ALL GLASS-BASED ACTUATOR FOR VALVES AND PUMPS USING ULTRA THIN GLASS MEMBRANE AND PIEZO ACTUATORS

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ABSTRACT
Here, an electric actuator in all glass-based microchip was demonstrated. Firstly, ultra thin glass was installed in a microchip and the actuation of the glass in small area was demonstrated manually. The glass ribbon displacement was more than 100 µm. Secondly, an all glass-based microchip with valve structure using glass ribbon was fabricated, and switching valve function was demonstrated using an electric piezo actuator. Flow in two channels was smoothly switched. This is the first demonstration of local fluid flow control using valves in a totally glass-based microchip.

KEYWORDS
Actuator, Glass ribbon, Valve, Pump

INTRODUCTION
In µTAS field, most of researchers use polydimethylsiloxane (PDMS) microchips. This is because PDMS is easy to be fabricated, the material is reasonable and also the flexibility is very useful for liquid handling in a microspace [1]. However, there are several disadvantages such as chemical instability, detection limit and fabrication limit (especially for high pressure in small channels). By contrast, Kitamori *et al.* developed glass-based microchips for multi-propose chemistry integration [2]. However, glass is not flexible, and easy to be broken with physical stress. Thus, direct liquid handling system such as valve, pump and other mechanical devices is really difficult. Although such kind of actuator on a glass microchip was partially reported, the main actuation parts are not glass [3]. On the other hand, by recent fabrication progress of glass, ultra thin glass ribbon (thickness: 6 um) appeared (shown in Figure 1). This is enough flexible for liquid handling and also not so easy to be broken because of very smooth surface and edge. By using this, chemical and physical stability, dead volume and response time will be improved much compared with conventional PDMS valves. Glass ribbon is fabricated by overflow fusion downdraw process [4] and commercially available. The objective in this report is to demonstrate the actuation of liquid in microchannels using this very thin and flexible glass.

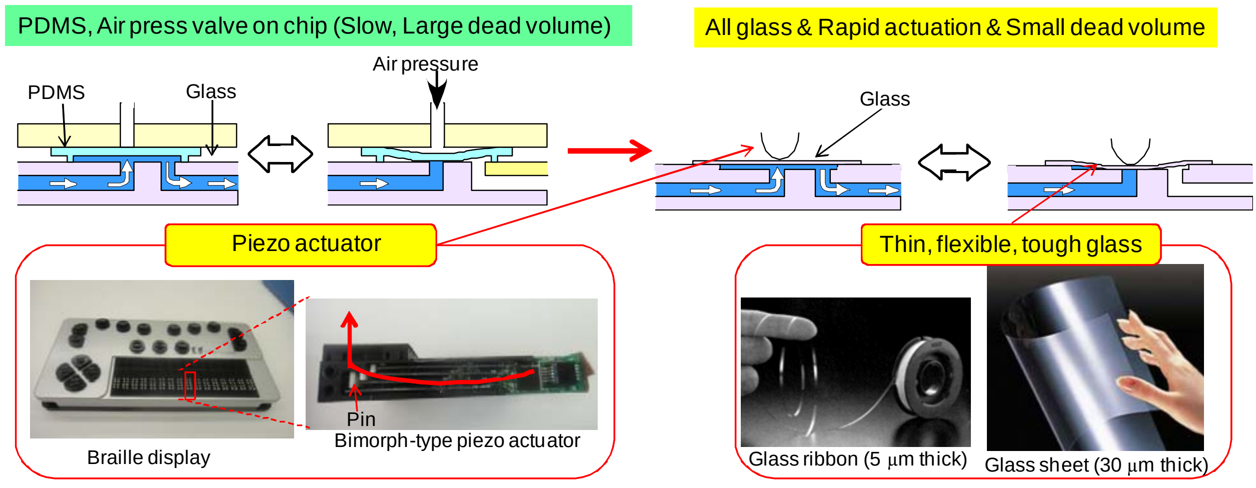

Figure 1: Concept of all glass-based actuator (valve) using thin glass ribbon (6 µm thickness) and bimorph type piezo actuator.

EXPERIMENT
Firstly, whether glass ribbon (ultra thin glass) could be actuated in small area or not was confirmed to demonstrate that the glass ribbon could be used for microfluidic device components. For this purpose, a very simple experiment was carried out. A 4 mm diameter hole was made in a PDMS sheet and glass ribbon (shown in Figure 2) was sealed on the sheet. Then, the PDMS sheet was immobilized on the microscope stage, and the glass ribbon part was observed from side view using a microscope. After that, 1 mm cubic PDMS block was placed in the center of the glass ribbon to protect glass ribbon, and the glass ribbon was fluctuated manually by using a pair of tweezers trough the PDMS block to measure the displacement.

