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Directional Spraying Systems Employing Surface Acoustic Wave Resonators

表面弾性波共振子を利用した指向性噴霧システムの開発

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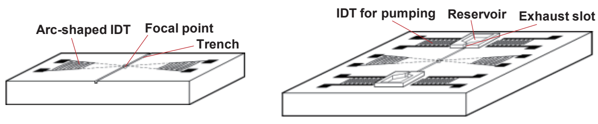
1. Introduction

The SAW spraying system is one of the most promising device for ultra-compact nebulizers or end devices mounted on surgery tools. It is also useful to generate polymeric nanoparticles for smart drug delivery [1]. This is based on agglomeration because of the volatilization of the liquid and is called evaporative-induced self-assembly (EISA). Convergence and direction control of the ejected mist spray are invaluable for these applications. We have proposed two approaches based on MEMS technologies to control the shape of spray as shown in Fig. 1 (a) [2]. One approach was to focus the SAW energy using a pair of arc-shaped IDT (AS-IDT). Another one was to hold the liquid at the focal point of the SAW with a trench .

However, an external syringe pump had to be used to control the liquid supply in previous works. The mode of ejection is changed considerably by the amount of liquid supply as shown in Fig. 2 [3]. Thus, the use of external manual pumps not only prevents the full integration of the system, but also induces undesirable ejection modes such as spreading or jetting as shown in Fig. 2. In this study, a SAW-driven micro pump was integrated with the atomizer on the same substrate to precisely control the amount of liquid. In addition, the design of the arc-shaped IDT was optimized using an optical observation technique [4] to decrease the voltage for atomization.

2. Structure of the device

Figure 1(b) shows a schematic illustration of the SAW spraying system with a micro pump. The system included facing AS-IDTs and a trench to achieve point source spray. The pump was constructed with a reservoir and IDTs, and was located at the trench edge. The fluid in the reservoir was pushed out by the SAW and transferred to the focal point along the trench as shown in Fig. 1. When a SAW is radiated from the AS-IDT, its energy can be focused on the fluid that atomizes perpendicularly from this focal point.



(a) (b)

Fig.1 Schematic illustration of the SAW based spraying system: previous work (a), present work (b)

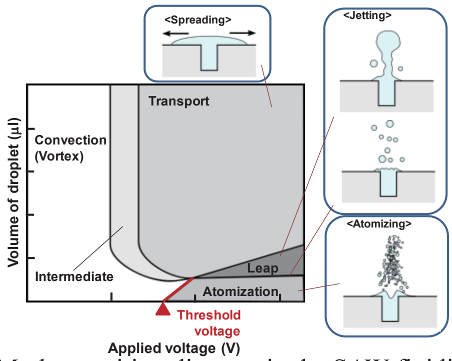


Fig.2 Mode transition diagram in the SAW fluidic device

3. Evaluation of the AS-IDTs

The black line in Fig. 3 shows frequency characteristics for a single AS-IDT desined in the previous report. There are some spurious responses. The vibration distribution for each spurious response was optically observed using a Sagnac interferometer-based system [4]. The observation results are shown in Fig. 4(b)(c). In these figures, The resonant frequency was different within the electrode area. This was caused by the deviation of the SAW velocity. Based on these results, the IDT pitch was optimized. Figure 4(d) shows the vibration distribution of the redesigned AS-IDT at resonance. By the optimization, the resonator vibrated entirely at a resonance point, and the radiated SAW had converged. As a result, threshold voltage to optimization was reduced from 46 to 21 $V_{p\text{-}p}$. The red line in Fig. 3 shows the optimized characteristic. The steepness of the resonance peak had improved and spurious peaks were suppressed.

