TWO-STAGE LIQUID DRIVING USING VACUUM TRANSFORMERS WITH BATTERY-POWERED MINI-HOTPLATES FOR SIMPLE-TO-USE MICROFLUIDIC BIOCHIPS

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ABSTRACT

This paper presents a novel vacuum transformer with battery-powered mini-hotplates for two-stage liquid driving for simple-to-use microfluidic biochips. The conception of the research is completely different from current traditional design, it could decrease the complexity of systematic design and procedure with smart polymer materials, it stylizes for memorizing the switch of two different geometric patterns in advance while synthesizing the material so as to complete the transformation. Experimental measurements show that the fluidic μ-transfomer with an effective cavity volume of 80 μl can achieve -4.7 psi differential pressure. The developed novel systems could provide the same delivery function with the traditional vacuum pumps for disposable simple-to-use microfluidic biochips.

KEYWORDS

Transformer, vacuum source, simple-to-use microfluidics, microfluidic liquid driving.

INTRODUCTION

Micropumps are the most popular devices as pressure sources for microfluidic systems. However, micropumps/valves make the microfluidic systems complicated and sometimes unsuitable for disposable biochips due to complexity in structure/assembly [1]. We have previously developed and characterized the μ-fluidic transformers based on shape memory polymers on a hotplate [2]. In this abstract, we further develop and characterize vacuum transformers with handheld battery-powered mini-hotplates for simple-to-use microfluidic biochips. The developed vacuum transformers are suitable for most of disposable lab-on-chips, which need to deliver liquids on a chip without any professional technicians.

DESIGN AND FABRICATION

Figure 1 shows a schematic drawing of the novel vacuum transformer with handheld battery-powered mini-hotplates for liquid driving. The vacuum transformers produce vacuum pressure to suck liquids in microchannel when heat is sent to the vacuum transformers by the handheld mini-hotplates. Vacuum pressure is generated to suck liquids in microfluidic chip and drive liquids in microchannel due to the morphology change of the vacuum transformers. The vacuum transformer was made by shape memory polymers (SMP), which were composed of MMA, BMA, TEGDMA and POSS. The glass temperature of the SMP in this study was designed to 38℃. The vacuum transformer was fabricated by casting mixed polymers into a defined micromold. After thermal curing, the vacuum transformer was demolded and then pressed to flat surface by hot embossing machine. Fabrication process of the vacuum transformer is shown in Figure 2a. Then, the vacuum transformer was integrated and packaged with microfluidic chips, as shown in Figure 2b.

