A MULTIFUNCTIONAL VENT VALVE SYSTEM IN A CENTRIFUGAL MICROFLUIDIC PLATFORM

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ABSTRACT

Valve operation is one of the most important functions in microfluidic systems. Either active or passive valves have been applied on microfluidic platforms [1-4]. This paper reports a novel vent valve system to enable sequential transfer of fluid. The system consists of an independent vent control plate (VCP) and suitable vents on the centrifugal microfluidic disk. The design is simple and easy to control without the need of surface modification, microchannel structure, additional material in microdevice, or ultra-precision manufacturing process.

KEYWORDS

Microfluidics, disk, valve.

INTRODUCTION

The lab-on-disk platforms that use centrifugal force to pump fluids in microfluidic system have various fluid-operating functions, such as valving, mixing, decanting, calibration, metering, sample splitting and separation. Those functions can integrate with analytical measurement techniques for optical imaging, absorbance detection, fluorescence spectroscopy and mass spectrometry, which make the centrifugal platform a powerful solution for medical and clinical diagnostics as well as high throughput screening in drug discovery.

The lab-on-disk platform also offers a unique way to propel fluid that depends on spinning speed of disk, distance of fluid away from the center of the disk, geometry of channels, and fluidic properties (density, viscosity, and surface energy). With various researches on passive valves, hydrophobic and capillary valves have been integrated into disk platforms [1, 2]. However, the passive valve switched by controlling rotation rate above a critical value would highly depended on fluid characteristics, surface properties, and dimensions of the microchannels. In other words, the channel requires ultra-precise structures, local surface modifications, and investigation of influence of different liquid characteristics to obtain a critical rotation rate. For active valves, Park and Cho et al. [3, 4] have implemented Laser Irradiated Ferrowax Microvalves (LIFM) on centrifugal disk platform, which used ferrowax plug to block the channel to stop the liquid and melted by highly heated laser to open the valve. While the LIFM is more stable than the passive valve, it requires high power laser system, laser position, ferrowax melting time and additional ferrowax in the microchannels.

This paper presents an innovative vent valve system that just controls the vent control plate (VCP) to enable sequential transfer of fluid by electromagnetic valves' machine. The operation of the vent valve system is simple, fast, stable and robust. Besides, this vent valve system is easy to build and cost effective since all materials are embedded in the channel disk for blocking the channels.

MATERIAL AND EQUIPMENT

As shown in Figure 1(a), the disk and VCP was fabricated with PMMA and protective tapes by a CO_2 laser engraver. All of them are bonded together via double-sided tapes. The VCP connects to electromagnetic valves' machine via tubes on a test disk (Figure 1(b)).

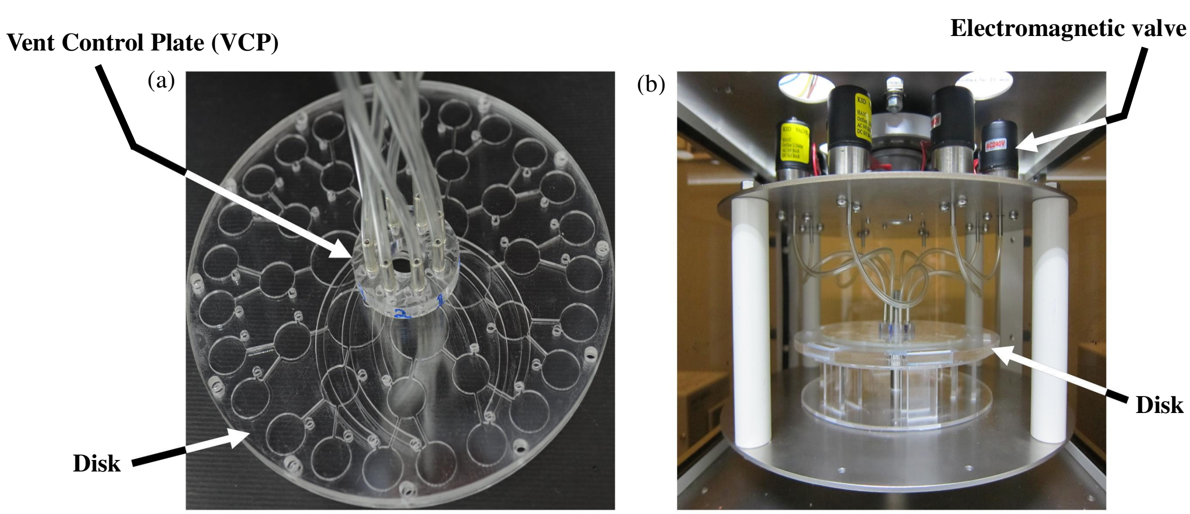

Figure 1. The disk-based microfluidic system. (a) Disk and Vent Control Plate (VCP). (b) Electromagnetic valves' machine.

RESULTS AND DISCUSSION

The physical principle of vent valve to control the liquid delivery is illustrated in Figure 2(a). When the disk platform spins, the centrifugal force provides pumping pressure to transfer the liquid. When V1 to V7 are closed, the generated negative-pressure pulls the equilibrium with the centrifugally generated pressure in the liquid. Similarly, the generated positive pressure pushes the centrifugal pressure when the V2 to V7 are closed. In contrast, the liquid could flow into downstream chamber by centrifugally generated pumping pressure while the V1 and V2 are opened. Figure 2(b) shows different liquids and different channel widths with increased burst frequencies for liquid transfer. The result shows the burst frequency is designed by liquid surface tension at same channel widths when opening vent valves. Data show the valves are very robust over a wide range of parameters.

