Novel Electro Magnetic Micro Pump

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ABSTRACT

In this work, a novel electro micro pump has been developed and realized by the combination of functional elements of micro actuators and microfluidics. Different fabrication processes including UV depth lithography using AZ9260 and Eopn SU-8, electroforming of copper and softlithography with PDMS were applied in order to produce successfully both, the electromagnetic actuator and the fluidic device comprised of a fluidic chamber and valve seats and valve lips. Further investigation on the combination and performance of the electro micro pump is under investigation.

Keywords: micro pump, micro valves, micro actuator, UV depth lithography, PDMS

1 INTRODUCTION

The integration and miniaturization of fluidic devices, especially complex µTAS or lab-on-a-chip, has received considerable attention in research. Particular interest is laid on fully integrated devices with micro fluidic components, like active micro valves and micro pumps, for example in the field of chemical analysis systems or microelectronics cooling. Micropumps can be classified into two main groups: the mechanical (rotary pumps, centrifugal pumps or phase change pumps) and the non-mechanical micropumps (electrohydrodynamic pumps or electroosmotic pumps). The latter is characterized by the increased reliability when compared to the mechanical micro pumps.

The demand for these active micro systems causes the mergence of partial aspects and functional components of micro actuators and micro fluidic technology. This enormous potential is shown in this article by the realization of an electro magnetic micro pump, which belongs to the non-mechanical micropumps.

2 CONCEPT AND DESIGN

The basic build-up consists of a polymer magnet integrated into a pump chamber of a fluidic PDMS device, which is located above a double layer micro coil (see Figure 1).

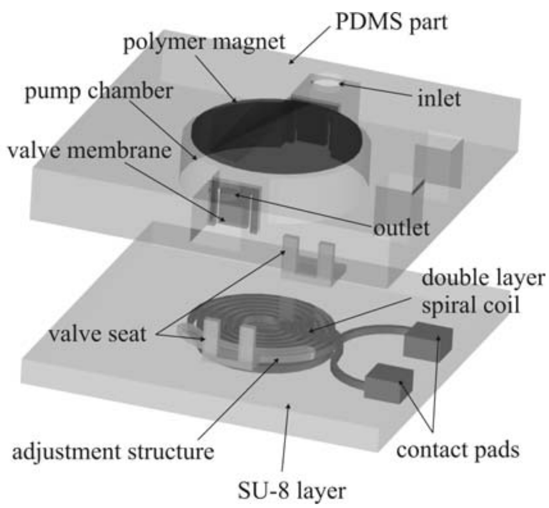

Figure 1: Concept of the electro magnetic micro pump.

When applying a current, the polymer magnet performs a bidirectional movement, which results in a pumping effect by the two passive check valves. The valves, which consist of a membrane and lips pressing on a valve seat, can thus completely seal the fluid channel. The valve membrane is flexible and opens towards the flow direction (see Figure 2). The advantage of this configuration is that leakage can be avoided by the special geometrical configuration of the valves.

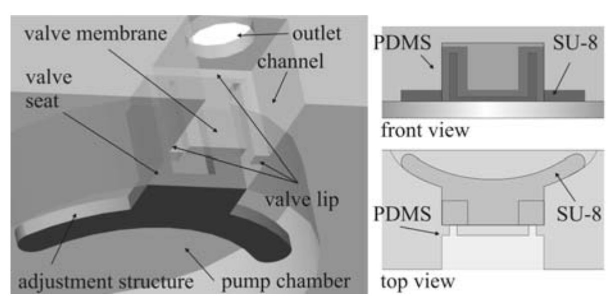

Figure 2: Concept of the check valve consisting of a PDMS-membrane and a SU-8 seat valve.

3 FABRICATION TECHNOLOGIES

The fabrication process includes UV depth lithography using AZ9260, electroforming of copper for the double layer spiral coil and Epon SU-8 for insulation, embedding and manufacturing of the valve seat. Furthermore, the fluidic devices are realized by replica molding of PDMS using a multilayer SU-8 master. The optimized process parameters enable structures with aspect ratios of 13 for AZ9260 and 60 and higher for Epon SU-8 (see Figure 3).

