CHARACTERISTICS OF A POLYIMIDE MICROVALVE

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ABSTRACT

A new micromachined microvalve has been designed and fabricated for a miniature micropump for nanodialysis[1]. Nanodialysis is an *in vivo* technique that permits continuous sampling of drugs and endogenous compounds in awake animals[2]. Twenty microvalves are fabricated on each 2" silicon wafer. These microvalves have been integrated into a micropump for on-line nanodialysis.

INTRODUCTION

Micromachining and microfabrication techniques are now established processes for the fabrication of miniature sensors, microactuators, and microfabricated devices for microsystems.

More recently, micromachining techniques have been applied to the fabrication of chemical and biochemical sensors, and more significantly to micro chemical systems[3,4]. Micropumps and microvalves are one of the key elements in these analytical systems. Especially, microvalves play an important role for micropumps to function properly.

The microvalves can be categorized in two types: active and passive[5-20]. The passive microvalves are function as check valves. The valves open under forward applied pressure and have small leakage under backward applied pressure. The polyimide microvalve discussed in this paper is a passive microvalve.

FABRICATION

The cavities and channels are 50 μm deep and made by anisotropic etching of silicon in 50% CsOH at 60°C for 4.5 hours, using SiO₂ masking layers on both sides of the wafer. The silicon wafer was anodically bonded to 2 1/4" diameter Pyrex glass disc by using 700-1000 V at 350°C in a nitrogen purged cabin to avoid oxidation of polyimide. The glass surface was damaged in the bonding process when using one contact point probe, however, there was no damage on the glass surface when using a gold coated surface beneath the contact. The glass opening is etched in 50% HF with Cr/Au masking layer to form the valves.

The polyimide microvalve, shown in Figure 1, has an opening diameter of 300 μm and 50 μm wide cross reinforcement strips.

Figure 1. Photograph of the polyimide check valve with opening diameter of 300 μm and 50 μm wide cross reinforcement strips.

EXPERIMENT

The flow rate of the microvalve was measured by using the setup shown in Figure 2. The different applied pressures were obtained by changing the water height. The height remains the same by adding the DI water or alcohol with a syringe. The flow volume is obtained by scaling the syringe every five minutes. The pressure loss of this measurement setup has been calculated by using Poiseuille's equation and the Bernoulli equation for viscous flow, and found negligible compared to the applied pressure.

Figure 2. Schematic diagram of measurement setup for flow rate at different pressures.

All valves tested show an aging effect. The fresh valve has a lower flow rate than after aging. Figure 3 shows the aging flow rates of DI water through a fresh 4.6 μm thick polyimide check valve with two $50 \times 200 \times 1500 \mu\text{m}$ channels under 20 $\text{cm-H}_2\text{O}$ pressure at 22°C.

Figure 3. Valve aging and saturation with 20 $\text{cm-H}_2\text{O}$ pressure applied. DI water flows through a fresh 4.6 μm thick polyimide check valve with two $50 \times 200 \times 1500 \mu\text{m}$ channels under 20 $\text{cm-H}_2\text{O}$ pressure at 22°C.

The first check valve was made with a 2.6 μm thick layer of polyimide. The flow rates of DI water under different forward pressures through the 2.6 μm thick polyimide check valve with a $58 \times 500 \times 1500 \mu\text{m}$ channel are shown in Figure 4.

The 4.6 μm check valve is stronger than 2.6 μm one for higher pressure applications. Figure 5 shows the flow rates of DI water through a 4.6 μm thick check valve and two $50 \times 200 \times 1500 \mu\text{m}$ channels at different forward pressures after aging. The dashed line indicates the flow rate is proportional to the applied pressure, and the minimum pressure to start flow is less than 5 $\text{cm-H}_2\text{O}$ pressure.

Figure 4. Comparison of the flow rates of DI water through two different 2.6 μm thick check valves and the $58 \times 500 \times 1500 \mu\text{m}$ channel under different forward pressures.

Figure 5. Flow rate of DI water through a 4.6 μm thick check valve and two $50 \times 200 \times 1500 \mu\text{m}$ channels at different forward pressures after aging.

The flow rate ratios of DI water for equal forward and backward pressures of the 4.6 μm thick microvalve are above 200, shown in Figure 6.

Figure 6. The ratio of flow rate of DI water for equal forward and backward pressures through a 4.6 μm thick polyimide check valve and two $50 \times 200 \times 1500 \mu\text{m}$ channels at 22°C.

The flow rates of isopropyl alcohol through a 4.6 μm check valve and three $50 \times 200 \times 1500 \mu\text{m}$ channels under different forward pressures are shown in Figure 7. Each measurement is 5 minutes at 22°C.

The isopropyl alcohol leakage through 4.6 μm thick check valves with three $50 \times 200 \times 1500 \mu\text{m}$ channels under different backward pressures are shown in Figure 8. The dashed lines of the flow rates indicate the leakage is proportional to the applied pressure.

The ratios of flow rate of isopropyl alcohol for equal forward and backward pressure through a 4.6 μm thick check valves with three $50 \times 200 \times 1500 \mu\text{m}$ channels for valve 6 and valve 7 are less than 15:1.

Figure 7. Comparison of two different $4.6\ \mu\text{m}$ check valves with isopropyl alcohol as the working fluid. The flow runs through a $4.6\ \mu\text{m}$ check valve and three $50 \times 200 \times 1500\ \mu\text{m}$ channels under different forward pressure.

Figure 8. The isopropyl alcohol leakage through a $4.6\ \mu\text{m}$ check valve and three $50 \times 200 \times 1500\ \mu\text{m}$ channels under different back pressures. The dashed lines are linear and indicate the leakage is proportional to the pressure, and the minimum pressure to start leakage is less than $5\ \text{cm-H}_2\text{O}$ pressure.

CONCLUSIONS

All valves have an aging effect. The fresh valve has a lower flow rate than after aging. The flow rate of this valve is proportional to the applied pressure, and the minimum pressure needed to start flow is quite small. The ratios of forward flow rate to backward leakage are above 200 with DI water as the working fluid. However, the ratios are less than 15 with isopropyl alcohol as the working fluid.

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