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Study on surface modification for droplet manipulation using surface acoustic waves

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1. Introduction

In the medical and biotechnology fields, microfluidic systems (MFS) that can move small amounts of fluid are required because of their advantages such as portability and the need for small amounts of specimens and chemicals. One method to move a small amount of fluid is to excite surface acoustic waves (SAW) using a piezoelectric substrate and comb-shaped electrodes (IDT) to move droplets. In this method, it is important that the droplet shape must not change before and after the transfer. This positioning method is called slippery liquid-infused porous surfaces (SLIPS) processing.[1)] We performed SLIPS processing based on the ref. 1). The difference between water-repellent and SLIPS processing is illustrated in **Fig. 1**. However, problems such as damage to the piezoelectric crystal and delamination of the metal of the IDT occurred during the processing. In this study, the optimization of the SLIPS processing method was investigated. Then, the contact angle and sliding angle were measured about the elapsed time after processing to determine the number of days after processing that SLIPS is suitable for use. Furthermore, the power required for droplet transfer on SLIPS was measured to investigate the durability of SLIPS. These results are reported in this paper.

2. Experimental method

The general SLIPS processing method is shown in **Fig. 2**. The cooling method and the electrode protection method for the IDT were modified in this study. Then, SLIPS processing was performed on the cover glass using silicon oil of different viscosities of 4.7 and 49.6 mPa·s, and the sliding angle was measured by tilting the cover glass at immediately after, 1 day after, and 1 week after.

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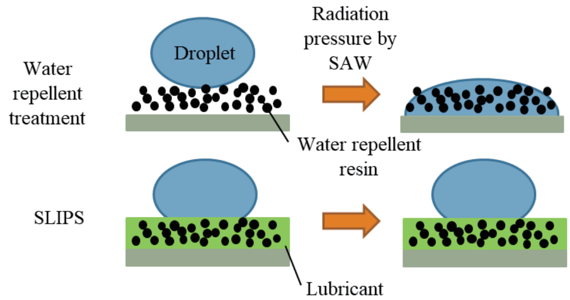

Fig. 1 The difference between water-repellent and SLIPS.

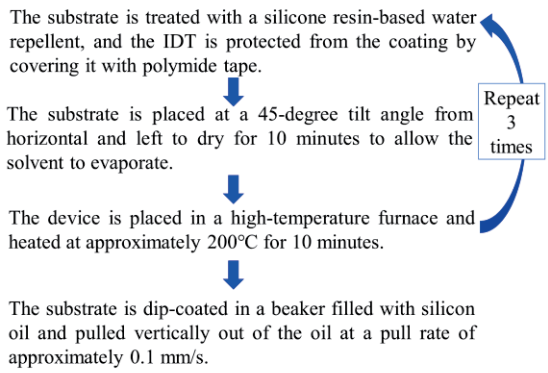

Fig. 2 General SLIPS processing method.

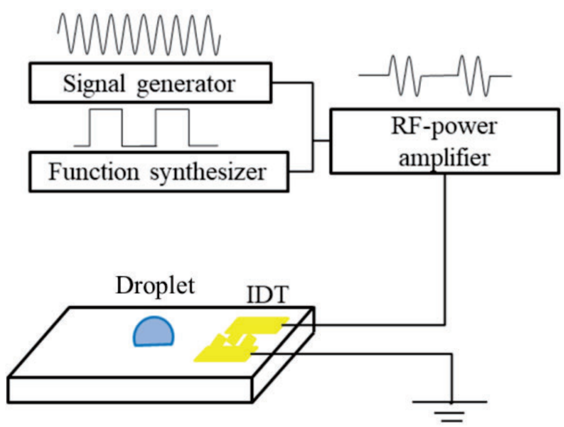

Fig. 3 Experimental system in this study.

