Translatory MEMS actuator with wafer level vacuum package for miniaturized NIR Fourier transform spectrometers

Thilo Sandner[a], Eric Gaumont[a], Thomas Grasshoff[a], Gerald Auböck[b], Andreas Kenda[b], Thomas Gisler[c], and Sergiu Langa[a], Andreas Herrmann[a], Jan Grahmann[a]

[a]Fraunhofer Institute for Photonic Microsystems (FhG-IPMS), Dresden, Germany,
[b]Carinthian Tech Research AG, Villach, Austria, [c]Metrohm AG, Herisau, Switzerland

ABSTRACT

A translatory MOEMS actuator with extraordinarily large stroke - especially developed for fast optical path-length modulation in miniaturized FT-spectrometers (FTS) designed for NIR spectral region (800 nm – 2500 nm) - is presented. A precise translational out-of-plane oscillation at 260 Hz with a stroke of up to 700 µm and minimized dynamic mirror deformation of 80 nm is realized by means of an optimized MEMS design. The MOEMS device is driven electro-statically near resonance and is manufactured in a CMOS-compatible SOI process. Due to the significant viscous gas damping, dominated by the drag resistance of the comparatively large mirror plate with 5mm diameter, the resonant MEMS device has to operate under reduced pressure. A mirror stroke of 700 µm at a driving voltage of 4V is achieved by hermetic encapsulation of the actuator at at a maximal pressure of 3.2 Pa. For FTS system integration the MOEMS actuator has been encapsulated in an optical vacuum wafer-level package (VWLP) to guarantee a long-term stable vacuum pressure of 0.1 Pa and lifetime t ≥ 10a.

Keywords: Optical SOI-MEMS, translatory micro mirror, optical path length modulation, Fourier-transform infrared spectrometers, optical wafer level vacuum packaging, MEMS VWLP

1. INTRODUCTION

Fourier-transform Infrared (FT-IR) spectroscopy is a widely used method to analyze different materials - organic and inorganic. Current FT-IR spectrometers are large, usually static, and are operated by qualified personnel. By using translational MOEMS devices for optical path length modulation instead of conventional highly shock sensitive mirror drives a new class of miniaturized, robust, high-speed and cost-efficient FTIR-systems can be addressed. An early approach of miniaturized MEMS-based FTIR spectrometer has been developed in the past by CTR and IPMS for the spectral range of 2…5 µm [1]-[3]. It was a combination of classical infrared optics with a translatory 5 kHz MEMS mirror of 1.65 mm² aperture using a folded bending spring mechanism [2]. Due to the limited amplitude of ± 100 µm a spectral resolution of only 32 cm^{-1} was realized, allowing dynamic FTIR measurements in the ms-range iwith an SNR of 8:1 for a single scan and improved SNR of 240:1 for averaging of 1000 scans, respectively [1]. To enhance the stroke IPMS introduced a new translational MEMS design using two pantograph mirror suspensions instead of a folded bending spring suspension [2, 3]. Unfortunately, only ± 140µm amplitude could be measured maximum for a 1 kHz device at 20 Pa and 100 V due to superimposed parasitic torsional modes [3]. In [4,7,8] IPMS presented an improved translatory MEMS device with 500 Hz resonance frequency and 5mm mirror diameter, which overcomes the previous limitations (see Figure 1). Due to an optimized, fully symmetric mechanical design using 4 pantograph suspensions of the 5 mm large mirror plate, previous problems with mode separation could be avoided. Extraordinary large stroke and a precise out-of-plane translation of ± 500 µm amplitude (resulting in a dynamic mirror p-p deformation of 80nm) were enabled in vacuum of 50 Pa, typically.

Further author information: (Send correspondence to Thilo Sandner)

Thilo Sandner: E-mail: thilo.sandner@ipms.fraunhofer.de, telephone: +49-351-8823-152

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