Secondly, a glass microchip with two substrates (upper and lower) and glass ribbon was fabricated for demonstration of all glass-based microvalve (switching valve). Glass substrates were 7×3 cm non-alaki glass and the channel design is simple Y-shaped structure. After the branch structure, there was a valve in both channels.

Before experiments, the substrates were annealed for stable etching and washed by piranha solution and ultra pure water. First, Cr and Au were spattered on the substrates and photoresist was coated on the glass substrates using a spin coater. Then, the substrates were exposed by UV through a Cr photomask with chamber and channel pattern using a mask aligner. Then, they were rinsed by Cr and Au etchant to remove the metal layers, and then immersed in 50% HF solution to etch to 20 μm depth (for upper substrate with chamber, 3 mm diameter) and 50 μm depth and 100 μm width (for lower substrate with channel). After that, penetrate holes for fluid flow (0.4 mm diameter) were made by a milling machine in the upper substrate at inlet, outlet and valve parts. The two substrates were carefully washed by acetone, Cr and Au etchant, and piranha solution and ultra pure water, and then fused in a vacuum furnace, and finally the chambers were sealed by glass ribbon and again fused in a furnace to complete the microchip.

A piezo actuator and a zig were customized for actuator (valve) demonstration as shown in Figure 3. The piezo actuator is just modification of actuator for Braille display [5]. The actuator force per 1 pin was about 200 mN which corresponds to about 30 kPa in the 3 mm chamber.

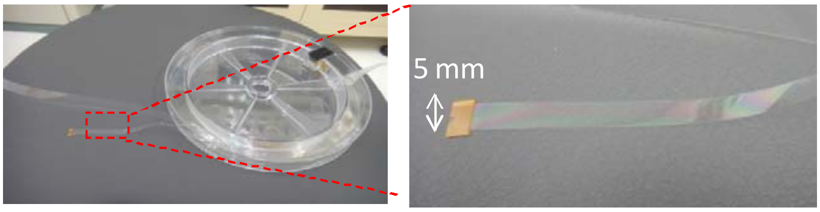

Figure 2: An actual picture of glass ribbon (6 μm thickness) used for this experiment. The ribbon was cut in a desired length.

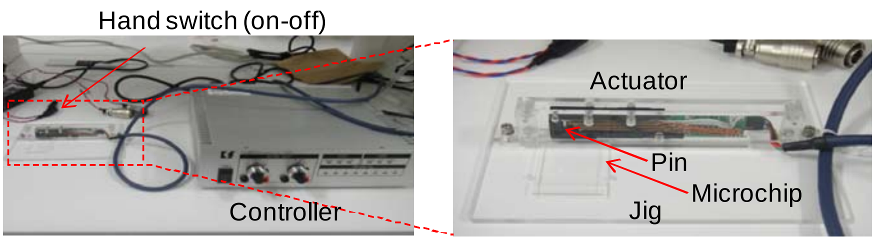

Figure 3: An actual picture of a piezo actuator with a controller. Glass ribbon installed in a glass microchip was pressed by the pins of this bimorph type piezo actuator.

RESULTS AND DISCUSSION

In the first experiment, displacement of glass membrane was observed by using a pair of tweezers as shown in Figure 4. Displacement was 110 μm which was almost just as calculated. To demonstrate no leakage, water was introduced in the chamber, and water did not get out from the chamber. Even after several times trial, glass was not broken. From this result, it was demonstrated that glass ribbon could be used for flexible materials for fluid control in a microchip.

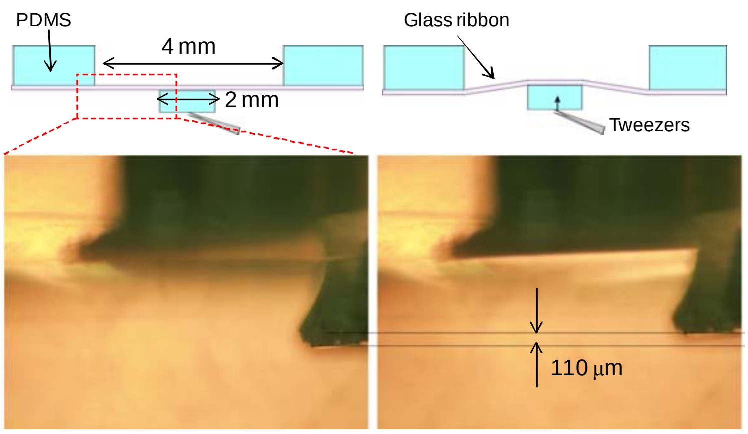

Figure 4: Cross sectional view for demonstration of actuation of glass ribbon manually. 4 mm chamber was sealed by glass ribbon. Maximum displacement at the center part of the chamber was about 110 μm which is enough for valve and pumps.