The contact angle at that time was also measured using a microscope. The piezoelectric substrate used in this study was 128°YX-$LiNbO_3$. The experimental system to generate SAW is shown in **Fig. 3**. SLIPS

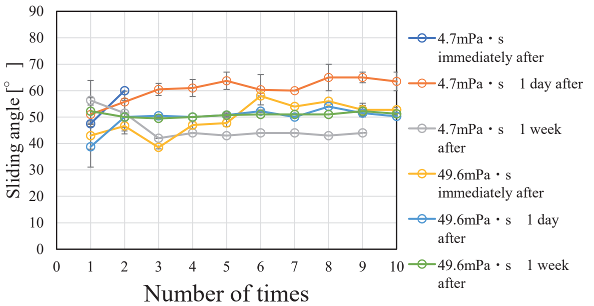

Fig. 4 Sliding angle of droplet when glass is tilted.

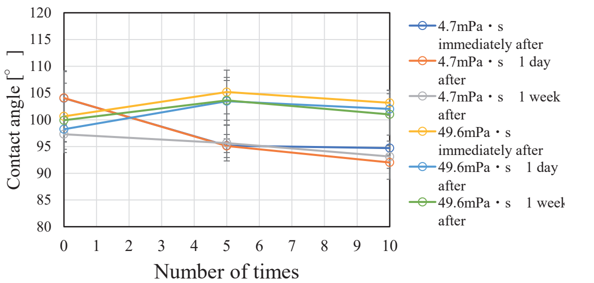

Fig. 5 Contact angle of a drop of liquid on glass.

was processed on the piezoelectric substrate, and the power required for droplet transfer on the SLIPS was measured to investigate the durability of the SLIPS.

3. Results and discussion

The cooling method was changed from air cooling, that is rapid cooling, to slow cooling in an electric furnace. The SAW device was kept on a metal tray during cooling to reduce damage due to the pyroelectric effect. The thickness of the piezoelectric crystal was changed from 0.5 mm to 0.7 mm, and a heat-resistant polyimide tape was attached directly to the IDT to protect the electrodes. A cover glass layer was added between the polyimide tape and the IDT to avoid the influence of the adhesive.

The results of SLIPS processing using silicone oil of different viscosities and the measurement of the sliding angle and contact angle at different elapsed times are shown in **Figs. 4** and **5**, respectively. When the sliding angle on SLIPS with 4.7 mPa·s silicon oil was measured, the slide stopped moving halfway and did not move the next time. On the other hand, when measuring the angle of fall on SLIPS with 49.6 mPa·s silicon oil, it stopped moving but moved the next time. The SLIPS film thickness increases with viscosity. Therefore, we believe that the SLIPS with 49.6 mPa-s silicon oil self-repairs the film.

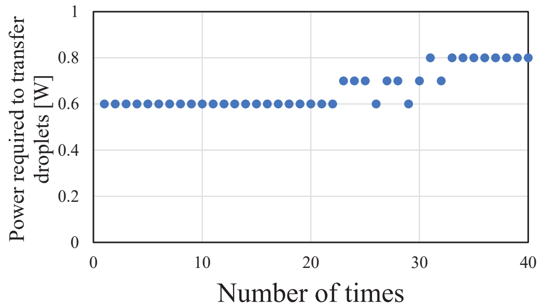

Fig. 6 Power required for droplet transfer on SLIPS.

The results of the change of the sliding angle and contact angle on SLIPS with 49.6 mPa·s silicon oil in Figs. 4 and 5 show that there is no significant change after 1 day and 1 week. This result indicates that the most suitable time for droplet transfer is after one day of SLIPS processing.

Fig. 6 shows the change in power required for droplet transfer using SAW on SLIPS with 49.6 mPa·s silicon oil. The power required for droplet transfer increased when the number of transfers exceeded 20 times. When the power required for droplet transfer increased, the droplets were extended before being transferred. This is because the droplets penetrate the uneven structure of the water-repellent resin due to the radiation pressure caused by SAW, and the droplets are transported after being extended. Based on these results, it is recommended that the SAW droplet transfer on SLIPS should be limited to 20 times.

4. Conclusion

In this study, the SLIPS machining method was optimized and SLIPS was evaluated. The results of measurements of sliding angle and contact angle at different times after SLIPS processing showed that it is better to wait about one day after SLIPS processing before transferring the droplets. The measurement results of the power required for droplet transfer showed that up to 20 times droplet transfer on SLIPS using SAW is recommended.

References

1) J. T. Lou, at al., Phys. Rev. Appl. 7, 014017(2017).