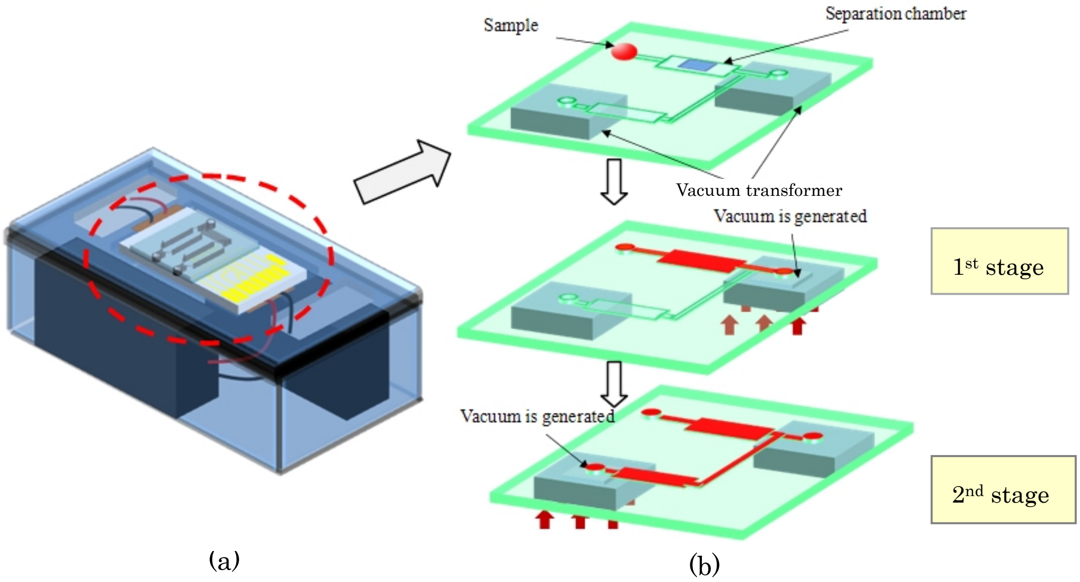
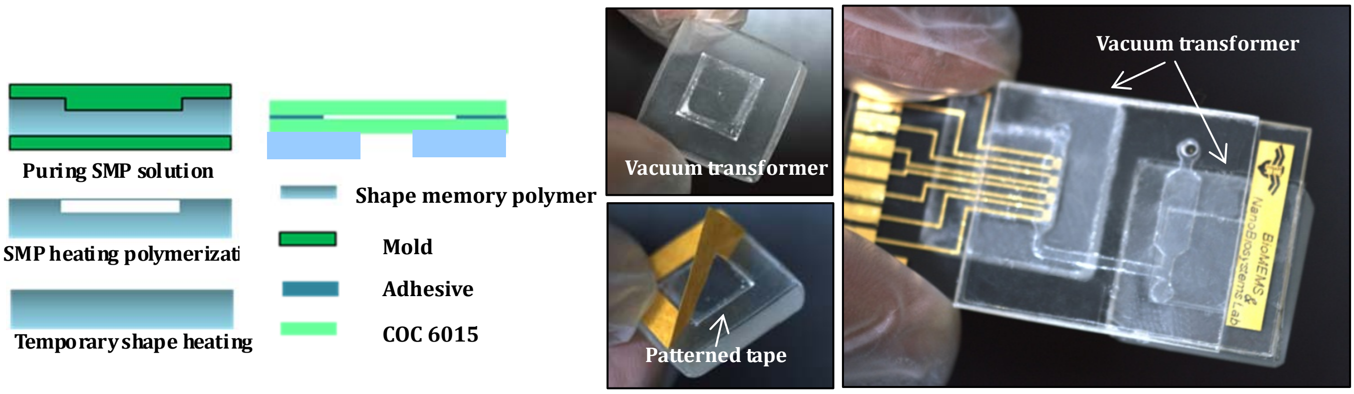


Figure 1. Schematic illustration of the novel vacuum transformer with battery-powered mini-hotplates for liquid driving: (a) 3D drawing of the system and (b) two-stage actuation.



(a) (b)

Figure 2. Fabrication of our developed vacuum transformer: (a) fabrication process, (b) the fabricated devices.

EXPERIMENTAL RESULTS

The handheld mini-hotplate includes two heating pads, two 9 V batteries, and a control circuit. Photographs of the fabricated handheld mini-hotplates are shown in Figure 3. The constant current (0.149 Amp) was applied to the heating pads, respectively. In Figure 4, it shows that the temperature reach 40℃ at the 50th second. The temperature reach 60℃ at the 300th second with constant current input. The heating rate could be changed by simply adjusting input current. The vacuum module began to deform at the 80th second according to the dynamic deformation measurements by using a laser distance measuring instrument, as shown in Figure 5. The maximum negative pressure of our developed vacuum transformer with an 80 μl cavity reached -4.7 psi, as shown in Figure 6. In the experiments, dyed water droplet was deposited on the inlet. After removing the protection layers of the patterned tapes, vacuum modules can be simply attached to the disposable microfluidic biochips before the experiments. Operators don't need to connect any long tubing and pumps to the microfluidic biochips. After the microfluidic biochip with vacuum transformers was placed on the mini-hotplates, it was triggered to execute the pre-programmed vacuum function. The microfluidic actuation steps include liquid sucking into the separation microchamber (stage 1), liquid stay for 150 seconds, and then liquid moving to the sensing microchamber (stage 2), respectively, as shown in Figure 7. The measured flow rate of the sample in the microfluidic biochip for this study was up to 3.5 μl/min. The flow rate could be increased by applying larger vacuum pressure, which is related to the size of the fabricated microcavity of the vacuum mocule.

