A Novel Reconfigurable Multi-Input Multi-Output (MIMO) Micropump for Micro Drug Delivery System

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Abstract

Micropumps are important bio-MEMS (bio-Microelectromechanical Systems) devices used to drive microfluid to flow along microchannels. They are widely used for Micro Total Analysis System (μTAS), Lab-on-a-chip, micro drug delivery systems and many other applications. A typical micropump has only one inlet and one outlet. In this poster, a reconfigurable multi-input multi-output (MIMO) micropump for micro drug delivery application is reported. The proposed micropump has six inlets and six outlets. The micro-valve in each inlet and outlet can be controlled individually. As a result, microfluid can be pumped in from any (or multiple) inlets(s), and pumped out to any (or multiple) outlet(s). Piozoelectric actuation is used in the micropump design. The proposed MIMO micropump can be used for multi-drug delivery system and other applications.

Introduction

Micropumps are MEMS actuators used to drive microfluid to flow toward certain destination. Micropumps usually refer to the pumps that are fabricated on the scale of microns (1μm=10^{-6}m). The proposed pump chamber is sealed by a thin silicon diaphragm with piezoelectric actuator deposited on top of it. When driving voltage is applied to the piezoelectric actuator, the expansion and shrinking of the piezoelectric actuator activates the silicon membrane to bend up and down. Hence the microfluid is sucked into the chamber from the inlet(s) and pressed out of the outlet(s) repeatedly. The MIMO micropump can deliver multiple medicines using a single micropump device. Compared to the traditional single-input single-output (SISO) micropump design, the reported MIMO micropump has more flexibility and better efficiency. It allows users to delivery multiple medicines using a single micropump device. The design and the working principle of the micropump are analyzed. ANSYS FEM simulation is used to verify the different working modes of the MIMO micropump.

Piezoelectric Micropump Design

Table 1. The optimized design parameters of the MEMS Piezoelectric Micropump

Measurement Variables	Values (μm)
Micropump width (W_b)	8000
Micropump length (L_b)	8000
Micropump thickness (t_p)	420
Chamber height (H_c)	400
Si membrane thickness (H_m)	20
Silicon frame width (W_f)	800
Inlet/Outlet width (W_{io})	800
Inlet/Outlet length (L_{io})	800
Inlet/Outlet height (H_{io})	400
Piezo actuator width (W_a)	1000
Piezo actuator length (L_a)	1000
Piezo actuator thickness (t_a)	20