In the second experiment, switching valve function was verified using a Y-shaped branch channel microchip.

As shown in Figure 4, a microchip made of non-alkali glass was fabricated. In this microchip, two chambers (20 µm height, 3 mm diameter) sealed with 6 µm thickness glass ribbon for valves were installed after the branch part. On this structure, piezo electric actuator shown in Figure 3 was installed. The actuator could be on-off controlled manually using a hand switch.

For demonstration of switching, a solution with 2 µm fluorescent polystyrene microbeads was introduced to visualize fluid by a syringe pump at 1.0 µL/min from the inlet (left side of Figure 5(A)). The branch part was observed by a fluorescent microscope. When both valves were open, fluid flowed in both channels. On the other hand, fluid only flowed into upper channel and the flow in the bottom channel was stopped as shown in Figure 5(C) after closing the valve in the bottom channel. Response time required to switching the flow was within 1 s. From these results, valve function of all glass-based microchip was demonstrated.

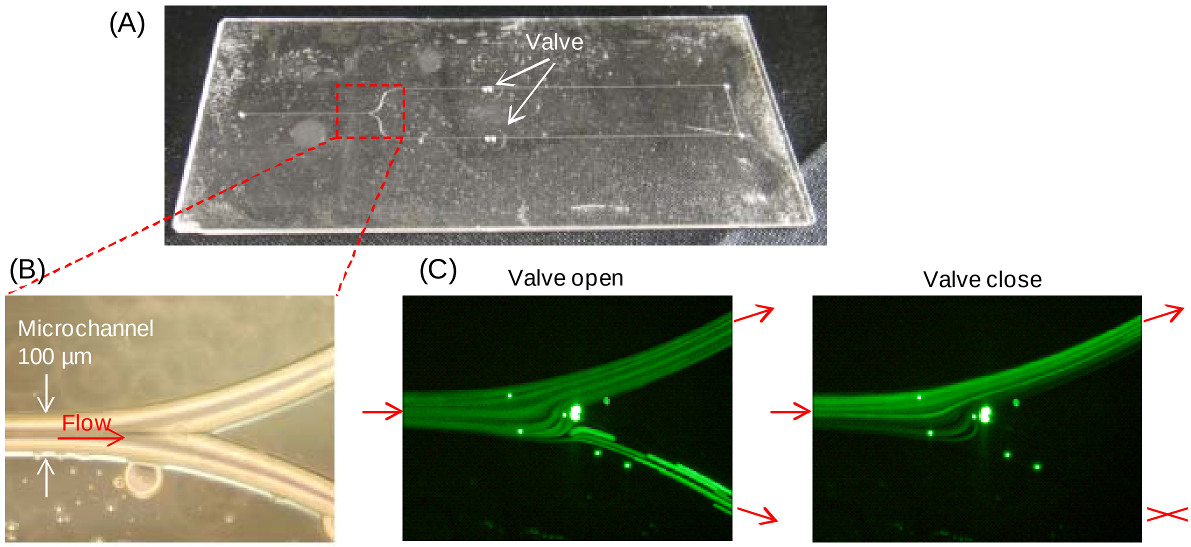

Figure 5: Demonstration of a switching valve. (A) A fabricated all glass microchip. (B) Transmitted light observation of a branch part. (C) Fluorescent light observation of fluid visualized by polystyrene tracking particles to demonstrate switching flow.

CONCLUSION

In this report, an all glass-based actuator for valves and pumps using ultra thin glass and piezo actuators was fabricated and demonstrated. Because this actuator has very small dead volume, response time, this is accommodated for single very small cell handling and other biological applications. Furthermore, this is very useful for glass-based integrated chemistry. So, this system can contribute to most of the micro unit operations (MUOs) process or continuous flow chemical processing (CFCP) systems [2].

ACKNOWLEDGEMENTS

The author is grateful to financial support from JSPS Grants-in-Aid for Young Scientist (A) (21681019), Challenging Exploratory Research (21056049), and Challenging Exploratory Research (23651133). The author also thanks Dr. H. R. Ueda, RIKEN for useful discussion.

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