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Evaluation of atomization using surface acoustic wave devices with different frequencies

周波数の異なる弾性表面波デバイスを用いた霧化現象の評価

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1. Introduction

Surface acoustic waves (SAW) travel along a surface of elastic materials, such as piezoelectric substrates. When a piezoelectric substrate surface is in contact with a small droplet, the longitudinal waves are radiated into the liquid at Rayleigh angle. Continuous flow known as an acoustic streaming are induced by the longitudinal wave radiated into the liquid. Further, capillary waves are excited on the liquid surface. Mist is ejected from the crest of the capillary wave (see **Fig. 1**). This is the principle of the SAW atomization. The SAW atomization has been studied in order to apply such as drug delivery applications, cooling spray, and deposition of nanoparticles for generating thin film [1-3].

A mist diameter is determined by using the Lang's equation,

$$D = 0.34\sqrt[3]{\frac{8\pi\gamma}{\rho f^2}} . \qquad (1)$$

Where D is the droplet diameter, f is the applied frequency, γ is the surface tension, and ρ is the density of the liquid [4]. Normally, Lang's equation is used in the lower frequency ultrasonic. Therefore, it is unclear determined the mist diameter atomized at the higher frequency ultrasonic. In addition, the quantity of atomization is also not possible to determine. In this paper, we measured quantity of atomization and mist diameter using SAW devices with different frequencies.

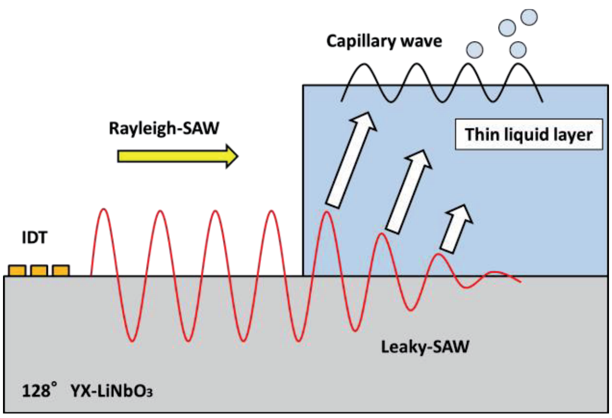

Fig.1 Schematic of the atomization process

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2. Equipment

2.1. SAW devices

An interdigital transducer (IDT) was fabricated on a piezoelectric substrate, 128°Y-X $LiNbO_3$, using an UV photolithography technique. The operating frequency of the SAW device is determined by the width of an electrode finger in the IDT. The frequencies in this study are 13, 50, 96, and 150 MHz. To excite the SAW, the burst wave applied to the IDT. Applied power was 3 W. Applied power for 13 MHz SAW device, however, was fixed at 10 W in the mist diameter measurements. Pulse frequency and duty ratio were fixed at 1Hz and 30 %, respectively.

2.2. SAW atomization system

The SAW atomization system used in the study is shown in **Fig. 2**. Cover to prevent evaporation was put in the acrylic pool. The SAW device was fixed onto the cover. There were holes in the cover. Filter paper was dipped in water at both ends as shown in Fig. 2. Due to capillary action, the filter paper pumped water up onto the SAW device. Therefore, this structure can be atomized in a long time. Further, ignoring the effects of evaporation, it is possible to measure the quantity of atomization.

