M-LOC Technologies: Assembly Automation of Microfluidic Chips for Point of Care Diagnostics

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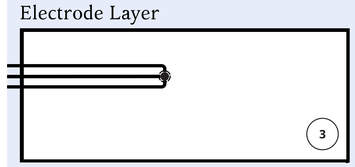
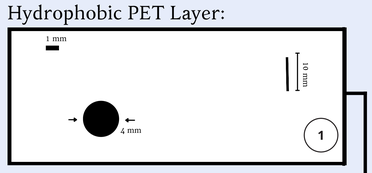
MICROFLUIDIC CHIP - 2D LAYERS

Electrode Layer



Hydrophobic PET Layer:



PSA + PET Layer:

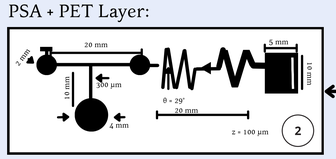


Figure 1: Cortisol Microfluidic Chip Layers. 2D visualization of the three layers involved in the assembly procedure, with PET representing the Polyethylene Terephthalate layer and PSA representing the Pressure Sensitive Adhesive layer.

01. Introduction

Point-of-care testing (POCT) has revolutionized the medical field since its inception forty years ago, providing convenient, fast, remote, and cost-effective diagnostic solutions, expanding its capabilities beyond glucose and pregnancy detection to include a wide range of tests. The development of microfluidic technology in the early 1990's integrated with ultrasensitive biosensors has enabled the automation of sample preparation and analysis, making POCT even more efficient and reliable — with sensitivity detection up to the picogram level! [1]

MICROFLUIDIC CHIP LAYERS AND DIMENSIONS

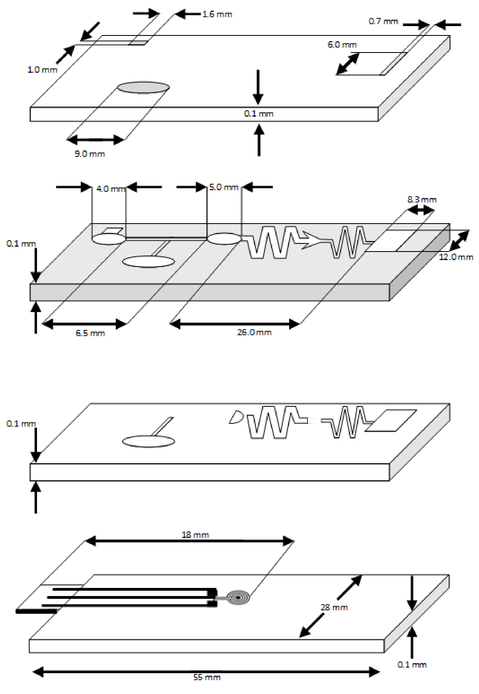


Figure 2: Architectural Diagram

02. Objective

- Develop and test a new microfluidic-based assay that automates the sample preparation steps of immunoassays, including cell filtration, extraction of the target molecule, aliquoting of the sample, mixing of reagents and valving, and on-chip incubation, all in one single chip.
- Determine the scalability and high functional reproducibility of the project by utilizing the Mecademic500® robotic arm for pick and place procedure of the individual micro-chip layers.
- Improve the efficiency and accuracy of immunoassays while reducing the time and cost associated with traditional sample preparation methods.

03. Methodology

Microfluidic Chip

The microfluidic chip design methodology discussed in the text involves the collaboration of both M-LOC Technologies and Dr. Nezhad and his graduate students. The design incorporates the following components:

1. **Computational Fluid Dynamics:** used to verify the initial architecture, and the number of layers, sample size, redox chemical compound using COMSOL Multiphysics.

2. **Manufacturing Process:** involves using a CO_2 laser cutter to fabricate the layers and a bionic robotic arm to automate the pick-and-place assembly process of the microfluidic chip. The design process is iterative, with numerous changes made to the design to address issues found during testing or external design constraints. The final design consists of an arrowhead trigger valve to allow for sufficient antibody-antigen interaction with the electrode layer in the mixing chamber.

BLOCK FLOW DIAGRAM
FLUID FLOW WITHIN THE MICROFLUIDIC CHIP

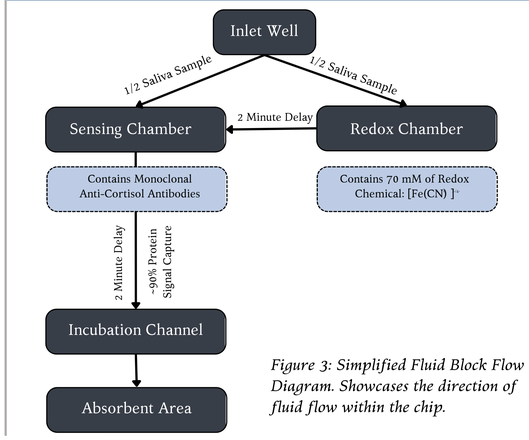


Figure 3: Simplified Fluid Block Flow Diagram. Showcases the direction of fluid flow within the chip.

