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Piezoelectric Optical Micro Scanner with Built-in Torsion Sensor

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1. Introduction

MEMS-based Optical micro scanner is attractive for its wide-range application such as laser microscope, display system, barcode reader and laser radar. In recent years, electrostatic, electromagnetic, thermal and piezoelectric optical micro scanners have been developed [1-4]. Among them, the piezoelectric optical micro scanner (piezoelectric scanner) is advantageous in low power consumption and low voltage operation. Such characteristics are desirable for the application of scanners to a compact optical system.

The piezoelectric scanner is usually operated at resonant frequency [5-7]. For the precise control of the piezoelectric scanner, the dynamic response of the torsion hinge connected to the mirror should be monitored in-situ. To our knowledge, none of the reported piezoelectric scanners can monitor the dynamic response of the torsion hinge.

Thus, the objective of the present study is to develop the piezoelectric optical micro scanner with built-in torsion sensor directly onto the torsion hinge. Design, fabrication and test of the scanner will be reported.

2. Design

Based on the previously-reported design [7], we have designed the piezoelectric scanner equipped with torsion sensor as illustrated in Fig. 1. The mirror (1 mm x 1 mm) is supported by the torsion hinges (1 mm-long x 0.1 mm-wide). By applying ac voltage to the resonators made of PZT thin film as a piezoelectric and silicon as an elastic layer, the mirror is rotated around the torsion hinges. Figure 2 illustrates the magnified view of the scanner surrounded by the square shown in Fig. 1. Similar to the resonator, the torsion hinges are composed of PZT thin film and silicon. The end of the hinge is expected to act as the torsion sensor through direct piezoelectric effect of the PZT thin film. The reference capacitor is as large as the torsion sensor. With this design, the present piezoelectric scanner can monitor the dynamic response of the torsion hinge without any other external sensors.

3. Fabrication

We have fabricated the piezoelectric scanners from Pt/Ti/PZT/Pt/Ti/SiO_2/SOI multi-layered structure. SOI with 10 mm-thick elastic layer was thermally oxidized and Pt/Ti as bottom electrode was sputtered. Then, PZT thin film was coated by chemical solution deposition (sol-gel). The PZT deposition is reported in our previous study [8]. Finally, Pt/Ti as top electrode was sputtered. The sputtering temperature and pressure were controlled to form a flat structure.

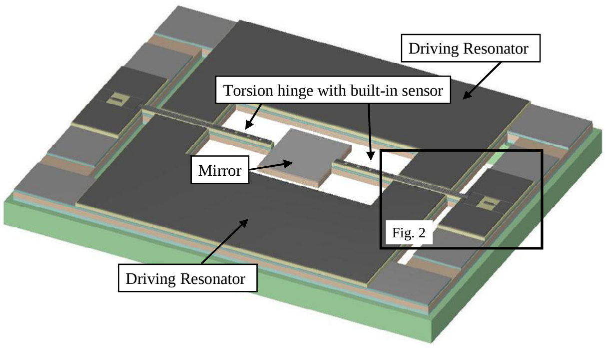

Fig. 1. Schematic of the designed piezoelectric optical micro scanner.

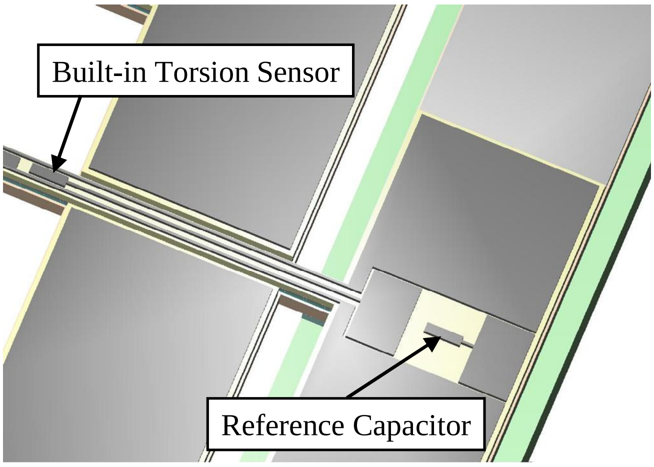

Fig. 2. Magnified view of the scanner surrounded by the square shown in Fig. 1

The present piezoelectric micro scanner was fabricated from the multi-layered structure through a conventional MEMS bulk micromachning. First, the top Pt/Ti layer was etched by Ar-ion. Next, the PZT thin film was wet-etched by the mixture of HF, HNO_3 and H_2O. Thirdly, the bottom Pt/Ti layer was etched by Ar-ion. Fourthly, the thermal SiO_2 layer, Si elastic layer and buried SiO_2 layer were etched by reactive ion etching (by CHF_3 for SiO_2 and by SF_6 for Si). Finally, the Si substrate was etched from backside to release the structures.

4. Test

The resonant frequency of the present piezoelectric scanner was measured by laser Doppler vibrometer. The resonant frequency corresponding to the torsion vibration of the mirror was measured to be 6500 Hz. It was confirmed by the irradiating the laser light to the mirror and observing the scanning reflected light projected on the screen.

Sweeping sine wave was applied to the two resonators. Then, output voltage and phase of the torsion sensor was recorded as a function of the sweeping frequency. Figure 3 shows the output voltage and phase of the torsion sensor as a function of sweeping frequency. The output and phase of the reference capacitor, and the data from laser Doppler vibrometer is also shown in the same figure. The results clearly shows that the torsion sensor detect the dynamic response of the torsion hinge.

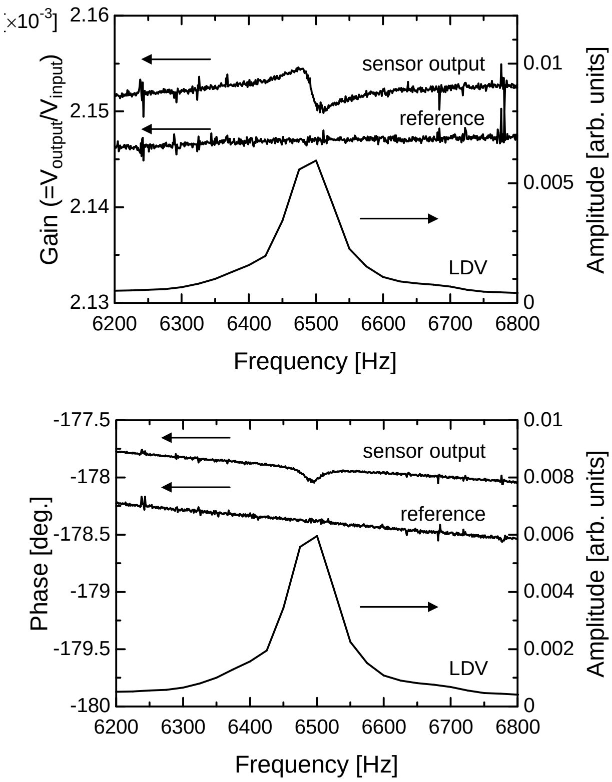

Fig. 3. Output voltage (top) and phase (bottom) of the torsion sensor as a function of sweeping frequency. The output and phase of the reference capacitor, and the data from laser Doppler vibrometer is also shown.

5. Conclusion

The present study reported the development of piezoelectric optical micro scanner with a torsion sensor. We have demonstrated that the PZT thin film built at the end of the torsion hinge act as the torsion sensor.

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