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Abstract

Biaxial Piezoelectrically Driven MEMS Mirror with Large Design Flexibility †

Lena Wysocki , Patrick Schütt, Jörg Albers, Gunnar Wille, Erdem Yarar, Paul Raschdorf , Lianzhi Wen and Shanshan Gu-Stoppel *

Fraunhofer Institute for Silicon Technology, Fraunhoferstraße 1, 25524 Itzehoe, Germany; lena.wysocki@isit.fraunhofer.de (L.W.); patrick.schuett@isit.fraunhofer.de (P.S.); joerg.albers@isit.fraunhofer.de (J.A.); gunnar.wille@isit.fraunhofer.de (G.W.); erdem.yarar@isit.fraunhofer.de (E.Y.); paul.raschdorf@isit.fraunhofer.de (P.R.); lianzhi.wen@isit.fraunhofer.de (L.W.)

* Correspondence: shanshan.gu-stoppel@isit.fraunhofer.de; Tel.: +49-4821-17-1424

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Abstract: In this work, a biaxial, piezoelectrically driven resonant MEMS mirror with large design flexibility is presented. After FEM-based design optimization to reduce material stress and thereby maximize the achievable total optical scanning angles, fabricated MEMS mirrors were electrically, mechanically, and optically characterized. While the achievable optical scanning angles were determined using a home-built optical setup, a laser Doppler vibrometer was used to characterize the resonance frequencies of the rotational modes and their respective quality factors. The encapsulation of the mirror by a glass window ensures its operation in vacuum, which increases the Q-factor up to 15,000.

Keywords: resonant MEMS mirror; piezoelectric actuation; Lissajous scanning

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1. Introduction

Multiaxial resonant MEMS mirrors are frequently applied in miniaturized detection or projection systems since they combine the advantages of compactness, speed, and low power consumption [1,2]. The presented design was optimized utilizing finite element method (FEM) simulations with a focus on reducing material stress as well as the realization of resonance frequencies of the torsional modes which are suitable for Lissajous scanning with high frame rates and/or fill factors [3]. The current work focuses on the experimental characterization of these optical MEMS scanners as well as improving the FEM simulations in order to increase the simulation-based prediction capabilities for future designs.

2. Design Concept and FEM Simulations

The design exhibits two separate actuator groups responsible for the rotation of the mirror along two orthogonal axes, which reduces mechanical coupling and thereby the mutual influence of the rotations. The geometry used for the FEM simulations, as presented exemplarily in Figure 1, was built from the real geometry of the lithography masks. Here, the masks for the epitaxially grown polycrystalline Si (Epi-poly Si) etching, the etching from the backside, and the active piezoelectric area were imported into COMSOL Multiphysics. Subsequently, the results of the eigenfrequency study will be compared with experimental results from frequency studies of the MEMS mirrors.

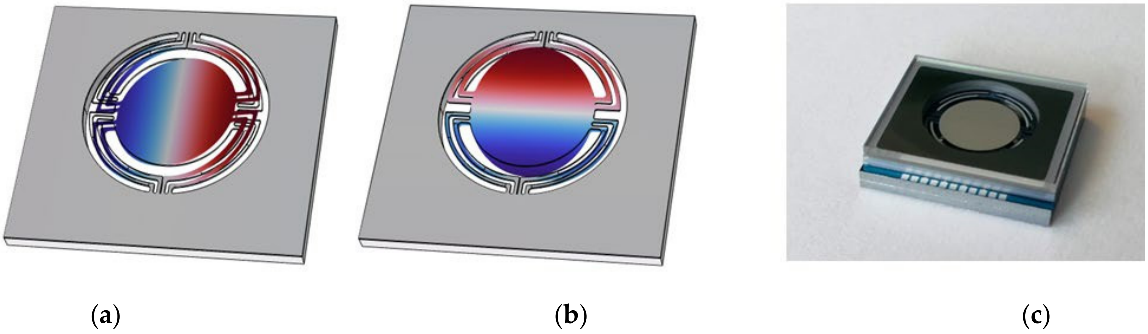

Figure 1. The results of the FEM-based eigenfrequency study of the active wafer of the MEMS scanner. Presented are the slow rotational mode (**a**) and fast rotational mode (**b**). The color code represents the z-component of the deflection in arbitrary units. (**c**) A photograph of the final optical MEMS scanner.

3. Experimental Results

The characterization of the dynamic modes, the respective resonance frequencies, the quality factors, and the achieved total optical scanning angles was performed using a combination of laser Doppler vibrometry and measurements obtained using a home-built optical setup. The results of the experimental characterization and the comparison with the FEM-simulations are summarized in Table 1.

Table 1. Comparison of the eigenfrequencies from the FEM simulations and the experimental results.

Design	Simulated Frequencies (Slow and Fast)	Mean of Measured Frequencies (Slow and Fast)	Quality Factor
A	2.7 kHz; 3.8 kHz	2.3 kHz; 3.2 kHz	15,000

4. Outlook

The replacement of AlN with AlScN, which exhibits an enhanced piezoelectric coefficient, $e_{31,f}$ [4], represents a promising possibility to increase the optical scanning angles of the presented MEMS mirrors. The integration of AlScN is currently underway and will be addressed in future publications.

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