ABSTRACT

Here we present and demonstrate the concept of a versatile ‘human-powered’ cell encapsulation system for a wide variety of droplet-based point-of-care diagnostics applications. Several distinctive accomplishments have been achieved: (1) human finger as the actuation force for droplet generation, (2) integrated pump actuating both water and oil fluid at the same time, and (3) forming microdroplets containing cells with the T-junction microchannel. For the first time, we successfully demonstrated the formation of water droplets in oil by a human finger with average size of 120µm in diameter, and encapsulated cells in the microdroplets.

KEYWORDS: Cell Encapsulation, Micropump, Microdroplet, Point-of-Care Diagnostics, Microfluidics, Lab-on-a-chip

INTRODUCTION

Human cells are full of information reflecting the body health condition. Cell encapsulating microdroplet technology holds great promise for diagnostic purposes such as allergic response or cancer screening [1-5]. For cell encapsulation, however, droplet formation is necessary and precise control of the flow inside a microchannel for droplet formation requires bulky and power-hungry pumps, which remains as a bottleneck for practical point-of-care applications. To overcome these challenges, we have previously reported a finger-powered pump system that can generate pressure to pump fluid into microfluidic devices [6], and a portable finger-powered microdroplet generator utilizing this pump [7]. Here, we propose and advance the technology by demonstrating a low-cost and easy-to-operate finger-powered cell encapsulation system that is capable of forming droplets containing cells without any electricity.

THEORY

Figure 1 illustrates the basic concept of the finger-powered cell encapsulation system. The finger-powered pump has a deformable chamber which can be activated by a human finger to infuse water and oil fluids simultaneously for the formation of droplets containing cells. Figure 2 shows the design details of the device, consisting of four major components: (i) a pressure chamber (1cm in diameter) as the pressure generator to pump fluids, (ii) one safety valve and several one-way diode-type valves to regulate the flow [8, 9], (iii) filters to prevent unnecessary particles such as dust, and (iv) a T-junction [10] that has a 100µm -wide main channel for the oil fluid and a 50µm -wide subchannel for water and cells to form microdroplets. By repeating the push-and-release sequence at the pressure chamber using a human finger, cells and oil are continuously pumped into the T-junction. Fluidic diodes prevent backward flows to the inlets by positive pressure, and Diode valves prevent backward flow to the sample storages by negative pressure. Due to the difference of the fluidic resistance, faster oil flow cuts out slower water fluids to generate microdroplets and encapsulate cells inside microdroplets. Generated droplets containing cells are transferred to the outlet through observation chamber for following experiments.

Figure 1: Concept of the finger-powered cell encapsulation system. All the inlets are connected to the pressure chamber that generate pressure and pump fluids when pushed by a human finger. Cells are encapsulated in the form of microdroplets generated by flows with different speeds of flows of water and oil at the T-junction.
Figure 2: Design details of the device. Cells/water and oil inlets are connected to a single pressure chamber via sample storage wells. By repeating the push-and-release sequence using a human finger on the pressure chamber, sample solutions are guided from inlets to the T-junction section. Diode valves and fluidic diodes are used to prevent the backward flow when the pressure from finger is released. At the T-junction section, droplet solution is cut by the faster oil flow to form micro-droplets containing cells, which flow to the observation chamber.

FABRICATION

Figures 3a-h show the fabrication process. We utilized common soft lithography process with SU-8. SU-8 droplets are used to form the pressure chambers and sample storage chambers. The device is made of three layers of poly (dimethylsiloxane) (PDMS) including the PDMS membrane with a thickness of 40µm for valves. The layers are permanently bonded with the assistance of oxygen plasma. Figure 3i shows the fabricated, 3.0cm-long, 2.5cm-wide, and 0.8cm-thick prototype device.

RESULTS AND DISCUSSION

The capability in encapsulating cells by human finger is experimentally verified. First, we formed red-color water droplets in Hexadecane. We added Span 80 into Hexadecane (10% v/v) to prevent the merge of droplets. Water and oil fluids were infused at once by the push-and-release sequence at the pressure chamber and water droplets were formed at the T-junction (Fig. 4a). We measured that the average diameter of the droplets was 120µm at the observation chamber which had wider channel width (2500µm).
Next, we encapsulated bovine aortic endothelial cells (BAEC) in Dulbecco’s modified Eagle medium (DMEM) supplemented with 10% FBS. We put yellow dye to the medium for better visibility. With the same experimental procedure, we infused Hexadecane with Span 80 from oil inlets and medium with BAEC from water inlets with the push-and-release sequence. DMEM droplets containing cells were formed as shown in Figure 4b.

**CONCLUSION**

A finger-powered cell encapsulation system has been developed. With this device, we have successfully generated microdroplets containing BAEC cells inside DMEM medium by a human finger. As our device has another inlets connected with cell inlets, it is possible to mix chemicals or reagents with cells and observe their chemical response in a closed droplet. We believe that this portable and easy-to-operate cell encapsulation system holds great potential in quick and low-cost point-of-care diagnostic applications.

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**REFERENCES**


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