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Development of Friction Drive MEMS Rotary Actuator Using Multilayer Piezoelectric Element

積層圧電素子を用いた摩擦駆動型 MEMS ロータリーアクチュエータの開発

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1. Introduction

Actuators are an important factor for various devices. Although conventional actuators have been manufactured by a mechanical machining, the conventional mechanical machining is not suitable for a miniaturized actuator such as millimeter. Therefore, the MEMS (micro electro mechanical systems) technology that based on an IC fabrication process was applied to achieve extremely small size [1]. Among the miniaturized actuator, a piezoelectric element as a drive system has been researched. By using the element for the drive system directly, the miniature structure is achieved. However, the displacement of piezoelectric element is insufficient, and therefore combination of mechanical systems is used in order to obtain a long stroke in many cases [2]. One example is SIDM (Smooth Impact Drive Mechanism) that use a friction and an inertial [3] [4]. The SIDM actuator showed unlimited stroke.

In this research, we developed a rotary type actuator which uses the friction as driving force. The friction head moves by vibration of a multilayer piezoelectric element. The miniaturized components were fabricated by the MEMS technology. In this paper, a developed rotational mechanism and a rotational motion were discussed.

2. Design and Actuation System

Fig. 1 shows a design of the developed friction drive MEMS rotary actuator. In this figure, (a) is an overall view of the friction drive MEMS rotary actuator, (b) is a top view of the friction head and the rotor without a top plate, and (c) is a cross-sectional view of the actuator. Sizes of the actuator are 4.4 mm (width) × 3.2 mm (height) × 1.0 mm (depth), respectively. The rotor diameter is 2 mm. The rotor is held by three disks that have a diameter of 0.4 mm, and reduce a friction between the rotor and the frame. The piezoelectric element is fixed to the outside of the rotor, and held in the main body frame. The friction head is attached to the piezoelectric element, and the friction head is in contact with the side of the rotor. The frames, the friction head, the discs and the rotor were made from a single crystal silicon wafer by MEMS technology.

A driving mechanism utilized the inertia and friction. A sawtooth wave is used for the driving waveform. Therefore, the rotor stays by inertial force and the rotor is rotated by frictional force depend on the waveforms. The drive condition is that the inertial force is less than the friction force.

The multilayer piezoelectric element was used because it shows the low voltage drive and the large displacement. The displacement of the used multilayer piezoelectric element was 110 nm at an applied voltage of 6 V.

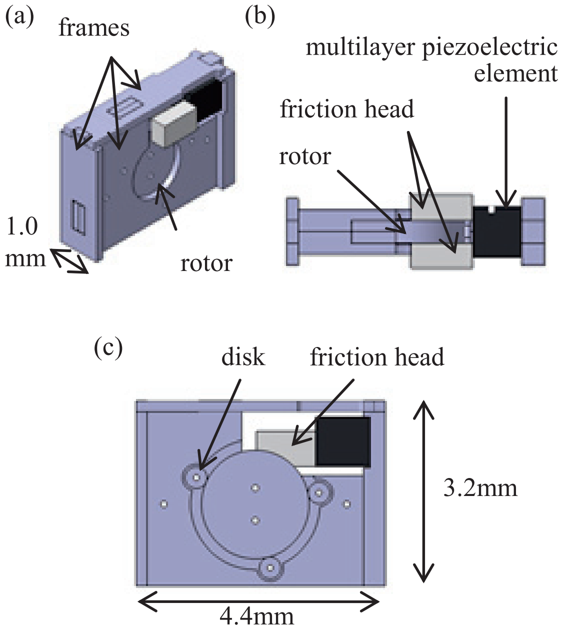

Fig.1 Friction drive MEMS rotary actuator
(a) Overall view of the friction drive MEMS rotary actuator
(b) Top view of the friction head and the rotor
(c) Cross-sectional view of the actuator

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3. Result and Discuss

Fig. 2 shows the fabricated components and the assembled friction drive MEMS rotary actuator, respectively. The error in the dimensions of the actuator component was measured by an optical con-focal microscope and was found to be always within ±5 mm. Result of the calculation of the friction force between the rotor and the friction head was 0.36×10^{-9} N. Result of calculation the inertial force was 0.622×10^{-15} N. Since the inertial force is less than the friction force, it allowed the rotational motion of the rotor. Dimensions of the fabricated actuator were 4.4 mm (width) × 3.2 mm (height) × 1.0 mm (depth), respectively.

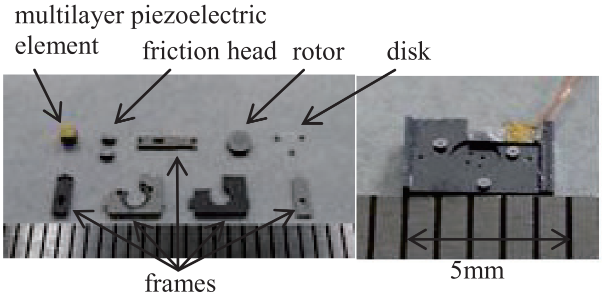

Fig.2 Fabricated components and the assembled friction drive MEMS rotary actuator

The developed actuator reaches the rotational motion of 114 rpm at an applied voltage 10 V and the input frequency was 36 kHz. **Fig. 3** shows the rotation motion of the developed actuator.

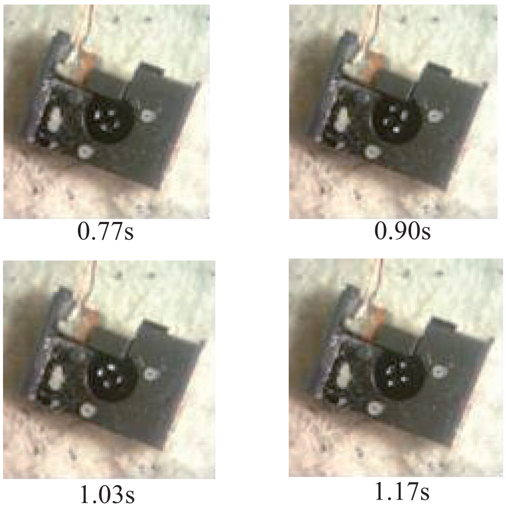
0.77s
0.90s
1.03s
1.17s

Fig. 3 Rotation motion of the developed actuator

Fig. 4 shows a top view of the assembled friction head and the rotor. In this figure, the rotor and the friction head were in contacted. However, the positioning of the friction head was adjusted by hand in the assemble process, and therefore the rotational motion was not stable in each fabricated actuator. For this reason, the suitable shape and mechanism of the friction head will contribute the stable holding position.

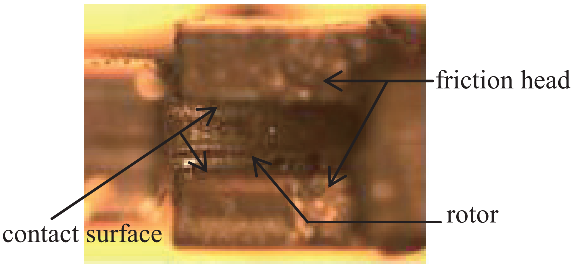

Fig.4 Top view of the assembled friction head and the rotor

4. Conclusion

In this paper, the friction drive MEMS rotary actuator was developed. The components were fabricated by the MEMS technology, and the sizes were 4.4 mm (width) × 3.2 mm (height) × 1.0 mm (depth), respectively. The rotational motion was realized by the vibration of the multilayer piezoelectric element, and it reached 114 rpm at an applied voltage 10 V, and the input frequency was 36 kHz.

Acknowledgment

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