ENCAPSULATING BEADS/CELLS IN UNIFORM-SIZED DROPLETS ON A MICROFLUIDIC CHIP UTILIZING HYDROPHILIC MODIFICATION OF A SURFACE

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ABSTRACT

In this study we present a simple method to encapsulate beads or cells in the droplets on the microfluidic chip. The proposed chip integrates surface modification technique and pneumatic components, the droplets are formed directly without cross contamination of the carrier buffer. Therefore, the superfluous sample is recycled, which significantly reduces the sample consumption. Moreover, Beads and cells are encapsulated in a generated droplet and fixed in a defined area ready for assay and observation. Due to the advantages, this chip is promising to realize facile and reliable platform for biological and chemical applications.

KEYWORDS: Droplet Generation, Cell Encapsulation, Digital Microfluidic

INTRODUCTION

Droplet-based microfluidic systems have been a powerful tool for biological and chemical applications [1]. These devices can produce monodisperse droplets in the nanometer to micrometer range, rates of up to thousand per second. Due to high surface area to volume ratios at the microscale, heat and mass transfer times and diffusion distances can be greatly decreased [2]. As a result, droplets can be generated, processed, and analyzed within a few seconds. However, many biological analyses and chemical synthesis do not require large throughput but need greater control during sample reaction, such as cell culture/assay and nanoparticle synthesis [3, 4]. In order to address the needs of these applications, we present a new microfluidic system for droplet generation in the defined area. Our simple method uses an array of hydrophilic area well defined to generate droplets of uniform size to encapsulate beads or cells. Relative to a conventional droplet-based microfluidic system, the proposed chip offers advantages: droplets can be formed directly without additional control for droplet generation upstream (e.g. T-junction or flow focusing); droplets of varied size caused by an unstable inlet flow are avoidable; superfluous sample can be recycled without cross contamination of the carrier buffer (e.g. oil), which can significantly decrease sample consumption; beads or cells can be encapsulated in a generated droplet and fixed in a defined area ready for assay and observation. Through these particular characteristics, this method can become a key essential in droplet-based microfluidic applications such as cell culture or analysis and rare sample detection.

WORKING PRINCIPLE

Figure 1 shows the operating principle of the proposed chip. A buffer medium containing the beads or cells is injected into the chip (Fig. 1(a)); after withdrawal of the buffer medium, the droplets encapsulating beads or cells are formed in the hydrophilic area (Fig. 1(b)). Superfluous sample can be recycled without cross contamination. To collect the droplets, the carrier oil is firstly injected into the liquid channel. On adjusting the operating frequency and air pressure to vibrate the PDMS membranes, the droplets become lifted (Fig. 1(c). All droplets are then carried by the carrier oil and collected in a reservoir.

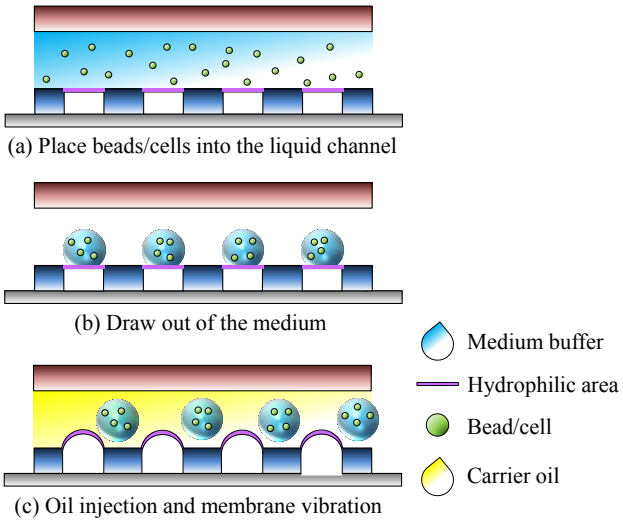


Figure 1: Schematic illustration of an experimental procedure for rapid generation of droplets encapsulating beads or cells.

EXPERIMENTAL

Figure 2 illustrates schematically the proposed chip, which comprises two PDMS layers – a thick-film liquid channel and a thin-film pneumatic component, and one glass substrate. Figure 3(a-d) is a schematic representation of the microfabrication of this chip using CNC machining and PDMS replication. We used a solution of poly(ethylene oxide)-poly(propylene oxide)-poly(ethylene oxide) triblock copolymer (Pluronic P123, MW 5750, 2.5 % w/v) in 99 wt% aqueous ethanol to modify part of a PDMS surface with hydrophilic functionality [5]. The experimental results show that droplets formed in only the modified areas (Fig. 3(e)). Figure 4 presents a photograph of the proposed chip. The dimensions of the microfluidic chip are 1.6 cm x 3.3 cm.

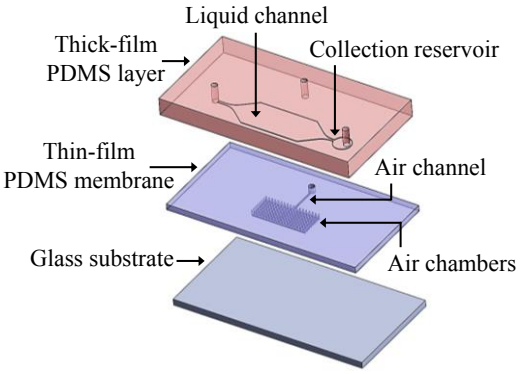


Figure 2: Schematic illustration of the droplet generation chip.

