Design, Fabrication and Optimization of Novel Micro Electromagnetic Actuator for Micro Valveless Impedance Pump

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ABSTRACT

This dissertation develops a novel micro electromagnetic actuator comprising a permanent magnet mounted on a flexible PDMS diaphragm and an electroplated Cu micro coil fabricated on a glass substrate. The major components within the actuator, namely the magnet, the diaphragm and the micro coil, are designed, modeled and optimized using a combined theoretical and numerical approach. A prototype version of the actuator is fabricated using conventional MEMS techniques and its performance is compared with that predicted by the theoretical and simulation models. The flow rate generated by the designed actuator is predicted using mathematical models of the volume change in the microchannel and the actuator diaphragm deflection, respectively. An analytical expression relating the magnetic actuating force, the volume change, the diaphragm displacement and the diaphragm strength is developed and is used to optimize the actuator design under the twin constraints of maximizing the flow rate while maintaining the mechanical integrity of the actuator. To find the natural frequency of the micro pump, the vibrational response of the pump structure is characterized using a systematic theoretical method in vibration analysis. The analytical results developed for the optimal diaphragm, magnet and micro coil designs are verified both experimentally and by constructing a model of the micro actuator using Ansoft/Maxwell3D FEA software and predicting its performance by the theoretical model. The valveless micro impedance pump proposed in this dissertation has a planar structure and is therefore readily integrated with current-generation biomedical chips. Furthermore, the theoretical and simulation models developed in this study, not only provide a convenient means of characterizing the performance of the current micro electromagnetic actuator, but also provide a powerful design tool for supporting the development of next-generation Lab-on-a-Chip systems.

Keywords : Micro electromagnetic actuator, Micro Electro Mechanical System (MEMS), Micro valveless impedance pump, PDMS, Vibration analysis, Volume change.

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