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Micromanipulation of particles in a microchannel with a geometric space using ultrasound

超音波を用いた溜まり場を持つマイクロ流路中での微粒子操作

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1. Introduction

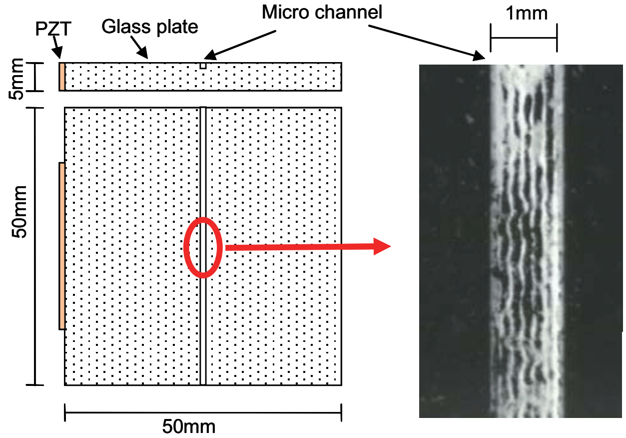
Noncontact micromanipulation technique is needed in micromachine technology, biotechnology, and other fields. The radiation pressure of ultrasound may be used for this purpose. Masuda *et al*. [1] have attempted to control a microbubble flow in a blood vessel using acoustic radiation pressure. Yamakoshi and Miwa [2] have analyzed the behavior of a microbubble in a standing wave field generated by two focused-type transducers in water.

The authors have realized an acoustic manipulation technique for transporting particles using a standing wave field in water or air [3-5]. In the present study, a sound wave was transmitted into the microchannel through the glass plate, and a standing wave field was formed in the microchannel. Solid particles were trapped in the sound pressure nodes of the sound field, and the particle flow direction was controlled by changing the frequency.

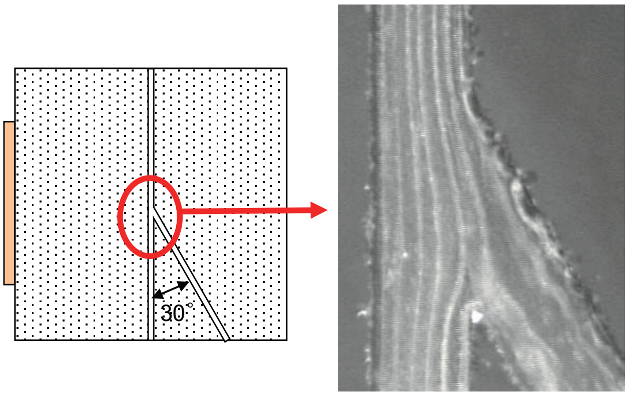
2. Experiment

Figure 1(a) shows a basic microchannel system in the experiment. The size of the glass plate is 50×50×5 mm^3. A microchannel of 1×50×1 mm^3 was set at the center of the plate. The microchannel is surrounded by three glass walls, and the top surface is open to air. A PZT transducer of 30×5 mm^2 is adhered to the left end of a glass plate using grease. When a suspension of alumina particles was poured into the microchannel, the alumina particles agglomerated into several layers. Figure 1(b) shows the experimental result for a frequency of 4.5 MHz; particles agglomerated into six layers in the microchannel. The ultrasound wave propagates into the microchannel through the glass plate, and a standing wave field is formed in the microchannel. As a result, particles were trapped at the sound pressure nodes of the sound field.

A microchannel with a branch on the glass plate, as shown in Fig. 2(a), was used. A suspension of polyethylene particles was poured from the upper end of the microchannel at a speed of 16.7 mm/s using a pump. When the driving frequency was swept from 5.25 to 3.75 MHz every 0.1 s, it was observed that the particles were pushed to the left side of the channel. Figure 2(b) shows the behavior at the branch point in the microchannel. In other words, it was possible to control the direction of the particle flow by ultrasound. The trace of particles was only partly controlled by changing frequency in the branched microchannel, because the region of the branched space is small. Therefore a geometric space was added in the center of the microchannel and the particle behaviour was observed in the region.



