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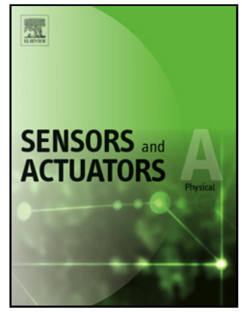

Title: Static and dynamic performance of bistable MEMS membranes

Authors: M. Dorfmeister, M. Schneider, U. Schmid

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Static and dynamic performance of bistable MEMS membranes

M. Dorfmeister, M. Schneider, U. Schmid
Institute of Sensor and Actuator Systems, TU Wien, 1040 Vienna, Austria; manuel.dorfmeister@tuwien.ac.at

Highlights

- Theoretical plate model is feasible for MEMS membranes with diameters of 300 – 800 µm
- Membranes are still flexible in the ground states
- Dynamic behaviour of membranes measured for the first time with a laser Doppler Vibrometer
- The bi-stable switching shows high velocities and very high accelerations
- The swinging after switching the ground states has a characteristic Eigenfrequency depending on the diameter and thickness of the membrane

Abstract

This paper reports on the characteristic behaviour of bistable MEMS membranes before, during and after switching between the two ground states. For this purpose, silicon membranes with a diameter in the range of 300 to 800 µm and a thickness in the range of 2 to 5 µm were investigated. To achieve bistability, hydrogenated amorphous silicon carbide layers with different thicknesses in the range of 50 nm to 400 nm were deposited on the silicon membranes using an inductively-coupled plasma-enhanced chemical vapour deposition process. With this bi-layered approach, an initial deflection of 2.5 to 8.1 µm was achieved which results in a total switching displacement of 5 to 16.2 µm. A setup for bulge testing in combination with a Whitelight interferometer was used to analyse the membrane behaviour before the bi-stable switching. The pressure difference required to initiate switching between the ground states was in the range of 20 to 320 mbar. Both parameters (i.e. static deflection and switching pressure) are in excellent agreement with an analytical model. When increasing the pressure the membranes deflect up to 2.4 µm before switching, strongly depending on the diameter of the membranes. The dynamic measurements with the laser Doppler vibrometer showed switching times in the range of 5 to 20 µs, maximum velocities in the range of 1.5 to 4.3 $m \cdot s^{-1}$ and high maximum accelerations between 2 to $11 \cdot 10^6$ $m \cdot s^{-2}$ depending on membrane properties such as diameter, thickness and mechanical stress. Finally, with fast Fourier transform analyses of the measured velocity signal characteristics Eigenmodes of the membrane are determined dominating the oscillation behaviour after switching, thus indicating approaches for effective damping with integrated actuators.

Introduction

Due to the strongly growing importance of MEMS (micro electromechanical systems) sensors and acuators in mobile systems for e.g. consumer applications, the demand for such devices to be operated with reduced energy consumption is increasing simultaneously. To enable long operation times at a given amount of energy provided by e.g. a battery, they need to be designed as power efficient as possible. To reach this goal, bistablity could be a key feature within such devices because energy is only required when switching between the two ground states as they remain in one of the latter positions without consuming energy. Additionally, there are high displacements achievable when switching