

# **A PDMS DIFFUSION PUMP FOR ON-CHIP FLUID HANDLING IN MICROFLUIDIC DEVICES**

**Mark A. Eddings<sup>1</sup> and Bruce K. Gale<sup>2</sup>**

<sup>1</sup>Department of Bioengineering, University of Utah, Salt Lake City, UT

<sup>2</sup>Department of Mechanical Engineering, University of Utah, Salt Lake City, UT

## **Abstract**

A PDMS diffusion-based membrane pump has been developed for on-chip fluid handling within microfluidic devices. Vacuum and air pressure applied across a thin PDMS membrane were used to bi-directionally manipulate fluid at flow rates of 10-200 nl/min. Flow rates can be altered by changing diffusion area, membrane thickness, and applied pressure or vacuum. The pump has been used to rapidly fill and evacuate dead-end channels and chambers. Desired volume plugs are easily isolated and manipulated. The pump can be integrated within densely arrayed microfluidic channels and chambers for mixing, separation, and analysis.

**Keywords: PDMS, pump, dead-end filling, membrane, microfluidics**

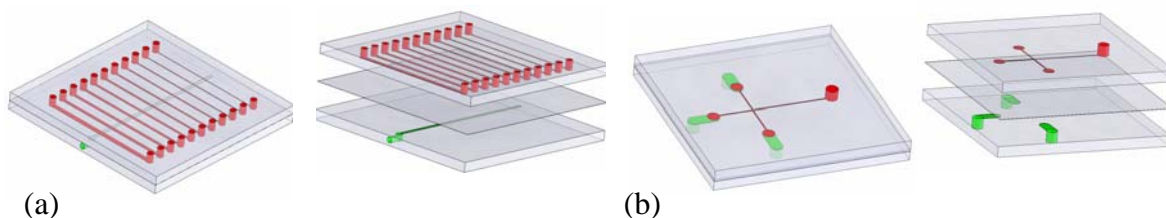
## **1. Introduction**

A significant number of micropumps have been developed for PDMS microfluidic devices based on deflecting thin PDMS membranes through pneumatic actuation. [1-2] However, rapid off-chip valving is required to generate flow. In addition, mechanical actuation within the microfluidic channels may not be suitable for all biological applications. Other micropumps have focused on the gas permeability of PDMS to generate flow. The bulk of these methods have focused on applying pressure or vacuum to the bulk microfluidic device, rather than localized diffusion areas. The bulk degassing requires additional preparation time and limits the device to one-time fluidic control. [3] The diffusion-based membrane pump solves many of these problems by applying direct pressure or vacuum on the flow without mechanical actuation, enabling continuous fluidic control, and removing bulk-degassing preparation.

## **2. Experimental**

In order to fabricate the diffusion membrane pump, previously reported multi-layer soft lithography methods were utilized [1-2]. Devices consisted of a microfluidic channel layer, a thin membrane layer, and the pressure/vacuum control layer. PDMS at 10:1 base to curing agent was poured into molds and was partially cured at 65 C° for 45 minutes. Reservoirs and tubing inlets were then cored in the channel and control layers using a 2mm diameter coring tool. A thin membrane layer was spun on a PMMA wafer and cured at 65 C° for 45 minutes. The three layers were combined and baked

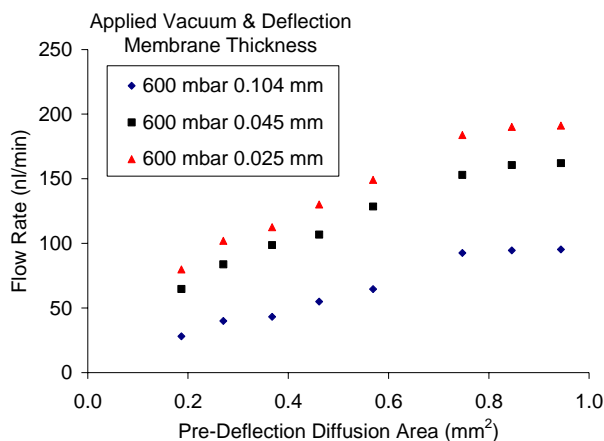
overnight at 65 C° (See Figure 1a). Tests were run varying parameters such as diffusion area, membrane thickness, and applied pressure/vacuum to determine the change in flow rate. Separate devices were fabricated using soft lithography methods to demonstrate fluid handling and dead-end channel filling (See Figure 1b).



