A PIEZOELECTRIC MICROPUMP BASED ON POLYMERIC MICROMACHINING

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Abstract

This paper presents a functional, fully polymeric micropump. The pump was fabricated with a novel polymeric micromachining process, which is a combination of three basic techniques: thick-resist photolithography, laser cutting, and adhesive lamination. The pump is able to deliver a maximum flow rate of 2.6 ml/min and a backpressure of 1.4 m water (13.7 kPa). The micropump was made of different laminated polymer layers. The pump body was fabricated in PMMA (polymethylmethacrylate) with laser cutting techniques. The checkvalves were made of SU8 2100. The PMMA- and SU8-layers were laminated using adhesive layers, which are selectively cut by CO_2-laser.

Keywords: Microfluidics, micropump, microvalve, SU8 2100

1. Introduction

Most of the tools used in biology and chemistry are glassware-based. Microfluidic devices developed in the past are mostly based on silicon, which is in many cases not fully compatible to biochemical and chemical processes and causes high cost in consumable materials. Thus, fully polymeric microfluidic devices promise to revolutionize the way biologists and chemists conducting research [1].

Because of the relatively large size of microfluidic systems compared to other MEMS-devices, the basic philosophy of our fabrication process is to combine low-cost, low-resolution techniques such as laser ablation and lamination with high-resolution thick-resist photolithography. While size-critical components such as microvalves are fabricated with photolithography, relatively large channel structures can be fabricated with laser cutting.

Lamination technique can be used for a variety of materials such as ceramics, metals, polymers, silicon or glass. This technique allows bonding and combining different functional layers, which are based on different technology approaches. Lamination of several layers results to a complex three-dimensional device. In this paper, our technology approach is illustrated in the fabrication of a piezoelectric micropump.

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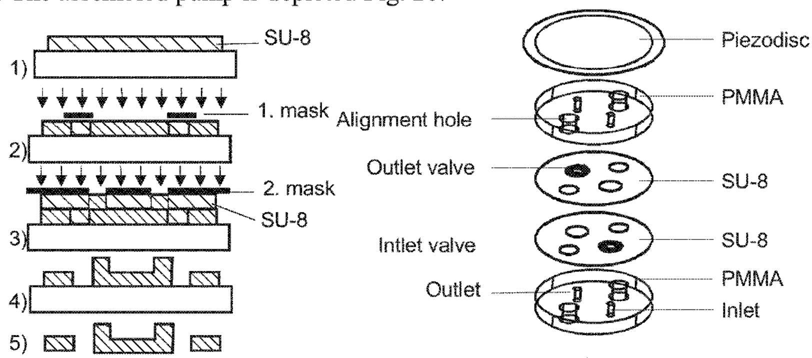
2. Fabrication

The most important parts of a reciprocating micropump are micro checkvalves [2]. Because of the required resolution, the micro checkvalves were fabricated in a 100-micron-thick SU8-layer by photolithography. The fabrication of SU8-valves is based on the so-called polymeric micromachining technique [1], where SU8 is coated and structured on top of a sacrificial layer. The SU8 part is then released by etching away the sacrificial layer. In our case, a silicon wafer was used as both the handler substrate and the sacrificial material.

The SU-8 process (Fig. 1a) started with coating and exposure of the first SU-8 layer. The first lithography mask contains the valve disc and the valve springs. A second SU-8 layer is coated and structured using another mask to form the sealing ring on the valve disc. Both layers are developed and hard-baked in the same process. Underetching the silicon substrate in a KOH solution at room temperature releases the SU-8 valve discs. Tiny circular holes incorporated on the SU-8 disc avoid micro cracks and works as etch access for fast release.

The micropump consists of two SU-8 valve discs, several single-sheet adhesive layers, PMMA layers, which are structured by CO_2-laser (Fig. 1b). All layers have the form of a disc with 1-cm diameter. The pump was assembled by laminating the different layers using a mechanical alignment system. Two alignment holes are positioned on all discs. The pump actuator is a commercially available piezoelectric bimorph disc that is bonded on the assembled pump stack by an adhesive layer. The inlet and outlet of the micropump are stainless steel needles of 600-micron outer diameter. The needles are glued on the inlet/outlet holes of the pump body. Fig. 2a shows the SEM-image of the fabricated SU8-valves. The assembled pump is depicted Fig. 2b.



(a) (b)

Figure 1. Fabrication of the micropump: (a) the SU-8 process, (b) the stacked concept.

