

A NEW MICROFLUIDIC DEVICE FOR FORMATION AND SWITCHING OF MICRO-DROPLETS

Chen-Yi Lee¹, Yen-Heng Lin² and Gwo-Bin Lee^{1,2,3*}

¹*Institution of Nanotechnology and Microsystems Engineering,* ²*Department of Engineering Science, National Cheng Kung University, Tainan, Taiwan* ³*Medical Electronics and Device Technology Center, Industrial Technology Research Institute, Hsinchu, Taiwan*

ABSTRACT

This study presents a new microfluidic chip capable of generating tunable and uniform droplets. The generated micro-droplets can be further switched to different directions for further sorting applications. A pneumatic air chamber called controllable moving-wall structures was designed near the flow-focusing microchannels to locally accelerate the sheath flow velocity and increase the shear force without adjusting syringe pumps. When supplied compressed air to both of the moving-wall structure, the micro-droplets diameters ranging from 31.4 to 146.2 μm with coefficient of variation less than 5.39% could be precisely generated. When supplied compressed air to only one moving wall structure, micro-droplets departure angle can be controlled from 0° to 53.5° . The development of the chip may be used for emulsion applications.

KEYWORDS: Emulsification, Moving wall, Flow focusing, Microfluidics, MEMS

INTRODUCTION

Recently, the chip device using the instability between shear forces and surface tension was reported for generation of emulsion micro-droplets [1-2]. The emulsion droplets size can be controlled by the flow rates and flow rate ratios of the two liquids and also by the dimension of orifice width. By using the combination of flow focusing and a controllable moving-wall structure, one could fine tune the emulsion droplets size [3]. In this study, we report a new active emulsion chip for droplet formation and switching.

DESIGN

The device provided a new design using controllable moving-wall structure to locally accelerate the velocity of sheath flows in flow-focusing channel. Thus, the device can not only control the emulsion droplets size but also achieve the function of switching the droplets. Figure 1(a) shows the design of this emulsion chip, including two controllable moving wall structures, flow-focusing channels, and a sample collection reservoir. Figure 1(b) shows cross-sectional schematic illustrations of the moving-wall structures. When the compressed air injected into the air side-chambers, the controllable moving-wall structures were deformed as shown in Fig. 1(b). The deformed moving-wall structure would squeeze the liquid channel and cause the cross section of microchannel to become smaller. Thus the moving-wall structure could locally adjust the velocity of sheath flows, and provides a higher shear force without adjusting the flow rates of syringe pumps. Two different operation modes

regarding applying variable pressure into the moving wall structures are illustrated in Fig. 2. First, the emulsion droplets can be formed by introducing the continuous and disperse phase liquids into the flow-focusing channels by using syringe pumps with a fixed initial flow rate ratio. For different operation conditions ($P_1=P_2$, $P_1 \neq 0$ $P_2=0$, and $P_1=0$ $P_2 \neq 0$, respectively), the droplet size and droplet departure angle can be fine-tuned.

The experimental setup for the formation and switching of emulsion droplets consists of an optical microscope, a charge-coupled device, two syringe pumps, and a compressed air control system. Olive oil (Sigma Chemical, USA) were used as the dispersed-phase liquid and deionized (DI) water as the continuous-phase liquid. Triton X100 (HLB=13.5, SIGMA, USA) was added into DI water as surfactant.

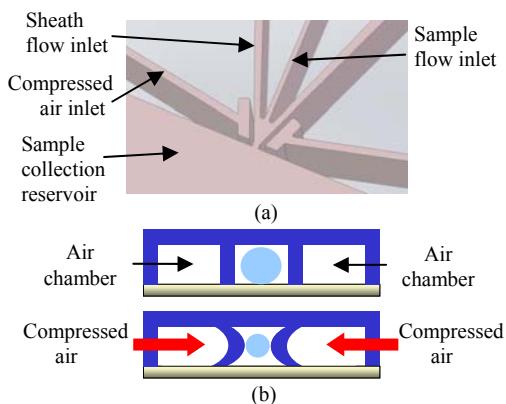


Fig. 1 (a) Schematic illustration of the working principle of the microfluidic chips. (b) Cross-sectional schematic illustrations of the moving wall structures.

