Research on Microfluidic Chip Design and Droplet Related Technology

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Abstract. Microfluidic Chips, also known as chip labs, integrate basic operating units in the fields of chemistry and biology on a chip. The droplet is a technique for controlling a small volume of liquid on a microfluidic chip. One of the two incompatible liquids is used as one continuous phase and the other as a dispersed phase, and the dispersed phase is dispersed in a continuous phase in a micro volume unit. Droplet fusion is the basic tool for controlling droplets in microfluidic devices and their use as microreactors, allowing precise mixing of reagents and fusion of samples at well-defined points in space and time. This topic is based on microfluidic technology, designed and processed PDMS chip, research on droplet generation and droplet fusion technology in microfluidic chip. Using a constant pressure pump designed by the laboratory to drive the sample injection, study the effects of continuous phase, discrete phase convergence angle, flow path width, liquid flow rate, etc. on the droplet formation of the cross-shaped structure. Based on the droplet generation technology, the subject then studied the droplet fusion technology, completed the droplet fusion chip design and processing, and achieved 1:1 1:2 fusion of two sample droplets.

Keywords. Microfluidic Chips; PDMS; Droplet; Droplet fusion; Constant pressure pump

1. Introduction

Microfluidic Chip, also known as the chip lab, integrates or basically integrates basic operation units such as sample preparation, reaction, separation, detection, and cell culture, sorting, and lysis in the fields of chemistry and biology. On a chip of a few square centimeters (or even smaller) \cite{1}, Droplets are a technique for manipulating tiny volumes of liquid on a microfluidic chip. Its formation is similar to the emulsification phenomenon. The droplets are generated on the microfluidic chip, and the two incompatible liquids are used as one of the continuous phase and the other as the dispersed phase, and the dispersed phase is dispersed in the continuous phase as a micro volume unit to form a liquid. Drop \cite{4}.

Droplet fusion is the basic tool for controlling droplets in microfluidic devices and their use as microreactors, allowing precise mixing of reagents at a well-defined point in space and time, fused to the sample \cite{4}.

This topic is based on microfluidic technology, designed and processed PDMS chip, research on droplet generation and droplet fusion technology in microfluidic chip.

2. Materials and Methods
2.1 Chip design and processing

![Diagram of chip design and processing]

**Figure 1.** Chip production process: design chip graphics, mask production, exposure, development, mold making, pouring PDMS, stripping, punching bonding, channel treatment.

This topic uses cad drawing software, design chip structure, process mask, make mold, process PDMS chip. It is divided into two major steps: wafer mold fabrication, PDMS casting molding. First, silicon wafer mold production:

Mold making process: Silicone coating -> Exposure development -> Silicon etching -> Degumming cleaning.

Silicon wafer coating: 1 Wafer pretreatment: acetone cleaning, nitrogen drying. 2 Select the appropriate size tray, put the silicon wafer on the tray, open the vacuum pump and test whether the silicon wafer is fixed. 3 Take the photoresist with a dropper and cover the silicon wafer. 4 Set the spin speed and time, run the program, and take out the silicon wafer after the end. 5 Before baking, the silicon wafer is moved to the set hot plate before baking.

Exposure development: 1 Place the lithography mask device on the exposure machine and fix the mask (the mask needs to be designed and processed). 2 Put the dried silicon device into the exposure machine tray, set the exposure machine program, set the exposure mode and exposure time, and perform exposure. 3 Development, the exposed silicon wafer is treated with developer, and the development process is slightly shaken. 4 Deionized water cleaning, nitrogen drying. 5 Post-baking, drying on a hot plate with a set temperature.

