In-Line Micro Ball Valve Through Polymer Tubing

Kwang W. Oh*, Rong Rong, and Chong H. Ahn

*BioChip Project Team
MEMS Lab
Samsung Advanced Institute of Technology
P. O. Box 111, Suwon 440-600, KOREA
MrOhio@Samsung.com

MicroSystems and BioMEMS Lab
Center for Microelectronic Sensors and MEMS
Department of Electrical & Computer Engineering and Computer Science
University of Cincinnati
P.O. Box 210030, Cincinnati, OH 45221-0030 U.S.A

ABSTRACT

A magnetically driven in-line micro ball valve through polymer tubing has been realized in this work. By using biomedical grade silicone rubber tubing, good sealing has been achieved, and by adding an electromagnet ring or permanent magnet ring around the outlet position, much better sealing is achievable. The valve structure is symmetric so that it can be operated bi-directionally and it is very simple making it easily interfaceable with other microfluidic systems. Thus, the new ball-type microvalve developed in this work will have tremendous applications in various biochemical microfluidic systems.

INTRODUCTION

Microvalves for Microfluidics

- Zero dead volume
- Fast response
- Biochemical compatibility
- Normally-closed mode
- Low power consumption
- Various pressure and flow control capability
- Dual use for both gas and liquid
- Insensitivity to particulate contamination

Previous Work

Stainless Steel Ball and Si Valve Seat

- O. Krusemark *et. al* (1998)
- Spherical stainless steel ball can stay on a circular silicon valve seat
- Difficult to make circular shape of valve seat with silicon, so large leakage

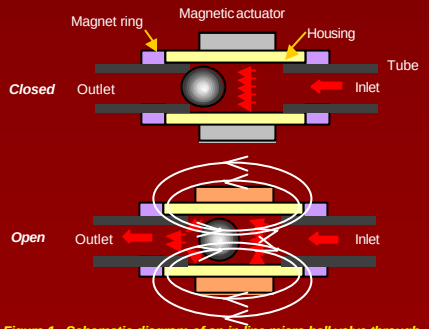

Figure 1. Schematic diagram of an in-line micro ball valve through polymer tubing.

Our Approach

In-Line Micro Ball Valve Through Polymer Tubing

- Low dead volume
- Movable ball as valve cap, remotely controlled using magnetic flux
- Ferromagnetic metal ball (stainless steel or nickel)
- Normally-closed, bi-directional, or bi-stable mode
- Magnetic force calculation to determine the position of the metal ball
- Biomedical grade silicone tubing

DESIGN AND SIMULATION

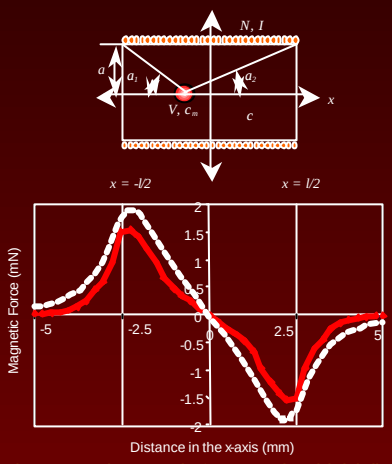

Figure 2. The magnetic forces on the nickel ball: (a) analytically calculated result (dashed line) and (b) the MagNet simulation result (solid line). a = 0.8 mm, l = 5 mm, I = 1 A, N = 500, the diameter of wire = 0.2 mm, the diameter of nickel ball = 760 μm

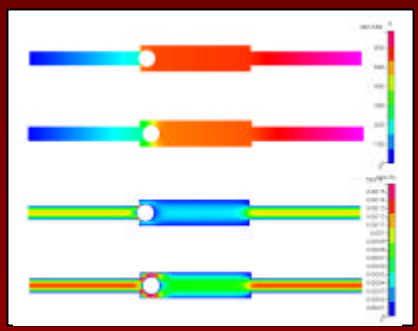

Figure 3. CFD simulation results: The pressure drop profiles when the balls (a) 100 μm and (b) 300 μm distance from the outlet, respectively; The fluidic velocity profiles when the ball is (c) 100 μm and (d) 300 μm distance from the outlet, respectively.

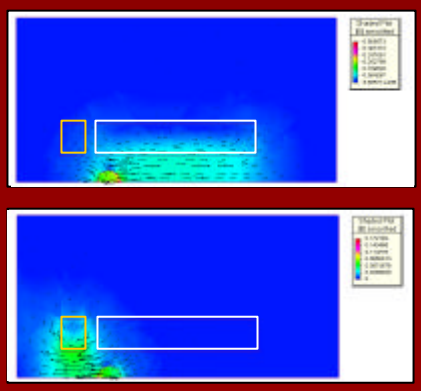

Figure 4. Simulated magnetic flux when (a) the magnetic actuator is activated for the ball to start towards downstream and (b) the electromagnet ring is activated for the ball to be ensured tight sealing.

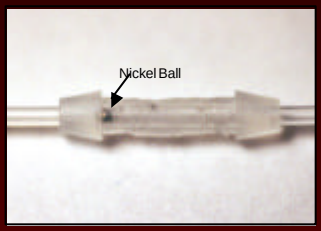

Figure 5. Photographs of micro ball valves before assembling with magnetic actuators. The diameter of the ball is 760 μm with 625 μm ID x 1190 μm OD tubes.

EXPERIMANTAL RESULTS

- Operation current: 500 - 800 mA
- Flow rate: 30 - 1300 μL/min @ 0.3 psi

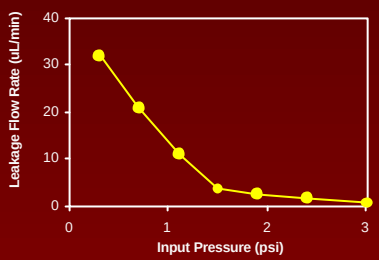

Figure 6. The leakage flow rate vs. the input pressure for DI water.

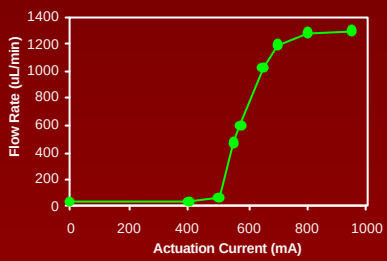

Figure 7. The flow rate vs. the input pressure for DI water at 0.3 psi.

CONCLUSION

- In-line magnetically driven normally-closed micro ball valve using polymer tubing has been prototyped.
- Low leakage flow using magnet/electromagnet rings has been suggested.
- Leakage flow and flow rate has been characterized.
- Surface mountable scheme on microfluidic board has been realized.
- BioMEMS applications are possible due to the use of biomedical grade silicone tubing.

ACKNOWLEDGEMENT

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