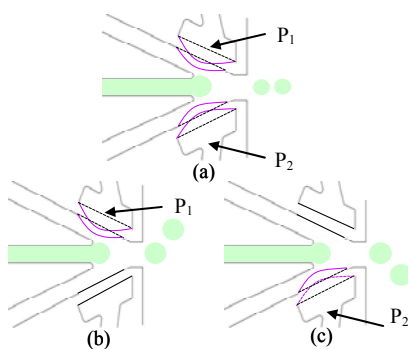


Fig. 2 Two types of operation principles to control the moving-wall structure. (a) $P_1 = P_2$, droplets size became smaller. (b) $P_2 = 0$, droplets direction was deflected upwards. (c) $P_1 = 0$, droplets direction was deflected downwards.

RESULTS AND DISCUSSION

Experimental data indicate that micro-droplets with different sizes can be successfully formed by using the first operation mode. In this case, the sheath/sample flow velocity ratio (V_2/V_1) is 6 at an applied pressure of 0, 10, 20, and 35 psi, respectively. The average droplet diameter is measured to be 146, 125, 85, and 31 μm , respectively (Fig. 3). It can be clearly seen that the deformation of the moving wall structure could be used to control the droplets diameter without changing the flow rate of syringe pumps. The relation between the droplet size and the applied pressure is shown in Fig. 4. The higher the air pressure is supplied, the smaller the droplets size becomes. The experimental results for the second operation mode are shown in Fig. 5. The applied pressures were 0, 10, 15, and 20 psi, respectively. The droplets deflection angles were measured to be 0° , 29.2° , 41.4° , and 53.5° , respectively. As expected, the higher the pressure is applied to the moving wall structure, the more the micro-droplets are deflected from the center (Fig. 6).

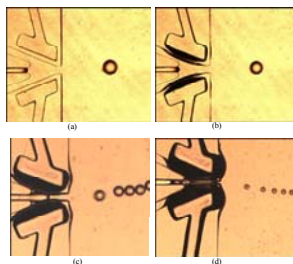


Fig. 3 (a) & (b) & (c) & (d) are for formation of micro-droplets using controllable moving wall structure.

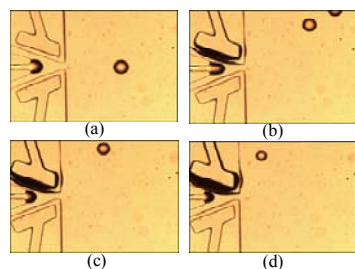


Fig. 5 The images of the second operation method.

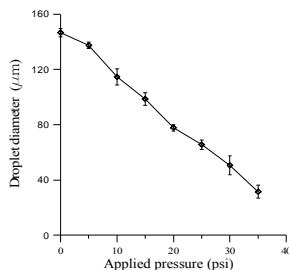


Fig. 4 The relationship between the applied pressure and droplets diameter.

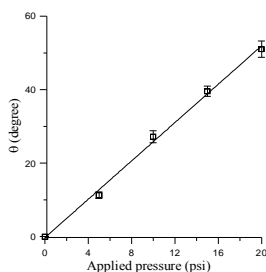


Fig. 6 The relation between the pressure supplied to the moving wall structure and the droplets departure angle θ .

CONCLUSIONS

We have successfully demonstrated a new microfluidic chip integrated with controllable moving wall structures and flow-focusing technology to generate tunable emulsion droplets. The droplet trajectory can also be switched without adjusting syringe pumps. The development of this microfluidic chip can be promising for formation and sorting of emulsion droplets and further biomedical applications.

ACKNOWLEDGEMENTS

The authors would like to thank the National Science Council in Taiwan for their financial support (NSC 96-2120-M-006-008).

REFERENCES

- [1] S. L. Anna, N. Bontoux, and H. A. Stone, Formation of dispersions using ‘flow-focusing’ in microchannels, *Applied Physics Letters*, 82, pp. 364-366, (2003).
- [2] Y. C. Tan, V. Cristini, and A. P. Lee, Monodispersed microfluidic droplet generation by shear focusing microfluidic device, *Sensors and Actuators B: Chemical*, 114, pp. 350-356, (2006).
- [3] S. K. Hsiung, C. T. Chen, and G. B. Lee, Micro-droplet formation utilizing microfluidic flow focusing and controllable moving-wall chopping techniques, *J. Micromech. Microeng.*, 16, pp. 2403-2410, (2006).