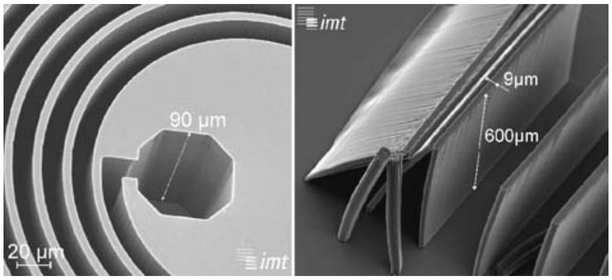

Figure 3: Aspect ratio of AZ9260 and Epon SU-8.

In order to be able to produce the permanent micro magnets of arbitrary designs we developed several fabrication processes, e.g. structuring the magnet directly in a single lithography step or creating a resist mould for screen printing [1]. Moreover, it was proven that the composite of PDMS mixed with magnetical powder allows very good structuring; high resolutions and flexibility (see Figure 4). The concentration levels of the composites are determined by the weight percentages (wt%) in the cured polymer and permit, depending on the load, the type of powders and structure height, residual induction of up to 300 mT and higher (see Figure 5) [2].

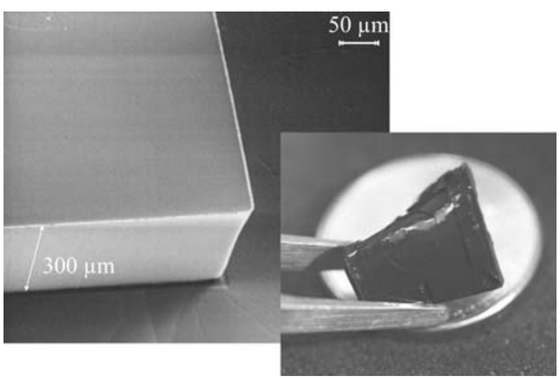

Figure 4: PDMS polymer magnet with hard magnetic powder at 70 wt%; left: resolution and replication right: structured and filled PDMS part deformed by tweezers.

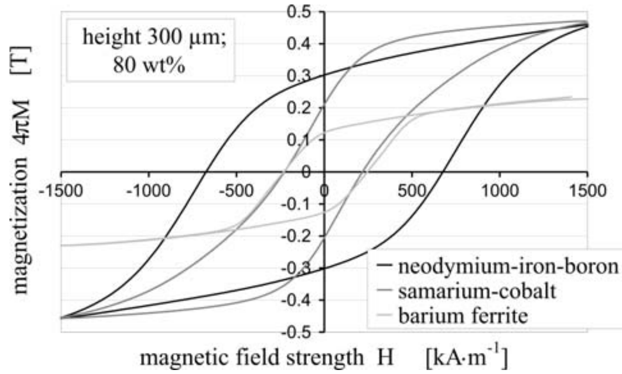

Figure 5: polymer magnet with hard magnetic powder and exemplary reachable residual induction depending on the magnetic material.

4 PLUNGER COIL MICRO ACTUATOR

Using these fabrication processes for polymer magnets, a magnetic micro actuator has already been developed based on the movable plunger principle (see Figure 6) [3]. This actuator was monolithically fabricated and successfully tested. The deflection of the polymer magnet depends on the applied current and can reach up to 200 µm (see Figure 7). The magnet is movable and well suspended by the SU 8 spring leafs. The achieved forces were up to 1 mN, which can be increased by bigger magnets that will be integrated into the novel micro pump.

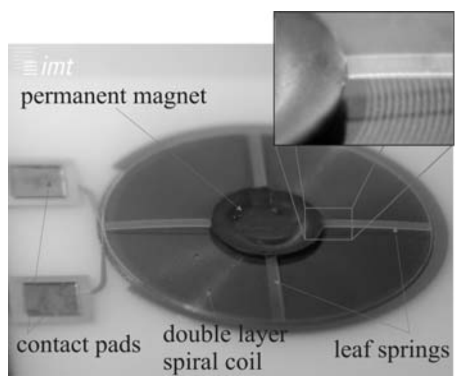

Figure 6: Plunger coil micro actuator with double layer spiral coil and integrated polymer magnet.

