A Large Stroke Inverse Series Connected Electrothermal Bimorph Micromirror Platform for Optical Applications

Amit Kumar[1,2], Deepak Bansal[1,2], Maninder Kaur[2], and Kamaljit Rangra[1,2]

[1]Academy of Scientific and Innovative Research, Taramani, Chennai
[2]CSIR-Central Electronics Engineering Research Institute, Pilani, Rajasthan
Corresponding author's email: Amitfiem88@gmail.com

Abstract— This paper presents a large stroke surface micromachined micromirror platform actuated using inverse-series-connected (ISC) bimorph actuator. The platform is capable of producing both piston and tip-tilt motion. With a mirror plate size of 500x500 μm^2, the maximum displacement is 100 μm in piston mode and 69 μm in tip-tilt mode at 0.2 V. The micromirror is capable of scanning with resonance frequencies at 4.31 KHz and 6.70 KHz in piston and torsional mode respectively.

Keywords: Micromirror, MEMS Actuator, Electrothermal Bimorph Actuator

1. Introduction

Micro-electro-mechanical system based micromirrors have found numerous applications in projection display, multi-object spectroscopy, medical imaging, scanning and optical communication switching. This paper presents an electrothermally actuated micromirror platform for large stroke piston and tip-tilt motion. The actuator is made using Inverse-series-connected (ICS) bimorph structure of Al and SiO_2. The proposed micromirror is made using surface micromachining without use of costly SOI or DRIE processes.

2. Device Design and Process Flow

3D schematic diagram of the proposed design is shown in fig. 1(a). The mirror plate is supported by four bimorph actuators. The actuator is composed of Inverse-series-connected Al and SiO_2 layer with Al also working as embedded heater as shown in fig. 1(b) . The ICS actuator effectively cancels the tangential tip and lateral shift resulting in enhanced upward motion. The inverted (INV) and non-inverted (N-INV) segments of SiO_2 are symmetric and overlapping of segments gives additional robustness. Thickness of bottom oxide, Al, and top dioxide is taken as 0.5 μm, 1.5 μm and 0.5 μm respectively.

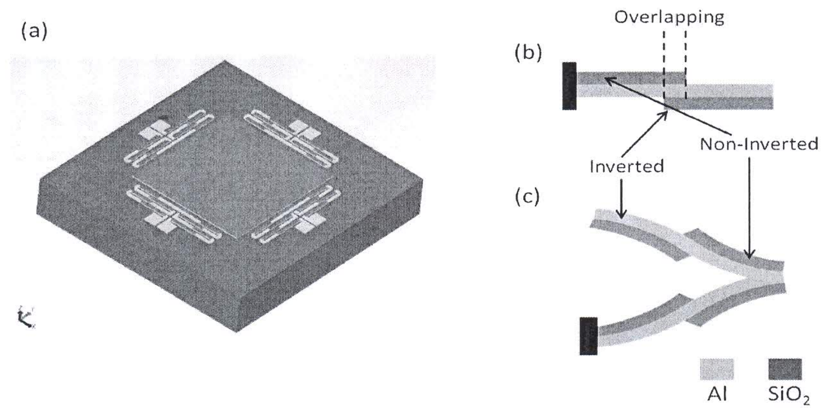

Fig. 1. (a) Schematic diagram of proposed device, **(b)** Overlapping of bimorph segments, **(c)** Double ladder ICS bimorph structure

The detailed process flow is shown in fig. 2. The process begins with 350 μm thick Silicon wafer deposited with a metal sacrificial layer and patterning. A 0.5 μm thick SiO_2 is deposited by PECVD. After SiO_2 patterning, Lift-off photoresist is deposited and patterned followed by deposition of 1.5 μm thick Al layer by sputtering and 0.5 μm SiO_2 by PECVD. Both layers are patterned using Lift-off. The structure is finally released using wet process.

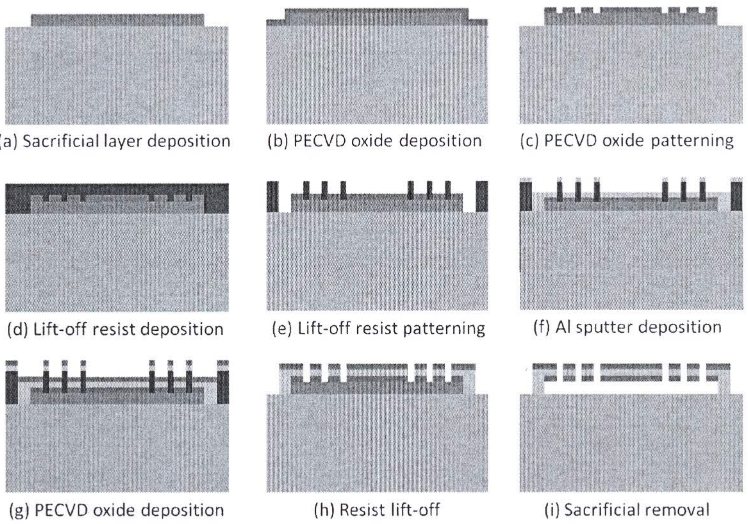

Fig. 2. Proposed process flow of micromirror fabrication

3. Results

For scanning applications, micromirrors need to operate at resonance frequencies. Different resonant modes with primary resonance (piston) at 4.31 KHz and 1^{st} and 2^{nd} harmonics (tip-tilt) at 6.70 and 6.75 KHz respectively are shown in fig. 3.

