A Comparison of Mass Reduction Methods for Silicon-on-Oxide (SOI) Based Micromirrors

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Introduction: Beam steering and adaptive optics micromirror applications commonly demand optically flat surfaces (ρ >0.5 m, 10% of wavelength) with minimal mass. This work presents initial findings quantitatively comparing different backside etch patterns to understand the design trades.

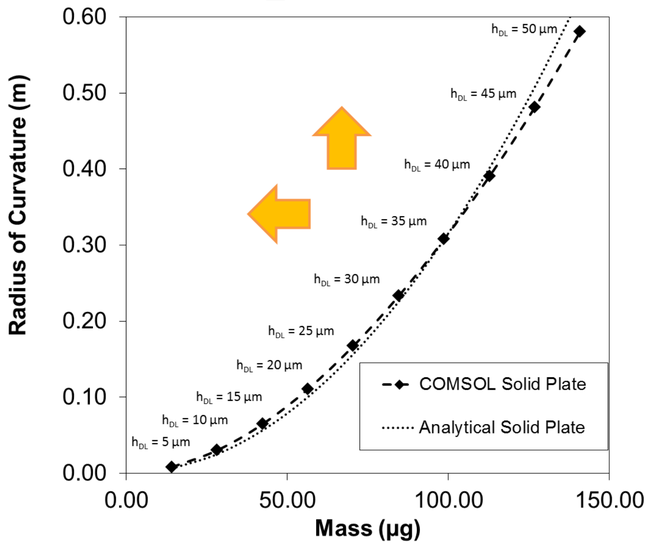


Figure 1. Baseline Solid Mirror Plate trade space.

Computational Methods: The Solid Mechanics module was used with experimentally determined film stress values applied to each layer. Parameter sweeps (array size, etch depth, pattern size) were performed to explore the trade space for each geometry. The post width was scaled to central pattern elements with a fixed B.C. at post bottom. Curvature profiles generated from least squares fitting of diagonal surface profiles in MS Excel.

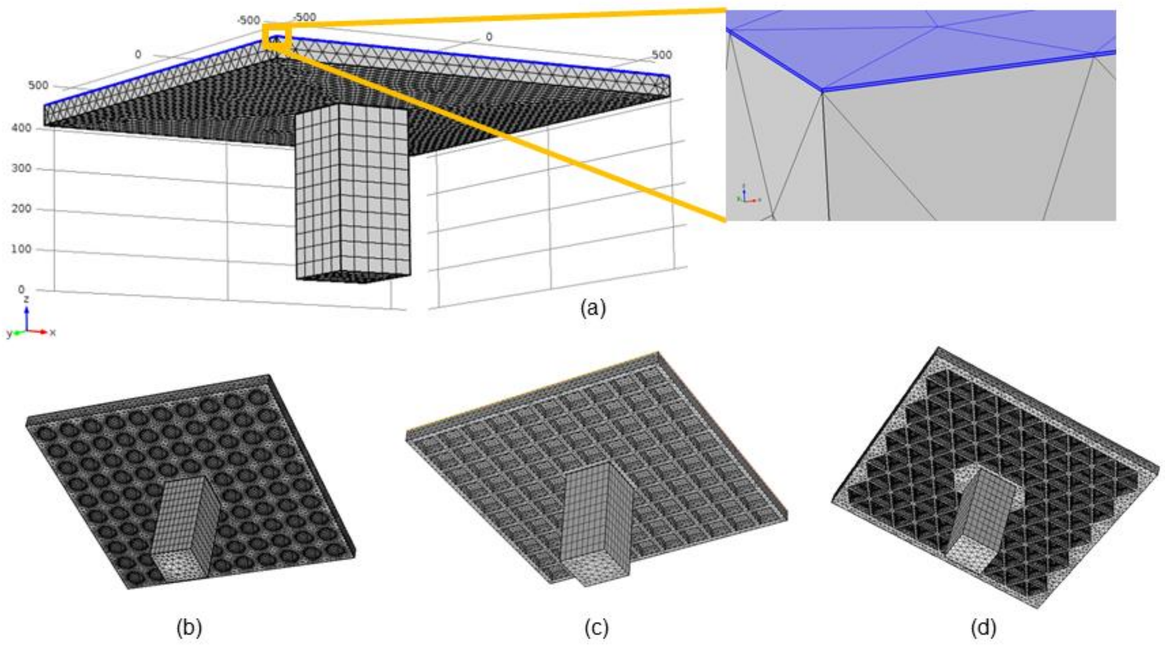
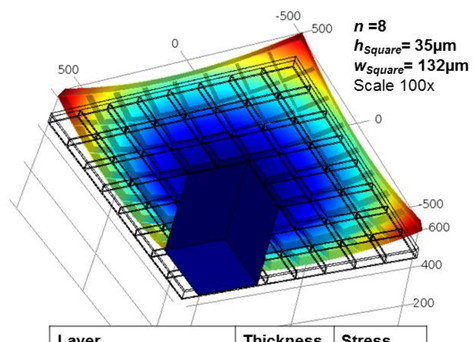


Figure 2. (a) Solid model of square solid plate micromirror (1.1 mm mirror width) with center post, inset shows metal layer (b) hemispherical (isotropic etch), (c) square, (d) equilateral triangular etch patterns.

