Micro-manipulation of small particles by surface acoustic streaming

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abstract: The possibility of micro-manipulation of small particles by surface acoustic streaming is proposed. At a capillary waves formation on the liquid surface, ultrasonic fountain is generated. We propose that at the time when ultrasonic atomization occurs, surface acoustic streaming, which locates on the very thin layer of liquid surface is generated. Surface acoustic streaming conveys small particles on the liquid surface, and gathers small particles to construct the rich layer of small particles. Thereafter ultrasonic atomization can separate small particles on the liquid surface.

Key wards: micro-manipulation, acoustic streaming, ultrasonic atomization

1. Introduction

Separation by ultrasonic atomization has been developed. The experimental data of ultrasonic separation of ethanol was reported by Matsuura et., al. in 1995 [1]. We have already discussed the mechanism of ultrasonic atomization and ultrasonic separation using parametric decay instability of ultrasonic waves [2]. Ultrasonic separation of ethanol has been practically utilized in brewing industry. **Figure 1** shows ultrasonic atomization and ultrasonic transducer. (Ultrasonic transducer: ф20 mm 2.4 MHz, 13 W).

Ultrasonic separation of solid-liquid solution was reported in the separation of salt-water solution [1]. Ultrasonic separation of surfactant has been reported and amino acid was condensed 1,000 times at several ppm concentration. It indicates that below the concentration of CMC (Critical Micelle Concentration), surface excess acts a very important role. We have also pointed out that surface excess affected the ultrasonic separation of ethanol [2].

Micro-manipulation by acoustic radiation pressure of standing wave was reported by Kozuka et., al. [4]. We have analyzed acoustic streaming using quantum mechanical representation of acoustic waves [5,6]. The conservation laws of energy and momentum give simple expression of driving force of acoustic streaming. Ultrasonic fountain is generated when ultrasonic atomization occurs. We consider ultrasonic fountain is generated by surface acoustic streaming, which is located on the very thin layer of liquid surface. Small particles on the liquid surface can be manipulated by surface acoustic streaming.

2. Surface acoustic streaming

We have proposed the mechanism of wave transformation from longitudinal waves to surface acoustic waves [2]. We also derived the driving force of acoustic streaming [5,6].

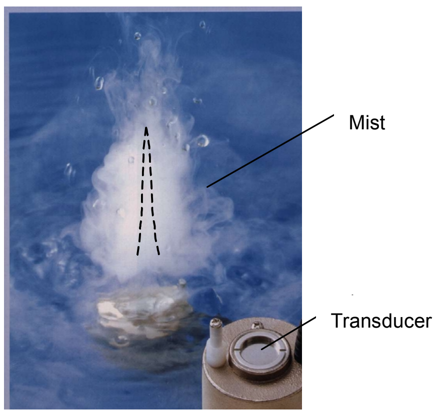

Fig.1 Ultrasonic atomization and ultrasonic transducer.

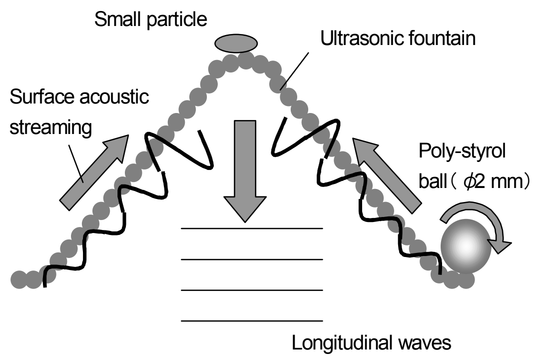

Fig. 2 Surface motion of ultrasonic fountain

In this report, we propose surface acoustic streaming, which locates on the very thin layer of liquid surface. Ultrasonic fountain is detected as shown in **Fig. 1** (dashed line). Longitudinal waves from ultrasonic transducer are converted to surface acoustic waves at the surface of ultrasonic fountain. The momentum of longitudinal waves is changed to the momentum of surface drift motion (i.e., surface acoustic streaming) of the liquid as shown in **Fig. 2**. We consider that there are capillary waves on the surface of liquid, however it is difficult to observe capillary waves, because there are fluctuations on the surface. (Capillary waves are conceptually illustrated in **Fig. 2**.) Surface acoustic streaming will drive particles on the liquid surface.

3. Experiment

The motion of the liquid surface of ultrasonic fountain was experimentally observed. The electrical input power to the transducer was adjusted (3~13W) to control the height of the ultrasonic fountain. **Figure 2** shows a conceptual illustration of the fountain at lower input power.

The motion of the pieces was observed by the piece of styrene foam floated on the surface. On the condition that the electrical input power to the transducer was just adjusted, the piece of styrene foam was trapped on the summit of the ultrasonic fountain. When experimented with powder, surface flow of the fountain can be observed.

With the sphere of styrene foam (ϕ2 mm), the sphere was trapped at the standup part of the fountain as shown in **Fig. 2**. We consider that the surface of the liquid moves toward the summit of the fountain. Arrows show the flow of water at low input power.

4. Summary

We showed surface acoustic streaming and the possibility of micro-manipulation of small particles. At the time when ultrasonic fountain occurs, surface acoustic streaming is generated. Surface acoustic streaming conveys small particles on the liquid surface, which will be used for the separation.

References

1) K. Matsuura, M. Kobayashi, M. Hirotsune, M. Sato, H. Sasaki, and K. Shimizu, Japan Soc. Chem. Eng. symposium series, **46**, 44, (1995).
2) M. Sato, K. Matsuura and T. Fujii: J. Chem. Phys., **114**, 2382, (2001).
3) T. Kozuka, T. Tuziuti, H. Mitome, and T. Fukuda, Jpn. J. Appl. Phys., **37**, 2974, (1998).
4) M. Sato and T. Fujii: Phys. Rev. E **64**, 026311, (2001).
5) M. Sato, T. Matsuo and T. Fujii: Phys. Rev. E **68,** 016301, (2003).