DOI 10.5162/EUROSENSORS2025/M3.2.2

Characterization of Sensor Responses in 1D and 2D Scan Patterns Via AlScN-Based MEMS Mirrors

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Summary: This paper presents an in-depth characterization of sensing capabilities using AlScN-based 3D-constructed MEMS mirror device. Generating 1D line scan or 2D Lissajous scan patterns while acquiring sensor signals simultaneously, this research investigated the correlation between scan angle and sensor output, as well as the potential applications in feedback control.

Keywords: MEMS Mirror, Piezoelectric, Aluminum Scandium Nitride (AlScN), Sensor

Introduction

Quasi-static MEMS mirror is primarily responsible for quasi-static actuation, tilting and holding the mirror plate at a specific scan angle under DC voltage. However, by utilizing resonant driving, the actuation efficiency can be improved, allowing for larger scan angles even under low voltage levels. Especially, this device has the potential to implement various scanning patterns including Lissajous, circular, and spiral scans [1]. In this research, the sensing capabilities of the device shown in Figure 1 have been investigated in depth.

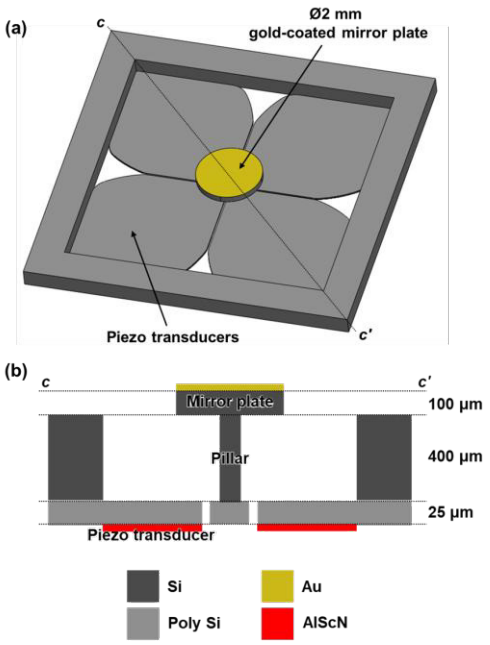

Fig. 1. (a) 3D schematic and (b) cross-sectional view of the analyzed MEMS mirror device.

Characterization of Sensing Capabilities

The photo of the MEMS mirror device and the schematic diagrams of the four independent piezoelectric transducers (P_1, P_2, P_3 and P_4) are shown in Figure 2(a). Figure 2(b) illustrates examples for simultaneous 1D or 2D scanning and sensing. For example, if P_1 is utilized as an actuator to generate 1D diagonal line scan, P_3 can be used as a sensor to detect the deflection angle level. This concept can also be applied in 2D Lissajous scan. P_1 and P_2 are driven at different frequencies, and P_3 ad P_4, located diagonally opposite, can be used as sensors.

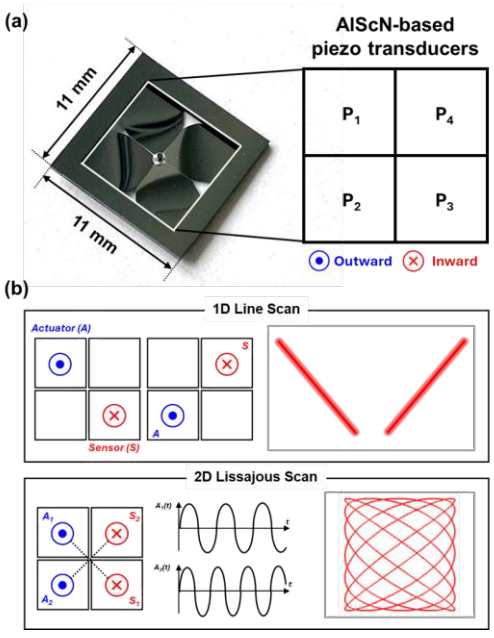

Fig. 2. (a) Overview of AlScN-based piezo transducers and (b) examples of implementation for 1D and 2D scanning.

Experimental Results

Figure 3(a) shows the resultant 1D laser scan trajectories under different voltage levels of 0.1 V_{pp} and 0.5 V_{pp}. The utilized actuator-sensor combinations are inserted in the top-right corner of the Figure 3(a). The frequency response result and corresponding senor output are shown in Figure 3(b). The results show that as the frequency increases, the total optical scan angle (TOSA) also increases, and the deflection level of the sensor located at the diagonal opposite increases, leading to an increment in the sensor output. The Figure 3(c) shows the linear increase in sensor output with increase in TOSA.

