An air-actuated valveless micropump with polyimide membrane

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Abstract

In this paper, a new way of applying polyimide (PI) film as a membrane of a MEMS micropump is reported; this is because the PI films have especial characteristics such as chemical stability, mechanical strength and large expandability. A simple structured air-actuated valveless micropump with a polyimide membrane was designed. The micropump was fabricated through processes including metal deposition spin-coating of PI, optical lithography and the ICP etching of silicon. The operation of the micropump is based on alternating air pressure to deflect the membrane. The tapered diffuser and nozzle work as valves.

1. Introduction

As an important component in microfluidic systems, the micropumps received great attentions because of many possible applications. Of special interests are utilization of many new materials to improve the performance of the micropumps. Since the polymer-based microdevice techniques had been established as new alternative in microtechnology, the high performance polymeric micropumps have been developed. Several polymer materials have been used to fabricate the micropump such as PDMS (polydimethylsiloxane) [1] and polypyrrole [2]. Using polymer materials can improve the biocompatibility and chemical resistance, that may make the microdevice used in more fields.

Polyimide films have been often used in electronic devices for a passivation layer of ICs or an insulation layer for multilayer interconnections. Here, we report a new way of applying PI film as a membrane of a MEMS micropump. This is because the PI films have special characteristics such as chemical stability, mechanical strength and large expandability.

2. Design and working principle

The operation of the micropump is based on air pressure to deflect the membrane. The deflection of the membrane causes the chamber volume change and generates the pressure variation, which activates the fluid flow. The tapered diffuser and nozzle work as valves. When the membrane is deflected, the fluid volume flowing out the diffuser is larger than the fluid volume flowing out from the nozzle.

Micropump design

Fig.1 shows the structural concept of the micropump. The first Polymethylmethacrylate (PMMA) plate has two opening holes for the tube; the second PMMA plate has an opening at the center for the actuator, these plates are used for fixing the micropump chip. The micropump chip is fabricated on a silicon chip. The diameter of the chamber is 7mm; the thickness of silicon chip is 525μm. The PI film is used for the membrane of micropump.

Diffuser design

For the valveless micropump, the design of the diffuser/nozzle determines the performance. According to the literature [3], flat-wall diffuser will be shorter than the conical one with the same flow performance, and also the flat-wall diffuser much easier to fabricate by microfabrication method on a silicon chip. So the flat-walled diffuser was chosen in this research.

According the performance map of the flat-wall diffuser [3], the diffuser used in this research is chosen as width of diffuser small side...
is 100 μm, length is 1700 μm, angle 2θ is 10°, the depth is 525 μm.

3. Fabrication process

The process (as shown in the Fig.2) involves the metal deposition, spin-coating, optical lithography and the inductively coupled plasma (ICP) etching. First the Al layer was deposited on the surface of the silicon wafer by using the vacuum depositing, the Al film is used as the mask in the after process. Then, the photoresist was coated on the Al film. The micropump structure was optically defined and the Al film was partially removed by wet chemical etching. The PI has been coated on the back side of wafer by spin-coating. The thickness of the PI film is controlled by modifying the rotation speed in the spin-coating process. The Al film was used for masking material for the ICP etching of silicon to release the PI membrane. Finally, the micropump chip has been fabricated.

![Fig.2] Fabrication process of micropump chip

4. Membrane Measurements

For the micropump chip, it is possible to measure the deflection of the PI membrane by using a conventional measurement system like a laser displacement sensor. In this paper, the measurement system is shown in Fig. 3.

![Fig.3] Membrane measurement system

The membrane has been actuated by the air push which caused by the injector, the press on the membrane has been measured by the air manometer. The deflection of membrane has been measured by using a laser position sensor form the back side. Fig.5 shows the displacement on the center of the membrane with different air pressure.

![Fig.4] Deflection of membrane with different pressure

![Fig.5] Displacement of membrane with 5kPa actuated pressure

The volume flow rate of micropump chamber correlated with the deflection of the membrane. As shown in Fig. 4, the deflection rate of membrane is composed by two approximate lines. When the actuation pressure is 10kPa, the displacement is nearly 200 μm. And also the membrane almost return to the point which before being actuated. Although the actuated pressure is increased to 250 kPa the PI membrane is not broken. The displacement of membrane is in a small deflection when the membrane is actuated by the same pressure 50 times (Fig. 5). The PI film shows the nice mechanical strength and large expandability for used as membrane of micropump.

5. Conclusions

In this paper, a simple structured air-actuated valveless micropump with polyimide membrane was designed and fabricated. The membrane displacement with air pressure actuated is measured. The PI film shows nice performance as a micropump membrane. Since the PI membrane has superior characteristics, the fabricated device is expected to exhibit good performance.

6. References