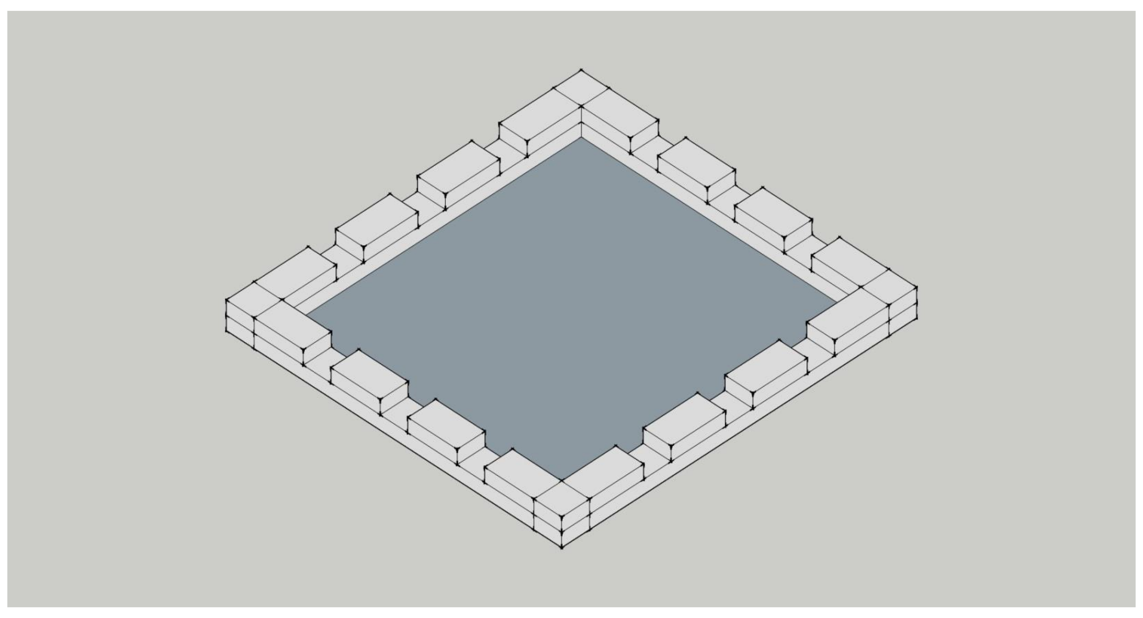

Figure 1. Micropump with multi-input and multi-output (substrate not shown)

ANSYS Simulation

ANSYS modal analysis is performed to extract the top five vibrational modes of the micropump (Figs 4-8). Among them, the first vibrational mode (Fig. 4) is the working mode where the membrane bends up and down. The corresponding resonant frequency is found to be f1=52.177kHz. Other higher vibration modes have resonant frequencies far away from working mode. The Z-component displacement and stress intensity plot of activated micropump is shown in Figs. 10-11. Fig 12 shows the relationship between maximum membrane displacement and membrane thickness. As membrane thickness increases, maximum membrane displacement decreases. This can guide us in device design optimization.