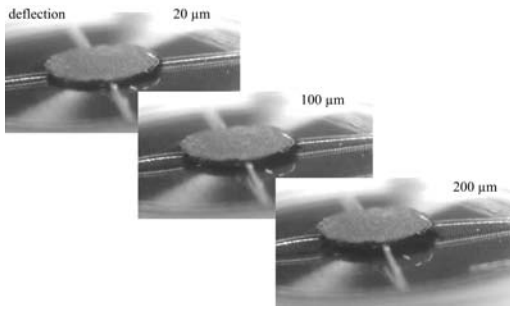

Figure 7: Deflection of the polymer magnet of the plunger coil actuator.

5 FLUIDIC DEVICE

The fluidic system for the newly presented micro pump was at first fabricated without the double layer spiral coil and successfully tested (see Figure 8).

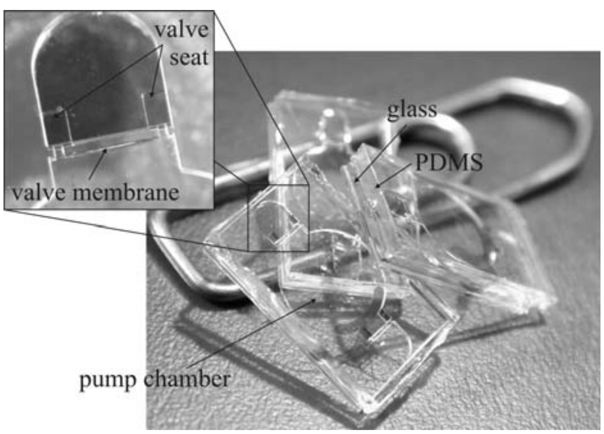

Figure 8: Fabricated fluidic part of the novel micro pump.

Different design variations of the valve membrane were provided by the SU-8 master (see Figure 9). The replica molded PDMS was very flexible and robust.

In order to connect the valve seats based on SU-8 with the PDMS fluid chamber and valve lips, a special bonding process was developed using an additional intermediate layer. Materials such as silicon oxide and silicon nitride were tested under different plasma process parameters (e.g. pressure, duration of plasma activation, oxygen flow) in order to optimize the bonding process layer. The best result was achieved with an intermediate layer of silicon nitride deposited wire PECVD-process at a temperature of 150°C. The best bonded connections were realized wire subsequent plasma activation with the following parameters: 15 s of duration, 85 W of power, 40 sccm oxygen flow, 80 mTorr of process pressure.

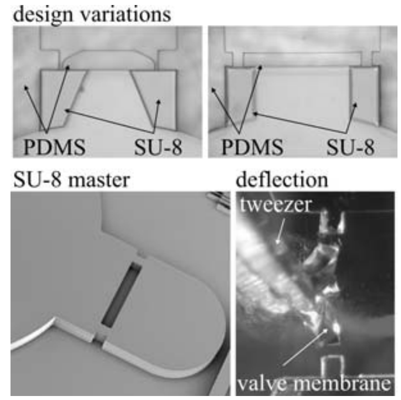

Figure 9: Fabricated fluidic part of the novel micro pump.

6 CONCLUSION

The purpose of this work was to develop a complex micro system for microfluidic application combining process technologies and functional components of both, micro actuators and micro fluidics.

The novel non-mechanical micropump consists of two main parts which could be both successfully fabricated by different micro process technologies. The first component was the plunger coil micro actuator based on a polymer magnet which performs a bidirectional movement resulting in the pumping effect. The second structural part comprised the pump chamber of a fluidic PDMS device including the valve lips and valve seats. In order to combine the pumping chamber made of PDMS with the SU-8 valve seats, a special bonding process was developed and successfully tested. Silicon nitride as an intermediated layer before plasma activation showed promising results for good bond connections.

The next step is to combine the fluidic system with the electromagnetic part which is currently under investigation.

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