Design and Simulation of Valveless Piezoelectric Micropump

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Abstract

MEMS technology has matured to the point where practical biological and chemical applications are possible. Any kind of active micro fluidic handling or analysis systems requires some kind of Micro pump system. Micropump is a miniaturized pumping device fabricated by micromachining technologies. Micropump is a key component of MEMS, which has been used widely in many fields, such as micro power systems including microturbomachinery, microfuel cells and microthrusters, chemical and biomedical applications such as lab on chip or micrototal analysis and drug delivery, aerospace , electronics, medical equipments and devices. The present work aims at design, analyze and simulation of valveless piezoelectric micropump for gentamicin intravenous administration. A Valveless Piezoelectric Micropump basically has actuator unit, pump chamber, two diffuser/nozzle element, inlet and outlet channel, power supply module and Diaphragm/ Pump membrane as shown in Figure 1. The actuator is made of a piezoelectric disc with the dimension of $\Phi 6mm \times 0.15mm$ thick and a silicon pump membrane with the dimension of $\Phi 6mm \times 0.1mm$ thick. The piezoelectric disc is made up of piezoelectric material such as Lead Zirconate Titanate (PZT-5A). The flat walled diffuser made up of silicon is selected for the proposed micropump design. The pump chamber is made of silicon and covered by glass substrate. An alternating voltage of 50V (0 to peak) is applied across piezoelectric disc. The pump operation is based on the fluid flow rectifying properties of the two diffuser/nozzle elements. The dimension difference at both ends of the diffuser causes the pressure difference and drives the fluid. Simulations are performed for actuator unit and diffuser/nozzle element individually: The pump flow depends on the excitation frequency exerted on the piezoelectric actuator and the deflection shape of the pump membrane. Eigen frequency analysis is performed to determine the vibration characteristics i.e. natural frequencies and natural mode shapes of a structure during free vibrations while it is designed. Figure 2 shows the results of Eigen frequency analysis. The first natural frequency is 58605.12Hz and the second natural frequency is 119671Hz. The maximum deflection obtained is 0.176μm at the center of the pump membrane. The relationship between the displacement at the central of the pump membrane and excitation frequency for different excitation voltages is shown in Figure 3. The excitation voltage is varied from 80V to 120V and the excitation frequency is varied from 200Hz to 500Hz. It is observed that the central displacement of pump membrane does not seem to be strongly affected by excitation frequency varied from 200 to 500Hz.

The two dimensional model of a diffuser element of length 1093μm, opening angle of 9.8 and smallest width of 80μm with the diverging-wall direction as positive direction and the converging-wall direction as positive direction is simulated. Simulations are performed for the pressure range 0-

100kPa, using water as a working fluid, thereby limiting the problem to incompressible flow. The laminar flow model is used to model the diffuser element. It is observed that Flow is greater at contraction and lower at expansion for the diffuser/nozzle elements.

Reference

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Figures used in the abstract

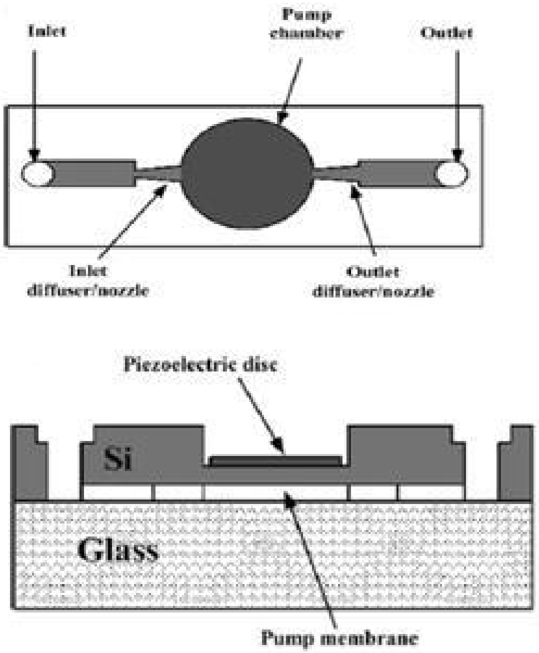

Figure 1: Schematic of Valveless Micropump top view and side view.

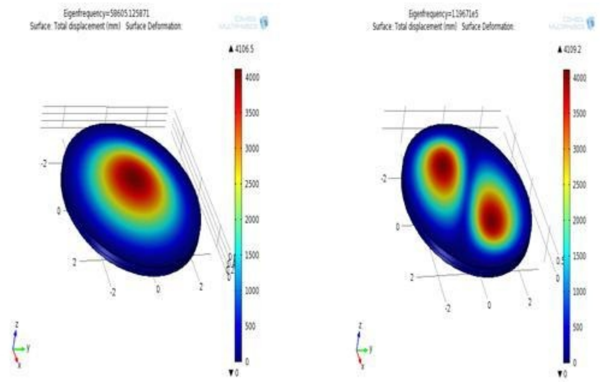

Figure 2: The modal shape of the piezoelectric actuator at the first and second natural frequencies.

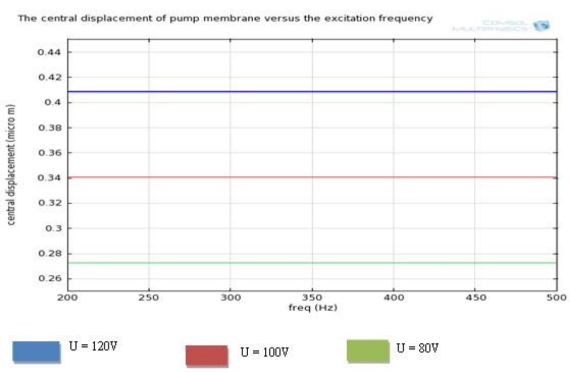

Figure 3: The central displacement of the pump membrane versus the excitation frequency.