

Development of Stress Relief Suspensions for Micro-Machined Silicon Membranes

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Introduction:

Micro machined Silicon membranes manufactured in Silicon on Insulator (SOI) technology often suffer from buckling caused by internal stress of the material. A new concept of a stress relief structure used for dynamically activated micro mirrors, as seen in Fig. 1, has been developed. It reduces the stress induced deformation and leads to substantially flat mirrors of high optical quality [1,2].

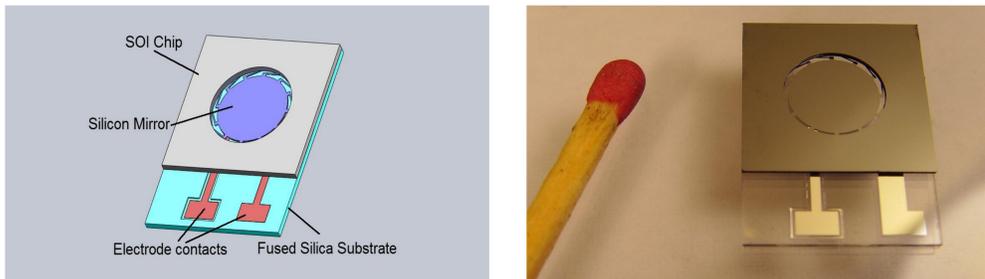


Fig. 1. Schematic (left) and fabricated micro mirror device (right)

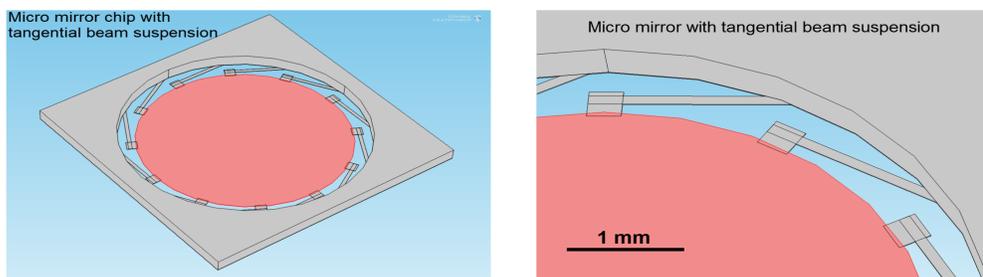


Fig. 2. : COMSOL 3D model of the mirror chip with the tangential suspension beams

A special tangential beam suspension allows an in-plane expansion or contraction of the membrane proportional to its inherent compressive or tensile stress (Fig. 2).

Computational Methods:

- 3D simulation using the MEMS Tool of COMSOL Multiphysics V4.2.
- Influence of material pre-stress of SOI wafer by use of the initial stress matrix \mathbf{S}_0 in the structural mechanics interface.

Geometry:

Membrane radius: 3 mm, 10 μm thick
Beams: L/W/H: 1800 μm /100 μm /10 μm
Chip size: 8 mm x 8 mm

FEM Results:

- In-plane expansion (xy - displacement) of the membrane of 327 nm enabled by the weak flexibility of the suspension beams (Fig. 3).
- Stress relief of compressive pre-stress $\sigma = -20$ MPa resulting in a flat membrane with only $\Delta z = 82$ nm out of plane distortion (Fig. 4).

