Subproject A1: Design of Micromechanical Components

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1 Development of accelerometer arrays for drift compensation

Micromechanical accelerometers have a lot of different applications. An upcoming field is inertial measurement, which means the tracking of the position and orientation of moved objects with an attached inertial measurement unit. Its position is calculated by integrating the acceleration twice. That's leading to a rapidly rising error in position calculation, in case of a small offset error in the acceleration signal. The aim of the project is to increase the long time stability of these sensors by a novel redundantly designed sensor array.

The basic idea is the arrangement of at least three similar accelerometers as an array in a Silicon chip. The sensors must have different measuring directions that are non-orthogonally aligned. The drift effects in time and temperature are eliminated by calculation of the resulting acceleration, assuming equal influence on every sensor.

The ageing and temperature changes lead to alterations in material stresses and strains which results in variations in the measured acceleration. Hence, a sensor and chip design is needed which provides similar effects on every sensor.

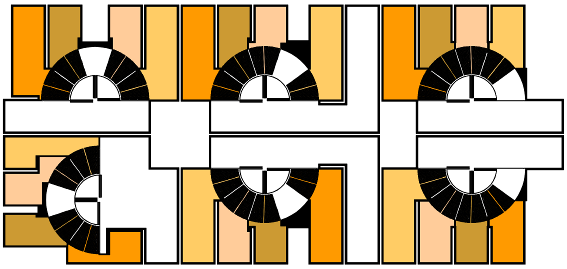


Figure 1: Acceleration sensor chip (similar colours corresponding to similar electrode properties)

Six redundant accelerometers [Fig. 1] are situated on a chip while five are non-orthogonally aligned [1]. Every sensor has one of six possible measuring directions.

The sensor forms a semicircle as shown in Fig. 2. At the outer radius a seismic mass and four capacitive comb segments are affixed. To vary measuring direction the positions of the seismic mass and a comb segment have to be swapped. The advantages are the centred anchor which results in less stress entry and the springs are similarly aligned in respect to crystal orientation for each sensor in the whole chip.

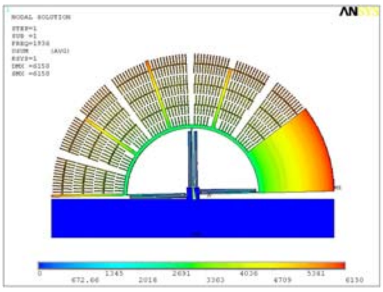


Figure 2: Simulation model of the sensor (1st Eigenmode)

First samples are fabricated in a BDRIE process [2], which provides high aspect ratio combined with high freedom in design [Fig. 3]. The transfer of the design to AIM technology [3] is in progress.

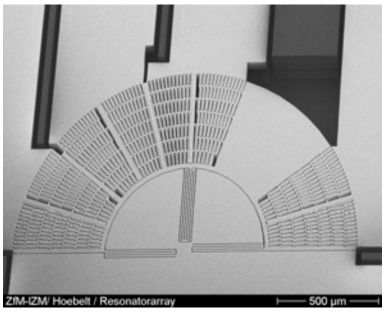


Figure 3: Sensor with seismic mass at 36° position [2]

2 Multiparametric Method Based on FEM for MEMS Electrostatic Problems

Nowadays Finite Element Method (FEM) is used at main CAD for MEMS design. FEM combines high accuracy of the solution, high solution speed, plentiful opportunities in a choice of geometry of a problem and boundary conditions.

The parametric models of complex MEMS devices are extracted by numerical data sampling and subsequent function fit algorithms. Each sample point must be obtained by a separate finite element run whereby the change of geometrical dimensions is realized by mesh morphing or re-mesh functionality. Usually one needs between several ten to some hundreds of sample data in order to capture the influence of design parameters accurately which is cumbersome for practical use [4]. Therefore, novel simulation techniques, combining, on the one hand, advantages of FEM and an opportunity to get the solution in analytic form, suitable for search of the optimum parameter combinations, are strongly required.

This work is concentrate on a novel technique, based on FEM, which account for parameter variations in a one finite element run. The method flow chart is shown in Fig. 4. As result one can obtain the Taylor vectors of the goal function covering the system response in the vicinity of the initial position with regard to design parameters [5].

