An alternative pathway to MEMS development in Brazil: conventional, modified and novel devices

V. Vecchia¹, M. Salmen¹ and D. W. de Lima Monteiro¹
¹Department of Electrical Engineering (DEE) - Universidade Federal de Minas Gerais UFMG
e-mail: viniciusvecchia@ufmg.br, marinasalmen@ufmg.br, davies@ufmg.br

1. Abstract

This work proposes an alternative strategy to tackle MEMS development in Brazil, initially aiming at speeding the time-to-prototype process while building up the know-how to design and characterize MEMS components, both traditional and novel. To foster the take-off of this approach, a 10x10 mm surface micromachined test chip has been designed with a number of sensor and actuator structures addressing transduction in various physical domains.

2. Introduction

The academic development, from scratch, of all process steps involved in the fabrication of most complete MEMS devices of major interest requires extensive research and funding, in addition to a reliable operational infrastructure, available consumables, timely technical support, and long-term students and staff. Despite the well-intended actions, know-how, historical developments and admirable determination of several Brazilian research groups, the current scenario makes it difficult to meet the demands to achieve a reliable prototype, in a reasonably short timeframe, that could be easily replicated and further improved in subsequent batches. Furthermore, the energy and time involved in that often leaves no room for a more thorough investigation of design alternatives and the later integration of the developed structures into an application-oriented system (structure, packaging, electronics). To master the fabrication steps and respective materials is fundamental for the long-run full custom development of microtransducers, but it must not be the only pathway towards MEMS prototypes in the country.

Our proposal attempts to reduce the time-to-prototype development, initially outsourcing the fabrication steps to well-established standard MEMS-process manufacturers elsewhere, and to focus on mastering the design of structures, tape-out flow and later the characterization and operation of the devices. In general, this approach reduces time, cost and complexity in the development of MEMS prototypes, rendering it more compatible with current funding opportunities and expected project execution time. Moreover, the development can be more easily compartmentalized, with a lower degree of interdependence of steps, allowing more flexibility in managing research teams along and across projects. By using an external fabrication service, more structures can be tried on a single batch, and more attention can be given to specialized layout, tailored performance, novel transduction mechanisms, and applications. This approach is equivalent to that adopted in microelectronics by fabless/fablite companies, and IC design houses. Among a few options worldwide, we have chosen the PolyMumps multi-project wafer service provided by MEMSCAP that enables the fabrication of a diversity of sensors and actuators utilizing a proven process flow. In summary, PolyMumps is a surface micromachining process with a standard silicon wafer as substrate, one nitride insulation layer, one fixed poly-Si layer, two movable poly-Si layers and a top metal layer. Between each poly-Si layer there is a sacrificial oxide layer.

In our work three different design classes were proposed: replication of devices well known in the literature; modification of devices well known in the literature; and novel designs. This approach was chosen so we could validate our design methods and compare our results against other reported results. Simulation is hard at the first stage and often involves a semi-empirical routine, due to the lack of specific simulation tools or databases, and complexity of some of the designs. Nevertheless, most of the basic actuation or sensing mechanisms deployed in our structures have been to a certain extent proven in the literature.

3. Proposed devices

In this section we will discuss some examples of the implemented devices and their characteristics. Figure 1 shows an electrostatic rotary micromotor. This device is given as an example in PolyMumps Design Kit and it was added to the project to serve as a design reference. Apart from its scale that was increased, the motor retains its original design and features, being a three-phase 12-pole design. This kind of motor can reach speeds up to 10,000 RPM [1], and numerous studies have been carried to study its operation and failure modes [1]. This device serves to illustrate and validate some of the functionalities that can be accomplished with PolyMumps, such as free pivoted gears and electrostatic actuation.
Figure 2a shows another implemented structure representing modifications to a formerly tested structure [2]. It consists of an array of tilting hexagonal micromirrors, suspended by the residual force between the poly-Si layer and the metal layer on each one of the three arms. Tilting is accomplished by applying an electrical potential between one of the three bottom electrodes and the top mirror surface, as shown in more detail in figure 2b. In this way, it is possible to tilt the mirrors in any direction, with a theoretically large tilting angle, enabled due to the suspension of the device from the substrate. Several of these mirrors were fabricated, each with a different peripheral shape and metal distribution on their supporting arms, to maximize tilt angle during actuation.

Figure 3 depicts one of the novel designs implemented. This device consists of two square arrays of long metal coated fingers, linear array, that can be stacked and aligned in or out of phase in relation to each other, thus implementing a variable diffraction grating.

As PolyMumps process allows only metal to be deposited on the top movable poly-Si layer, both arrays must be fabricated using the same layer, therefore on the same plane, and some assembling is required to first operate the device and stack the metal layers. This assembly is done by driving the Chevron actuators connected to the linear rack. Chevron actuators are thermal based and provide a relatively high force and high displacement, compared to electrostatic actuators [3]. Additional Chevron actuators are required to serve as a clutch mechanism to the linear rack and to move the top finger array, thus creating the variable grating effect. On figure 4 it is possible to see the device in its expected assembled position.

Figure 3. Overall view of the diffraction grating.

This device stands out among most of the the MEMS diffraction gratings already described in the literature [4] by having the possibility to tune the gap between two adjacent fingers from 3μm to, theoretically, zero. The implemented device has approximately 300x300 μm of optical usable area.

4. Conclusions

This work presented an alternative strategy to the design of MEMS transducers to speed up prototyping using a multi-project wafer service. The next steps include local post-processing in the clean room to stripe the sacrifice oxides away, thus releasing the movable structures, and subsequent packaging, wirebonding, and characterization of those devices.

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References