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An emulsion generating device by an ultrasonic vibration and a microchannel

超音波振動とマイクロ流路によるエマルション生成デバイス

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1. Introduction

An emulsification is an important technique and used in many fields such as cosmetics, food production and medical science. Especially, monodisperse emulsion is very useful because it improves the quality and stabilities of products and facilitates the control of properties. A lot of emulsification techniques have been studied.[1)] For example, a high pressure homoginization, a membrane emulsification, a microchannel emulsification and a PIT (Phase Inversion Temperature) method.

Some devices used an ultrasonic vibration to generate nano emulsions.[2-4)] (The nano emulsions mean that diameter of the emulsion is under 1µm.) However, as their driving frequency was around 20 kHz[3,4)], noise was made loudly. Futhermore, these process are batch process and devices were large.

The aim of this study is to fabricate an emulsion generating device using an ultrasonic vibration and a microchannel. Then, the small device will realize a flow process.

2. Methods and materials

The process to generate nano emulsion consists of Y-type microchannel and ultrasonic device. Schema of the nano emulsion generating system is shown in **Fig. 1**. Once oil and water are supplied by syringe pumps to Y-type microchannel, micro emulsions are generated because of the fluid shear fore caused by two flow rate difference.[5)] After that, micro emulsions are sonicated by an ultrasonic vibration and a microchannel to obtain nano emulsions.

The Y-type microchannel is made of stainless steel. **Figure 2** indicates the each microchannel width of the Y-type microchannel. The water phase, the oil phase and the emulsion phase microchannel width are 141µm, 104µm and 137µm, respectively.

The ultrasonic device consists of two plates. One is microchannel plate and the other is vibrating plate on which a piezoelectric element is bonded. These plates are made of stainless steel. These plates are clamped when they are used. **Figure 3** shows schematic view of the ultrasonic device and photograph of the microchannel plate. The corss-sectional view and the top view of the microchannel are indicated in **Fig. 4**. The microchannel is 0.711mm wide and 0.35mm deep. Total length of the microchannel is 24 times of the top view in Fig. 4. The plate is 50mm long, 80mm wide and 5mm thick. The piezoelectric element is 20mm long, 60mm wide and 5mm thick.

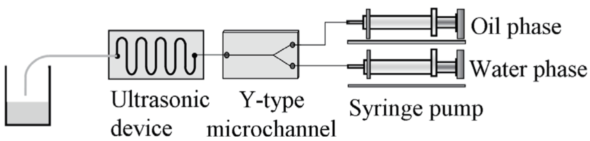
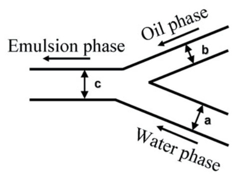


Fig. 1 Schema of the nano emulsion generating system



	Channel width（µm）
a	141
b	104
c	137

Fig. 2 Y-type microchannel

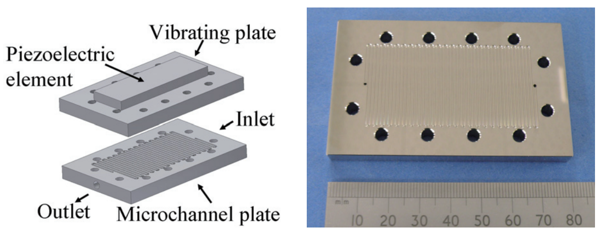


Fig. 3 Ultrasonic device; schematic view (left), photograph of the microchannel plate (right)

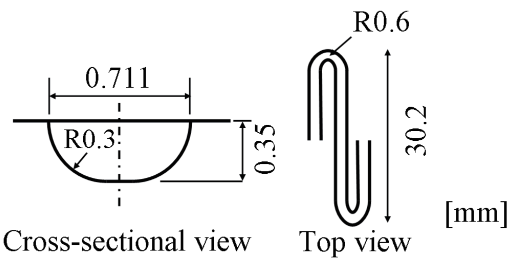


Fig. 4 Cross-sectional view (left) and top view (right) of the microchannel

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The materials used for generating emulsion in this study were aqueous glycerol solution as water phase, tricaproin, tricaprylin, Tween 80 and egg yolk lecithin as oil phase.[6] Tween 80 and egg yolk lecithin were used as a surfactant.

