Single Input Single Output MEMS Gas Sensor

Ayman Alneamy*, Navid Heidari**, Walter Lacarbonara* and Eihab Abdel-Rahman***

* *Department of Mechanical Engineering, Jazan University, Jazan, Saudi Arabia*

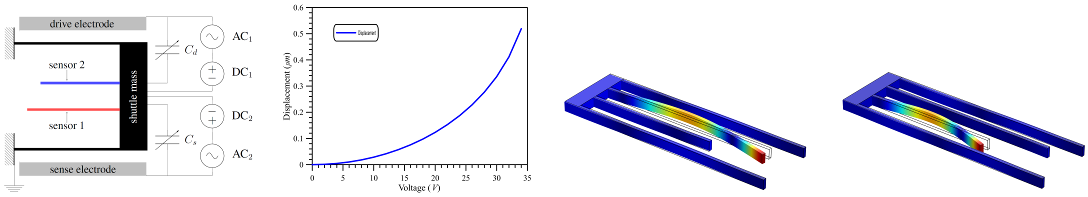
** *Department of Structural and Geotechnical Engineering, Sapienza University of Rome, Rome, Italy*

*** *Department of Systems Design Engineering, University of Waterloo, Waterloo, On, Canada*

Abstract. This paper presents a novel multi-beam, multiple resonance and single input single output MEMS gas sensor. It consists of a U-shaped shuttle mass supported by two beams and carrying two micro-cantilever resonators. It is excited electrostatically via sidewall electrodes. The shuttle mass is deployed to excite the inner beams through a base excitation. Initial analysis shows that the shuttle mass can serve as an actuator and sensor and the inner beams can detect similar or different gases depending on the detector material used and the actuation mode shapes.

Introduction and Sensor Design

There are two commonly used detection modes in the inertial gas sensors: static and dynamic. Most of the existing MEMS gas sensors are based on a simple resonant beam configuration [1]. Another configuration was proposed by Khater *et al.* [2] where a micro-plate is attached at the free end of a cantilever beam. In this paper, we propose a gas sensor design consisting of two resonators that are excited through a base excitation [3]. The sensor has also the capability to detect similar/different gases depending on the detecting material. The sensor consists of two cantilever beams "supported" by a shuttle mass attached at their ends as shown in Fig. 1(a). It is electrostatically excited by applying a static load DC and/or a time-varying signal AC to a sidewall electrode marked as drive. The shuttle mass, in turn, excites inner beams marked as sensor 1 and 2 through a base excitation. These beams serve as sensors which will be coated with similar or different detectors tailored to target gases. The design allows us to also excite the sensor with multiple excitation forces. The first one can be supplied via the drive electrode (DC_1 and AC_1) while the second force can be supplied through the sense electrode (DC_2 and AC_2). While the sensor is grounded in this case, there are two capacitance: C_d between the sensor and the drive electrode and C_s between the sensor and the sense electrode. Note that the detection mechanism will be done electrically by measuring the changes in those variable capacitances.



(a) (b) (c) (d)

Figure 1: A schematic of, (a) the single input single output gas sensor showing its actuation and sensing parameters, (b) static deflection of the shuttle mass tip under static load, (c) the first in-plane mode shape of sensor 1 and (d) the first in-plane mode shape of sensor 2.

Results and Discussion

The FEM package COMSOL Multi-physics (5.3a) was used to solve the static response of the sensor. The Electromechanics module was used to perform the static analysis. The applied voltage was set to 0 and gradually increased in steps of 0.5 V over a range of [0–40] V to capture the pull-in voltage. Figure 1(b) shows the shuttle mass tip-point values calculated by the FEM model under the static load. The pull-in voltage was found to be 34 V. An eigenvalue analysis was also performed using the developed FEM model to determine the operational mode shapes. Since the sensor sensitivity is a function of the operating frequency, we chose to excite the sensor at one of its' inner beams in-plane bending modes. The reason for this is to reduce the effect of the nonlinear squeeze-film damping and, therefore, increase the sensor's sensitivity. Figure 1(c) and (d) show the first in-plane bending modes of sensor 1 and 2 with resonance frequencies of 288.31 kHz and 532.37 kHz, respectively. In conclusion, we designed a single input single output gas sensor consisting of a U-shaped shuttle mass supported by two beams and carrying two micro-cantilever resonators. The static and eigenvalue preliminary studies showed the potential of using such a design to detect similar/different gases exploiting the in-plane bending modes of the inner beams. A full analytical model and analysis will are being developed to investigate the sensors response statically and dynamically in the presence and absence of the added mass.

References

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