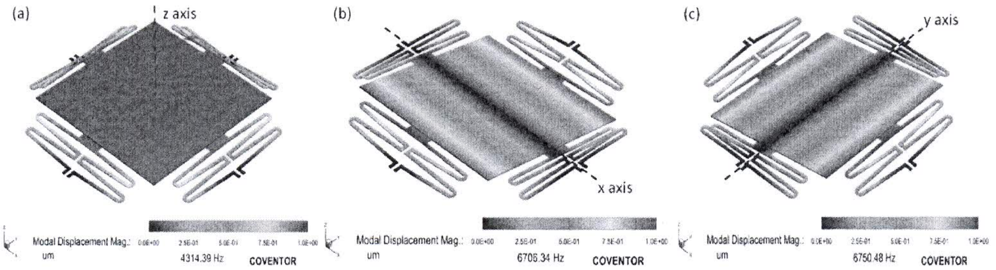

Fig. 3. Nodal resonance frequency of micromirror

All surfaces in contact with Silicon are kept at a 27^0C. For piston mode, 0.2 V is applied to all actuators. Current and heat flux distribution across device is shown in fig. 4(a) and fig. 4(b) respectively. For single ladder actuator, maximum deflection is 59 µm which increases to 100 µm for double ladder design. Tip-tilt deflection of 67 µm is obtained for 0.2 V applied across actuator 1 only.

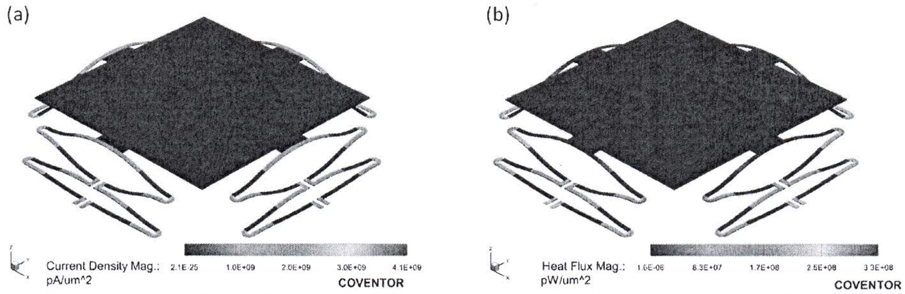

Fig. 4. (a) Current distribution across micromirror structure, **(b)** Heat flux across different layers of micromirror

Variation in micromirror displacement and temperature with voltage for piston and tip-tilt motion is shown in fig. 5(a) and fig. 5(b) respectively.

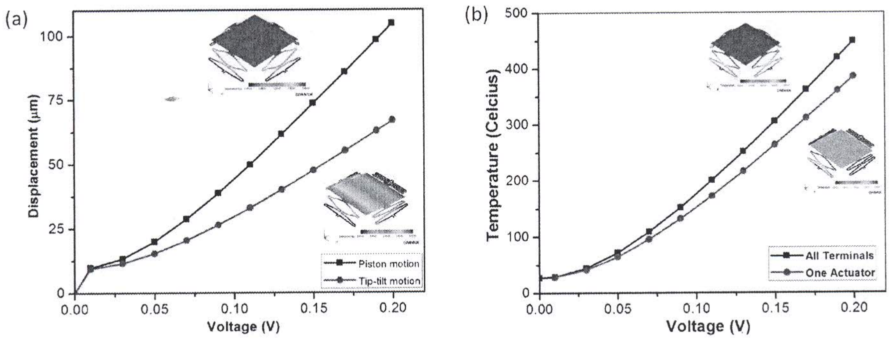

Fig. 5. **(a)** Displacement of micromirror Vs voltage, **(b)** Temperature of structure Vs voltage

4. Conclusion

A large stroke micromirror design is proposed in this paper which can be used for axial scanning in Optical Coherence Tomography (OCT) applications to replace motor controlled mirror movement.

Acknowledgment

The author acknowledges financial assistance under RESPOND Project sponsored by SAC-ISRO and CSIR-CEERI, India.

References

1. X Zhang et.al, "A Robust, Fast Electrothermal micromirror with Symmetric Bimorph Actuator made of Copper/ Tungsten" *Transducers 2015*, Alaska, USA
2. C.H. Tsai et. al., "Electrothermally-Actuated Micromirrors with Bimorph Actuators - Bending-Type and Torsion-Type", *Sensors 2015*, 15, 14745-14756.