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Non-contact stirring of liquid in micro container using by high-intensity aerial ultrasonic waves

強力空中超音波を用いた微小容器内液体の非接触撹拌

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1. Introduction

Non-contact techniques for stirring liquids are desirable for various applications in the chemical field [1-3]. We have proposed a non-contact stirring method using high-intensity aerial ultrasonic waves. Previously, we confirmed that flow of a liquid in a micro container is generated by irradiating the container wall with high-intensity aerial ultrasonic waves [4].

In this report, we demonstrate non-contact stirring of two liquids in a micro container by exploiting the flow generated by the ultrasonic waves.

2. Experimental setup

Fig. 1 shows a schematic view of the experimental apparatus. The apparatus comprised a high-intensity aerial ultrasonic wave source, a micro container filled with liquid, and a digital microscope with a high-speed camera (DMHC). The high-intensity aerial ultrasonic waves were generated by a point-converging sound source (drive frequency: 20 kHz) [5]. The ultrasonic waves from the sound source converged approximately 130 mm from the edge of the vibration plate. The high-intensity ultrasonic sound pressure was estimated to be 25 kPa at an electric input power of 150 W.

Fig. 2 shows a schematic of the acrylic micro container (internal dimensions: 4 × 5 × 30 mm) used to inject the liquid. The wall exposed to the ultrasonic wave irradiation was 0.2-mm-thick and the others walls were 2-mm-thick. After the liquid was injected, the top of the micro container was covered with a rubber sheet to prevent ultrasonic waves from entering through the top.

3. Behavior of the liquid in the micro container during ultrasonic irradiation

Ethanol (150 μL) was injected into the micro container, and the wall around the liquid surface of the container was irradiated with ultrasonic waves (Fig. 1). The behavior of the liquid during the ultrasonic irradiation was observed by DMHC through the wall of the container. The shutter speed

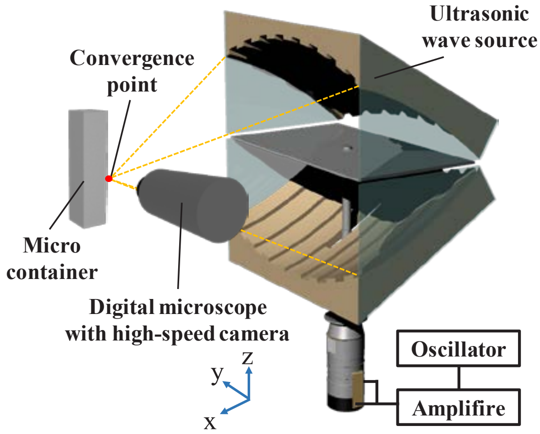
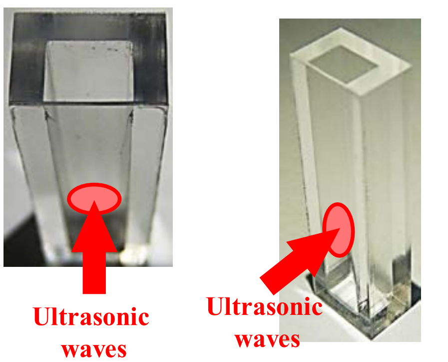
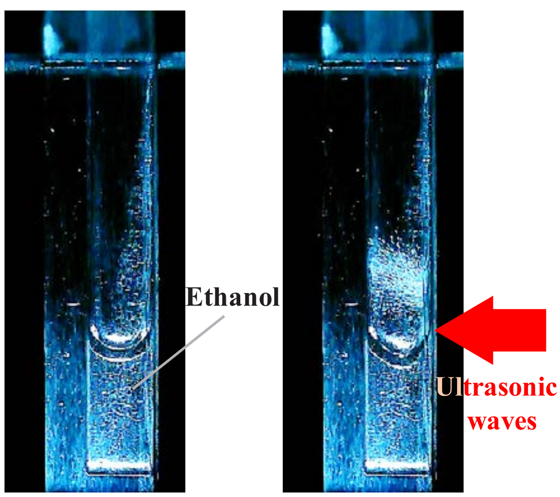


Fig. 1 Experimental apparatus



(a) Top view (b) Perspective view

Fig. 2 Acrylic micro container



(a) Initial (b) After 10 ms

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was 1/6000 s and the frame rate was 500 fps.

