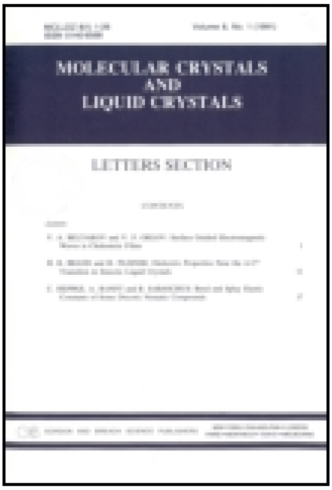

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Monodispersed Liquid Crystal Droplets Fabricated by the Droplet Break-up Process in the Microfluidic System

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Monodispersed Liquid Crystal Droplets Fabricated by the Droplet Break-up Process in the Microfluidic System

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With the microfluidic system, the monodispersed liquid crystal droplets can be fabricated. The size of the liquid crystal droplet can be controlled by changing the flow rates of continuous phase and dispersed phase. In this paper, we describe the fabrication process of the monodispersed liquid crystal droplets by the microfluidic device. We also demonstrate the monodispersed liquid crystal droplets with a diameter of about 40 um.

Keywords liquid crystals; monodispersed; liquid crystal droplets; droplet breakup

1. Introduction

Recently, flexible liquid crystal displays (LCDs) have received considerable attention due to the demand for inexpensive and various application. To protect their optical properties from bending or the external shock, the pixel isolation by the polymer wall [1] or encapsulation of liquid crystals [2] should be required. The typical methods for the encapsulation of liquid crystals are phase separation, emulsion-based processes, and permeation [3]. However, by those methods, the uniform size and uniform shape of liquid crystal droplets cannot be obtained. In the device application, the droplet size and shape affect not only the driving voltage, but also the optical properties of the device [4, 5].

In this paper, using the microfluidic device, the fabrication process of liquid crystal droplets with the uniform size is demonstrated. Two immiscible fluids of continuous phase

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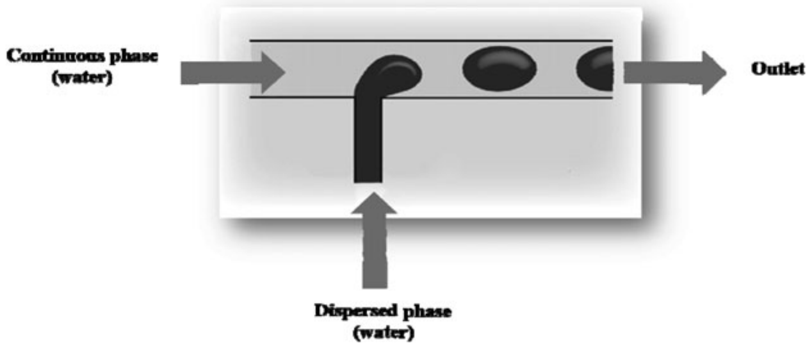

Figure 1. Streams of continuous phase and dispersed phase in the T-junction micro- channel.

of the water and dispersed phase of liquid crystal are used. The droplet size can be controlled by changing the flow rate of two immiscible fluids [6]. In our experiments, the liquid crystal droplets with a diameter of about 40 um were fabricated.

2. Experimental Procedure

The geometrical structure of the micro-channel is the most influential factors to form the droplets. We used micro-channel with T-shaped junction in the experiments. Droplet formation in the T-junction micro-channel was first reported by Thorsen et al [7]. This geometry is widely used in that uniform droplets can be simply formed. In the T- junction micro-channel, streams of continuous phase and dispersed phase are shown Fig. 1.

The size of the liquid crystal droplets can also be controlled by the droplet break-up conditions, on which the various forces such as the surface tension, the shear rate and the flow rates of two phases act. The diameter of the droplets formed in the T-junction micro-channel is proportional to the surface tension (σ) of the liquid crystal phase and inversely proportional to the viscosity (μ_c) of continuous phase and the shear rate ($\dot{\gamma}$) as [8]:

$$\mathrm{d} \sim \frac{\sigma}{\mu_c \dot{\gamma}} \tag{1}$$

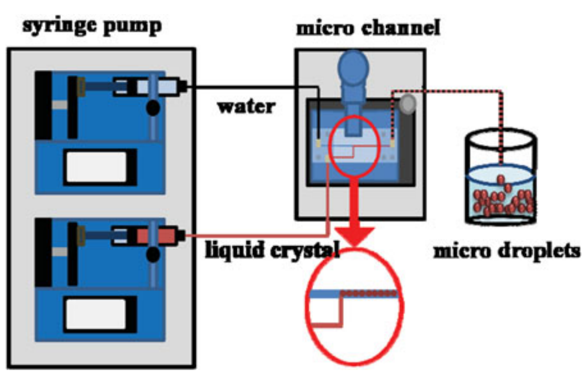

Figure 2. The schematic diagram of the microfluidic system.