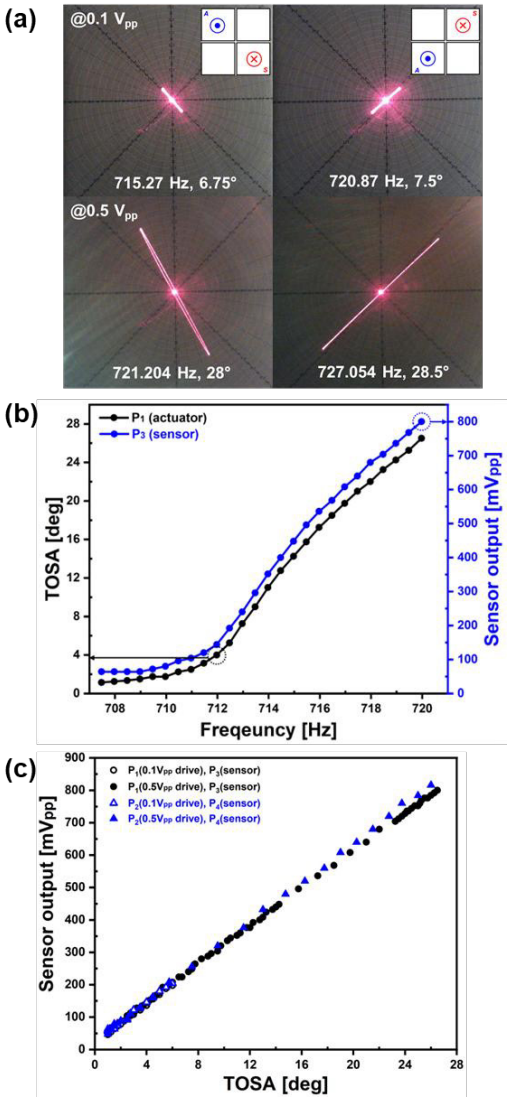

Fig. 3. (a) Resultant laser beam trajectories of 1D line scan under different voltage levels, (b) frequency response result and corresponding sensor output, (c) plot of the generated sensor output vs. total optical scan angle.

In addition, the 2D sensing capability was analyzed. The resultant Lissajous scan pattern is shown in Figure 4(a) and acquired sensor signals are presented in Figure 4(b). The sinusoidal signals extracted from the sensors (P_3 and P_4) can be used to predict the TOSA by utilizing the linear relationship between the TOSA and sensor output level presented in Figure 3(c). Subsequent studies on reconstruction of scan pattern and feedback control are ongoing. In addition to the characterization presented in this paper, further research leveraging the sensing capability-such as Q-factor estimation-is currently under investigation.

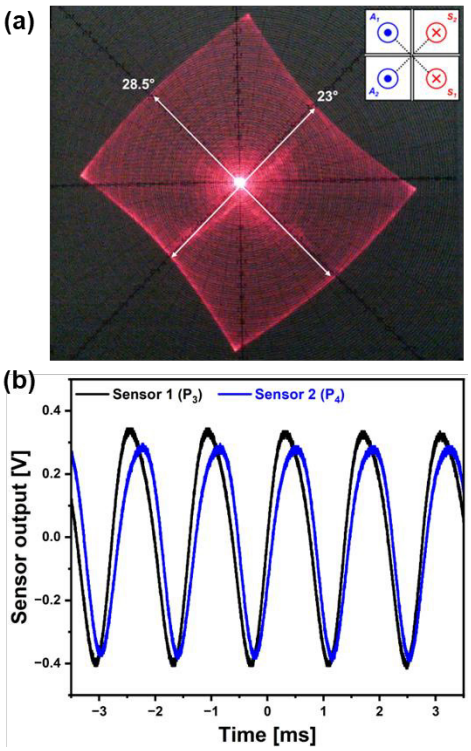

Fig. 4. (a) Generated 2D Lissajous scan pattern and (b) acquired sensor signals.

References

[1] J.-Y. Hwang et al., Low Power Compact 3D-Constructed AlScN Piezoelectric MEMS Mirrors for Various Scanning Strategies, *Micromachines* 14, 1789 (2023); doi: 10.3390/mi14091789.

Acknowledgements

This research was supported in part by the framework of the Fraunhofer Cluster of Excellence Advanced Photon Sources-CAPS funded by Fraunhofer Gesellschaft and in part (Investigation on piezoelectric material-based sensing) funded by the Ministry of Trade, Industry, and Energy (MOTIE), Korea, under the “Global Industrial Technology Cooperation Center (GITCC) program” supervised by the Korea Institute for Advancement of Technology (KIAT). (Task No. P0028389)