Magnetically Controlled Valve for Polymeric Microfluidic Devices

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ABSTRACT

Microfluidic devices (MDs) have emerged as novel analytical tools in many areas of science and industry. Their inherent qualities such as low power requirements, low sample consumption, rapid and parallel analysis, and automation provides unique opportunities to create novel and more powerful devices with a myriad of applications. Although MDs based on PDMS have been widely used, there is still a need to develop other mechanisms for the manipulation and injection of small volumes of sample in PDMS structrues. Herein, we describe a simple, external in-line magnetic valve for use in MDs constructed of PDMS and employing small magnets.

Keywords: microfluidic devices, microvalve, magnetically controlled valve

1 INTRODUCTION

In recent years polydimethylsiloxane (PDMS) has been widely used for microfluidic, optical, and nanoelectromechanical structures and in low-cost replication processes such as replication molding and templating.[1,2]

Research on microfluidics has focused on the development of the microfluidic components, and specifically micropumps, micromixers, word-to-chip microfluidic interfaces and microvalves. One of the most important elements of a successful MD is reliable microvalves since they make possible the manipulation of liquid flow in the channels, on/off switching of fluid flow, and injection of minute volumes of solution into the separation channel. To address the issue of sample loading and manipulation a number of valve-type techniques have been developed. A recent review by Oh and Ahn detailed several types of microvalves and classified them as active or passive employing mechanical, non-mechanical and external systems.[3]

Quake et al.[1,4] developed a microfluidic valving system based on a technique called multilayer soft lithography (MSL). They combined soft lithography with the capability to bond multiple patterned layers of elastomer.

Some magnetically controlled microvalves have been detailed. Miniaturized electromagnetic microvalves were first developed for gas chromatography.[5, 6] Later, movable silicon membranes were integrated with solenoid coils[7] or mounted with permanent magnets for glaucoma implants.[8, 9] A common disadvantage of many of these methods is that they all integrate either an electromagnetic or contain a metal part of the valve on a movable membrane which prevents the chips from being disposable.

Herein, we report a simple, external in-line valve for manipulation of fluid flow in microfluidic channels. The actuation of this valve is based on the principle that flexible polymer walls in a liquid channel can be pressed together by the aid of magnets, thereby, opening and closing the microfluidic channels.

2 EXPERIMENTAL

The microfluidic chip with magnetically controlled microvalve includes two PDMS layers stacked to each other and sealed on to a thin microscope cover glass. The upper thick PDMS layer is used to hold the metal bar and the liquid connections (and electrode connections if it is needed). The lower thin PDMS layer (membrane) contains the microfluidic channels. The lower PDMS layer that contains the channels was prepared by using a mold created by photolithography.[2]

The upper thick layer was punched for the hole(s) for the metal bar(s). The diameter of the holes is ~1 mm, slightly larger than the diameter of the bars. The holes containing the upper PDMS layer was aligned with the thin lower PDMS layer and sealed irreversibly using an Ar plasma.[2] Holes (300 µm) were punched through the combined PDMS layers for the liquid and electrode connections to the chip. The PDMS chip was irreversibly sealed onto a clean cover glass of 150 µm thickness (VWR micro cover glass, VWR, USA).

For the operation of the magnetic valve a small NdFeB magnet (1/8" x 1/8" x 1/16" thick, K&J Magnetics, Inc., Jamison, PA, USA), and a cylindrical shape of metal (0.7 mm x 5 mm) (paper clip stub) as the metal bar were used. To actuate the valve the metal bar is inserted into the valve-hole and upon moving the magnet the metal is attracted towards it from the opposite side.

3 RESULTS AND DISCUSSION

The operation of the magnetically controlled valve is based on the deformation of a thin (25 μm), flexible layer of PDMS that covers the top wall of the microfluidic channel (height: 25 μm, width: 50 μm) and is due to the downward movement of the metal bar caused by a permanent magnet which is placed below the chip. In the presence of a magnet, the metal bar is pulled downward simultaneously pushing the thin PDMS membrane down thereby closing the entire channel to fluid flow. In order to open the valve the magnet must be manually pulled 5 mm away from the closure position. The use of a magnet with smaller magnetic field, thicker layer of PDMS, or larger gap between magnet and bar, only partially closes the microfluidic channel.

