A HYBRID MICROFLUIDIC CHIP FOR DIGITAL ELECTRO-COALESCENCE OF DROPLETS

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ABSTRACT

We describe a universal mechanism for merging multiple aqueous microdroplets within a flowing stream consisting of an oil carrier phase. Our approach involves the use of both a pillar array acting as a passive merging element as well as integrated electrodes acting as an active merging element. The pillar array enables slowing down and trapping of the droplets via the drainage of the oil phase. This brings adjacent droplets into close proximity. At this point, a low electric field is applied to the electrodes which breaks up the thin oil film surrounding the droplets and subsequently results in merging.

KEYWORDS: electro-coalescence, droplet microfluidic

INTRODUCTION

In the past decade, droplet based microfluidic systems have drawn much attention in the scientific community [1]. For example, it has recently been shown that reactions and biological assays within these small nano- to pico- litre sized droplets can be performed and detected on a microsecond time scale. Within such applications, one often requires fusion or mixing of droplets in order to perform reactions or to complete assays. With this in mind, reproducible and selective merging of droplets is needed in order to ensure precise and accurate delivery of a particular analyte or solvent [2-5].

In this paper, we combine the advantages of both active [2,3] and passive [4-6] merging approaches, to create a novel merging element which can merge droplets regardless of droplet content. Significant advantages of our approach include the capability of adjusting the inter-droplet distance in a facile manner, precisely control the number of droplets being merged, and achieve efficient merging under high surfactant concentrations.

DESIGN&EXPERIMENTAL

Figure 1 illustrates a schematic of the fluidic chip design. The fluidic channels have a 50×50 μm rectangular cross section and dilate to a width of 250 μm. This wider chamber is effectively the heart of the 'merging element'. This chamber consists of two parallel pillar arrays. The size and location of the pillars were designed to ensure that droplets of similar size can be slowed down and trapped between the two sets of pillars. The pillars have a 20 μm square cross section and a pitch of 36 μm. Also embedded within the merging chamber are two parallel indium tin oxide

978-0-9798064-2-1/μTAS2009/$20

(ITO) electrodes, which were integrated onto the lower substrate. These electrodes were designed to run perpendicular to the pillars.

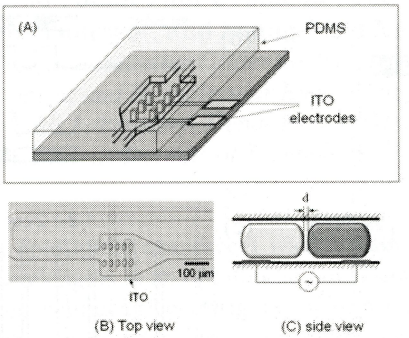

Figure 1: Schematic view of the microfluidic merging element. A PDMS channel layer was bonded onto patterned ITO glass to form the microfluidic chip. Droplets generated upstream were directed into the merging chamber and were trapped and merged inside. The channel height is 50 um.

RESULTS AND DISCUSSION

Figure 2 shows an optical image of the microfluidic device during operation. The mechanism can be described as follows. Firstly, a droplet enters the pillar array and is trapped. Secondly, without applying an electric field, the second droplet pushes the first one out of the merging chamber without merging. When an electric field is applied, the two droplets merge within a 1 millisecond timescale. Finally, the newly formed big droplet is pushed out of merging chamber due to the hydraulic pressure.

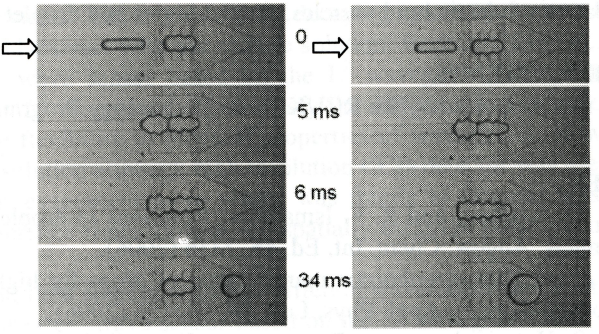

Figure 2. The merging device during operation. (a). in the absence of electric field, droplets get in close proximity but do not merge. (b). with electric field, the two droplets coalesce. Hexadecane was used as the continuous phase and DI water was used as the discrete phase. Span 80 (0.1 w/w/%) was used as the surfactant.

This chip was used along with a real-time feedback routine to control the merging process digitally as shown in Fig. 3. Such system can output arbitrary sequence of big and small droplets.

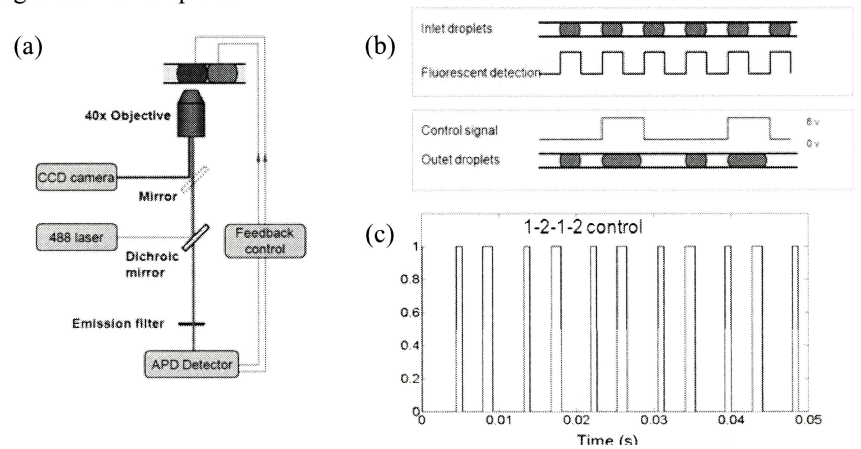

Figure 3. Selective merging of droplets. (a) Schematic view merging using a real-time feedback routine. (b) The process of detection and signal output. (c) Detected optical signal at the outlet of the merging chamber for different control sequences.

CONCLUSIONS

We have engineered a system capable of selectivly merging one or more micro-droplets. The hybrid platform exploits the advantage of both passive and active merging mechanisms. The chip was designed to permit low voltage coalescence events. The platform will prove especially useful when surfactants have to be added to the carrier oil. Potential applications include sequential chemical/biological reactions, manipulation of elastic lipid vesicles, droplet logics and droplet sorting.

ACKNOWLEDGEMENTS

This work was supported by the RCUK Basic Technology Programme.

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