PDMS casting molding: 1 PDMS -> Pouring -> Binding -> Reinforcement, punching, dicing

1 PDMS: Curing agent=5:1 Remove the PDMS in a clean small beaker, take out the curing agent in a test tube, mix and mix, stir for more than 10min, place in a centrifuge, set 3000 rpm for 5 min, mix PDMS and curing agent. 2 Pour the mixed PDMS on the silicon mold, put it in the vacuum chamber and vacuum it, no bubbles appear on the PDMS surface. 3 After vacuuming, place the mold on a 100-degree hot plate, remove it for 30 minutes, and carefully remove the solidified PDMS from the mold.

Bonding, reinforcement, punching, dicing: 1 First treat the PDMS, glass or quartz with an O2 plasma cleaner, then place the PDMS and quartz into the bonder and run the bonding program. 2 At the entrance of the PDMS chip, the outlet is thickened. A thickness-determined, uniform PDMS film was produced. Prepare the silicon wafer to be fixed on the spinner tray, pour the prepared PDMS liquid, set the rotation...
speed of the specified thickness, and perform the spin coating procedure. The wafer was placed on a hot plate at 100 °C for 10 minutes and the PDMS film was carefully removed. 3 bonded film and PDMS chip, baked at 70 °C, can achieve permanent bonding. 4 punching: puncher.

2.2 *Research on Technology of Droplet Generation and Droplet Fusion*

![Figure 2. Droplet experiment system: a constant pressure driven pump is used to drive the liquid injection, and the droplet experiment is carried out in the microfluidic chip to collect the droplet analysis experiment results.](image)

Three kinds of droplets of 45 degrees and 90 degrees and 135 degrees were designed to form a crisscross structure. The effects of continuous phase and discrete intersection angle on droplet size and stability were studied. Then, the flow velocity of one of the phases is kept unchanged, and the gradient is changed to observe the change of the droplet formation. By reading the literature, reference design droplet passive fusion chip structure, active fusion chip structure, based on the stable generation of droplets, realize 1:1 1:2 fusion of two kinds of sample droplets, and analyze and summarize the droplet fusion experiment. The chip structure and liquid flow rate, the effect of droplet formation speed.

3. **Results and Discussion**

This chapter mainly discusses the results and analysis of droplet formation and droplet fusion experiments, observes the influence of experimental factors on experimental results, analyzes experimental schemes, and the advantages and disadvantages of chip structure design.
3.1. Droplet generation

**Figure 3.** Keep the oil phase 400mbar constant, increase the water phase gradient. 150-300mbar, \( \Delta = 50 \text{mbar} \).

From Fig. 3 we can see that the oil phase pressure is kept constant. When the water phase is increased from 150 mbar to 300 mbar, the droplet formation rate is increased, the droplet volume becomes larger, and the pitch becomes smaller.
As can be seen from Figure 4, the water phase is maintained at 100 mbar and the oil phase varies from 200 to 400 mbar. The droplet formation rate is increased, the droplet size becomes smaller, and the pitch becomes larger.

3.2. Droplet fusion
Figure 5. Droplet fusion chip design, including 2 droplet generation modules, 2 oil phase retardation modules, and droplet collection ports.

Figure 6. 2 sample droplets confluence. Achieve 1:1 1:2 convergence of 2 sample droplets. Figure 6 shows the precise control of droplet fusion in this subject. The reaction volume of different samples and the reaction time are proportionally controlled. The following is to control the fusion of two sample droplets.

Figure 7. The ratio of the two sample droplets is fused in a ratio of 1:1 1:2.
It can be seen from Figure 7 that for the two sample modules, the subject achieves a 1:1 1:2 droplet fusion, and a wider range of proportional fusion can be achieved by adjusting the experimental conditions.

4. Conclusions References
There are experimental data to draw conclusions. For the droplet formation experiment, when the oil phase pressure is kept constant, the water phase is increased, the droplet formation rate is increased, the droplet volume becomes larger, and the pitch becomes smaller. When the water phase pressure is kept constant, the oil phase pressure is increased, the droplet formation rate is increased, the volume is reduced, and the pitch is increased. This project has achieved the realization of proportional fusion of sample droplets based on two stable droplet generation modules.

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