Novel high precision micromachined gyroscope

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1 Introduction

Within the project "EKOFEM" a novel high precision silicon gyroscope fabricated by a special high aspect ratio technology is under development. The planar structure exhibits two in-plane vibration modes for drive and detection. Comb drive electrodes are used to force the resonator to vibrate with it's primary mode resonance frequency, and differential detection electrodes measure the vibration amplitude of the secondary mode caused by Coriolis forces. Due to the very high requirements to accuracy and resolution (bias stability 10°/h, angle random walk $< 0.3°/\sqrt{h}$), it is necessary to compensate fabrication tolerances as well as other influences (e.g. thermal drift). This is achieved by electronics; the control loops are implemented in a digital signal processor. The working principle and the basics of design and technology have been described in the 2003 report and in [1], [2].

2 Fabrication of prototypes with an optimised design

The gyroscope is fabricated by a new technology approach based on SOI-wafers with a buried cavity (see Fig. 1). The thickness of the active layer is 50 µm. Deep dry RIE etching (time multiplexed deep etch technique with STS equipment) via photoresist mask is used for the trench patterning process. Much effort has been spent on the optimisation of this trench etch process (rectangular and symmetric trench profile, reduced ARDE and notching). Presently a trench angle of 90.2...90.3° has already been achieved (Fig. 2), a further reduction is aspired. In order to avoid notching the Bias voltage is generated at substrate electrode by means of a pulsed rf generator operating at 380 kHz (LF process, especially for SOI processing).

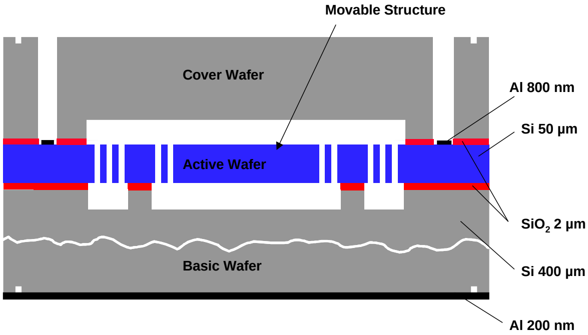

Fig. 1: Schematic cross section of the sensor

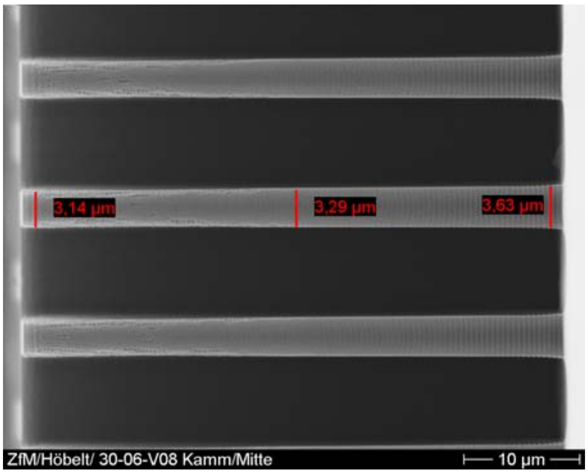

Fig. 2: View on the front end of a comb drive (SEM)

Targets of design optimisation have been
- reduction of frequency difference between excitation and detection mode
- ratio between mass and stability of the frames
- high linearity
- low bias.

Different designs including single and dual linear configuration have been developed and fabricated. Fig. 3 and 4 show details of the excitation comb drive as well as the detection capacitor.