Results:



Layer	Thickness	Stress
Al metal layer	300 nm	+400 MPa
Si Device layer	50 µm	+25 MPa
BOX (above post only)	2 µm	-300 MPa

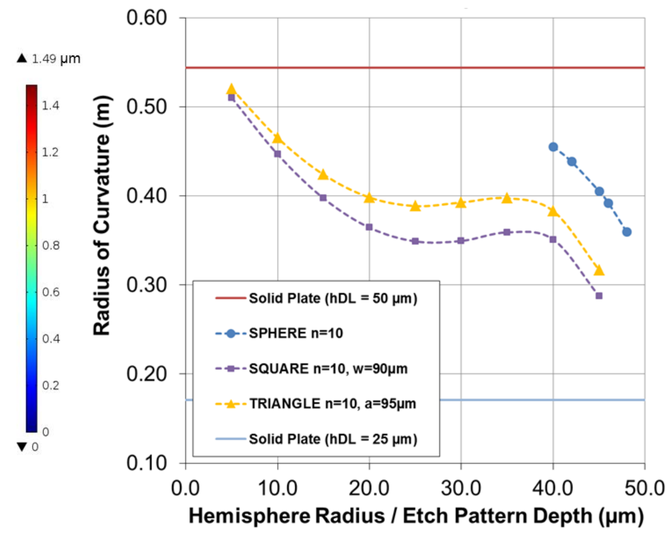


Figure 3. (left) Representative steady-state deflection profile for micromirror with square etch pattern. (right) Effect of etch depth/etch radius on radius of curvature.

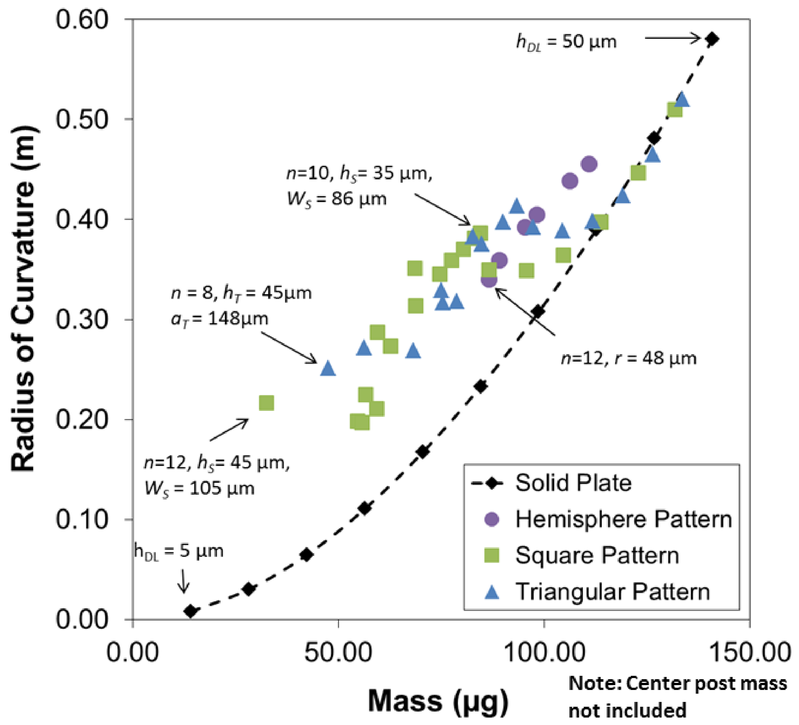


Figure 4. Depiction of trade space between curvature and plate mass for the different designs simulated.

Conclusions: Knowledge of tradespace is essential to understand the degree to which backside etch mass reduction provides worthwhile benefit. Future work is directed towards additional geometries, optimization methods, and experimental demonstration of patterning.

References:

1. Su G-D, et.al., "Surface-micromachined 2D optical scanners with optically flat single crystalline silicon micromirrors", *Silicon-based and Hybrid Optoelectronics III Proceedings of SPIE,* Vol. 4293 (2001)
2. Milanovic V., et. al. "Gimbal-Less Monolithic Silicon Actuators for Tip-Tilt-Piston Micromirror Applications" *IEEE Journal of Selected Topics in Quantum Electronics*, Vol 10, pp. 462-471 (2004)
3. Chui B.W. et. al., "Simplified Monolithic Process for Fabricating Low-Cost, High Frequency, High Flatness Scanning Micromirrors", *Proc. of Solid-State Sensors, Actuators, and Microsystems (TRANSDUCERS 2013*), pp. 1036-1039 (2013)