PROJECT DESCRIPTION - ASSEMBLY PROCEDURE - PRE-SET COORDINATES

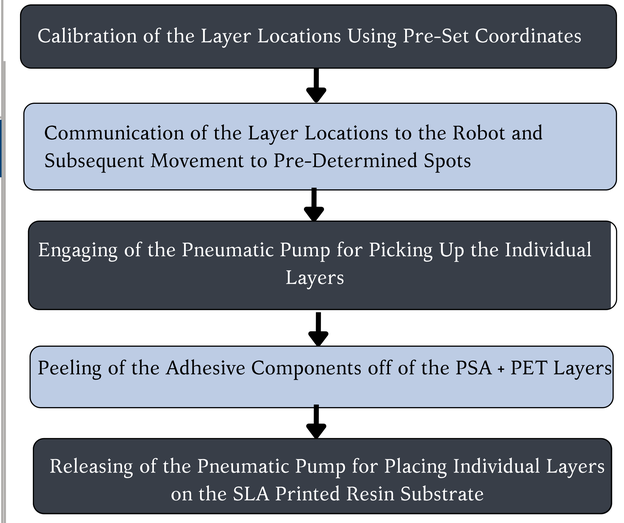
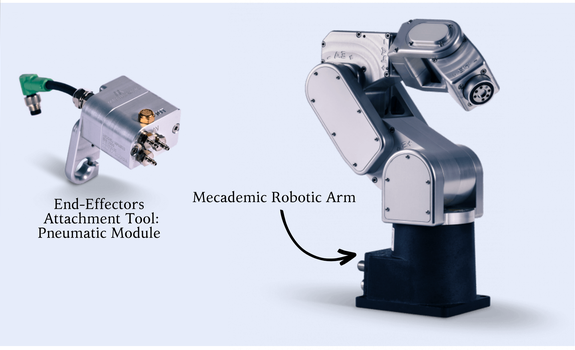


Figure 4 Assembly Procedure High Level Process Flow Diagram. Component breakdown of the methodology behind the automation section of the project. Process is repeated for each microfluidic chip and ends once the chip is assembled.

03. Methodology

Assembly Procedure [2]



To facilitate the communication of the layer numbers and coordinates for accurate transportation and layer manipulation, a Kepner-Tregoe analysis was conducted to determine the most effective method, with the following criteria: accuracy, reliability, development time, generalization, and hardware and software requirements. The following were assessed and ranked:

1. Template matching
2. Pre-trained single shot detector (SSD) region-based convolutional neural network (R-CNN), and
3. Pre-set coordinates.

The pre-set coordinate process was found to be the most reliable and cost-effective choice.

04. Fluid Flow Analysis

The movement of the liquid at different time frames was analyzed to determine the velocity profile of the fluid flow and how it changes over time. This information is particularly important for understanding how the fluid interacts with the walls and structures of the microfluidic chip, which can have significant implications for the performance and accuracy of the chip. An ideal power trend line should initially start off high and then decrease as as the fluid reaches a steady-state flow, allowing for precise control and manipulation of the fluid in the microchannels.

Inlet Well Displacement Profile

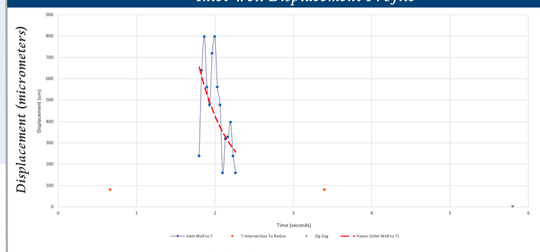


Figure 5: The displacement profile of the saliva sample, depicting the distance traveled by the sample over time, with a linear trendline

Time (seconds)

Inlet Well Velocity Profile

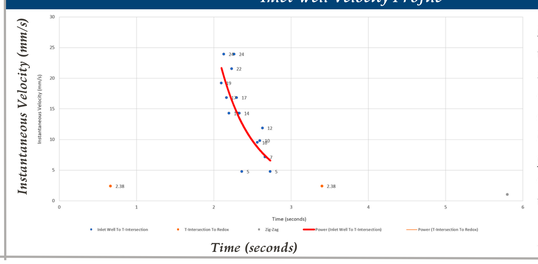


Figure 6: The velocity profile showing a linear decrease in velocity over time, indicating laminar flow and proper capillary action with a peak velocity of 24 mm/s.

Time (seconds)

05. Conclusion

Over the past year of working on the Capstone Project, M-LOC Technologies has successfully completed the following:

1. Chip design involving 3 layers, and a total dimension of 55 mm x 28 mm x 0.3 mm (length, width, and thickness) to test for cortisol levels. Cortisol was chosen as the target protein due to its abundance in saliva and the low comparative costs associated with it, as well as the lack of ethical implications or stigma correlated with it.

2. Full automation of the fabrication process using pre-set coordinates. This approach led to the development of a reliable and accurate assembly process for capillary microfluidic chips, without consuming too much developmental time, and enabling a quick and iterative process to take place. The automation of the layer assembly process will significantly reduce the overall production time and cost, while also enabsemi-scale production of capillary microfluidic chips for point-of-care diagnostics on a scale has never been achieved before.

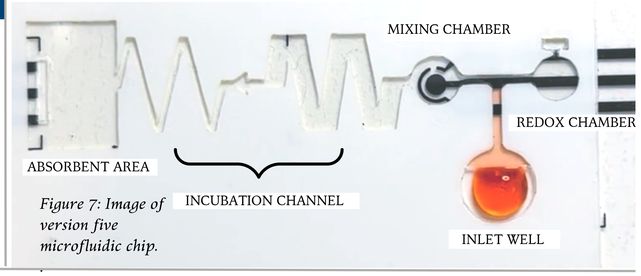


Figure 7: Image of version five microfluidic chip.

06. References

1) Salahandish, R., Hassani, M., Zare, A., Haghayegh, F., & Sanati-Nezhad, A. (2022, March 10). Autonomous electrochemical biosensing of glial fibrillary acidic protein for point-of-care detection of central nervous system injuries. Lab on a Chip. Retrieved March 26, 2023, from https://pubs.rsc.org/en/content/articlelanding/2022/lc/d2lc00025c

2) The world's smallest, most precise and compact six-axis robot arm. Mecademic Robotics. (n.d.). Retrieved March 26, 2023, from https://www.mecademic.com/en/meca500-robot-arm