Electronic compensation of fabrication tolerances demonstrated for a novel micromachined gyroscope

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Within the project EKOFEM a novel gyroscope for navigation systems is developed. The working principle is based on coriolis forces acting on a vibrating mass when the whole system rotates. The planary structure (see Fig. 1) uses two in-plane vibration modes for drive and detection. Eletrostatic drive and capacitive readout are used for transducer principle. There exist very high requirements to accuracy and resolution (bias stability 10°/h, angle random walk < 0.3°/√h). The movable structure is forced to vibrate with the designed vibration modes, but there are also parasitic cross axis motions which contribute to a higher bias signal. The reason are unavoidable fabrication tolerances. Therefore, additional electrostatic forces are applied to eliminate these motions and compensate fabrication tolerances therewith.

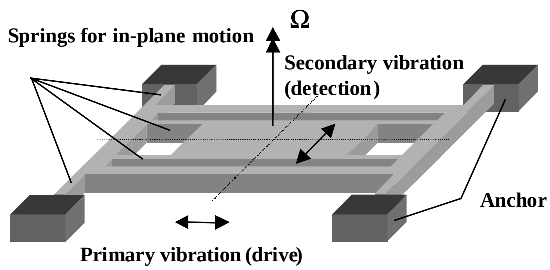

Fig. 1: Schematic view of the silicon resonator

However, the utilized eigenmodes of the structure are clearly separated from parasitic modes. This is an important advantage of the designed structure and a result of the geometrical optimization. Matlab/Simulink, MEMSPro and ANSYS are used for system and structure optimization. The FEM simulation supplies important results to mechanical stess and strain, to modal andransient behavior and for dimensioning of electrostatic forces.

The gyroscope is fabricated using a new technology approach based on SOI-wafers with a buried cavity (see Fig. 2). The thickness of the active layer is 50 µm. Deep dry etching via photoresist mask is used for the trench patterning process. With this technology, a large variation of trench width is possible. Electrical insulation of the movable part to the fixed part is reached by surrounding air gaps, while both areas use the bonding oxide for insulation to the substrate of the handle wafer. Different capacitor arrangements with aspect ratios up to 25:1 have already been demonstrated. Fig. 3 shows a detail of the structure (comb drives). At the present state of technology development, the Al wire bond pads are patterned on top of the active layer. Within the following period, the sensors will be hermetically encapsulated using another Si cover wafer.
First sensor elements have been fabricated and tested, which show promising results of the dynamic behaviour (high quality factors in vacuum, less than 10% deviation of the measured resonant frequencies in comparison to the simulation results). Further sensor tests including tolerance compensation schemes are under investigation.

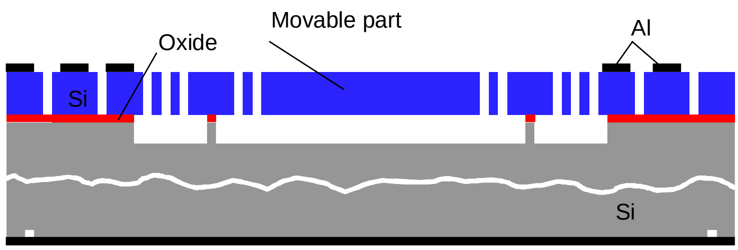

Fig. 2: High aspect ratio bulk technology with buried cavities

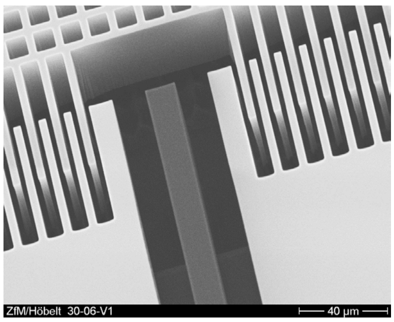

Fig. 3: SEM picture of a detail after trench etching