A Fabrication of the Micro Valve with Free Floating Structure.

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Free Floating 구조를 갖는 마이크로 밸브의 제작

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Abstract

Previous valves have initial gap problem, high voltage or high pressure problem. In this paper, various micro valves with free floating structure have been fabricated and tested to solve the initial gap and high pressure problems. The paper presents how to etch Parylene-C which is a valve cap material without Al mask layer. The maximum flow-rate of fabricated micro valve is 118$\mu\ell$/min with 370μm orifice size and the leakage at the initial and reverse pressure is not observed.

Key Words : Initial gap problem, Free floating structure, Parylene-C, Leakage.

1. Introduction

Various micro valves are fabricated with MEMS technologies and applied. Micro valves are classified by operating principle. One is an micro active valve which can control the flow-rate of gas or liquid and the other type is micro passive check valve with which flow-rate is controlled by the orifice size and valve cap[1-3].

In case of the micro active valves, disadvantages are that high supply voltage is needed and deflection is very low so that the flow-rate is relatively small. On the other hand, micro passive check valves have a problem that leakage problem is created during the MEMS fabrication process due to the initial gap[4]. To solve the high supply voltage and the leakage problem simultaneously, However, the study of micro valves is still going on to the design and the fabrication of a novel structure and to find a new material.

In this paper, the various shape and size of valves are fabricated and tested with free floating structure. Au/Au/Cr layer and Parylene-C are used as the free floating structure and the cap material of valves respectively. Some of this structure have a guider to compare the flow-rates with and without it.

Also, this paper presents Parylene-C etching method. To etch Parylene-C, O_2 plasma etching method is adapted. Generally, Parylene-C is etched with Al mask layer, however, in this paper, Parylene-C etching is done with PR mask layer instead of Al layer.

2. Fabrication

2.1 Operating principle

The major problem of previous micro passive check valves is the leakage at initial state due to the initial gap between orifice and valve cap. Fig.1 shows the leakage problem on the

conventional micro passive check valve. During the MEMS fabrication processes, stiction problem is sometimes originated. To solve these problems, in case of micro valve fabrication, a sacrificial layer under the membrane which is a valve cap must be thick, or anti-stiction technologies must be used.

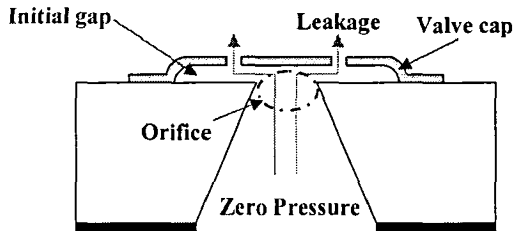
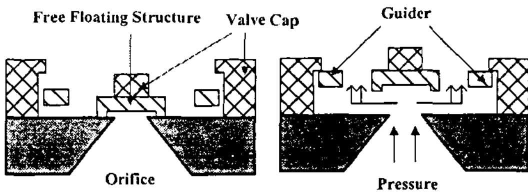


Fig. 1. Problem of micro passive check valve.

Novel micro passive check valve is designed to solve the leakage problem and high pressure problem. Fig.2 shows the operating principle of designed novel micro passive check valve.

This micro check valve consists of three parts, orifice, free floating structure and valve cap. The free floating structure is placed under the valve cap. The valve cap which is made up of Parylene-C presses down the free floating structure at initial state, so designed micro passive check valve does not have initial gap. On loading the pressure, micro valve is opened because the free floating structure pushes up the valve cap. When the pressure is unloaded, The valve cap and the free floating structure come back to the initial place.



(a) Initial state (b) Pressure loading

Fig 2. Operation principle.

2.2 Fabrication process

For the fabrication, n-type silicon wafer, (1 0 0) is used. First of all, 1㎛ oxide layer is grown on both sides of wafer by wet oxidation. The front side oxide layer is for making surface rough to improve the adhesion between Parylene-C and surface of the substrate. While oxide layer on the back side of wafer is for the passivation of the wafer during the silicon bulketching.

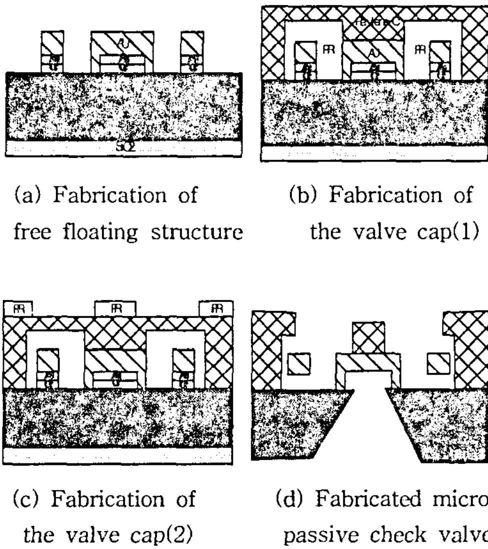
500Å Cr layer is deposited by evaporator and then photoresist (AZ1512) is coated as a passivation layer and patterned. Au, which is a material of free floating structure, is not deposited on the silicon wafer therefore, Cr layer is used as a seed layer to deposit Au. 1500Å Au layer is also deposited by evaporator on the Cr layer and second Au layer is deposited by electroplating. By conducting these processes, the free floating structure is fabricated shown by Fig.3 (a).