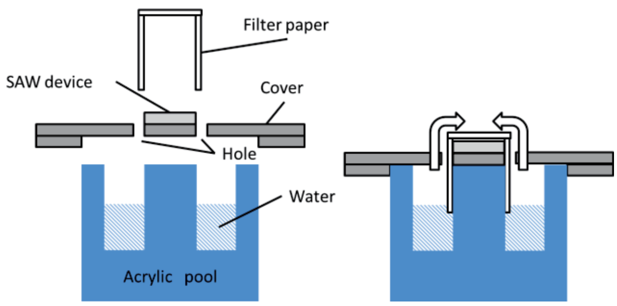

Fig. 2 Cross-section of the atomization system

3. Measurement

We measured quantity of atomization and mist diameter as a function of the SAW frequency. Quantity of atomization was measured in 10 minutes. The mist was collected for 5 seconds on a cover glass with a silicon oil thin layer. Then, mist diameter was observed with a microscope. The mist diameter was determined from the average of 150 samples at each frequency. The results are shown in **Figs. 3** and **4**. The quantity of atomization was 16.7 mg/10min (13 MHz), 16.3 mg/10min (50 MHz), 14.3 mg/10min (96 MHz), and 10.3 mg/10min (150 MHz), respectively. This result shows that the quantity of atomization decreases with increasing frequency. The mean mist diameter was 4.67 µm (13 MHz), 3.47 µm (50 MHz), 2.98 µm (96 MHz), and 2.51 µm (150 MHz), respectively. This result shows that the mean mist diameter is reduced as the frequency increases. However, by the detection limit of the optical microscope, liquid droplets having a diameter of less than 1 µm could be observed. Therefore, the actual value may be lower than the measured value. In any case, the measured value at 13MHz was smaller than the estimated value by Lang's equation. **Fig. 5** is an observation image of the mist droplets in at 96MHz, which were taken using an optical microscope at 400x magnification. **Fig. 6** is a histogram of the droplet size and particle number in 96MHz. Particle number was the maximum value when mist diameter was 3.7 µm. The maximum value of particle number was larger than the mean mist diameter of 96 MHz.

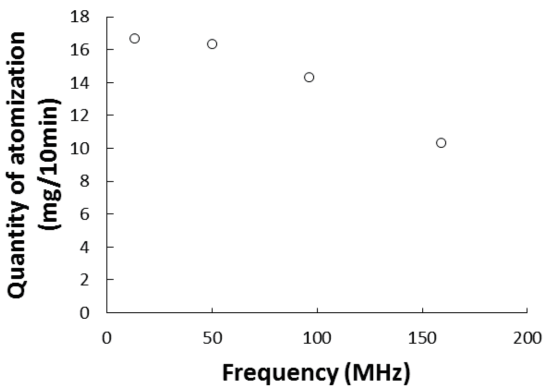

Fig. 3 Quantity of atomization as a function of frequency

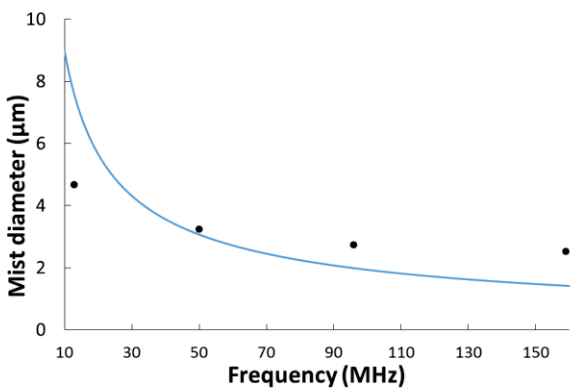

Fig. 4 Mist diameter as a function of frequency (● is measured value and the estimated value of Lang's equation)

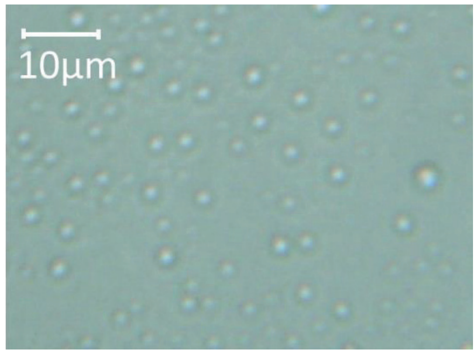

Fig. 5 Observation image of the mist droplets (400x Magnification, 96MHz)

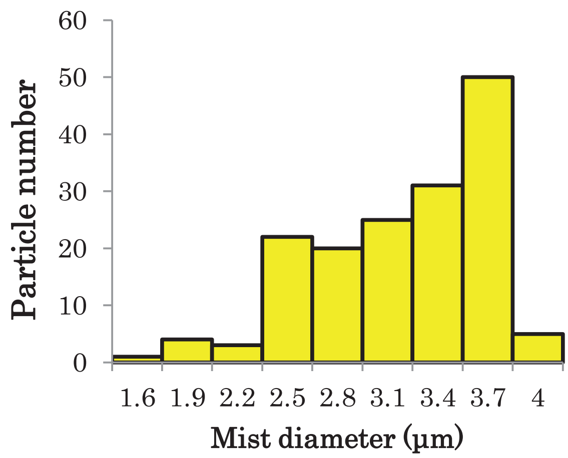

Fig. 6 Histogram of the droplet size and particle number (96MHz)

4. Conclusion

In this study, we measured quantity of atomization and mist diameter as a function of frequency. Observation images and particle size distribution of the mist was obtained. When the frequency is increased, the mist diameter is reduced. Further, atomization amount is also reduced. Due to adjust the frequency, it is possible to obtain the required atomize characteristics.

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