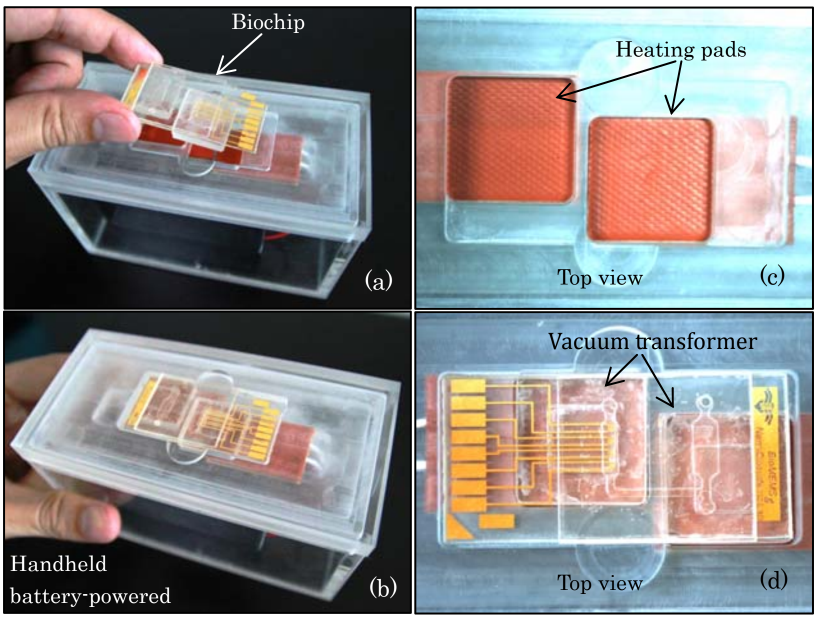


Figure 3. Photographs of the fabricated system: (a) and (b) mini-hotplates with biochips, (c) the top view of the heating pads, and (d) the top view of the biochips on the heating pads.

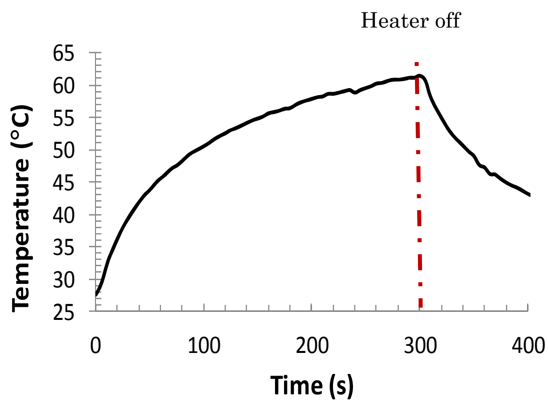


Figure 4. Dynamic temperature measurements with mini-hotplates powered by battery (current output: 0.149 Amp).

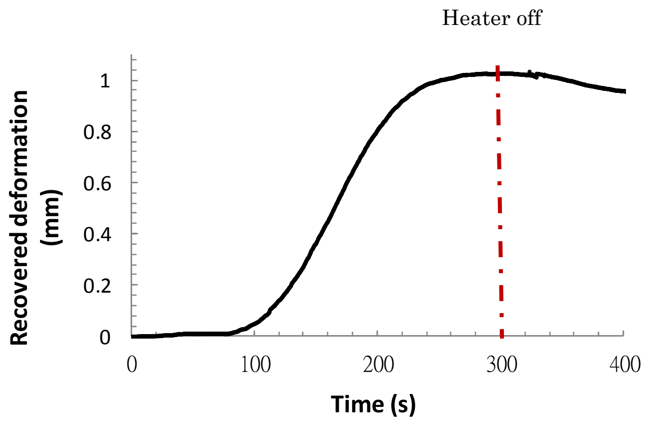


Figure 5. Dynamic deformation measurements of the microcavity with mini-hotplates powered by battery (current output: 0.149 Amp).

