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Development of a Microfluidic Liquid Dispensing System for Lab-on-Chips †

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Abstract

This paper presents an innovative and low-cost approach to the dispensing of multiple liquids on a microfluidic chip with the aim of dispensing liquids in a controlled sequence. The project focused on the design and development of a microfluidic liquid dispensing system that is an integral part of the Lab-on-Chip (LOC). Liquids are often dispensed into LOCs through blisters, syringes, or electric microfluidic pumps, but these can be impractical for Point-of-Care (POC) settings, especially in remote areas. Additionally, incorrect volumes of biochemical reagents and the introduction of reagents outside the sequence can distort the results of the diagnosis. The process undertaken involved designing and 3D printing prototypes of the dispensing system, along with laser cutting and manufacturing the Polymethyl Methacrylate (PMMA) LOC devices intended for receiving the liquids. The proposed novel low-cost dispensing system uses manually operated actuators and cams to disperse metered fluids sequentially to minimise end-user errors at POC settings.

Keywords: liquid dispenser; microfluidic dispenser; lab-on-chip; blister pack

1. Introduction

Microfluidic devices miniaturise lab processes into micro-processes of chemical reactions that separate and detect biochemical compounds using small volumes of samples and reagents, that flow through micro-channels and cavities incorporated on the LOC device, normally not larger than a credit card [1]. This microfabrication has revolutionised the fields of biology and chemistry by making it possible to produce structures on a microliter scale [1]. These miniaturised structures are a platform where microchemical reactions occur using microliters of sample volume [1]. Laboratory microfluidic systems use laboratory pressure pumps or syringe pumps as instruments to distribute these microliter volumes in a microfluidic device [2]. A laboratory syringe pump system uses syringes that must be mounted on a rack and connected to the device using microfluidic tubes [2]. Multiple liquid dispensing may require more than one syringe to facilitate microprocesses of mixing, incubation, and reactions in a microfluidic device to detect and diagnose pathogens [3]. By automating and combining various laboratory processes, LOC devices offer a versatile tool for POC diagnosis [4]. Given that the application is in POC, it can be expected that medical personnel have limited facilities and laboratories, highlighting the need for low-cost microfluidic-based POC diagnosis on a larger scale [5].

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2. Materials and Methodology

2.1. Design and Fabrication of Components

The origin of the design was created through brainstorming sessions where freehand sketches were drawn and further refined to produce the final concept, which was then modelled on Solid Edge 2023 CAD to produce stereolithography files (STL) for 3D printing (Figure 1 on Formlabs, Form 3B+, using Formlabs White Resin at a layer thickness of 0.05 mm. After removal from the printer, cleaning, and curing; the printed parts were assembled into a microfluidic chip with an embedded blister pack.

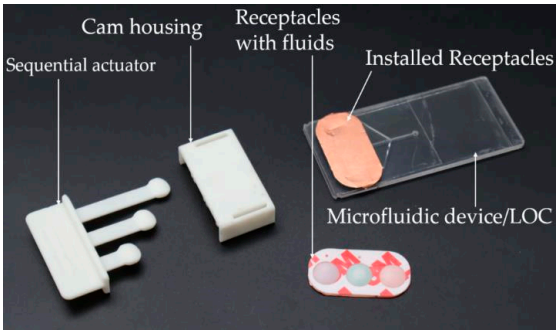


Figure 1. 3D printed dispenser and laser cut LOC prototype.

2.2. System Configuration

The liquid dispensing system is designed to have two components. The main component is the cam housing (Figure 2a), which serves as a guide to align each liquid blister with an actuator for the sequential release of fluid into the microfluidic device. The second component is the actuator (Figure 2b), which has three spoon-like elements, each with a length difference of 11.2 mm from the other. These align with the cams on the main component. When the spoon-shaped element is pushed, it moves along the cam shape. The fluid storage used in this prototype has three receptacles, each containing 55 µL of volume. The central distance between the cams and the floor of the receptacle is equal to the height of the actuator; see Figure 2c. The shape of the receptacle conforms to the shape of the actuator as it is pushed through. Therefore, the actuator exerts pressure on the sealing film, and the liquid is forced through the channels into the LOC. The actuator fits in the cavity of the receptacles for maximum volume control and sustained pressure to drive fluid into the channels.

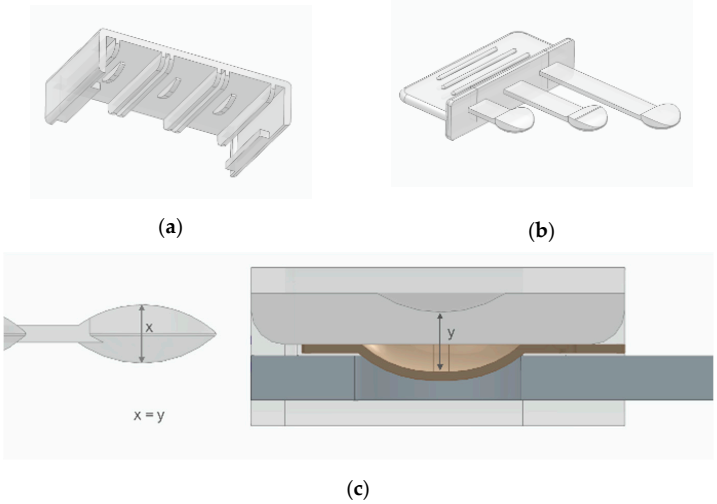


Figure 2. (**a**) CAD view of the cam housing. (**b**) Spoon-like actuator elements. (**c**) Section view of the liquid dispensing system.