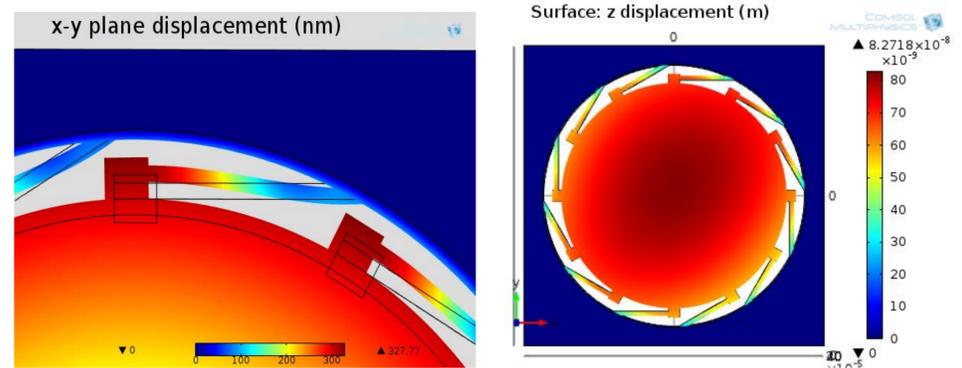


Fig. 3. xy - displacement (in plane) Fig. 4. z - displacement

Comparison with measurements:

Conventional rigidly clamped membrane: Large distortion $\Delta z = 335$ nm (simulated for an pre-stress of $\sigma = -1$ MPa) and $\Delta z = 340$ nm measured.

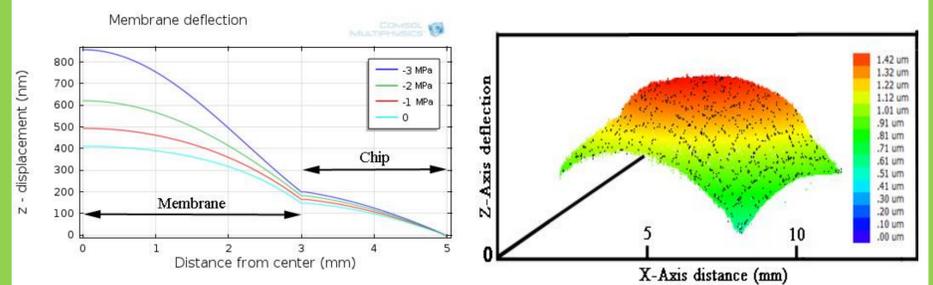


Figure 5. Rigidly clamped membrane distortion; left: FEM, pre-stress $\sigma = -3 - 0$ MPa; right: measured

New tangential beam suspended membrane: z-displacement $\Delta z = 53$ nm (simulated); $\sigma = -1$ MPa) and $\Delta z = 54$ nm (measured).

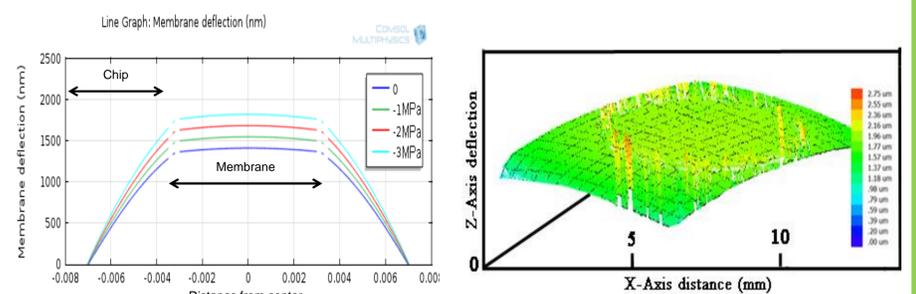


Figure 6. Novel design membrane distortion; left: FEM, pre-stress $\sigma = -3 - 0$ MPa; right: measured

Conclusions:

FEM simulation together with measurements prove the novel concept of stress relief suspensions.

References:

1. W. Kronast, U. Mescheder, B. Müller, R. Huster, "Development of a focusing micromirror device with an in-plane stress relief structure in SOI technology", Proc. of SPIE, MOEMS and Miniaturized Systems XII, Vol. 8616, (2013)
2. W. Kronast, U. Mescheder, R. Huster; Stressuntersuchung und Optimierung von SOI basierten Membranen; Mikrosystemtechnik Kongress 2009, Berlin, Proceedings pp. 590-593, ISBN 978-3-8007-3183-1 © VDE VERLAG GMBH • Berlin • Offenbach