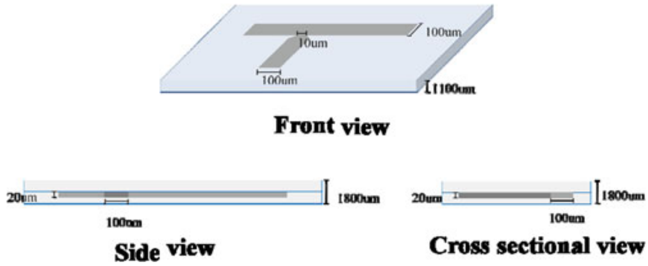

Figure 3. The geometrical structure of the micro-channel.

Figure 2 shows the schematic diagram of the microfluidic system used in the experiments. Two syringe pumps inject the continuous phase and dispersed phase in the T-shaped micro channel, respectively. We have used commercialized micro-channel (Micronit Microfluidics co.). The geometrical structure of the micro-channel used in the experiments is described in Fig. 3. To create channel structures in a borosilicate glass, wet etching techniques with a hydrofluoric acid were applied. Two borosilicate glasses are aligned and directly bonded at high temperature without any intermediate layer [9]. The thickness and width of the channel are 20 um and 100 um respectively. We observed droplet formation

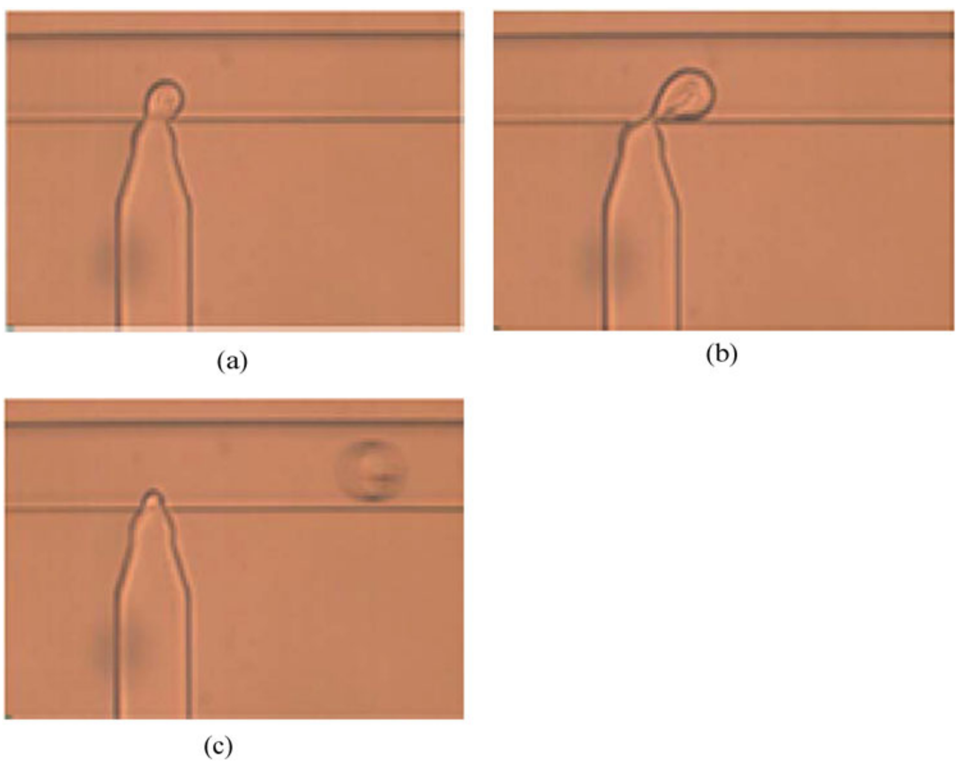

Figure 4. Droplet breakup process: (a) growth, (b) pinch off and (c) breakup.

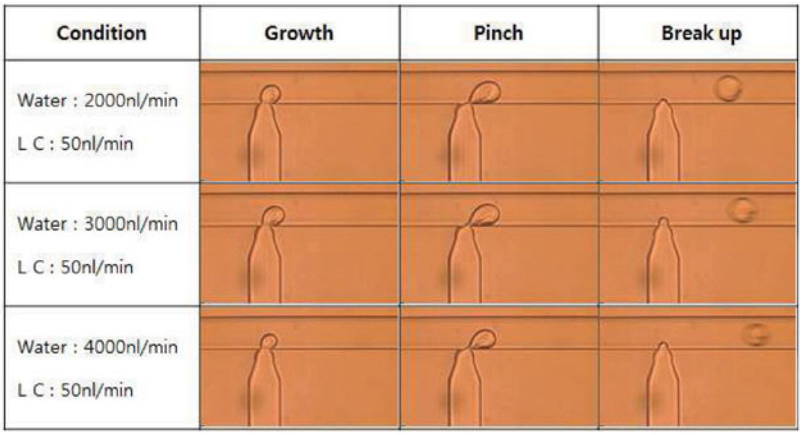

Figure 5. The fabrication process of liquid crystal droplets with various flow rates of the continuous phase.

process inside the T-shaped micro-channel with high speed video camera (MIKROTRON), which can record the image by 1000 frames in one second.