4. Evaluation of the micro pumps

Figure 5 shows discharge characteristics of the micro pumps. In this study, two types of reservoir were fabricated. In reservoir B, micro

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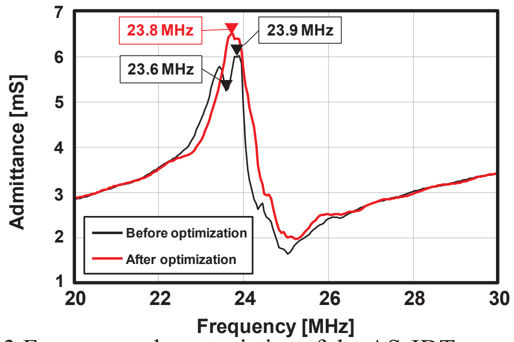

Fig.3 Frequency characteristics of the AS-IDTs

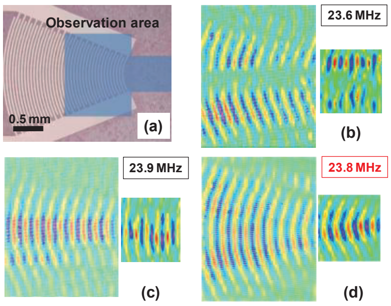

Fig.4 Optical vibration observation for the AS-IDTs

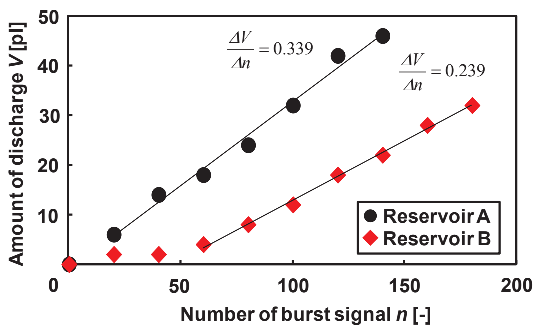

Fig.5 Discharge characteristics of the micro pumps

surge tank was integrated into the exhausted slot. Micro pump was operated with burst signals. In Fig.5, characteristics were plotted with the number of bursts. From Fig.5, fabricated pump obtained the discharge rate of sub pico-liter order. Particularly, precision of the micro pump was improved due to the integration of micro surge tank.

5. Point-source-atomization test

Figure 7 (a) and (b) shows a point source atomization with D. I. water. The width of the ejected mist spray was 0.7 mm near the substrate and was maintained at less than 1 mm within the ejection height of 8 mm. Atomization of volatile organic solvent was also important in the application of polymeric nanoparticle synthesis based on the EISA technique. Figure 7(c) shows a point source atomization of acetone, which is a typical solvent for EISA [18]. In Fig. 7(a), the ejected mist of the water lost kinetic energy over ejection heights of 8 mm and drifted with air convection. In contrast, the oriented mist spray of the acetone vanished without convection because of the volatilization at the height of 1 cm.

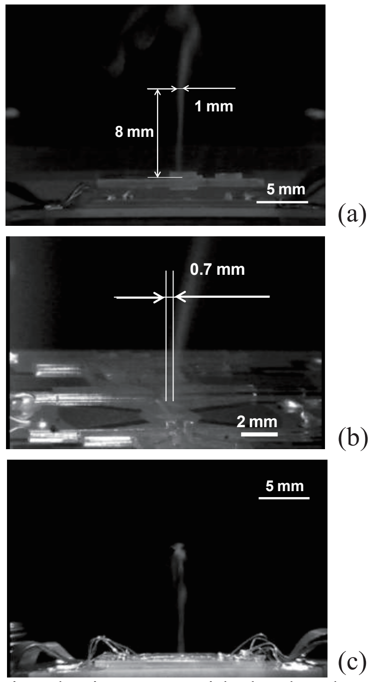

Fig.6 Directional mist spray with the developed device

6. Conclusion

This report describes a directional spraying system integrated with pico-liter pumps. The micro pump consisted of a fluid reservoir with an exhaust slot and interdigital transducers (IDTs). The atomizer was constituted by a pair of Arc-shaped IDTs (AS-IDTs) and the trench. The AS-IDT pitch was optimized by feed-backing the vibration observation using an optical interferometer. As a result, the minimum voltage to atomize the water was reduced to less than 50% compared with previous work [2]. In the ejection test with D. I. water, we succeeded in directionally ejecting the mist spray from the substrate. The mist spray was 0.7 mm wide near the substrate, which was maintained at less than 1 mm within the ejection height of 8 mm. In addition, the atomization of acetone was succeeded as well.

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