Design and Microfabrication of an Electrostatically Actuated Scanning Micromirror with Elevated Electrodes

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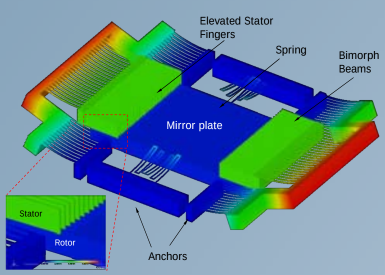
Abstract

This paper reports the design and microfabrication of an electrostatically actuated CMOS-MEMS micromirror with elevated electrodes. Two sets of bimorphs are employed to create mismatched vertical comb drives for mirror actuation. Device structural design and fabrication process are detailed and device performance such as scanning angles is simulated using CoventorWare, an integrated MEMS simulator. With a 21 V driving voltage applied to the mismatched comb drives alternatively, a rotational angle of over ±12° can be realized. The device chips were fabricated using AMI 0.5 µm CMOS technology through MOSIS. DRIE post-CMOS microfabrication was performed for device release.

Keywords: CMOS-MEMS, electrostatic, micromirror, vertical comb-drive.

Device Design

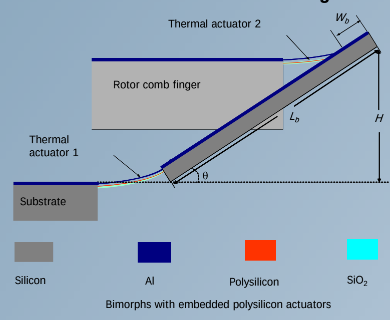


Device features:

- Mismatched vertical comb drive with single-crystal silicon
- Electrothermally driven for elevation height
- Electrostatically driven for rotational mirror plate
- Maskless post-CMOS process

Actuating Principle

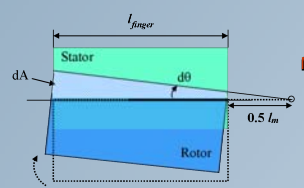
Pure vertical elevation of the stator comb fingers



The vertical elevation, *H*:

$$H = \left(L_b - W_b\right)\sin\theta$$

Rotating VCD mirror along the torsional spring

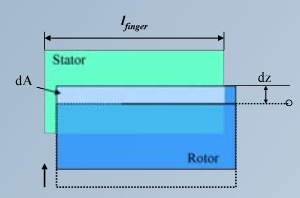


Cross-section of VCD for mirror rotation analysis.

Maximum rotation angle:

$$\theta_{\max} = \frac{t}{l_f + \dfrac{l_m}{2}} = 12^o$$

Vertically VCD upward motion due to the vertical electrostatic force



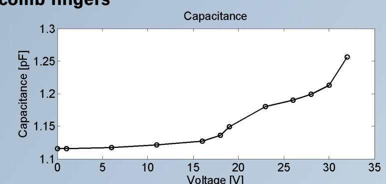
VCD analysis for mirror piston motion

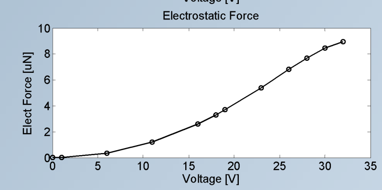
The electrostatic force:

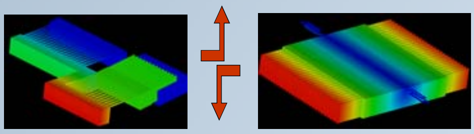
$$F = \frac{1}{2}\cdot\frac{dC_z}{dz}\cdot V^2$$

Simulation Results

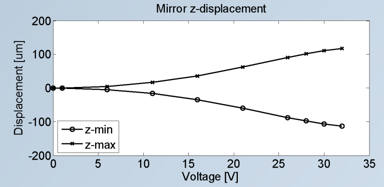
Capacitance and Electrostatic Force between stator and rotor comb fingers

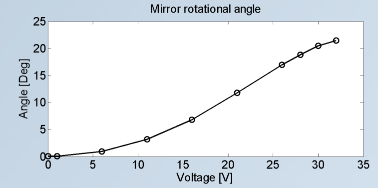




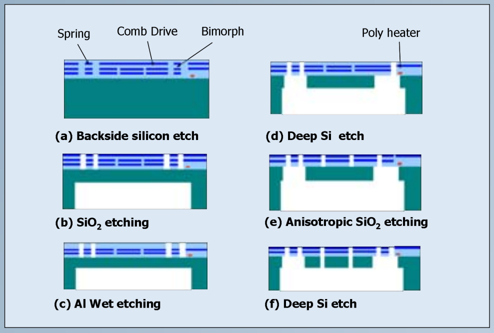


Displacement and Angle of the VCD mirror

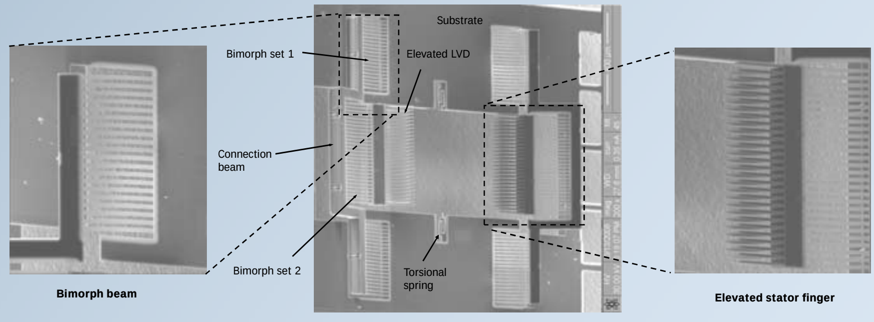




Microfabrication Technology



Fabricated Device



SEM image of the fabricated device

Major Parameters

Parameter	Definition	Value
Mirror Length	l_m	0.4 mm
Mirror Width	w_m	0.4 mm
SCS Thickness	t	60 µm
VCD Finger Gap	g	2 µm
VCD Finger Width	w_f	6 µm
VCD Finger Length	l_f	100 µm
Number of Fingers	N_f	25
Length of bimorph beam	l_b	150 µm
Width of bimorph beam	w	9 µm
Width of connecting beam	w_b	50 µm
Thickness of beam	t	1.8 µm
Number of bimorph beams in LVD	N	24

Conclusion

An electrostatic micromirror capable of rotational and vertical piston motion has been designed and fabricated. The novel LVD structure elevates the stator fingers 100 µm above the substrate plane. This elevation can be tuned by passing current through the polysilicon actuator embedded in the bimorphs. This mirror can provide bi-directional scanning angles of ±12° at 21 V dc. The simulation was performed up to 32V dc.

Maskless post-CMOS processes was employed in the device fabrication. Since this mask-less fabrication process is foundry-CMOS compatible, it has the potential to be cost effective over other complex processes that are currently used in fabricating VCDs. The bi-directional rotational scanning and vertical piston motion scanning capabilities of this devices make it useful in the areas of optical coherence tomography (OCT), adaptive optics and interferometry systems.

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