Utilizing Paper Microfluidics in the Design of Wearable Biosensors

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Abstract

Modern biosensing technology has applications in many fields including, agriculture, mining, health, and fitness. However, the products currently available do not utilize the full potential of the technology. There are not many marketable designs that are affordable, user friendly, and capable of delivering accurate, onsite readings.

The purpose of our work was to successfully fabricate a wearable biosensor that measures the levels of lactate present in human sweat. The primary variables were the width of the lateral assay channels, the volume of the pump's well, and the arrangement of the paper pumps. The optimal result would be a design that transfers a target flow rate of sweat through the lateral flow assays to each well over a consistent period of time. A paper microfluidic approach will be implemented in the design allowing for an affordable and possibly disposable product.

Introduction

Paper microfluidics is an emerging field with a wide range of applications particularly in the development of point-of-care testing. Due to the limitations associated with time, expenses, and travel in many regions of the world, reliable PoC testing via microfluidics presents an opportunity to revolutionize healthcare models in these parts of the world. Paper microfluidics lateral flow assays can be coupled with electrochemical, optical, colorimetric and fluorescent detection processes through nanoparticle enhancements (1) which enable them to be used to sense a host of different analytes. Our work this summer focused on applying these techniques in the design of a colorimetric lateral flow assay for a lactate biosensor.

Why Lactate detection?

The presence of lactate in sweat correlates with muscle exertion (2). There may be a relationship between sweat lactate levels and blood lactate levels(3).

Darcy's law was used in determining the capillary flow in the different microfluidic channel designs throughout the experiment. Two hypotheses were formulated when determining the flow rate of the different microfluidic channels.

1. If the channel width is increased, then the flow rate will increase.
2. If the volume of the well is increased, then the fill time will increase.
3. By manipulating the width and volume of a system of pumps can be designed where each has approximately the same fill time.

Procedure

1. Channels were designed in Solidworks.
2. Both sides of the cut paper channel were covered with adhesive.
3. Design was printed using the Silhouette paper cutter.
4. Adhesive layer was removed from the entry point.
5. Dyed water was dropped on the entry point and timed.
6a. Time was marked at two different points in the channel to determine flow rate
6b. Time was marked when the solution reached the end of the channel.
7. Time was stopped and recorded when it completely filled the well.
8. The process was repeated for a network of pumps.

Data / Observations

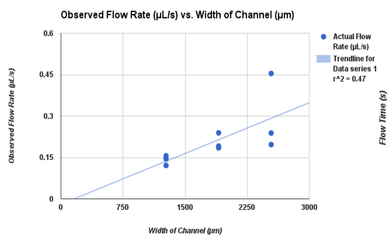

Figure 1: Flow rate vs. channel width.

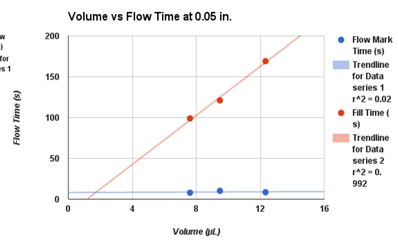

Figure 2: Flow time at channel width 0.05 in.

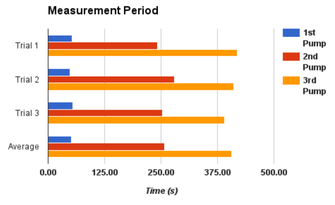

Figure 3: Measurement period.

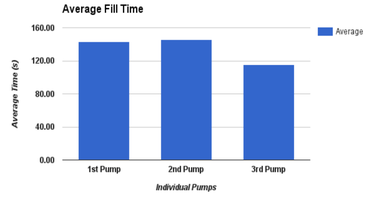

Figure 4: Average fill time.

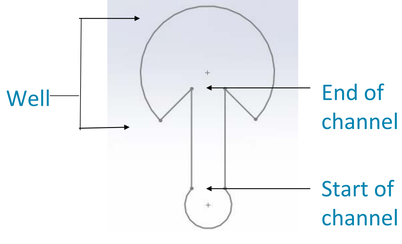

Figure 5: Microfluidic pump.

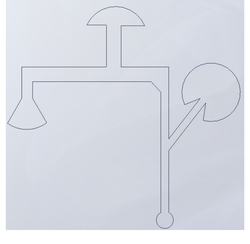

Figure 6: Final microfluidic network design.

Conclusion

Each design had either the shape, size, or configuration of its paper pumps varied so as to determine the effect of each variable on the flow rate of sample solution through the paper pump. There was a clear correlation between the width of the channel and the observed flow rate as seen in Figure 1. The initial hypothesis was supported in that the flow rate increased with the channel width. When keeping the channel width constant it was also observed that there was no change in the flow rate. As a result the time necessary to reach from one end of the channel to the other only increase if the volume of the well increased as seen in Figure 2.

Finally the well volume and channel widths of pumps in a system were manipulated until a combination where each pump had a similar fill time was discovered. The average fill time for each pump in the final design can be found in Figure 4.

Future Directions

1. Coat lateral flow assay with colorimetric indicator
2. Extend pump fill times
3. Increase the consistency of each pumps fill time
4. Analysis of other biochemicals
5. Multiplexing (analysis of multiple biochemicals at simultaneously)
6. Incorporation of multi- layered channels
7. Utilize other detection processes (electrochemical, optical, fluorescent etc.)

Works Cited

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Acknowledgements

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