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Evaluation of a Microchannel Device for an Emulsion Generation by using a Piezoelectric Polymer Sensor

エマルション生成用マイクロ流路デバイスの圧電高分子センサによる評価

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1. Back Ground and Purpose

Generation of small droplets and emulsions has been an important technique in industrial processes. To generate emulsions, an ultrasonic emulsicication has been used widely. On the other hand, the conventional ultrasonic emusification is obtained by using cavitation effect and the process is too loud and difficult to avoid contaminations.

Recentlly, ultrasonical emulsification using microchannel devices oscillated by piezoelectric transducer has been reported [1, 2]. By using the device, the emulsification in the flow proceess can be realized. In these devices, the driving frequency was higher than 2 MHz. This is higher than maximum audibile field. On the other hand, the frequency is too high to utilize the cavitation effect. This is because the cavitation threshold value depends on the frequency.

In this study, a micro patterned cavitation detecting sensor has been fabricated and evaluated. The aim of this study is to confirm the cavitation condition in the microchannel device by using the piezoelectric polymer sensor.

2. Structure and Principle

The fabricated sensor is attached on a microchannel of an emulsion generation device using ultrasonic vibration. **Figure 1** shows the schema of the sensor attached on the microchannel device. The microchannel device plates are made of stainless stell and oscillated by piezoelectric element which is glued on the surface of the plate.

The sensor consists of a piezoelectric polymer film and electrodes patterned by using a photo fabrication process. The piezoelectric polymer, P(VDF/TrFE), is used to detect the acoustic signal. The piezoelectric polymer film has been repolarized under a high electric field after the deposition process. **Figure 2** shows the photographs of electrode pattern of the sensor and the assembled device.

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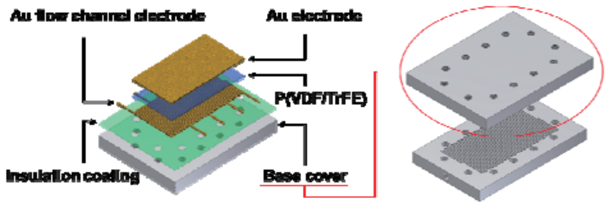

Fig.1 Structure of the sensor attached on the microchannel device

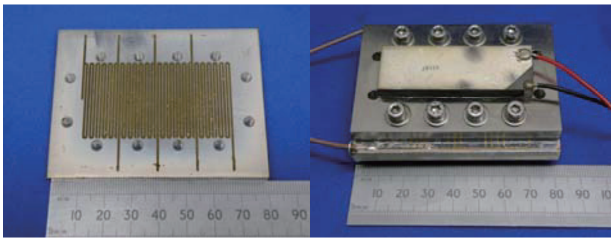

Fig.2 Sensor electrode pattern and fabricated device

3. Cavitation Sensing

To evaluate the sensor, a receivng sensitivity was tested in the underwater experiment. The acoustic signal was successfully detected by the sensor. Additionally, cavitation sensing test was conducted. The cavitation field was oscillated by using a bolt clamped type Langevin transducer. From the detected acoustic power spectrum distribution, an evaluation index was estimated. The estimated AOC (Amount Of Cavitation) index can indicate the cavitation condition by usnig acoustic emission sensor [3]. The AOC value is defined as

$$AOC = \int_{1\mathrm{MHz}}^{5\mathrm{MHz}} D(f) \qquad (1)$$

when $D(f)$ [V^2/MHz] is the observed power spectrum density. **Figure 3** shows the frequency distribution of the power spectrum density detected by using the fabricated sensor. When the oscillating power was increased, the estimated AOC was also increased to be 1.5 times larger.