Operation of the VCP enables system sequential transfer of fluid for complex fluid processes. Figure 2(c-1) shows the initial state of a test disk, in which 100µl of blue liquids (C1), 50µl of yellow liquid and 50µl red liquid (C2 and C3). At first, the valves (V1 and V2) were opened and the disk was spun by the rotational motor. Then, a portion of blue liquid in C1 was transferred to C2. In C2, transferred blue and yellow liquids were mixed by alternative spinning with the color changed from yellow to green (Figure 2(c-2)). After opening V1 and V3 in the same manner, the color changed from red to indigo in C3 (Figure 2(c-3)). Finally, the mixed liquids were transferred to C5 and C6 at the same time by opening V1, V5 and V6 as the disk was spun, as shown in Figure 2(c-4).

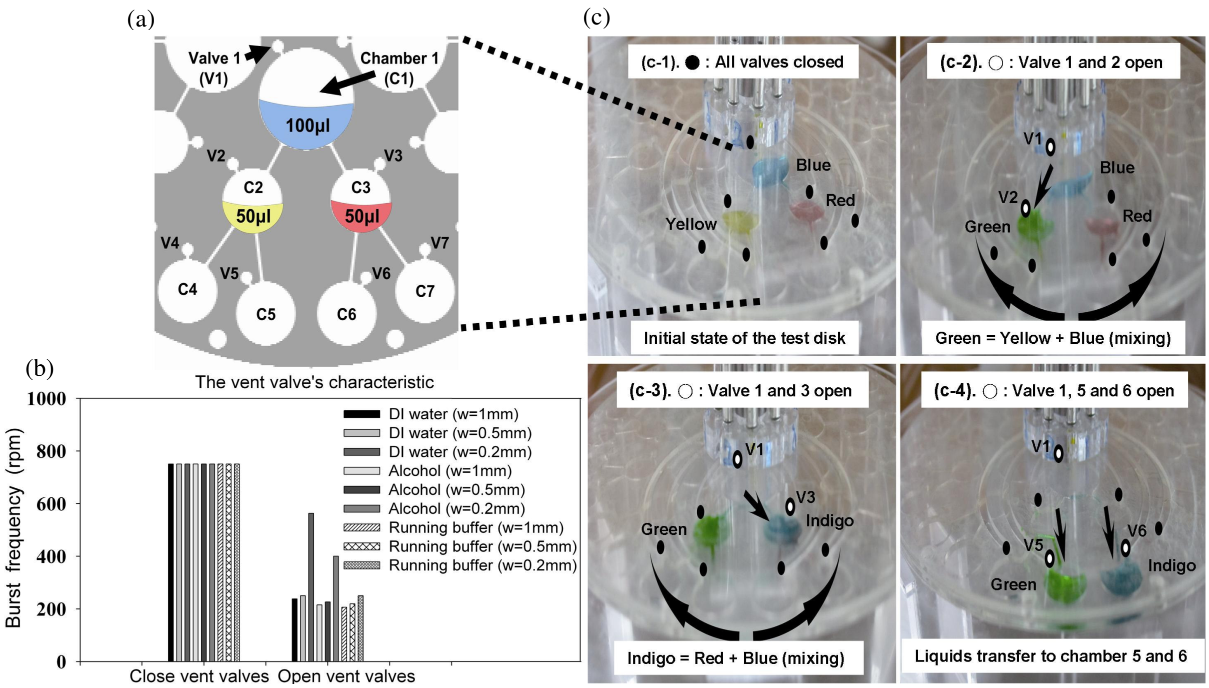

Figure 2. (a) Schematic diagram of the layout of a test disk. (b) The results of different liquids (DI water, Alcohol and Running buffer) and different channel widths (w=1mm, 0.5mm and 0.2mm) relate to burst frequency on our vent valve system. (c) (c-1~c-4) Photo images captured during the operation of the spinning process.

CONCLUSION

Table 1 shows comparison of characteristic of our vent valve with other valve system in centrifugal microfluidic platforms. Our system shows relatively independent on fluid characteristics, surface properties, channels dimensions and requires no ultra-precision channel structure, local surface modifications, or additional material in the microchannels. This vent valve system design may be suitable for a wide range of applications in microfluidic devices, including enzyme-linked-immunosorbent serologic assay (ELISA), metering and sedimentation of blood, DNA or RNA extracting, and molecular analysis.

Table 1. Comparison of several valve system for microfludics disk.

Comparison	**Active valve**		**Passive valve**	
	Our vent valve	**Paraffin wax valve /Ferrowax valve**	**Hydrophobic valve**	**Capillary valve**
Principle	Pressure	Solid barrier blocking	Surface tension	
Effect of liquid property	No	No	Yes	
Operation	VCP with machine of electromagnetic value	Laser heating	Variation of rotational spin	
Fabrication Specifics	No surface modification needed No channel structure and additional material required	Wax in channels	Surface modification	Ultra-precision channel structure required

REFERENCES

[1]M. Madou, et al., "Lab on a CD," Annual Review of Biomedical Engineering, vol. 8, pp. 601-628, 2006.
[2]J. Ducree, et al., "The centrifugal microfluidic bio-disk platform," Journal of Micromechanics and Microengineering, vol. 17, pp. S103-S115, 2007.
[3]J. M. Park, et al., "Multifunctional microvalves control by optical illumination on nanoheaters and its application in centrifugal microfluidic devices," Lab on a Chip, vol. 7, pp. 557-564, 2007.
[4]Y. K. Cho, et al., "One-step pathogen specific DNA extraction from whole blood on a centrifugal microfluidic device," Lab on a Chip, vol. 7, pp. 565-573, 2007.

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