The cap of micro passive check valve is fabricated on the free floating structure by the deposition of Parylene-C. 5㎛ thick Parylene-C is deposited for 1 hour. These processes are shown by Fig.3 (b).

To etch Parylene-C, Photoresist(AZ9260) is coated and patterned as a mask. Parylene-C is etched by O_2 plasma etcher with the photoresist as shown by Fig.3 (c).

Fig.3 (d) shows below processes. To etch the oxide layer on the back side of silicon wafer, BOE(Buffered Oxide Etch 7:1) is used. The wafer is immersed into BOE for 45 minutes at 23℃. After etching oxide layer, the back side silicon etching step is done by immersing the wafer into TMAH(TetraMethylAmmonium Hydroxide) for 7 hours

The maximum volume of fabricated valve is 960㎛×960㎛×12㎛.



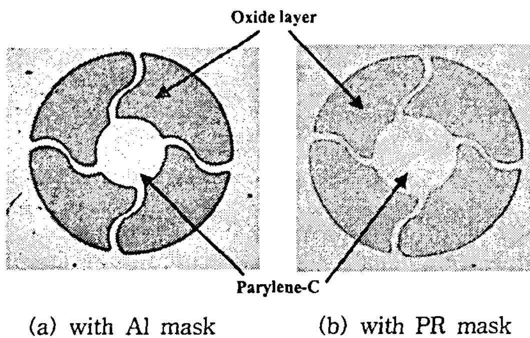
(a) Fabrication of free floating structure (b) Fabrication of the valve cap(1)

(c) Fabrication of the valve cap(2) (d) Fabricated micro passive check valve

Fig 3. Fabrication process.

3. Results and Discussion

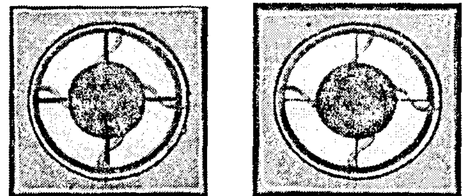
In general, Al mask layer is used when Parylene-C is etched by O_2 plasma etcher. However, in this paper, etching of Parylene-C is conducted without Al mask layer. Fig.4 (a) shows the etched Parylene-C with a Al mask layer. On the other hand, in case of Fig.4 (b), photoresist is used as a mask layer when Parylene-C is etching. Without Al layer, Parylene-C can be etched relatively well and the fabrication process can be simple.



(a) with Al mask (b) with PR mask

Fig. 4. Parylene-C etching.

Fabricated micro passive check valve is shown by Fig.5. In case of Fig.5 (a), orifice size is 370 ㎛ and free floating structure size is 462.5㎛ which is 1.25 times as orifice size and valve cap size is 0.35 larger than orifice size. The shape of valve cap is twist up. In this case, micro passive check valve operates upper 3psi and its maximum flow-rate is 118㎕/min. In Fig.5 (b), orifice size and free floating structure size is the same as (a). However the size of valve cap is larger than that of (a). In this case, the maximum flow-rate is lower than that of case (a).



(a) small valve cap (b) large valve cap

Fig. 5. Fabricated micro passive check valve.

Flow-rate is estimated by fabricated measurement tool with the pressure between 220 ㎛ and 370㎛ orifice size. Fig.6 shows the maximum flow-rate according to the orifice size and the pressure. In addition, The flow is not observed until 1psi.

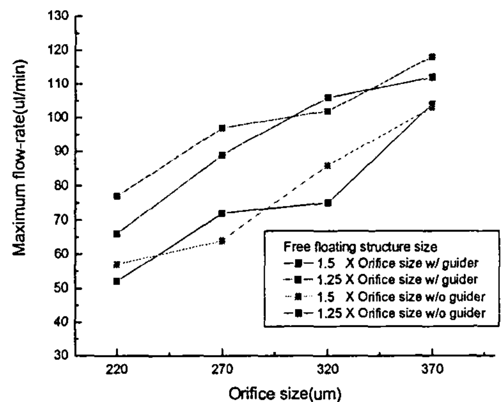


Fig. 6. Maximum flow-rate with the pressure.

4. Conclusions

In this paper, novel micro passive check valve is fabricated and tested to solve the leakage problem that previous micro passive check valves have and the high supply voltage problem that previous micro active valves have. The maximum size of Micro Passive Check Valve is 960㎛×960㎛×12㎛.

In case of etching Parylene-C, we used only photoresist layer as a mask without using Al layer to reduce the fabrication process and the result of etching Parylene-C with photoresist mask layer is almost same as the result with Al mask layer.

Fabricated micro passive check valve is tested. The free floating structure under the valve cap can completely block up the leakage below initial release pressure completely.

Maximum flow-rate of fabricated micro passive check valve is estimated at 118㎕/min at 3psi in the case of 370㎛ orifice size.

Fabricated micro passive check valve can be applied various fields such as Drug Delivery System.

5. Acknowledgement

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