2.3. Control Mechanism

The flow rate of the fluid is controlled by the force exerted manually by the user's hand operation. The higher the force with which the actuator is inserted, the higher the flow rate of the fluids dispensed. In addition, the liquid dispensing system can be designed for different liquid volumes and dispensing sequences. This eliminates the risk that an end-user dispenses incorrect volumes. The distance between each spoon-shaped element (Figure 3a) determined the dispensing time for each receptacle. In the prototype (Figure 3b), the LOC has three channels connected to each receptacle. The channels are arranged in three parallel arrays spaced 12 mm apart, and finally converge into one channel.

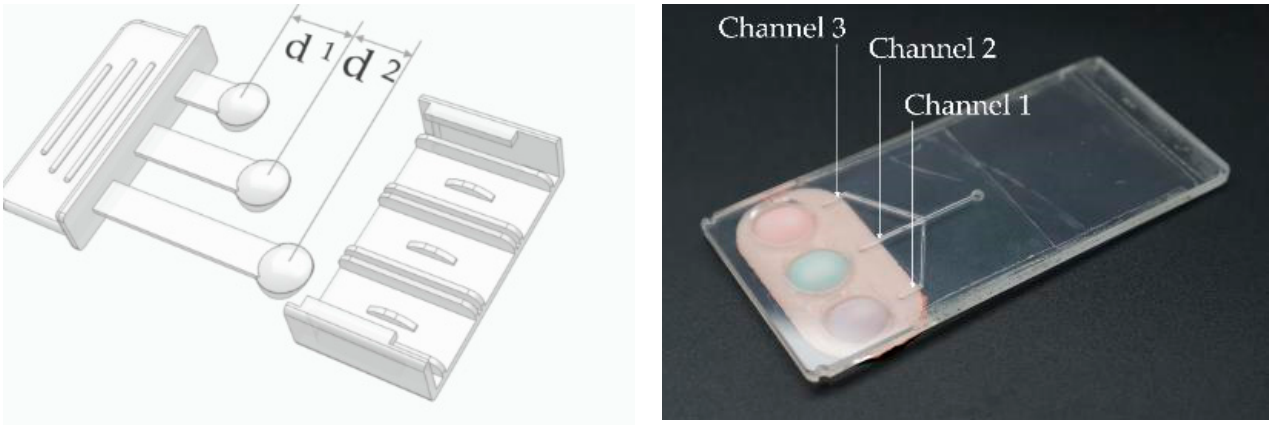


Figure 3. (**a**) Actuator precision spacing; (**b**) View below of the LOC prototype.

3. Results and Discussion

Multiple prototypes were produced by 3D printing and tested using food-coloured water as liquid. As shown in Figure 4, three and two liquid dispensing tests were concluded. The system works and sufficient pressure from the spoon and cam system results in the dispensing of the liquid into the microchannel of the LOC in the set sequences. This low-cost point-of-care liquid dispensing system offers great opportunities for integration into various and complex diagnostic processes implemented on a LOC.

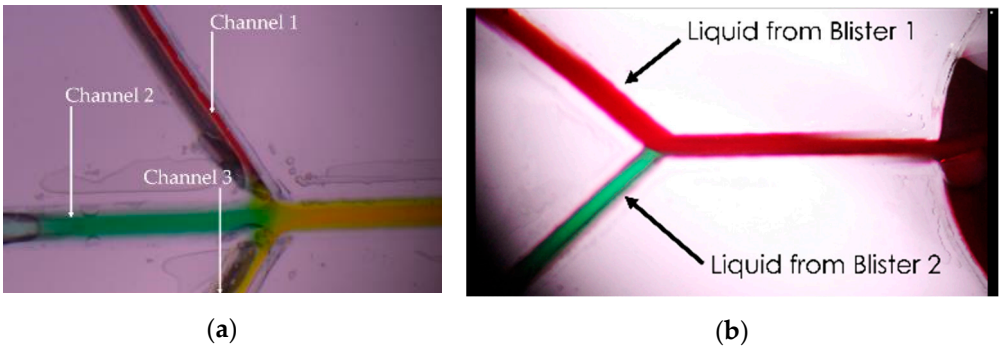


Figure 4. (**a**) Three receptacle dispensed fluid; (**b**) two fluids dispersed in the receptacle.

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