**Figure 1-** a) Drawing of a microfluidic device used for measuring flow rates. The three-layer PDMS device consists of a fluid channel layer, diffusion membrane, and vacuum source layer. Fluid was placed in each of the wells (red) and vacuum was applied at the control inlet (green). Flow rates were measured by determining fluid displacement after a fixed time for channels of varying widths, 200  $\mu\text{m}$  to 1mm (red). b) Drawing of a microfluidic device used for demonstrating dead-end chamber filling. The chambers (red) are separated from the vacuum/pressure source by a 25  $\mu\text{m}$  diffusion membrane. One well (red) is open to atmospheric pressure. Three pressure/vacuum inlets (green) are located below each of the three chambers.

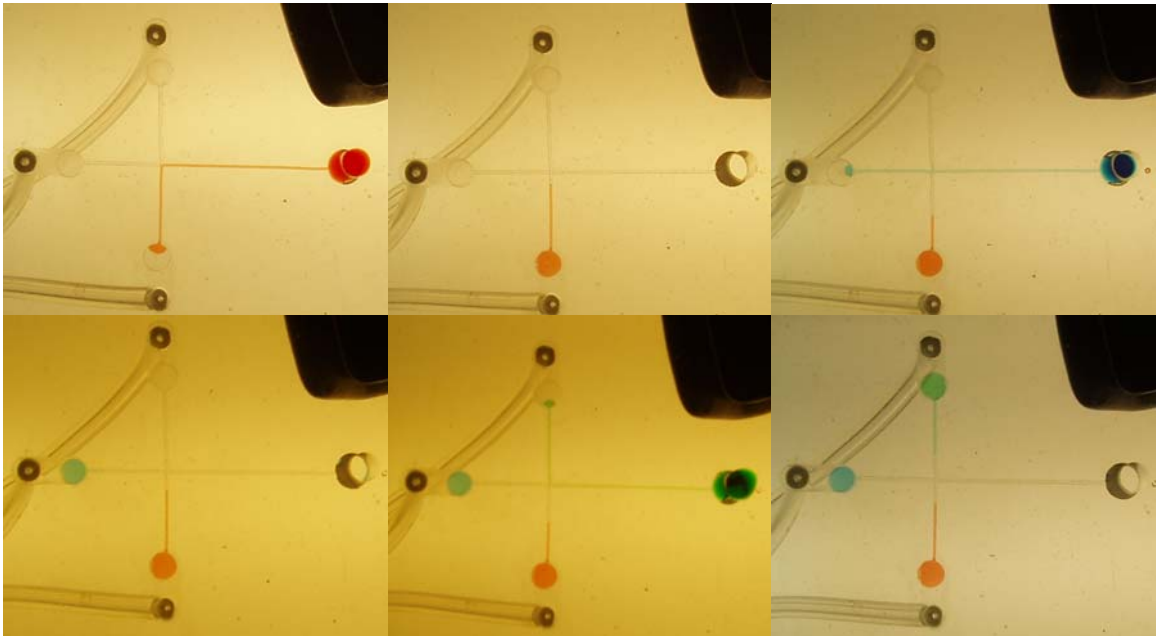
### 3. Results and Discussion

As expected, the flow rate varied linearly with diffusion area and pressure/vacuum (Figure 2). Flow rates from 10-200 nl/min were achieved with the fabricated device. Higher flow rates should be possible with larger diffusion areas.



**Figure 2-** Measured flow rates at different diffusion areas for 600 mbar applied vacuum. Data was acquired for three different diffusion membrane thicknesses 0.104, 0.045, and 0.025 mm.

Also, fluid was easily manipulated through turns in cross intersections and filling dead-end channels and chambers (Figure 3). Individual chambers were filled with different colored fluids without mixing. Rapid fluid plug dispensing and fluid mixing was possible by toggling chambers between pressure and vacuum.



**Figure 3-** Pictures of three different fluids, red, green, and blue, filling dead-end chambers. Pressure differentials across the membrane below the chambers enabled the flow to make turns at the intersection. Each fluid was placed in the open well and pumped to each individual chamber. Each chamber can be individually returned to the well or can mix with the other wells at the intersection by toggling between pressure and vacuum below the membrane at each chamber. This technique also enables the isolation of fluid plugs for dispensing and metering similar to an electroosmotic flow setup.

#### 4. Conclusion

The PDMS diffusion pump is a feasible option for complex lab-on-a-chip applications. The micropump is easily fabricated using existing methods and can be highly arrayed for multi-channel configurations. Rapid dead-end channel filling and flow rates in the 200 nl/min range have been demonstrated.

#### Acknowledgements

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#### References

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