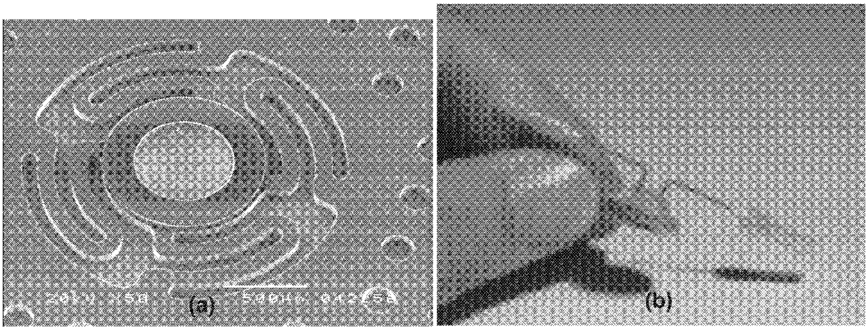


Figure 2. Fabricated micropump: (a) SU8 micro checkvalves, (b) the assembled pump.

3. Experimental results and discussion

The pump was characterized using the measurement setup described in a previous paper [3]. The pump was tested with DI-water. Different pump characteristics were measured: leakage rates in forward and reverse direction in the absence of driving voltages, flow rates versus peak voltages, flow rates versus frequencies and flow rates versus backpressures.

Fig. 3a shows the leakage rates versus applied pressures across the pump in forward and reverse directions. The results show a tenfold increase of fluidic impedance across the pump compared to the early version in [3]. The lamination technique and the sealing ring on the valve disc play here significant roles. Better sealing also improves the pumping performance shown in Fig. 3b and Fig. 3c. A twofold increase of flow rates at the same peak voltage and frequency can be observed. The higher fluidic impedance across the pump also improves the flow rates/back-pressures behaviour. A tenfold increase of backpressures was achieved. The pump is able to work against a maximum backpressure of 14 kPa at 100Hz and ±100V. Higher fluidic impedance leads to higher damping force, which affects the dynamic behaviour of the pump. The pump reaches its maximum flow rate at 50 Hz, which is lower than the frequency of the previous version in [3].

5. Conclusions

This paper presents a functional piezoelectric micropump based on polymeric micromachining technology. The pump is made of different polymeric materials, which are bonded by lamination. The sealing ring and the good bond between the laminated layers improve the pump performance significantly. Compared two an older version, the micropump delivers a twofold and tenfold increase of flow rate and backpressure, respectively. This functional micropump proves that our micromachining approach is feasible for making more complex polymeric microfluidic systems.

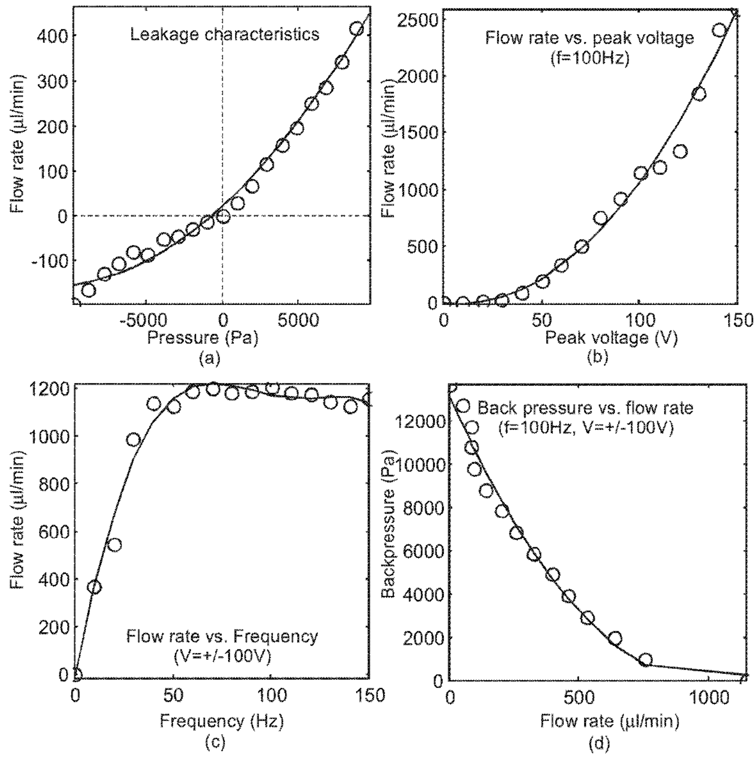


Figure 3. Characteristics of the micropump (circles are measurement points, lines are fitting curves): (a) Leak rates versus pressure drop across the pump in forward and reverse directions, (b) Flow rates versus peak voltages (f = 100Hz), (c) Flow rates versus frequencies at (V = ±100V), (d) Flow rate versus back pressure (f = 100 Hz, V = ±100V).

Acknowledgements

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