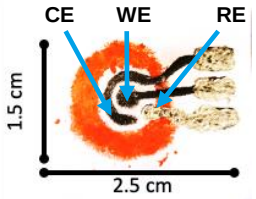
Sample volume optimization for determining ideal channel length

- **Narrow channel width most ideal as long as wax does not melt into channel**
- **Optimal heating time is 2 min in a 300°F oven**
- **Shorter channel lengths are desired to accommodate smaller sample/reagent volumes**
- **Arrow shape has proven to work the best.**
- **Wax printed devices allow for easier optimization than crayon drawn devices**

Optimizations

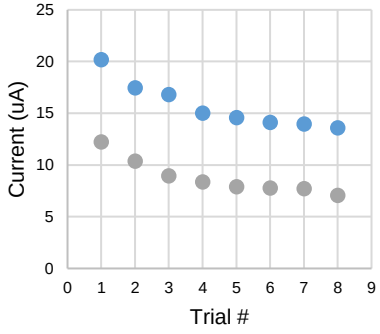
Electrochemical

Electrode size, resistance reduction, paper type, wax heating & thickness, noise reduction, potentiostat parameters



Microfluidic electrochemical device on lined paper, made with 6B graphite pencils, crayons, and liquid silver pen

Results



Signal reproducibility of a single device

Same Sample	13.53%	16.76%	25.63%	27.81%	30.09%	30.79%	32.62%
Replaced Sample	15.07%	26.70%	31.70%	35.38%	36.53%	37.02%	42.34%

Observed percent decrease in signal of 4 mM ascorbic acid in 1.0 M KCl, compared to initial current. Blue points represent the percent decrease during multiple scans of a single sample, while gray points represent sample being replaced between runs. A larger percent decrease was observed when the sample was replaced between runs, likely due to a loss of surface level graphite of the working electrode, resulting in decreased sensitivity.

Reflection & Future Study

- Provides undergraduates w/ method development/validation and research experience, despite limited access to resources, limited device robustness, and slower pace of fabrication/testing
- Future studies will test the devices' sensitivity, limit of detection (LOD), and stability for replicate measurements - through these figures of merit, the devices can then be compared to the traditional spectrophotometer and electrochemical methods in lab
- The devices can be adapted for other analytes – specifically the colorimetric assay will be extrapolated to a Griess assay and electrochemical to other biological molecules

Acknowledgements

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