Experimental Investigation of Piezoelectric Micropumps with Single, Series or Parallel Pump Chambers

Yanfang Guan†, Mingyang Bai, Xiangxin Meng, Yansheng Liu and Fengqian Xu
College of Mechanical Engineering, Henan University of Technology, Zhengzhou 450001, China.
† Corresponding author

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Three types of piezoelectric micropumps following different configurations: single, series, and parallel connection, are developed and investigated. All the micropumps are fabricated by wet etching technology and sealed by high temperature glass bonding. They share the same dimension characteristic of diffuser/nozzle microchannels. Verifying the impact of adding series or parallel connected pump chambers on single chambers, as well as verifying the performance of the flow rate, pressure and piezoelectric transducer vibration of three micropumps have been examined. Through the comparisons between three kinds of micropumps, the results show that the flow rate of the micropumps with parallel connected pump chambers have a higher flow rate than that of micropumps with single and serial connected pump chambers under the same driving conditions. In addition, both the flow rate and pressure with the serial micropump are the lowest. The pressure of the micropump with single pump chamber is larger than other kinds of micropumps at certain driving frequencies. Consequently, increasing the pump chambers cannot always increase the performance of the micropump. This coincides with the theory analysis. Finally, the vibration performance of piezoelectric transducers with three micropumps have been carried out. The parallel transducer has a higher vibration displacement than the other two kinds of micropumps. These results have great potentials for integration into labs with a chip or microfluidic driven systems.

1. INTRODUCTION

The microfluidic systems play an important role in the industry along with the fast-growing economy, especially in the fields of chemistry, life science, biology and aerospace. For instance, these systems have been used to synthesize, separate and analyze cells, medicines and DNA, thus benefiting the development of new medicine and therapy.

To successfully implement the microfluidic systems in these applications, the connection between microscale and macro environments is critical. In most cases, fluids are pumped through the system, and one of the most commonly used tools is the micropump. From the 1990s, A. Olsson put forward the first micropump with a diffuser/nozzle microchannel, followed by numerous micropumps being developed and improved for several decades, including a drug delivery micropump, an EHD driving micropump, a thermo-pneumatic micropump and an electroosmotic pump, etc.

Although the micropumps with a single pump chamber have been widely studied recently, micropumps with series and parallel connections of pump chambers have been proposed due to their favorable pumping performance. For example, Li Guo and Azarbadegan fabricated a micropump with parallel connected pump chambers when the measured flow rate is 151.7 µl/min. Hsu and Fangsheng Huang have tested the performance of a micropump with a series connected pump chamber. The results demonstrated that the series and parallel micropump possessed better performance compared to that of micropumps with a single pump chamber. However, it seemed that these studies did not compare the differences of working principle between single, series and parallel connected micropumps, which are the crucial points resulting in these performance differences. In this paper, these differences are discussed, and more detailed experimental data is given between three types of micropumps with the same diffuser/nozzle microchannels.

2. THEORY ANALYSIS

A schematic configuration of the piezoelectric micropumps with a single chamber, series and parallel connected pump chambers are shown in Fig. 1(a), (b) and (c), respectively. The performance of the micropump is based on a unique trait of the “diffuser-nozzle” microchannels, which has been shown to have lower flow resistance for diffuser direction flow than nozzle direction flow. Consequently, a reciprocating piezoelectric transducer motion results in a net flow from the left to right for the three kinds of micropumps.

The pressure $P$ and flow rate $Q$ of every inlet and outlet are shown in Fig. 1. The conductivity coefficient $C$ for every flow direction have been listed in Fig. 1.

\[ Q = C(\Delta P). \] (1)