3. Experimental Results

The continuous phase and dispersed phase flow into channel and converge on the orifice. The liquid crystal droplets are generated by the droplet break-up process. There are three steps in the droplet break-up process: droplet growth, pinch off, and breakup, which are shown in Fig. 4.

Figure 5 shows the fabrication process of liquid crystal droplets with various flow rates of the continuous phase. As the flow rate of continuous phase increases, the interval time of droplet breakup and the volume of liquid crystal droplet decrease, due to the stronger shear rate. When the flow rates of the continuous phase were 2 ul/min, 3 ul/min, and 4 nl/min, the interval time of the droplet breakup is summarized in the Table 1. On the other hand, the flow rate of dispersed phase increases, the interval time and volume increase as shown in Fig. 6. When the flow rate of the dispersed phase were 40 nl/min, 50 nl/min, and 60 nl/min, the interval time is summarized in the Table 2. The volumes of the liquid crystal droplets were calculated by the interval time and flow rate of the liquid crystal. From the

Table 1. Interval time of the droplet breakup depending on the flow rate of the continuous phase

Flow rate of the continuous phase (ul/min)	Flow rate of the dispersed phase (nl/min)	Interval time (s)	Volume (nl)
2	50	0.141	0.117
3	50	0.106	0.088
4	50	0.085	0.071

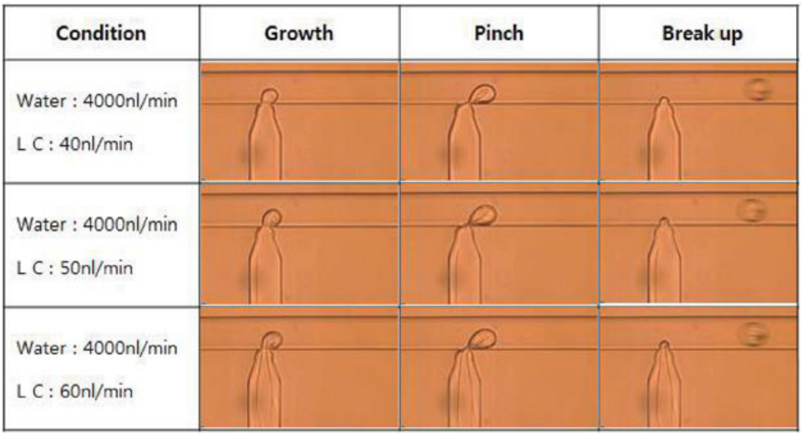

Figure 6. The fabrication process of liquid crystal droplets with various flow rates of the dispersive phase.

experimental results, the size of the liquid crystal droplet can be controlled by changing the flow rates of continuous phase and dispersed phase.

Figure 7 shows the fabricated monodispersed liquid crystal droplets observed by the optical microscope (BX-51, Olympus Optical). Droplet breakup process occurs when the flow rate of continuous phase was 6 ul/min and the flow rate of dispersed phase was 40 nl/min. The monodispersed liquid crystal droplets were fabricated. The diameter of the fabricated liquid crystal droplets were about 40 um. The fabricated droplets are hexagonally arranged due to the uniform size.

4. Summary

In this paper, we demonstrated the fabrication process of the monodispersed liquid crystal droplets by the microfluidic device. The size of the liquid crystal droplet can be controlled by changing the flow rates of continuous phase and dispersed phase. With the microfluidic system, the monodispersed liquid crystal droplets were fabricated. When flow rate of continuous phase and dispersed phase were 6 ul/min and 40 nl/min, respectively, the diameter of the monodispersed liquid crystal droplets was about 40 um.

Table 2. Interval time of the droplet breakup depending on the flow rate of the dispersed phase

Flow rate of the continuous phase (ul/min)	Flow rate of the dispersed phase (nl/min)	Interval time (s)	Volume (nl)
4	40	0.098	0.065
4	50	0.085	0.071
4	60	0.075	0.075

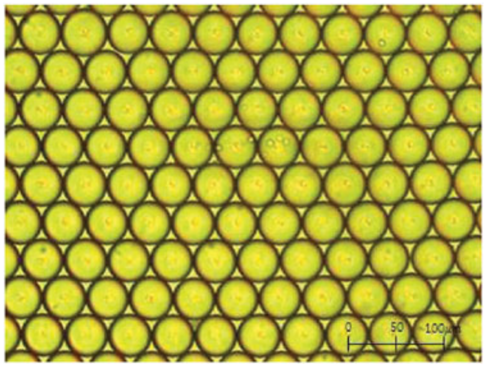

Figure 7. The fabricated monodispersed liquid crystal droplets observed by the optical microscope.

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