PRECISE CONTROL OF TRAPPING/RELEASE OF INDIVIDUAL LABEL-FREE DROPLETS IN COMB-SHAPED MICROFLUIDIC CHIP USING MAGNETIC REPULSION

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ABSTRACT

An improved magnetic repulsion-actuated method is presented for precise control of trapping and release of individual picoliter droplets in comb-shaped microfluidic chip. The initial distance between droplets and microwells are same and maximized by forcing droplets to flow along a straight microchannel wall, making single droplet easier to be selected and trapped into designated microwell. Trapped droplets are isolated from ferrofluid by utilizing the effect of laminar flow between ferrofluid and mineral oil, effectively reducing undesired interference from magnetic repulsion to adjacent droplets. Moreover, ferrofluid can be completely displaced by mineral oil for eliminating adverse effects from surfactants.

KEYWORDS: Droplet, Trapping/Release, Microfluidic Chip, Magnetic Repulsion

INTRODUCTION

Picoliter water droplets play an important role in miniaturized chemical and biological research due to their excellent properties such as less samples/reagents consumption and faster time-to-results. Because they are usually tiny, soft and evaporating rapidly resulting from high surface area to volume ratio, conventional methods such as pipettes/syringes are difficult to obtain and manage them effectively. Recently, thanks to the fast development of microfluidics, these droplets can be manipulated effectively by combining microfluidic chip with kinds of external energy fields involving valve-, electricity-, light-, surface acoustic wave-, and magnetism-actuation,[1] Because the magnetism-actuation is independent of solution dielectric/optical/ionic-strength properties and easy to operate, it has recently attracted much more attentions.[2] In most models, however, droplets should be labeled with magnetic materials in advance in response to external magnetic attraction,[3] resulting in detection of nontransparent solution and potential interference from magnetic materials. Most recently, we reported a method of magnetic label-free droplet manipulation by magnetic repulsion.[4] Compared to the way of magnetic label droplet manipulation, this method has many advantages such as no magnetic labeling process, detection of transparent droplet and no interference from magnetic materials. Herein, an improved method is presented for more precise control of trapping and release of individual picoliter droplets by magnetic repulsion.

EXPERIMENTAL

The PDMS microfluidic chip (Figure 1) was designed and fabricated containing three inlets (ferrofluid, water and mineral oil), a comb-shaped microstructure (1 straight microchannel and 20 microwells) and an outlet. The depth of microstructure was 100 µm. In order to facilitate obtainment of external magnetic field gradient provided by combinational NdFeB magnet (1, 2 and 5 mm diameters, with a surface magnetic flux of 100-300 mT), two pieces of rectangle PDMS near the microwells and straight microchannel were respectively removed. The nearest distance between microstructures and chip edge was 0.4~0.8 mm. Fluids were controlled by precision syringe pump (Harvard Apparatus, America).
Figure 2. Removal of air bubbles and loading of ferrofluid/mineral oil in comb-shaped microstructure.

Figure 3. (a) Precise trapping and release of single-droplet orderly by magnetic repulsion and rapid exchange of oil-phase. (b) Precise trapping and release of single-droplet arbitrary. (c) Droplet arrays containing identical concentration FITC and corresponding fluorescence intensity profiles across dashed white line.
RESULTS AND DISCUSSION

After air in the straight microchannel was displaced by ferrofluid, generated mother bubbles in microwells were divided into several daughter bubbles by external pressure for easier removing them by magnetic repulsion (Figure 2). Because the carrier of ferrofluid was composed almost purely of mineral oil, ferrofluid could be easily and completely exchanged with mineral oil (Figure 2) and both of the two oil phases could form a stable laminar flow in the straight microchannel (Figure 3a). Picoliter water droplets were generated by shear force of ferrofluid in a typical microfluidic T-junction. The initial distance between droplets and microwells are maximized (~400 µm) by forcing droplets to flow along the straight microchannel wall, making single droplet easier to be selected and trapped into the designated microwell (Figure 3a). Trapped droplets are isolated from ferrofluid by utilizing the effect of laminar flow between ferrofluid and mineral oil, effectively reducing undesired interference of magnetic repulsion to adjacent droplets (Figure 3a). With external magnetic field gradient applied, single-droplet could be precisely trapped and released orderly (Figure 3a) and arbitrary (Figure 3b). After trapping of droplets, ferrofluid was rapidly exchanged with biocompatible mineral oil within 10 seconds and droplets still remained in microwells safely, highly eliminating possible adverse effects from surfactants into ferrofluid. With the advantages of precise positioning of single-droplet into designated microwell and transparent detection of droplet, static droplet arrays-based fluorescence analyses could be well implemented (Figure 3c).

CONCLUSION

A magnetically controlled method for precise trapping and release of individual magnetic label-free picoliter droplets is presented. Because magnetism-actuation is independent of solution dielectric/optical/ionic-strength properties and easy to access, this technique can be used for various droplet-based miniaturized biochemical analyses including static droplet assays and real-time detection.

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REFERENCES


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