A FLUIDIC μ-TRANSFORMER WITH PRE-PROGRAMMED VACUUM ACTUATION FUNCTIONS FOR DISPOSABLE LAB-ON-A-CHIPS

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ABSTRACT
This paper presents a novel fluidic μ-transformer with pre-programmed vacuum actuation functions, which can deliver liquid samples on a chip without any micropumps or microfluidic actuators. 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. It takes around 30 seconds to drive the fluid for completely filling the microfluidic channel with a total volume of 14 μl. Experimental measurements show that the fluidic μ-transformer with an effective cavity volume of 268 μl can achieve -1.8 psi differential pressure. The conception of the research relies on integration and actuation of smart polymer materials. Therefore, it could design the simplest system and provide the same delivery function with the traditional vacuum pumps for disposable lab-on-a-chips.

KEYWORDS: Fluidic μ-Transformer, Smart Polymer, On-Chip Vacuum Generation, Disposable Lab-on-a-Chip

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. Vacuum glass capillaries have been applied to generate vacuum within a laminated pouch by manually breaking the glass capillaries [1]. However, it’s difficult to integrate the vacuum glass capillaries with microfluidic chips for lab-on-chip applications. Also, pneumatic control microfluidic systems have been developed by using pressurized gas tanks or off-chip pressure sources with electromagnetic valves to manipulate polydimethylsiloxane (PDMS) multilayer soft microchannels [2]. we can find that the designs of microfluidic control devices have been simplified to only contain valving functions on chips, but leave pressure driving units out of chips, which cannot easily be minimized. Normally, they still need fluidic connectors, long tubes, electromagnetic valves, and gas tanks. End users would feel uncomfortable to prepare procedures and operate microfluidic systems.

Fig. 1 shows a schematic drawing of the novel fluidic μ-transformer with pre-programmed vacuum actuation functions. The fluidic μ-transformer produces vacuum pressure to suck liquids into microchannel once “triggered”. When heat is sent to the μ-transformer, it will restore to the pre-memory morphology – the pre-programmed vacuum actuation function is then “executed”. Vacuum pressure is generated to suck liquids into microfluidic chip and drive liquids in microchannel due to the morphology change of the fluidic μ-transformer.

Figure 1. Schematic illustration of the novel fluidic μ-transformer with pre-programmed vacuum actuation functions: (a) 2D cross section and (b) 3D drawing.
PRINCIPLE AND DESIGN

The working principle of the fluidic μ-transformer using shape memory polymers is shown in Fig. 2. The μ-transformer was made by shape memory polymers (SMP), which were composed of triethylene glycol dimethacrylate (TEGDMA), butyl methacrylate (BMA), methyl methacrylate (MMA), azobis-isobutynitrile (AIBN), and Polyhedral oligosilsesquioxane (POSS). The glass temperature of the SMP can be designed from 27°C to 70°C depending on the ratios of BMA and MMA polymer composition [3]. The trigger temperature of shape memory polymers is determined by the glass temperature. BMA and MMA co-monomers have large strain elasticity and strong recovery ability due to covalent crosslinks. When the copolymers are heated to the temperature above Tg, it can be reshaped to the designed shape. After cooling down, the elastic strain energy is stored inside the copolymers. Then, when the materials are heated to the temperature above Tg, the stored energy is released to recover its original shape. In our design, this pre-programmed functions can be triggered to perform the vacuum actuation.

FABRICATION

The fluidic μ-transformer was fabricated by casting mixed polymers onto a patterned micromold. SMP was made of MMA/BMA:TEGDMA:POSS:AIBN upon the weight ratio of 79.2 : 8 : 12 : 0.8. Fabrication process and packaging process of the μ-transformer is shown in Fig. 3. After thermal curing, the 5 mm-thick fluidic μ-transformer was demolded. Then the morphology of the fluidic microtransformer was changed with pressure and heat by a hot embossing machine. After cooling down below glass temperature, the fluidic μ-transformer was structurally programmed to the temporary shape. Cyclic olefin copolymers (Topas® COC 6015) were chosen as microfluidic chip substrates. UV curable epoxy (Norland Optical Adhesive 74) was used as an adhesive for bonding of the fluidic μ-transformer and the microfluidic chip.

EXPERIMENTAL RESULTS

In Fig. 4, it shows the dynamic deformation recovery ratios of SMP for two different temperatures. Fig. 5 shows the dynamic measurements of generated negative pressure from the fluidic microtransformer in a closed microchamber. In
order to verify the validity, a microfluidic channel was integrated with our developed fluidic μ-transformer. A cavity was pre-programmed in the μ-transformer and was press to be flat in advance. Then, the μ-transformer was integrated and packaged with microfluidic chips by UV epoxy bonding. For demonstration of the device, dyed water droplets were deposited on the inlets. After the μ-transformer was heated to 50°C (designed Tg=38°C) on a hotplate, it was triggered to execute the pre-programmed vacuum function within 30 seconds to suck droplets into the microfluidic chip, as shown in Fig. 6.

**CONCLUSIONS**

The novel μ-transformer presented in this work showed excellent performance in producing vacuum pressure to suck liquids through microchannels. Compact and simple structure makes it easy to integrate on microfluidic systems for applications in disposable lab on chips.

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**REFERENCES**


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