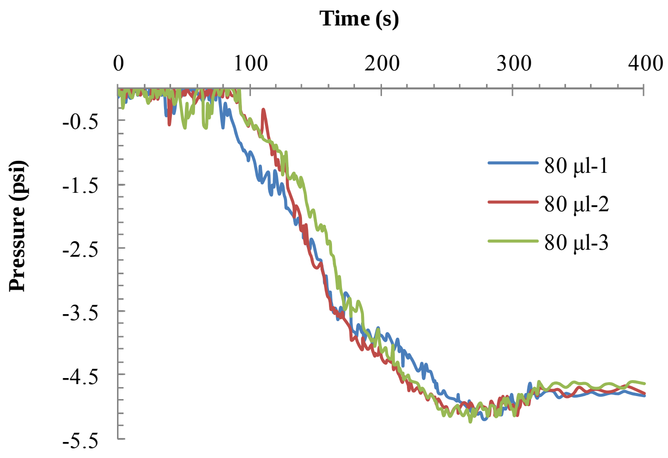


Figure 6. Dynamic pressure measurements of the three different vacuum modules in a closed microchamber.

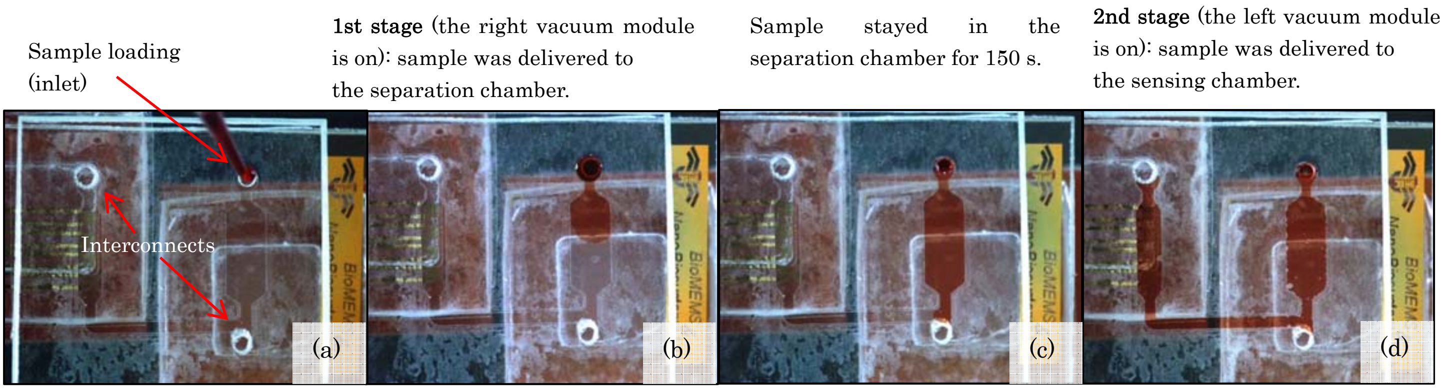


Figure 7. Captured video frames of microfluidic actuation by our developed vacuum transformers;(a) droplets deposition on the inlet, (b) the transformer was triggered by heat and then droplet was sucked into the chip, (c) the sample stayed in the chamber for separation, and (d) sample was sucked into the sensing microchamber.

CONCLUSIONS

The novel vacuum transformer with battery-powered mini-hotplates presented in this work showed excellent performance in driving tiny liquid in two stages on a microfluidic biochip without any tube connection, complex manual procedures, or professional technicians. Compact and simple structure makes it easy to integrate on microfluidic systems for applications in disposable simple-to-use microfluidic biochips.

ACKNOWLEDGEMENTS

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REFERENCES

[1] K.W. Oh, etal., "Miniaturization of Pinch-Type Valves and Pumps for Practical Micro Total Analysis System Integration," Journal of Micromechanics and Microengineering, 2005, 15, 2449-2455.

[2] C.-C. Hong, et al., "A Fluidic μ-Transformer with Pre-Programmed Vacuum Actuation Functions for Disposable Lab-on-a-Chips," Proceedings of the 14th International Conference on Micro Total Analysis Systems (micro-TAS 2010), Groningen, NETHERLANDS, October 3-7, 2010, pp. 34-36.

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