PERFORMANCE OF MICRO-INJECTOR WITH INNER BLOCK FOR DROP ON DEMAND APPLICATIONS

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This paper investigates the characteristics of a piezoelectric micro-injector for drop-on-demand (DOD) applications. The micro-injector is designed with an inner block inside the chamber to enhance the instability energy for the production of mono-size droplet. The micro-nozzle was fabricated by MEMS processes. The upper chip is a silicon chip with two holes as the inlet and outlet of the liquid matter. A diaphragm is mounted on the center of the upper chip. The lower chip has an orifice of 50 μm in diameter. The flow through the chamber is used to promote the refilling mechanism for droplet generation. A piezoelectric actuator operated in push mode (D33) was mounted on the upper chip to drive the liquid through the nozzle. An inner block is designed on the inner side of the upper chip. Results show that the micro-injector with inner block could generate mono-size droplet under the driving voltage ranging from 62.5 to 150 volt at frequency of 3.2 kHz. The droplets size was 60 μm with velocity ranging from 3.3 to 4.7 m/s which is higher than the case without inner block. As a comparison, the injection of the micro-injector without inner block needs a much higher driving voltage of 112.5 volt at driving frequency of 9.7kHz. It is concluded that the micro-injector with the inner block performs better than the one without the inner block.

Keywords: Micro-injector, Mono-size, Piezoelectric, inner block, drop-on-demand.

1. Introduction

In recent years, droplet-on-demand (DOD) printing system is widely used in many applications. In terms of the driving force, the drop-on-demand inkjet printing can be divided into several types: PZT actuated, thermal bubble actuated, electrostatic actuated, acoustic actuated and so on [1]. In the micro-droplet-ejecting technology, inkjet printing is the most valuable application. According to the deformation modes of piezoelectric actuators, the commercial piezoelectric inkjet-printing technologies are divided into four main types as Squeeze Mode, Push Mode, Bend Mode, and Shear Mode. In this study, our designs of micro-injector are related to push mode on D33 direction of PZT crystal.

The mechanism of droplet generated has been described by Lord Rayleigh in 1878 [2]. The actuator suddenly changes the volume of liquid chamber to build the liquid pressure up. The pressure leads to the ejection of liquid jet from the orifice. Then the jet breaks up into one or more droplets.
In 1999, Laurell et al. [3] made a new micro-nozzle with flow-through design. The nozzle has additional liquid outlet and creative cross flow through the chamber. The flow would remove the air bubble in the chamber, and improve the ejecting performance [4]. In 2007, Wang et al. [5] made a Push-Pull feeding nozzle that could work in very high driving frequency as 200kHz. The cross flow could feed the liquid which is pushed out from the orifice and increase the driving frequency. In this research, we use the similar design to study the characteristics of the injector and add the inner block in chamber to improve the performance.

2. Micro-injector Design, Fabrication and Experimental Setup

Figure 1 shows the sketch of PZT micro-injector. The flow through the chamber is used to remove the bubbles in the micro-injector and promote the refilling mechanism for droplet generation. A piezoelectric actuator with size 12mm×4mm×0.7mm operated in push mode (D33) was attached on the upper chip to drive the liquid through the nozzle. The height of the chamber is 230μm. A block with dimensions of 1mm×1mm×50μm is designed on the inner side of the upper chip.

The micro-injector consists of the upper and lower chips with substrate dimensions of 20mm×10mm×0.25mm, as shown in Fig. 2. The upper chip is a silicon chip with two holes as the inlet and outlet of the liquid matter. A diaphragm with dimension of 3mm×3mm×20μm is fabricated on the center of the upper chip with an inner block at the center. The lower chip has an orifice of 50μm in diameter. Surface modification is used to make hydrophilic surface around orifice. The lower and upper chips were bonded by polyepoxide.

As demonstrated in Fig. 3, the experimental setup includes a liquid supply container, liquid collected tank, and droplet visualized system. Working media (water) is supplied by an elevation head. The progression of droplet was visualized employing a microscope and CCD camera with a synchronized stroboscope LED light. The driving signal is generated by function generator and amplified by voltage amplifier. The PZT actuator driving signal is the modulated square wave. The synchronization of stroboscope is controlled by the delay generator. The velocity and size of droplets are measured by image analysis.

3. Results and Discussion

Figure 4 shows the image of droplet ejected from two nozzles, one is the nozzle with inner block (See Fig. 4 (a)) and the other is the one without inner block (see Fig. 4 (b)). The driving frequency of Fig.4 (a) and Fig. 4(b) are 3.2kHz and 9.7kHz or multiple that base on the fundamental frequency of the nozzle. It is observed that the nozzle with inner block has the better ejection quality. The droplets of Fig.4 (a) are more stable and energetic than that of Fig.4 (b). Note that the stability of droplet ejections could increase the accuracy of printing. The locations of droplets shown in Fig.4 (b) are not fixed precisely. It means that the droplets are less energetic and are easily influenced by the
surrounding air motion. Comparing with these two figures, the nozzle with inner block will have better printing quality.

Figure 5 presents a comparison of the driving voltage and mean velocity of the droplets from the two nozzles. Results show that the droplet velocity increases with increasing driving voltage. It is due to the larger amplitude of piezoelectric actuation with voltage increase. The relationship of velocity and voltage is found to be linear in Fig. 5. Fig. 5 also shows the comparison between the droplets velocity of two nozzles. In the same driving voltage, the droplet velocity of the nozzle with inner block is higher than that without inner block. It shows that the design of inner block could improve the performance of droplet generation.

The relationship between the droplet size and voltage is shown in Fig. 6. It could be seen that the mean droplet size is almost the same at voltage ranging from 125 to 150 V. It indicates that the driving voltage has no significant effects on droplet size within this range. The droplet size is mainly controlled by the dimensions of nozzle according to the current result. Comparing between two nozzles, the mean droplet size of the nozzle with inner block is larger than the one without inner block. It indicates that the mass pushed out from the orifice is greater with the inner block due to the change of flow direction near the orifice. The higher jet velocity and lower driving frequency of the case with the inner block justify the above observation.

4. Conclusions

The new design of micro-injector with inner block was presented. The nozzle with inner block has higher droplet ejection. The mass pushed out from the orifice is greater with the inner block due to the change of flow direction near the orifice. The higher jet velocity and lower driving frequency of the case with the inner block justify the observation. Moreover, the droplet velocity increases linearly with the driving voltage. The droplet size depends on the driving frequency but not the driving voltage. Hence the droplet size can be controlled by the design of the inner block and the driving frequency.

5. Illustrations and Photographs
Fig. 3 Schematic sketch of experimental setup

Fig. 4 Injection tests with and without inner block (a) with inner block (b) without inner block

Fig. 5 Relationship between droplet velocity and driving voltage

Fig. 6 Relationship between mean droplet size and driving voltage

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Reference