(a) The glass plate (b) The experimental result
Fig. 1. The basic microchannel system



(a) The glass plate (b)The experimental result
Fig. 2. The branched microchannel system

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Figure 3 shows the particles behavior with a half circular region of 5 mm in diameter and an additional exit microchennel at the right side. The particles were agglomerated in a geometric pattern in 4.5 MHz fixed (Fig. 3(b)). Moreover, when the frequency was repeatedly swept from 4.2 MHz to 4.6 MHz every 0.2 s, the particles moved to the right as shown in Fig. 3(c). When the frequency sweep was reversed, the particles moved to the left in Fig. 3(d). When the suspension particles were poured from the upper end of the microchannel, the water flowed to both right and lower directions. On the other hand the direction of the particles' flow was controlled by changing ultrasonic frequency.

3. Discussion

The particle agglomerated pattern in the microchannel was of interest. It is difficult to measure the sound pressure in a microchannel by a hydrophonic or Schlieren method. Therefore, numerical analysis was performed by the finite element method (FEM, COMSOL Multiphysics). Figure 4 shows the calculated sound pressure distribution on the horizontal surface of the center of the microchannel at 4.5 MHz. Figure 4(a) is for microchannel only and (b) is with a circular region and a right exit microchannel. The scale for pressure distribution in each figure is normalized by the maximum sound pressure. A standing wave field was formed in each cases, the calculated pattern is similar to that of particles experimentally observed.

4. Conclusion

In conclusion, a standing wave field was formed in a microchannel with a 1×1 mm^2 cross section on a glass plate. An ultrasonic wave successfully propagated into the microchannel on the glass plate. When a suspension of particles was introduced into the microchannel, the particles agglomerated into a few layers, each separated by a half wavelength. If the frequency of the ultrasound was swept in the microchannel with a half circular region, the particles were spatially shifted. It was able to control the direction of the particle flow by changing the ultrasound frequency in the branched microchannels. A sound field was numerically calculated by FEM under the experimental conditions and the experimental results were discussed.

Acknowledgment
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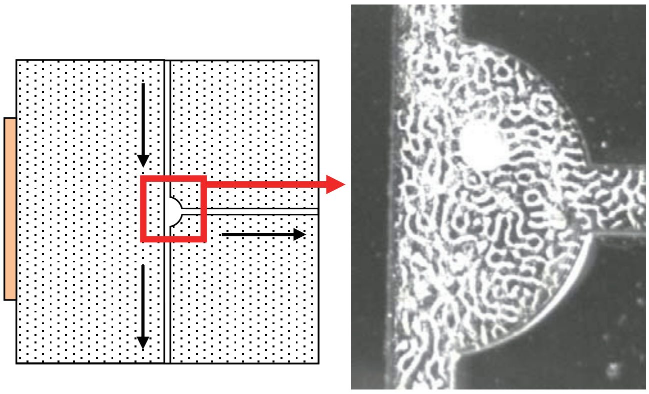
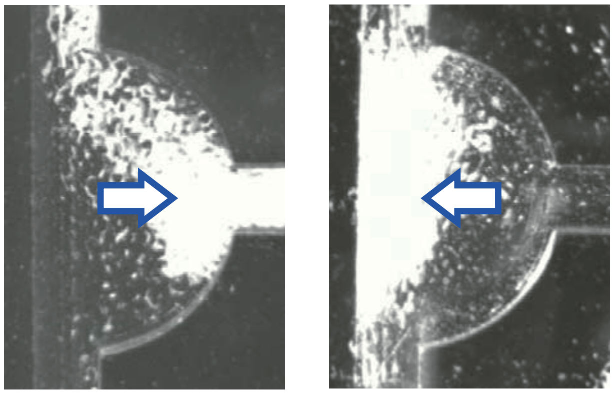
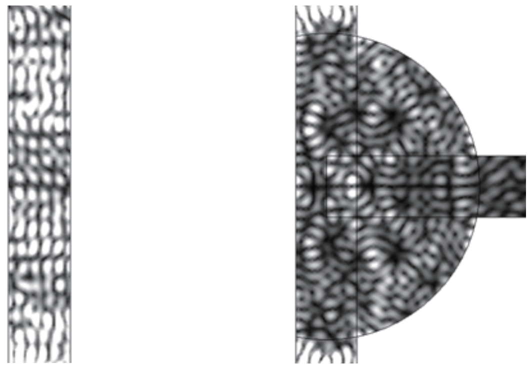


(a)The glass plate (b) The experimental result



(c)(d)With frequency sweep (c)upward and (d)downward
Fig. 3. With a half circular region and an additional exit microchannel



(a)Microchannel (b)With a half circular region and a exit
Fig. 4. Numerically calculated sound pressure distribution

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