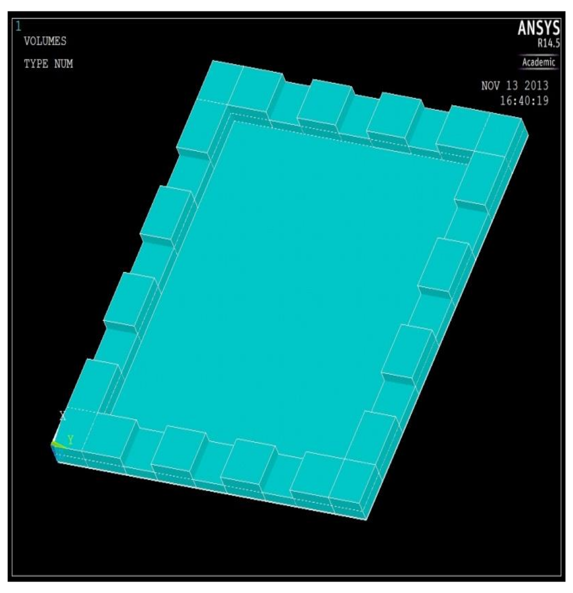

Figure 2. ANSYS model of the micropump

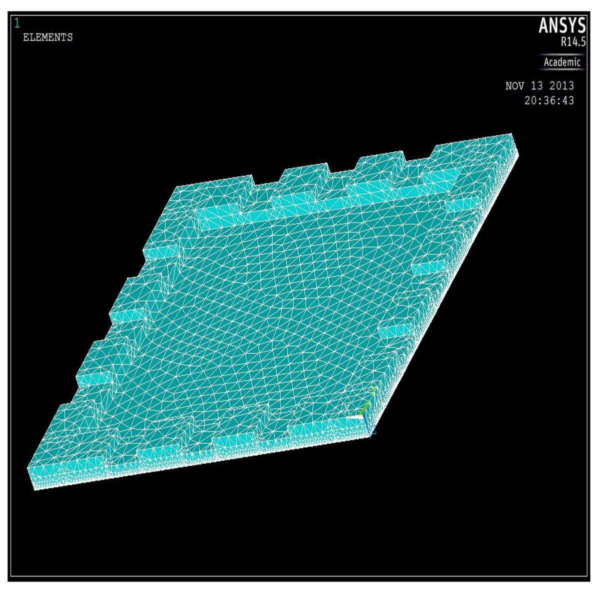

Figure 3. Micropump after Meshing

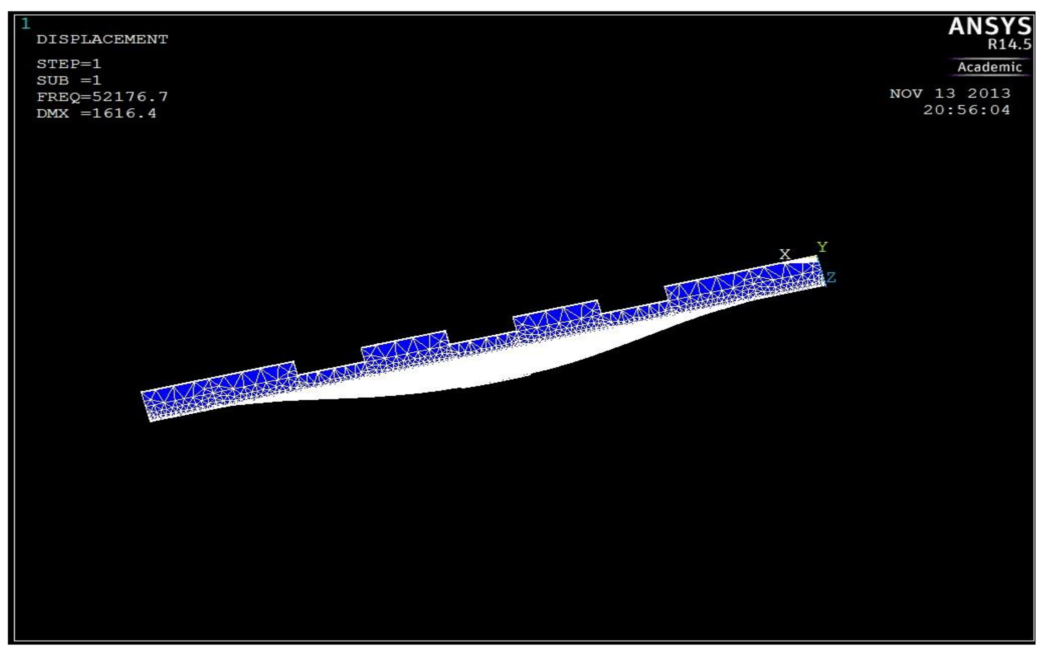

Figure 4. First vibrational mode (f1 = 52.177kHz)

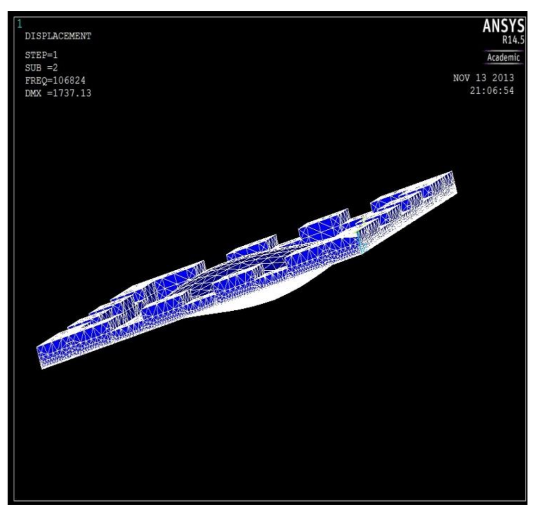

Figure 5. 2nd vibrational mode (f2= 106.824kHz)