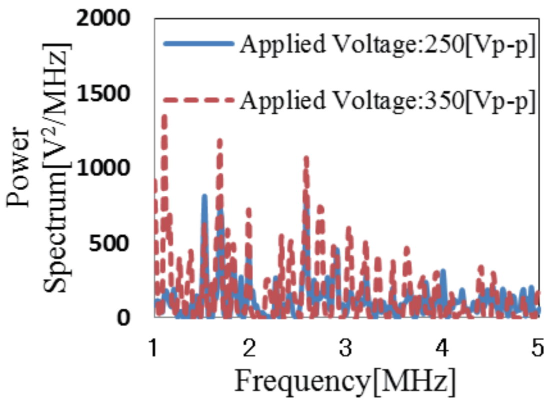

Fig.3 Relationship between the power spectrum density and frequency when the applied voltage to the transducer was changed

4. Evaluation of the Microchannel Device

Finally, by using the sensor and the emulsion generation device, we have evaluated the acoustic condition in the microchannel of the device. **Figure 4** shows the schema of the experimental setup. The emulsion was an oil in water (o/w) type and generated by using sylinge pumps, a Y-type microchannel device and the microchannel device oscillated by using the piezoelectric transducer [1, 2]. This emulsion generation system has been used to generate a drug emulsion. In the experiment, as the contiuous and dispersed phases, those for drug emulsion was used. The generated oil droplets' diameter was sub-micron size. The driving frequency of the transducer was 2.28 MHz. The driving frqeuency depends on the dimensions of the microchannel and the transducer [1, 2].

Figure 5 shows the frequency distribution of power spectrum in the microchannel device when the driving frequency was 50 $V_{p\text{-}p}$. The larger peaks are found at the frequency of the half wavelength, the driving frequency and the second harmonic frequency. The result indicates that the sensor has successfully detected the acoustic signals.

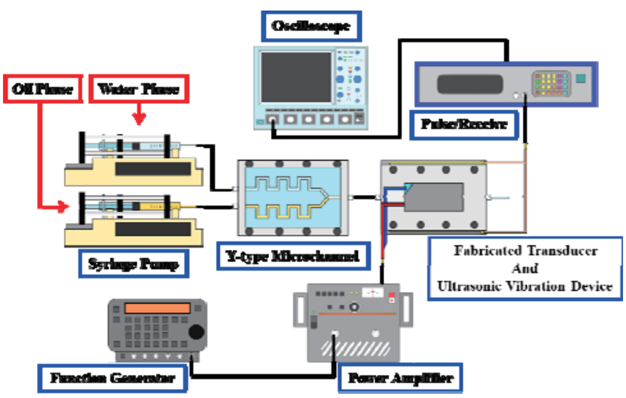

Fig.4 Schema of the experiment to evaluate the cavitation condition in the microchannel device oscillated by the piezoelectric transducer

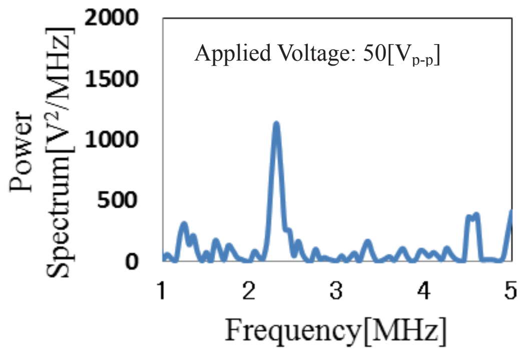

Fig.5 Distribution of power spectrum in the microchannel device observed by using the fabricated sensor

Additionally, the relationship between the power spectrum and the frequency was estimated by changing the applied voltage. The large peaks were shown in the frequencies which were observed in the first case. In addition, irregular peaks were not emerged. The estimated AOC values in each condition have only 2 % difference. These results means that the cavitation effect was not observed in the microchannel device.

5. Conclusion

We have fabricated and evaluated the cavitation sensor attached on the microchannel of an emulsion generation device using ultrasonic vibration. The piezoelectric polymer has been used to detect the acoustic signal. From the acoustic power spectrum distribution, an evaluation index value was estimated. In the experiment using the fabricated sensor and the emulsion generation device, the cavitation was not observed in the microchannel.

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