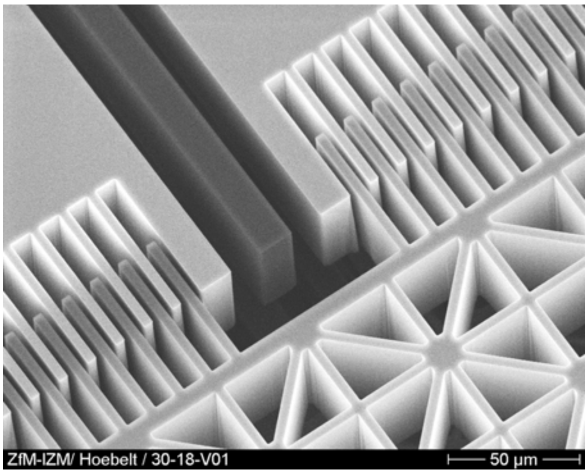

Fig. 3: Detail view (SEM) on the comb drive

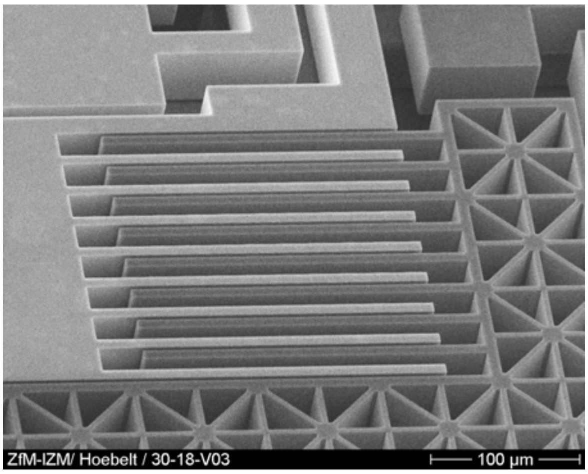

Fig.4: Detail view (SEM) on the detection system

The smallest trench width is 2.5 µm, the widest trenches are about 30 µm. The resonant frequencies of the resonators are about 9.2 kHz and 9.4 kHz.

3 Packaging

For hermetic encapsulation of the resonators, a Si cover wafer with thermal oxide is used (see Fig. 1). A special direct bonding regime has been developed and applied. Fig. 5 shows a cross section of such a sensor compound. With this bonding approach, hermetic sealing of the sensors with residual cavity pressure as low as 1 Pa has been achieved.

4 Measurements

Both uncapped and capped sensors have been tested at LITEF GmbH Freiburg (see Fig. 6). The resonators show very high quality factors (up to 120,000 at a pressure of 1 Pa for excitation mode). Over a time period of 15 months no change of the Q factor was observed [2]. Other promising measurement results of the capped sensors presented in [2] are the very low noise (< 0.09°/√h) and a bias stability over temperature of presently 27°/h, which is expected to be reduced to < 5°/h with the optimised design.

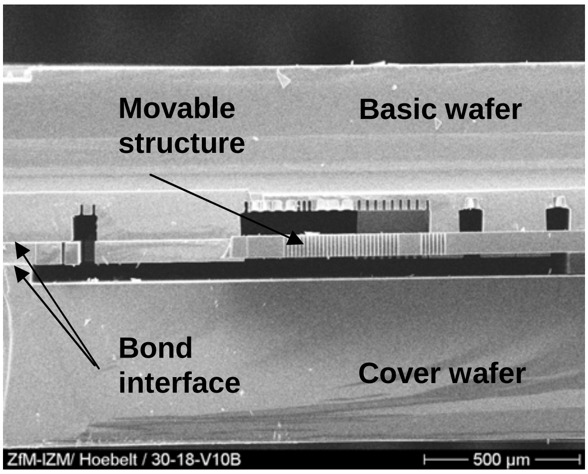

Fig.4: Cross section (SEM), chip face down

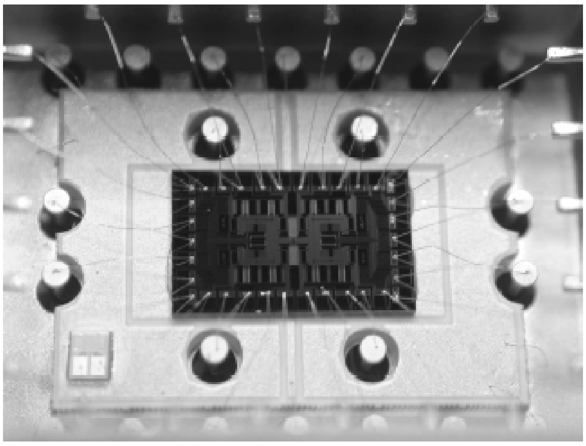

Fig 6: Photo of assembled chip (dual linear configuration)

The sensors can cover a measurement range of ± 200°/s (realised) up to ± 5000°/s, the scale factor non-linearity (maximum error) is 600 pm. With the fabricated prototypes II the target of the EKOFEM project can be fulfilled.

References

[1] Geiger, W. et al.: *The micromechanical Coriolis Rate Sensor µCORS II*, Symposium Gyro Technology, Stuttgart 2003

[2] Geiger, W. et al.: *Test results of the micromechanical Coriolis Rate Sensor µCORS II*, Symposium Gyro Technology, Stuttgart 2004