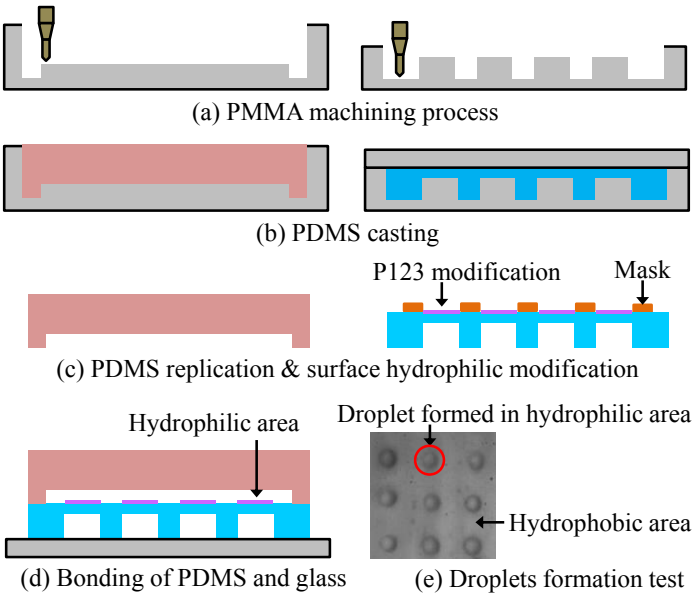


Figure 3: (a-d) Fabrication of the microfluidic chip, (e) Formation of a droplet array in a microfluidic channel using hydrophilic modification of the surface.

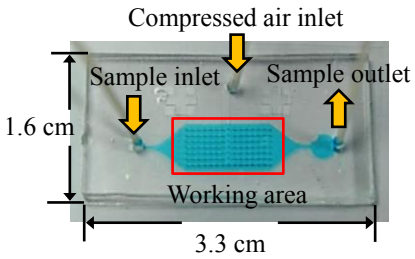
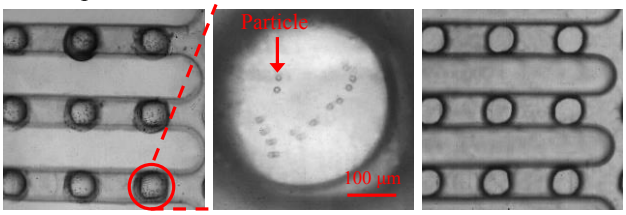


Figure 4: Photograph of the proposed chip of dimensions 1.6 cm × 3.3 cm.

RESULTS AND DISCUSSION

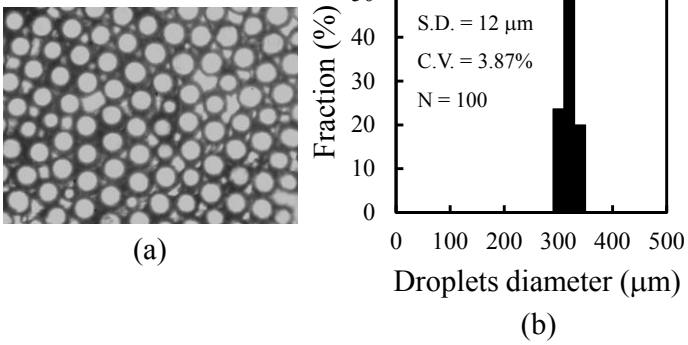
Droplet generation and particle encapsulation are demonstrated in Figure 5(a). Figure 5(b) is a magnified view of the droplet encapsulating the particles. Among 144 defined areas in the chip, 140 areas form a droplet with generating efficiency 97.2 %. All formed droplets are collected at the outlet as operated at frequency 20 Hz, pneumatic pressure 100 kPa and rate 35 µL/min of flow of mineral oil. Figure 5(c) shows the working area after oil washing. Figure 6(a) shows a photograph of droplets collected in a reservoir observed with an optical microscope. Figure 6(b) shows

histograms of the size distribution of droplets shown in Figure 6(a); the average diameter is measured to be 320 μm with variation 3.87 %. In total 100 droplets were counted.



(a) (b) (c)

Figure 5: (a) Generation of droplets encapsulating beads in the proposed chip, (b) Magnified view of the droplet, (c) After oil washing to remove droplets.



(a) (b)

Figure 6: (a) Photograph of droplets in the collection reservoir observed under an optical microscope, (b) Distribution of droplet size -- mean diameter 320 μm and C.V. 3.87 %.

CONCLUSION

We have successfully demonstrated a new microfluidic chip capable generating of uniform-sized microdroplets to encapsulate particle utilizing a surface modification technique and pneumatic components. Rapid and sample fabrication methods involving CNC machining and PDMS replication process were employed for the formation of the proposed chip device. Experimental result show that among 144 defined areas in the chip, 140 areas form a droplet with generating efficiency 97.2 %. Average diameter of the droplets is measured to be 320 μm with variation 3.8 %. This chip has the potential to provide novel solution for biological and chemical applications.

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