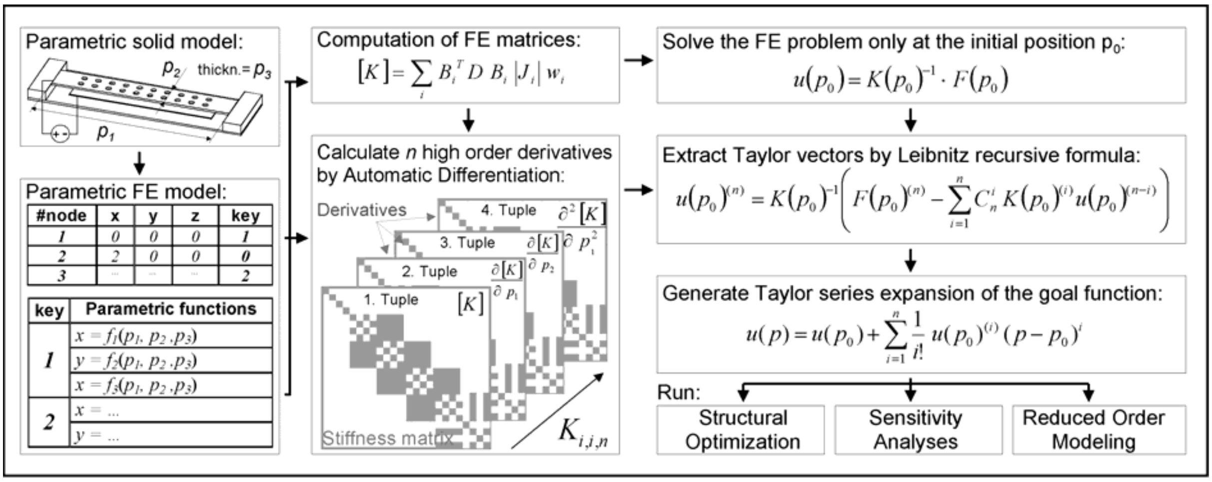


Figure 4: General approach of parametric model extraction for MEMS based on finite element methods.

Typical MEMS element – a comb-drive cell (Fig. 5.), was analyzed by this method [6]. The capacity of this structure depending on shift (Δl, Δt, Δh) of the movable electrode in the direction along main axes was obtained. Results of the simulation are shown in Fig. 6.

This method gives an opportunity of getting the results close enough to ones of reference finite element solution. Problem time weakly depends on an amount of variable parameters that gives advantage at work with multiparametric models. This method can be used as a part of ROM tool and as independent tool for structural optimization and sensitivity analysis.

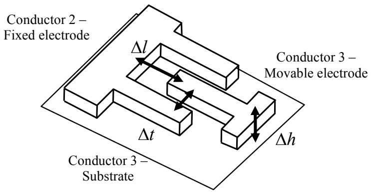


Figure 5: Model of comb drive cell

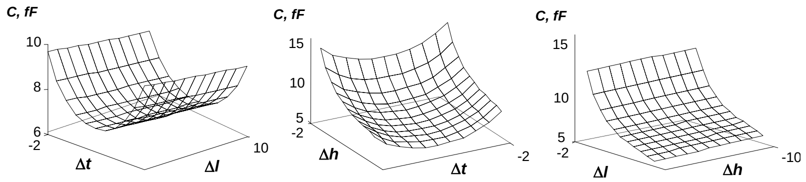
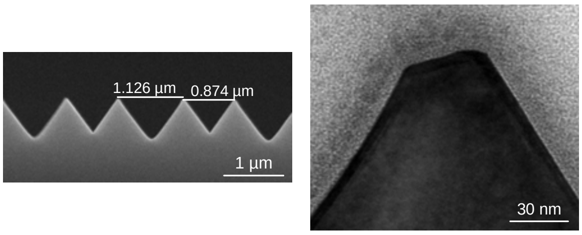


Figure 6: Simulation results.