3. Experimental results

Firstly, the generation of emulsion by Y-type microchannel was conducted. The flow rate of the water phase and the oil phase were 100µl/min and 1 µl/min, respectively. **Figure 5** shows the optical microscope photographs of generated emulsions by Y-type microchannel. According to Fig. 5, polydisperse emulsions were generated. Most diameters of the generated emulsions were about less than 50µm.

Figure 6 shows optical microscope photographs of the generated emulsions sonicated by ultrasonic device when driving frequency and applied voltage were 2.25MHz and $100V_{p\text{-}p}$, respectively. From the comparison of Fig. 5 and Fig. 6, emulsions became so small that it is difficult to observe emulsions by optical microscope. **Figure 7** indicates the distribution of the emulsion diameter measured by the dynamic light scattering (DLS) when applied voltage were $50V_{p\text{-}p}$, $80V_{p\text{-}p}$, and $100V_{p\text{-}p}$, respectively. From Fig. 7, as the applied voltage increased, the peak wide around 200nm became sharper and the distribution around 6µm reduced. This result means that the ultrasonic irradiation intensity was important factor and as the ultrasonic irradiation intensity increased, generated emulsion became small and distribution became sharp.

Furthermore, the generation of emulsion by changing the flow rate of water and oil phase was conducted. This experiment's aim was to investigate the emulsion generation by the difference of the residence time. **Figure 8** shows the distribution of the emulsion diameter measured by DLS when water and oil phase flow rate was 100-1µl/min, 200-2µl/min, and 50-0.5µl/min, respectively. According to Fig. 8, the difference of residence time had little effect on the emulsion diameter.

4. Conclusion

In this paper, the generation of nano emulsion was conducted by the ultrasonic device and the microchannel. As the applied voltage increased, sonicated emulsion became smaller and distribution became sharper. In the future, generation of emulsion would be conducted by increasing oil phase flow rate against water phase flow rate.

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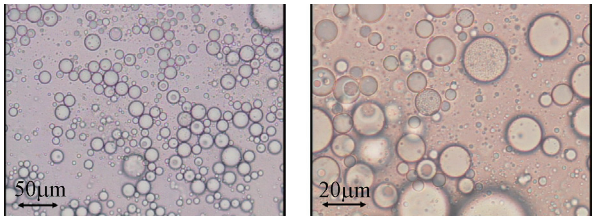

Fig. 5 Optical microscope photographs of generated emulsions by Y-type microchannel

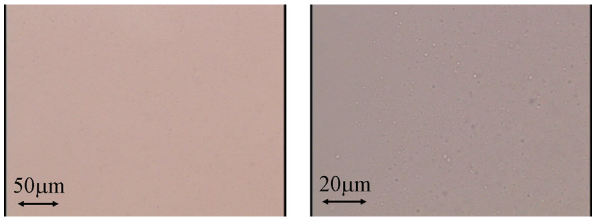

Fig. 6 Optical microscope photographs of generated emulsions by ultrasonic device

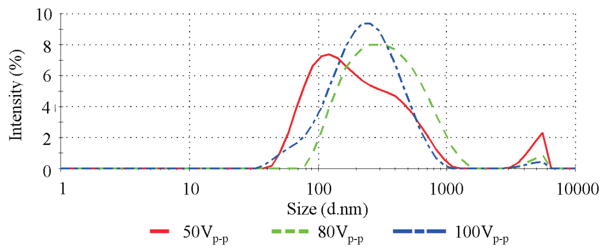

Fig. 7 Relationship between emulsion diameter and intensity measured by DLS when applied voltage was changed

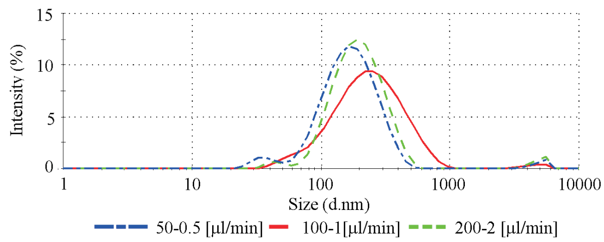

Fig. 8 Relationship between emulsion diameter and intensity measured by DLS when flow rate was changed