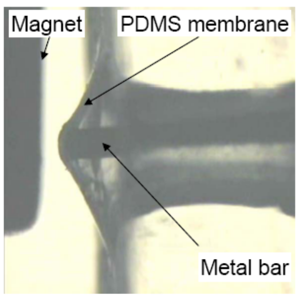

Figure 1. Microscopic photograph of deformation of a thin PDMS layer (d=30 μm) due to the movement of metal bar towards the approaching magnet monitored under the microscope. (Distance between the magnet and the PDMS layer is 2 mm; deformation {distance of the highest deformed point from its original position} is 7 mm.)

The microfluidic channels can be completely closed in flow rates ranging from 0.1-1.0 μL/min commonly used in microfluidic systems. The moving part of the valve is the upper wall of the channel itself yielding zero dead-volume.

Since the magnetic valve does not require pumps, a high voltage power supply or other components, as in the case of other microfluidic valve systems, the magnetically controlled valve-based chips can be readily portable for injection and fluid manipulation. In addition, since the magnetic valve operates externally (without any internal manipulation, integration of wires, electrodes or other units), chips made from PDMS can be easily manufactured at low cost and are disposable.

When a weaker magnet is used, the thickness of the PDMS layer or glass slide and/or gap between magnet and chip are changed, and the microfluidic channel will only partially open. We are in the process of automating the operation of the valve using miniaturized electromagnets instead of permanent magnets.

4 ACKNOWLEDGMENT

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REFERENCES

[1]Quake, S. R.; Scherer, A. Science 2000, 290, 1536-1540.
[2] Duffy, D. C.; McDonald, J. C.; Schueller, O. J. A.; Whitesides, G. M. Anal.Chem. 1998, 70, 4974-4984.
[3] Oh, K. W.; Ahn, C. H. J. Micromech. Microeng. 2006,16, R13-R39.
[4] Unger, M.A.; Chou, H-P.; Thorsen, T.; Scherer, A.; Quake, S. R. Science 2000, 288, 113-116.
[5] Terry, S. C.; Jerman, J. H.; Angell, J.B. IEE Trans. Electron Devices 1979, 26, 1880-1886.
[6] Yanagisawa, K.; Kuwano, H.; Tapo, A. Proc. Transducers'93 1993, 102-105.
[7] Bosh, D; Heimhofer, B; Muck, B.; Seidel, H.; Thumser, U.; Welser, W. Sensors Actuators A 1993, 37/38, 684.
[8] Bae, B.; Kee, H.; Kim, S.; Lee, Y.; Sim, T.; Kim, Y.; Park, K. J. Micromech. Microeng. 2003, 13, 613-619.
[9 Bae, B.; Kim, N.; Kee, H.; Kim, S.; Lee, Y.; Lee, S.; Park, K. J. Microelectromech. Syst. 2002, 11, 344-354.

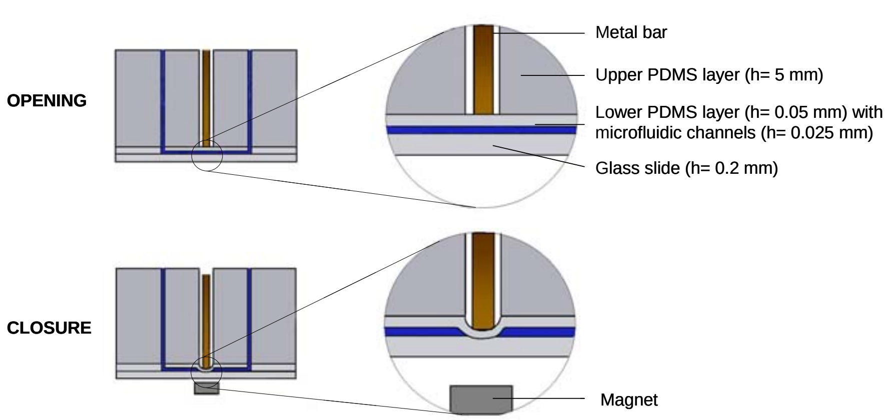

Figure 2: Schematic description of the opening and closing of the magnetically controlled valve.

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