Fig. 3 (a) shows the liquid before ultrasonic irradiation, and **Figs. 3 (b-d)** show the liquid at various times during ultrasonic irradiation. After 10 ms, the liquid rose along the irradiated wall and was atomized (Fig. 3 (b)). After 20 ms, the atomized liquid collided with the opposite wall and fell back to the liquid surface (Fig. 3 (c)). After 40 ms, more liquid rose, lowering the level of the liquid surface and violent atomization occurred (Fig. 3 (d)).

Subsequently, the liquid level decreased further as more of the liquid was atomized, inducing a large flow. These results confirmed that the proposed method created a large flow in the liquid in the micro container.

4. Non-contact liquid stirring

We stirred two liquids using our method. Ethanol (100 μL) and water containing red dye (50 μL) were placed in the micro container. The container was irradiated with high-intensity aerial ultrasonic waves at the liquid surface.

Fig. 4 (a) shows the liquids before ultrasonic irradiation, and **Figs. 4 (b-d)** show the behavior of the liquid in the micro container after ultrasonic wave irradiation at various times. After 80 ms, the water began to rise along the wall in response to the change in the ethanol liquid surface level (Fig. 4 (b)). After 300 ms, the two liquids were atomized at the same time when the water reached the liquid surface of the ethanol (Fig. 4 (c)), and the ethanol was mixed into the water at the same time. The two liquids were almost completely mixed after 2 s (Fig. 4 (d)).

5. Conclusion

We stirred two liquids in a micro container by using our proposed non-contact stirring method. As a result, a large flow was created by our proposed method, and the two liquids were mixed quickly.

References

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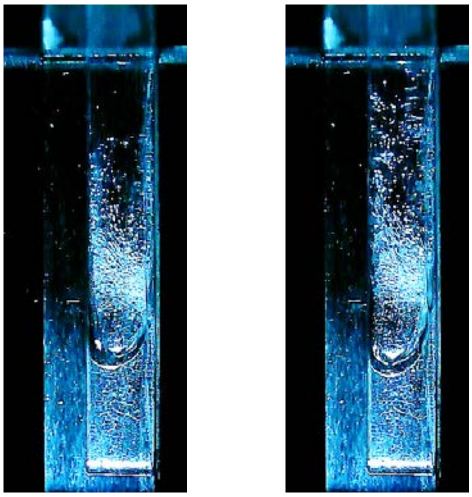
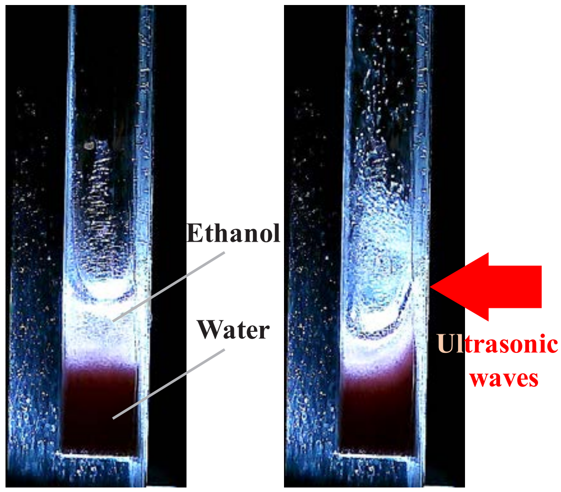
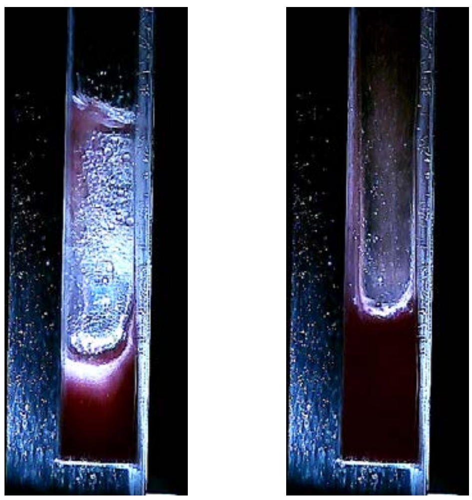


(c) After 20 ms (d) After 40 ms

Fig. 3 Behavior of the liquid in the micro container



(a) Initial (b) After 80 ms



(c) After 300 ms (d) After 2 s (stop)

Fig. 4 Non-contact liquid stirring