Miniaturized Liquid Pouch Motors Using Flexible Liquid Metal Heater

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1. INTRODUCTION

Pneumatic actuators have been widely used as a soft actuator due to the characteristics of softness and lightness. However, many conventional pneumatic actuators need bulky tubes and pumps, resulting in the complexity of the actuator system. Although liquid-to-gas phase change actuators [1] do not need such units, there is still the problem that the actuators and its heater devices are not united, and the total size of them becomes large. Therefore, we propose a novel actuator of the liquid-to-gas phase change actuators, which is integrated with a flexible heater made by a liquid metal (Fig.1). Thanks to the high flexibility and durability that depends on the liquid metal heater and thin plastic pouch, the size of the proposed actuator can be smaller than previous liquid-to-gas phase change actuators. In this study, we fabricated four actuators with different designs and evaluated the relationships between the actuator designs and actuator deformation and between the current applied to heater and actuator deformation.

2. METHODS AND EXPERIMENTS

Fig.2a shows a schematic illustration of the proposed actuator. Fig.2b shows that the liquid metal heater does not generate heat, and the actuator is flat in this state. When the liquid metal heater heats up as an electric current is applied to it, the low-boiling-point liquid in the pouch is heated and evaporates (Fig.2c). Then, the pressure in the pouch increases and induces deformations of the actuator.

Fig.3 shows the fabrication process of the proposed liquid-to-gas phase change actuator. A copper wire with a diameter of 120 µm was sandwiched between two thin plastic films (ONY15/LDPE15/L-LDPE60) and thermo-compressed (Fig.3a). The copper wire was pulled out of the film to form a microchannel. We injected the liquid metal to the microchannel and cut it to the desired size (Fig.3b). Electric wire with a diameter of 80 µm was inserted into the microchannel to connect the liquid metal hater with a power supply. The heater was sandwiched between two films and thermo-compressed the three sides of the film (Fig.3c). Finally, we injected low-boiling-point liquid (Novec 7000, 3M Company) to fill 40% of the maximum actuator volume and sealed (Fig.3d).

We evaluated the effect of the design of the actuator on the actuator deformation. Fig.4 shows the experimental setup. We experimented with four types of actuators with a width of 2.5 to 20 mm. The current applied to the heater was 0.30A, 0.35A, and 0.40A. We measured the actuator deformation by using camera capturing. The experimental results are shown in Fig.5. The actuator deformation increased as the width of the actuator increased. On the other hand, as the width of the actuator increased, the deformation speed decreased. In addition, the maximum deformation of the actuator and the deformation speed increased as the applied current was increased. Fig.5c and Fig.5d show that the actuator deformation was smaller at 20 mm than at 10 mm width of the actuator width. It was caused by the difference of the deformation speed. We measured the actuator deformations for 4 min. The actuator’s deformation speed with a width of 20 mm was slower than the actuator with a width of 10mm. Accordingly, 4 min of measurement time was not enough to transform for the actuator with a 20 mm width. The deformation speed can be expected to be faster with the optimization of the heater structure and volume of Novec 7000.

3. SUMMARY

We proposed a novel actuator of the liquid-to-gas phase change actuators by using a flexible liquid metal heater. We evaluated the basic characteristics of the actuator and its performance can be expected to improve with the optimization of the actuator structure. We will evaluate the relationship between the actuator deformation and the actuator’s generated force in future works.

REFERENCE

Fig. 1 Actuator structure.

Fig. 3 Fabrication process of the actuator; (a) a fabricated channel (b) a fabricated liquid metal heater, (c) a fabricated outer pouch, (d) injected Novec 7000 into the pouch.

Fig. 2 Actuator working principle; (a) schematic view, (b) without heat, (c) with heat.

Fig. 4 Experimental set up.

Fig. 5 Experimental result; (a) the width of actuator is 2.5 mm, (b) 5 mm, (c) 10 mm, (d) 20 mm.