MOEMS Electrostatic Scanning Micromirrors Design and Fabrication

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In this paper we present an overview of micro-opto-electro-mechanical systems, (MOEMS), scanning micromirror design and fabrication and describe in detail our single crystal silicon micromirror with a novel angular vertical comb drive (AVC). This micromirror employs a simplified, cost-effective, silicon on insulator micro-electro-mechanical systems, (SOI MEMS), process which features self-alignment of the fixed and moving teeth and is fabricated on a single SOI wafer. For the AVC scanner a resonant mode optical scan angle of ±18º at 1.4 kHz has been achieved.

Scanning micromirrors are key components in MOEMS designed for a broad range of applications including: optical switches, imaging, optical data storage, bar code reading, and beam steering for free-space optical communication. Micromachining is a particularly attractive technology, enabling the creation of miniaturized, lightweight, low energy, and reduced cost scanning micromirrors. The challenge is optimization of performance within a design space demanding tradeoffs. The desired outcome of micromirror design and fabrication is an optically smooth, flat surface ($<\lambda/20$), and an electrically fast (kHz range), low voltage (<100V), actuator with the combination of mirror and actuator capable of a large optical scan angle (±20°).

Electrostatic micromirrors may be of the parallel plate type or combdrive type and can be fabricated with surface micromachining [1], bulk micromachining [2], and integrations of the two [3,4]. Single crystalline silicon, derived from bulk or SOI micromachining methods, is a suitable mirror material with characteristic smooth, flat surfaces. For high-speed scanning, electrostatic comb drive actuation has several advantages. A relatively stiff torsion bar, required for high frequency operation, may be designed since the increased force generated by the large capacitance area provides more effective utilization of the driving voltage. In addition, decoupling of the mirror and actuator permits a large deflection angle since, the under mirror electrode is not required and the underside can be opened to accommodate a larger range of motion.

Vertical comb drives have been demonstrated, with a staggered vertical comb drive by patterning the fixed and moving teeth in distinct layers separated by sacrificial oxide [2], or by adding a metal offset electrode on top of the fixed teeth [5]. The staggered vertical comb drive typically requires critical alignment. Our approach, the angular vertical comb [6], is fabricated from the device layer of a single SOI wafer and our model shows that an angular vertical comb can achieve a 50% higher scan angle than a staggered vertical comb of equivalent dimensions. The self-aligned comb fingers are patterned in a single etching process and subsequently rotated out of the wafer plane, Fig 1. The resonant mode response for the AVC micromirror is shown in Fig. 2.

References

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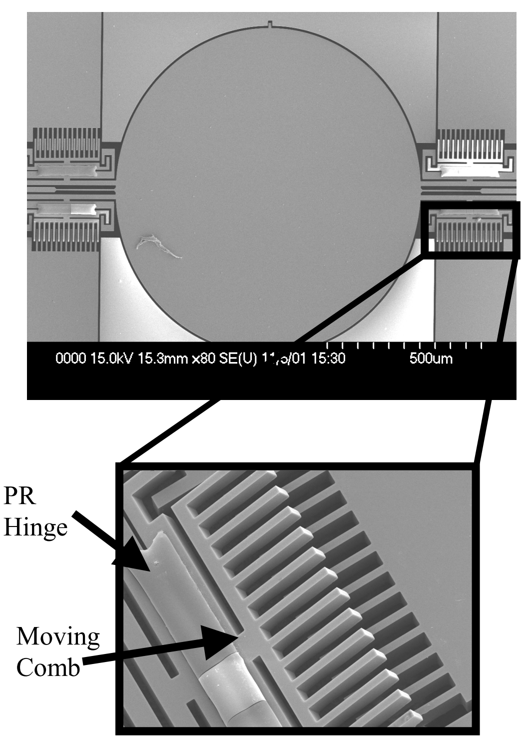

Figure 1. SEM of scanner with angular vertical comb drive, inset comb teeth.

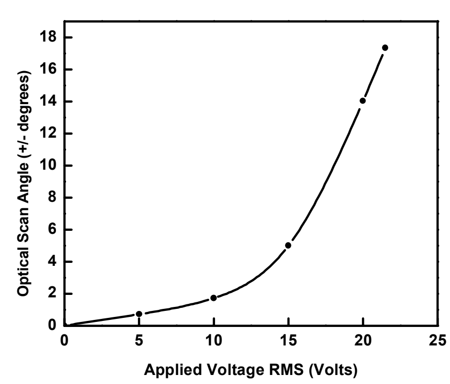

Figure 2. Optical scan angle vs. voltage at 1.4kH for AVC micromirror.