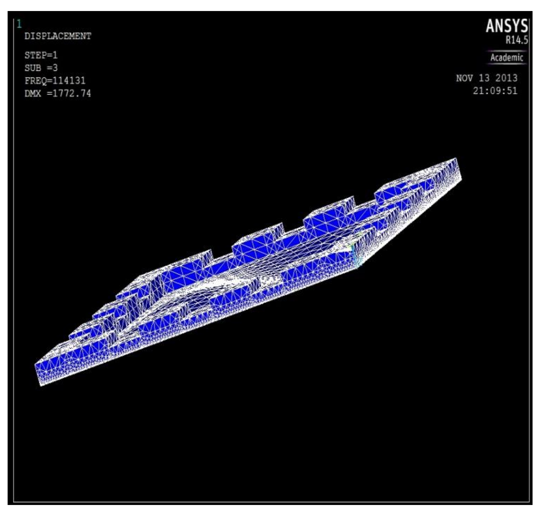

Figure 6. 3rd vibrational mode (f3 = 114.131kHz)

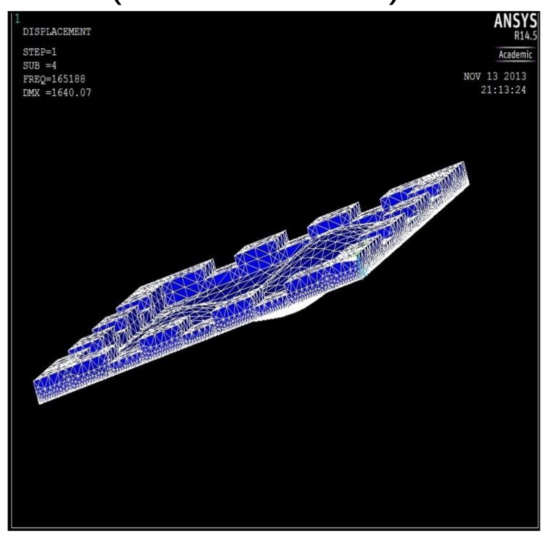

Figure 7. 4th vibrational mode (f4 = 165.188kHz)

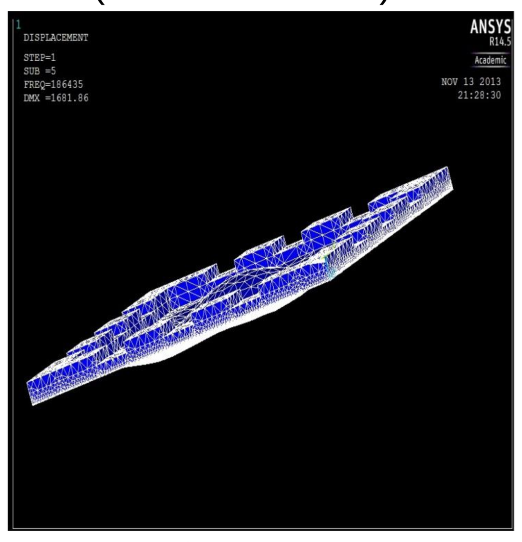

Figure 8. 5th vibrational mode (f5 = 186.435kHz)