3 Silicon form elements

3.1 Triangle gratings

The etching of Echelette gratings with a period of 1 µm starting with a mask pattern of 2 µm period and using an interim oxidation is described in the Annual Report 2003, p. 54 and p. 69. Because of this interim oxidation (silicon is consumed) the original windows are widened. Furthermore the oxide reaches into the interface between the nitride and the silicon ("birds beak" effect) diminishing the width of the secondly etched grooves. This technique results in different widths of neighboured grooves fig. 1a. Additionally the "birds beak" effect flats the convex edges of the grating, fig. 7b.



a) Different width of neighboured grooves *b) "birds beak" effect*

Figure 7: Pictures of gratings

The proposed solution to overcome this problem must accept the original period of the mask pattern on expensive {112}-Si wafers. Therefore an alternative solution was tested to produce the halfed period, fig 8. The tests were performed using cheap {100}-Si wafers and mask patterns having different periods (1.6; 2; 4; 5 µm).

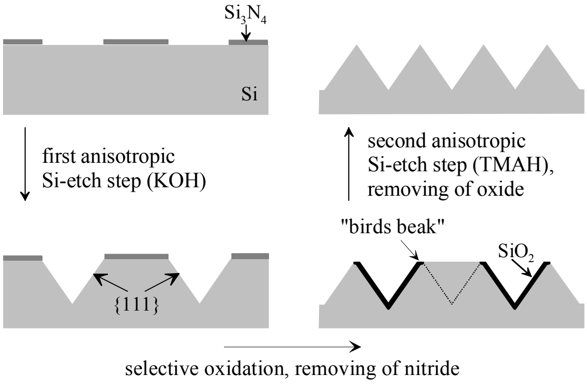
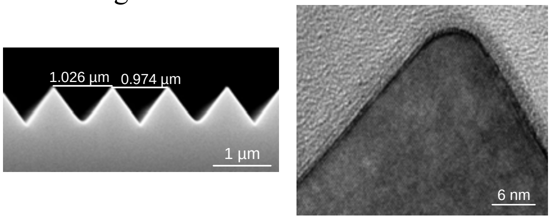


Figure 8: Scheme of preparation

Because TMAH has a lower selectivity and therefore a higher etch rate of the {111}-sidewalls the horizontal differences between two neighboured V-grooves can be adjusted up to ≤ 50 nm by using of TMAH in the second etch step, fig 9a. Furthermore the "birds beak" effect is removed, fig 9b. A very small radius of the convex edge of about 5 nm results.



a) Deviation of the width of the grooves is ≤ 50 nm *b) Convex edge without "birds beak" effect*

Figure 9: Pictures of gratings with improved features

3.2 Silicon solid hinge guide

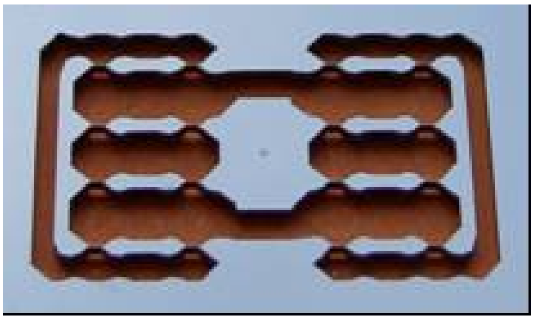


Figure 10: Solid hinge guide out of Si

A solid hinge guide is completely prepared out of silicon by wet anisotropic etching, fig. 10, as a development of the demonstrator in the Annual Report 2003. Using silicon wafers with a thickness of 1120 µm and etching the springs down to a thickness of 30 µm, the guide can be deflected up to ± 1.5 mm, fig 11.

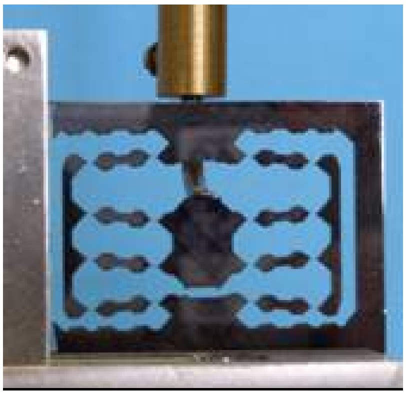


Figure 11: Solid hinge guide deflected up to 1 mm

The transverse stiffness and the in-plane deflection of the solid hinge guide were controlled. The measurements of the straightness (y-deviation from the translation axis x) using a laser scanning instrument show values in the region of 0.5 microns. This can be improved by a more optimal driving actor.

4 References

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