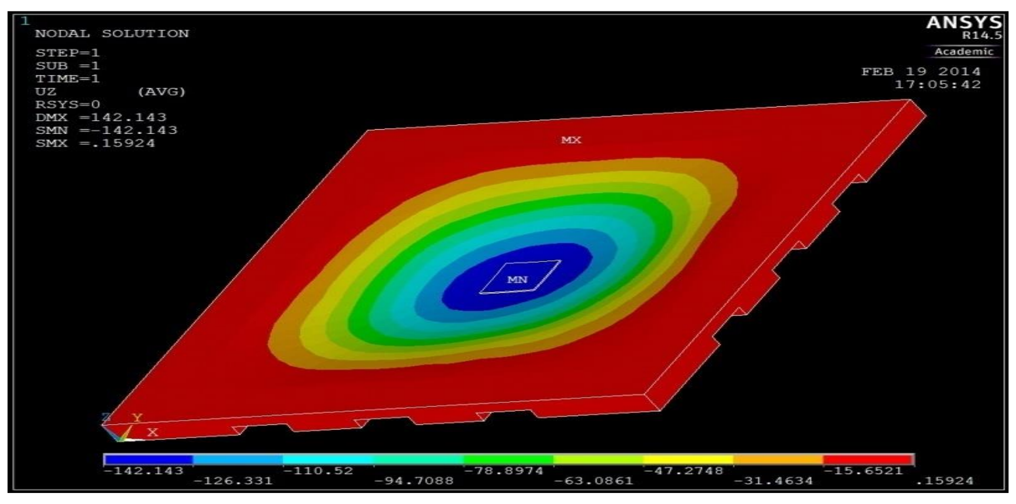

Figure 9. Contour plot of Z component displacement

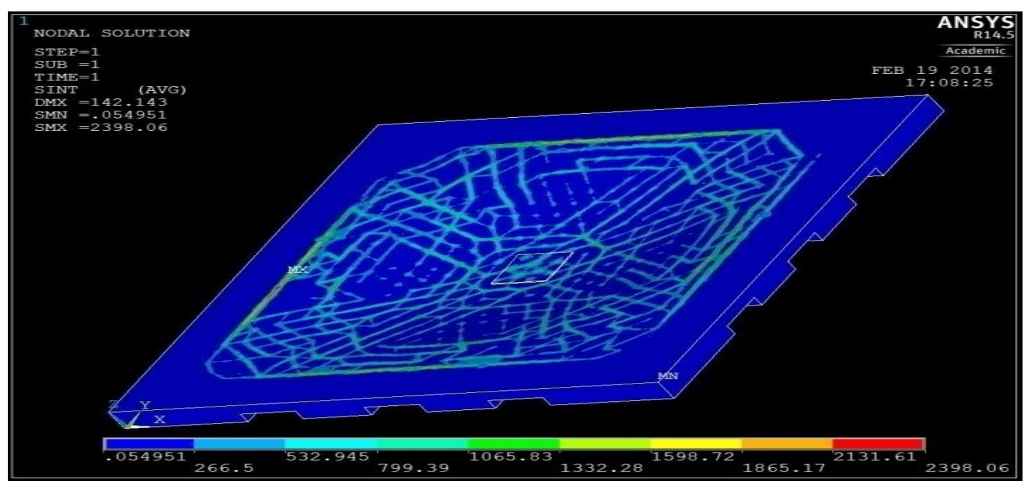

Figure 10. Contour plot of stress intensity

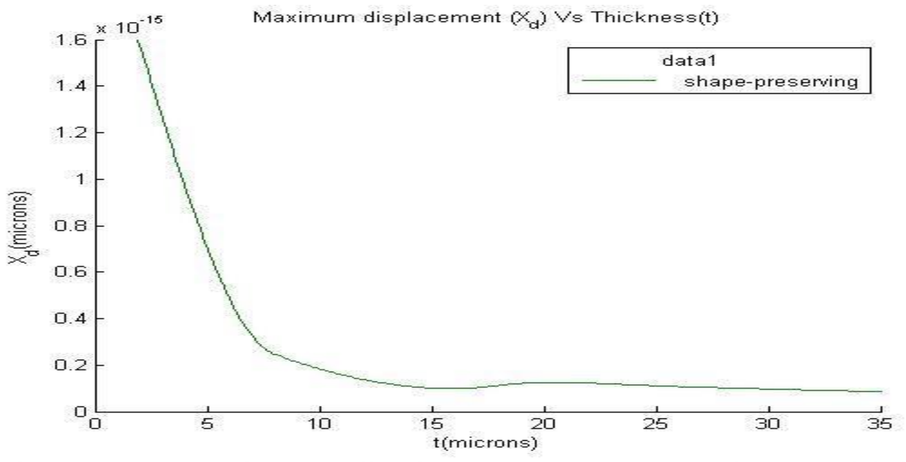

Figure 11. Maximum displacement v.s. membrane thickness

Conclusions

In this poster, a novel piezoelectric MIMO (multi-input multi-output) micropump design is proposed. Compared to traditional SISO micropump, the proposed MIMO micropump offers convenience and reconfigurability for multi-drug delivery system.